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NBS

URBAN NATURE-BASED SOLUTIONS AND WATER

A CATALOGUE FROM THE URWAN PROJECT

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INTRODUCTION TO THE NBS URWAN CATALOGUE

NBS and water

Nature-based Solutions (NBS) have gained worldwide momentum in the past few years particularly within the European Union, which strongly advocates their implementation for a variety of purposes. In urban areas, NBS are particularly valued as **key strategies for climate change adaptation**. Greening urban spaces - whether by planting trees or incorporating vegetation on the ground, rooftops, or walls - not only **mitigates the effects of heatwaves** by lowering city temperatures but also **supports urban biodiversity**, **manages stormwater**, **purifies polluted water and air**, **enhances city aesthetics**, and creates spaces that foster **community interaction** and **social well-being**.

However, plant growth is contingent upon **adequate water supply**, especially when intended to cool a city. Photosynthesis, fundamental to plant life, requires both water and carbon dioxide to produce organic matter. Additionally, the **cooling effect of plants** is primarily driven by **evapotranspiration**, a process in which water from plant leaves transitions from liquid to gas, absorbing heat from the surrounding environment.

Recognising the vital link between NBS and water, the **URWAN project's NBS catalogue** is designed to **emphasise these interdependencies**. It considers the ecosystem services NBS can provide while also highlighting **the importance of understanding the potential water requirements of these solutions**.

To address this, the catalogue classifies NBS into two categories: **Water "snob" NBS**, which do not account for their water requirements and **depend on conventional potable water** sources from public distribution networks, and **Water "smart" NBS**, which are designed to **utilise alternative water sources beyond potable supplies**. Some water-smart NBS even serve dual purposes, they can purify alternative water sources, such as wastewater, and are devised to treat volumes significantly exceeding their own needs. The surplus purified water can then be used for other applications, including irrigating water-snob NBS, transforming them into smart!

Instruction for use of the catalogue

The catalogue is conceived as a user-friendly tool for final users, typically public authorities and other stakeholders, **to easily understand the available nature-based solutions**, along with their main benefits and drawbacks, providing a comprehensive overview. Each NBS is presented in a **two-page format**, which includes:

- A **non-technical description** outlining the main features of the solution, accompanied by a **graphical scheme** illustrating how it works, when possible.
- The **application scale** indicates whether the solution applies to a single building (**Building**) or at the scale of a street, parking area, or neighbourhood (**Urban**).
- A selection of images showcasing **real-world examples** of the proposed solutions.
- A **summary overview of the main benefits and drawbacks** associated with each NBS.

The benefits: we have simplified the list of possible NBS benefits (compared to other available NBS catalogues). The following key benefits are highlighted when they are significant:

- **Water quantity** (stormwater management): when the solution helps reduce the adverse effects of stormwater
- **Water quality**: when the solution contributes to the purification of polluted water
- **Water provision**: when the solution provides excess for other uses
- **Support for urban biodiversity**: when the solution provides a habitat for species than Homo sapiens
- **Aesthetic**: when the solution transforms the urban space, making it more beautiful.
- **Cooling**: when the solution contributes to cooling the urban space
- **Recreation**: when the solution creates an area large enough to be directly used by people

The drawbacks: are the costs (investment and Operation and Maintenance – O&M) and the social acceptability of the solution. For each drawback, three categories—ranging from the best to the worst—are used: green, yellow, and red:

Investment costs (estimated for the construction of 1 square metre of NBS):

- **Green**: < 100€
- **Yellow**: from 100€ to 300€
- **Red**: > 300€

O&M costs (estimated for the maintenance of 1 square metre of NBS):

- **Green**: < 1€/year
- **Yellow**: ranging from 1€ and 5€/year
- **Red**: > 5€/year

Social acceptability:

- **Green**: high
- **Yellow**: medium
- **Red**: low

Each solution is described in **simple terms** to clearly communicate its **purpose**, along with its **main benefits and drawbacks**, without delving into technical details. However, for technicians or designers seeking more in-depth information on the design aspects of these solutions, a **list of the most relevant technical and scientific references** is provided at the end of the catalogue.

BENEFITS

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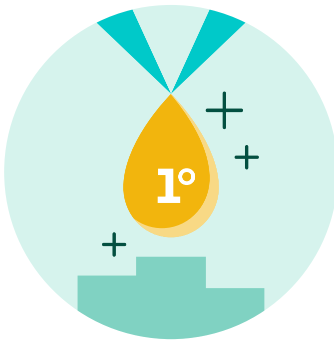
WATER QUANTITY

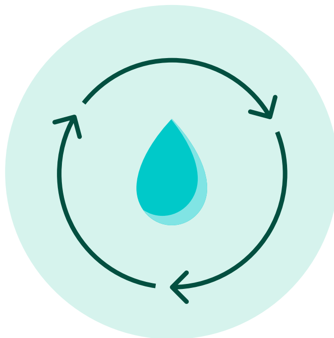
When the solution helps reduce the adverse effects of stormwater.

WATER QUALITY



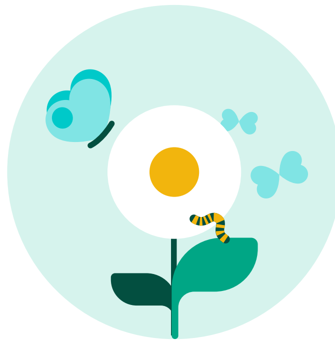
When the solution contributes to the purification of polluted water.

WATER PROVISION



When the solution provides excess for other uses.

URBAN BIODIVERSITY

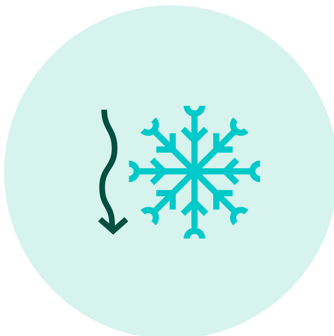


When the solution provides a habitat for species than Homo Sapiens.

AESTHETIC

When the solution transforms the urban space, making it more beautiful.

COOLING



When the solution creates an area large enough to be directly used by people.

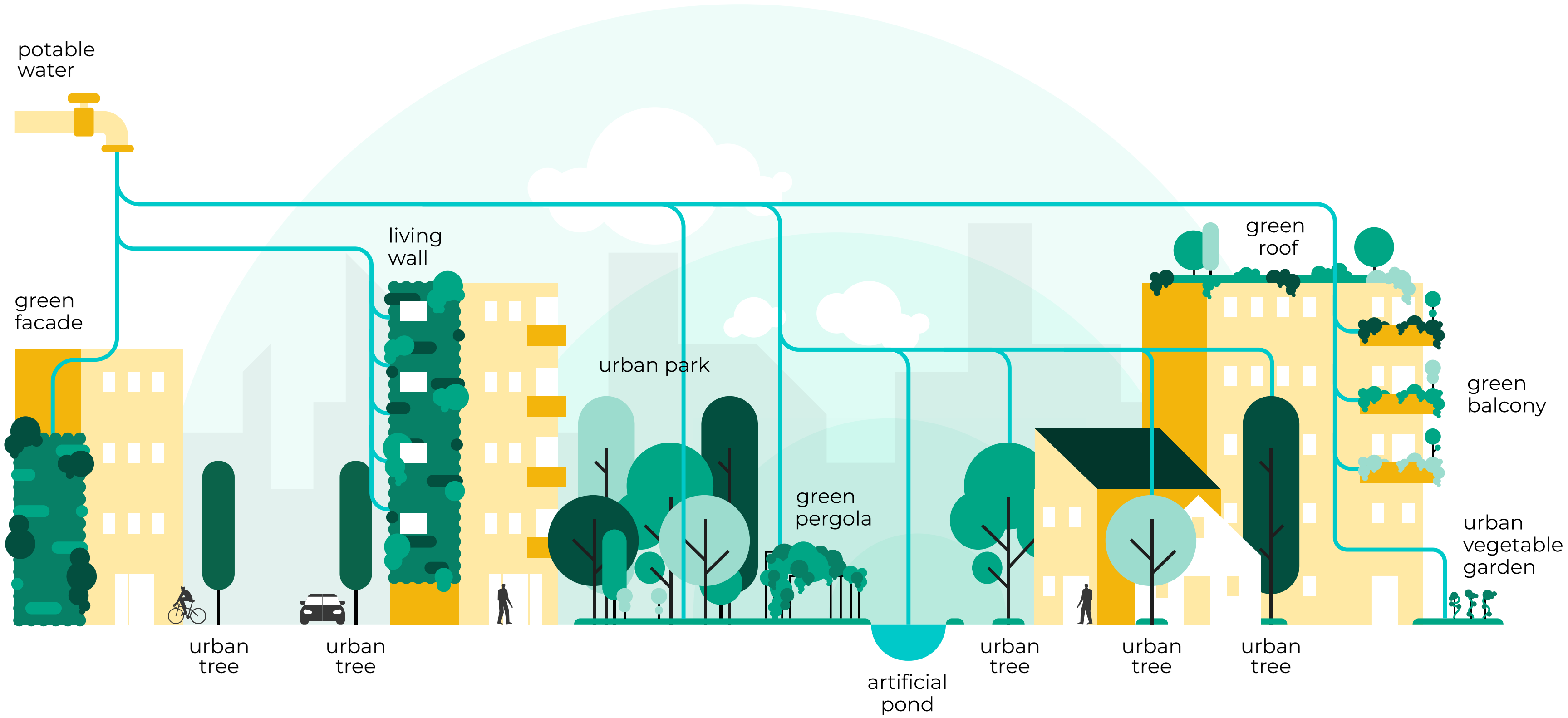
RECREATION

When the solution creates an area large enough to be directly used by people.

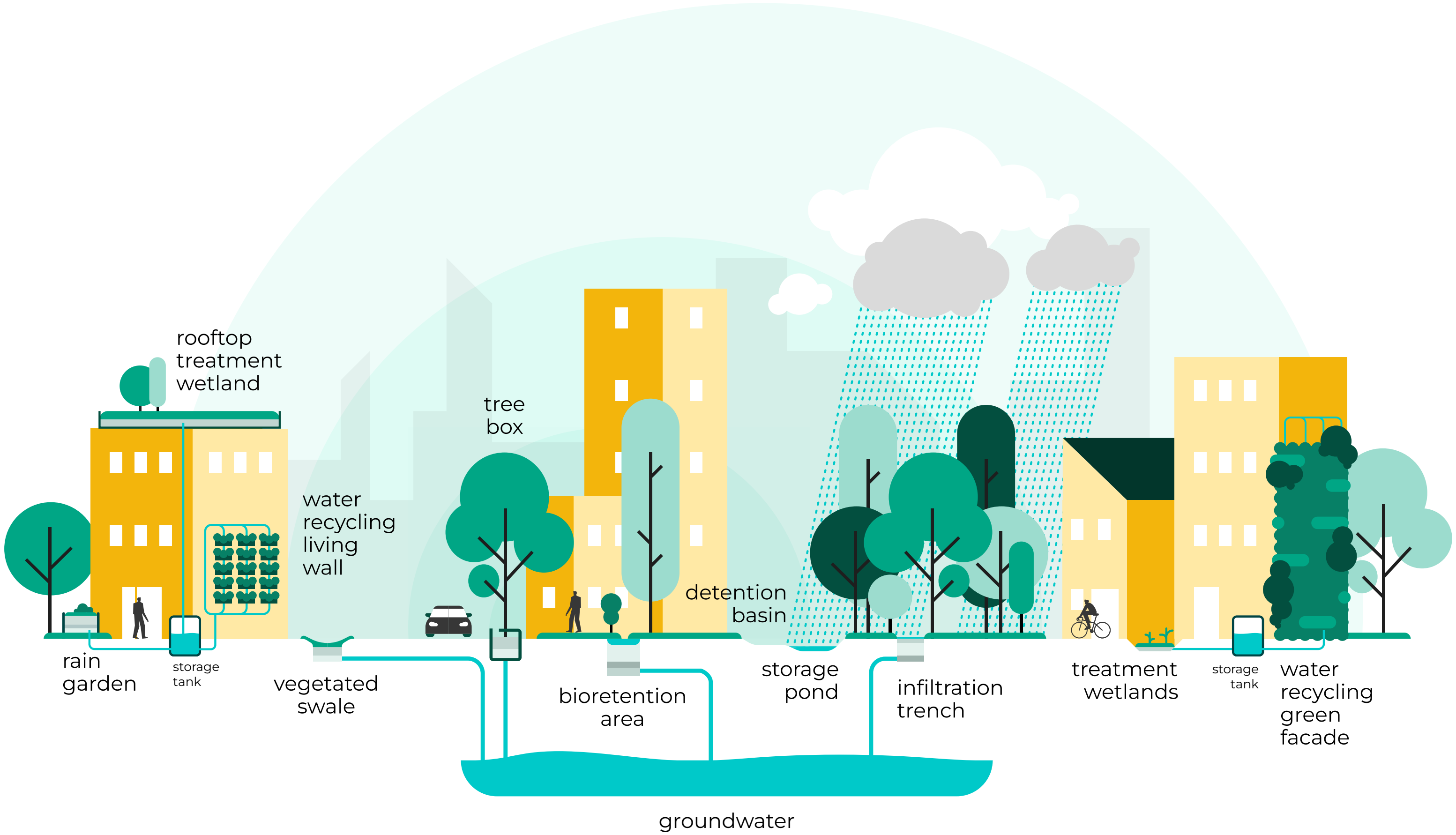
DRAWBACKS

SOCIAL ACCEPTABILITY	high	medium	low
INVESTMENT COSTS Estimated for the construction of 1 square metre of NBS.	< 100€	ranging from 100€ to 300€	> 300€
O&M COSTS Estimated for the maintenance of 1 square metre of NBS.	< 1 m²/year	ranging from 1€ and 5€ m²/year	> 5€ m²/year

WATER SNOB NBS



WATER SMART NBS



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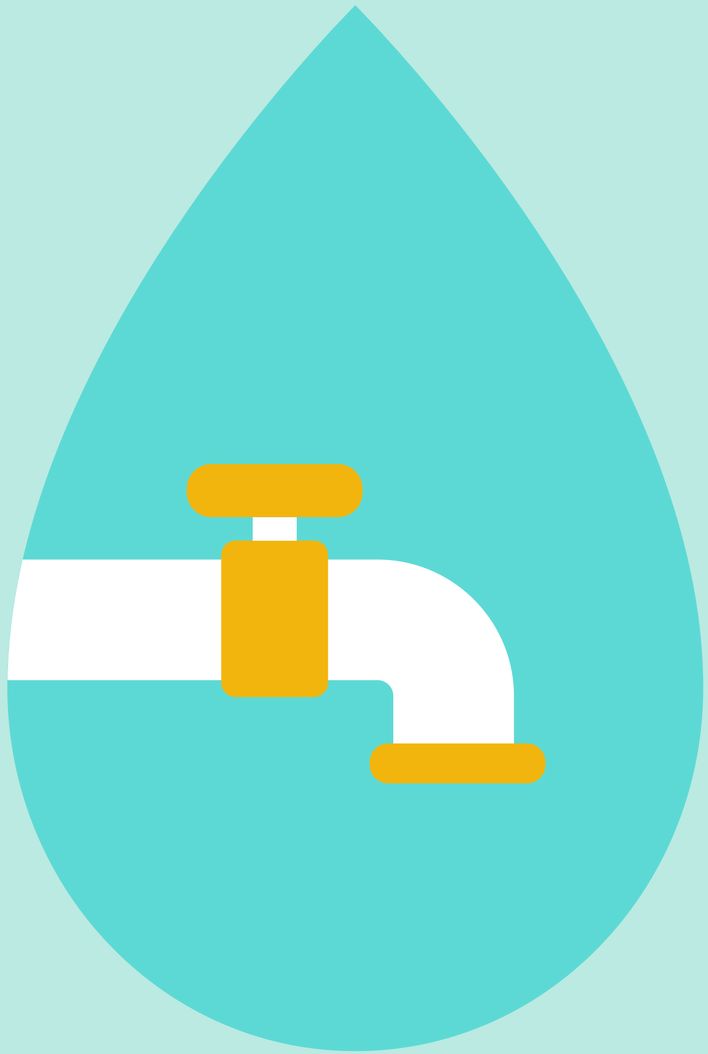
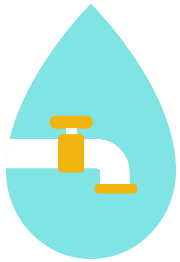
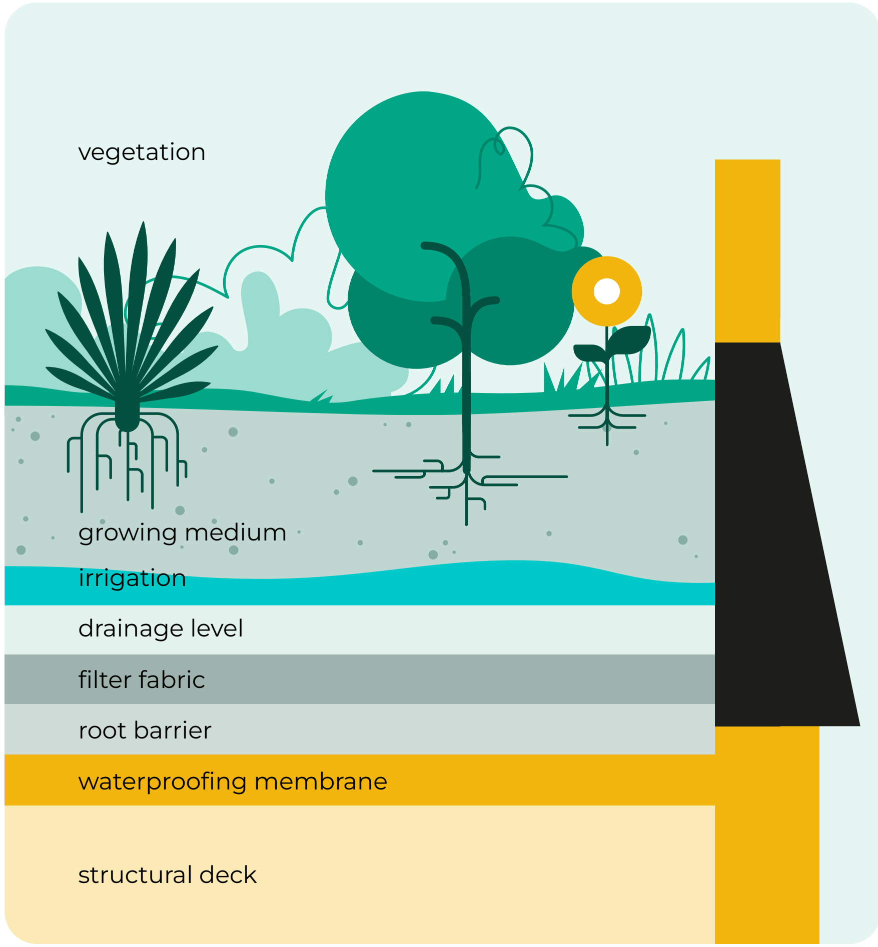
WATER SNOB NBS

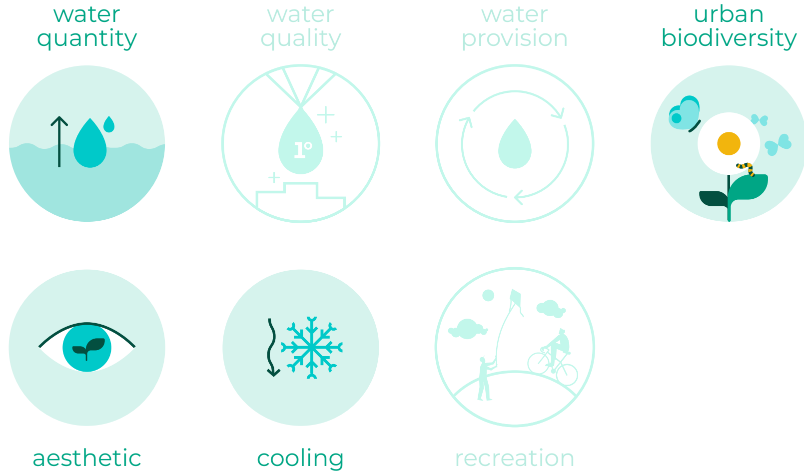


GREEN ROOF



water
SNOB
NBS





A green roof is a **lightweight, vegetated roof** over a **protective root barrier** and a **roof membrane**. There are two types of green roofs, depending on the depth of the substrate and the type of vegetation planted: **Extensive** and **Intensive**. Either type will **need temporary watering** for establishment and **regular irrigation** depending on the climatic conditions.

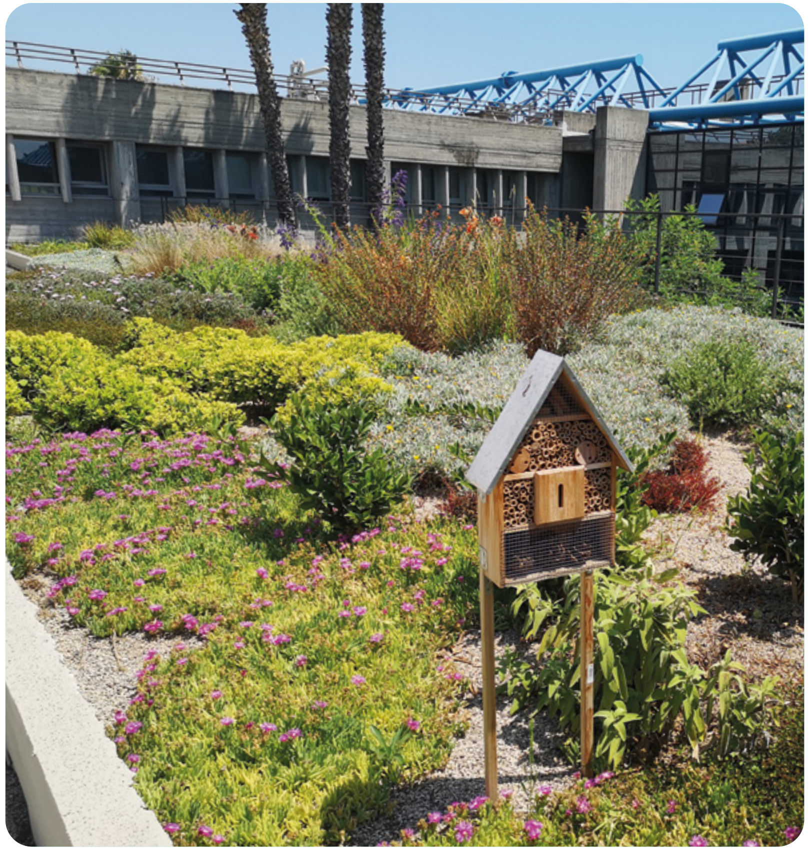
Green roofs can transform rooftops into **multifunctional spaces**, offering benefits such as **insulation for cooling**, reducing urban air temperatures, **enhancing biodiversity**, and **providing aesthetically pleasing landscapes** or **leisure areas**. They also aid in **stormwater management** by retaining rainwater in vegetation and soil, gradually releasing excess water after rainfall.

Green roofs generally fall into **two categories**, distinguished by factors such as weight, growing media, plant diversity, maintenance and irrigation needs, accessibility, usage, and costs.

Extensive green roofs are detailed to minimize the additional load on the roof structure, with only thin layers of soil (< 15 cm), have **minimal plant diversity** and require **minimal maintenance**, they are generally planted with grass, sedum or low plants. They are typically not designed for foot traffic or occupancy except for maintenance. These features result in **the lowest capital cost** of the different green roof types. Extensive roofs may ‘brown-out’ over dry summers, but dormant plants revive once the rainy season begins.

Intensive green roofs may be **accessible as a roof garden**. This type of green roof will have **deeper layer of soil** (> 15 cm), and therefore **heavier weight**. Deeper soil allows for a greater variety of plants, such as grasses, herbs, shrubs and (small) trees, thus making intensive green roofs more “attractive” but **higher maintenance** than extensive green roofs.

application scale:
building



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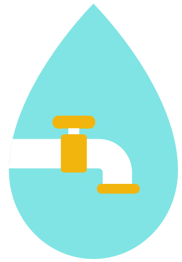
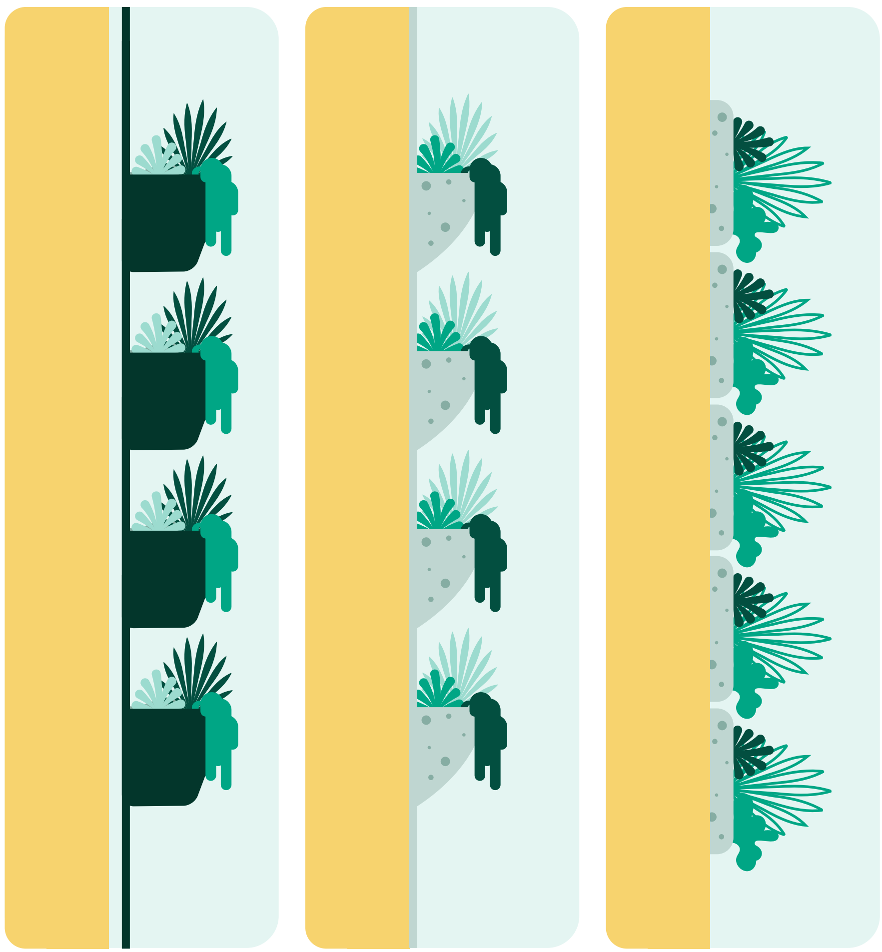
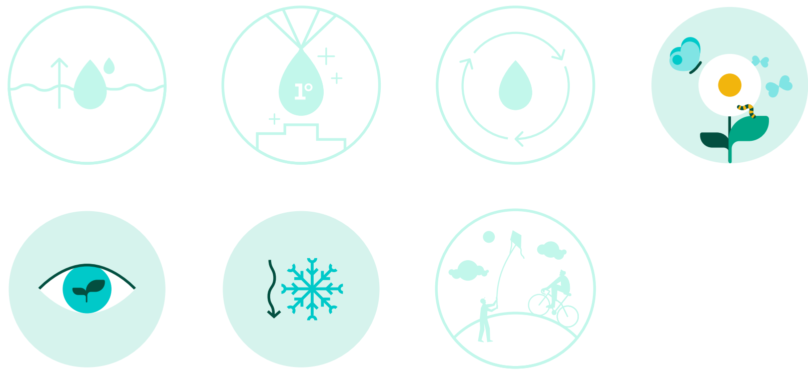
LIVING WALL



water
SNOB
NBS





A Living wall is a type of **green wall** or **vertical garden** made of modular trays or felt pockets containing substrate and plants, **mounted on building facades**. It requires watering for establishment and **regular irrigation** through the year, depending on the climatic conditions and plants specie. They are elements of renaturalisation providing a **variety of functions and benefits**.

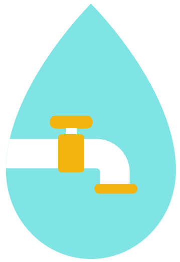
Living walls are essential elements of urban renaturalisation, delivering multiple ecosystem services such as **aesthetic enhancement**, **urban heat island mitigation**, and **biodiversity promotion**. As living art installations, they improve visual appeal while making **efficient use of vertical surfaces**, making them particularly suitable for cities. Additionally, in street canyons where polluted air tends to accumulate, green walls **can help absorb pollutants and purify the air**, contributing to a **healthier urban environment**.

Living walls can accommodate a **wide range of plant species** and also function as a form of urban agriculture, providing space for growing edible plants in cities. They consist of plants rooted in purpose-designed substrate cells mounted on building facades using modular systems. The growth medium is supported vertically on the host wall, typically within **modular trays** or **felt pockets** that contain organic or artificial substrates. These systems often employ **hydroponic cultivation**, using a nutrient solution to meet plant needs and ensure proper vegetation development. To optimise efficiency, living wall systems can incorporate **automated irrigation or fertigation systems**, often integrated with **humidity sensors** to activate watering only when necessary.

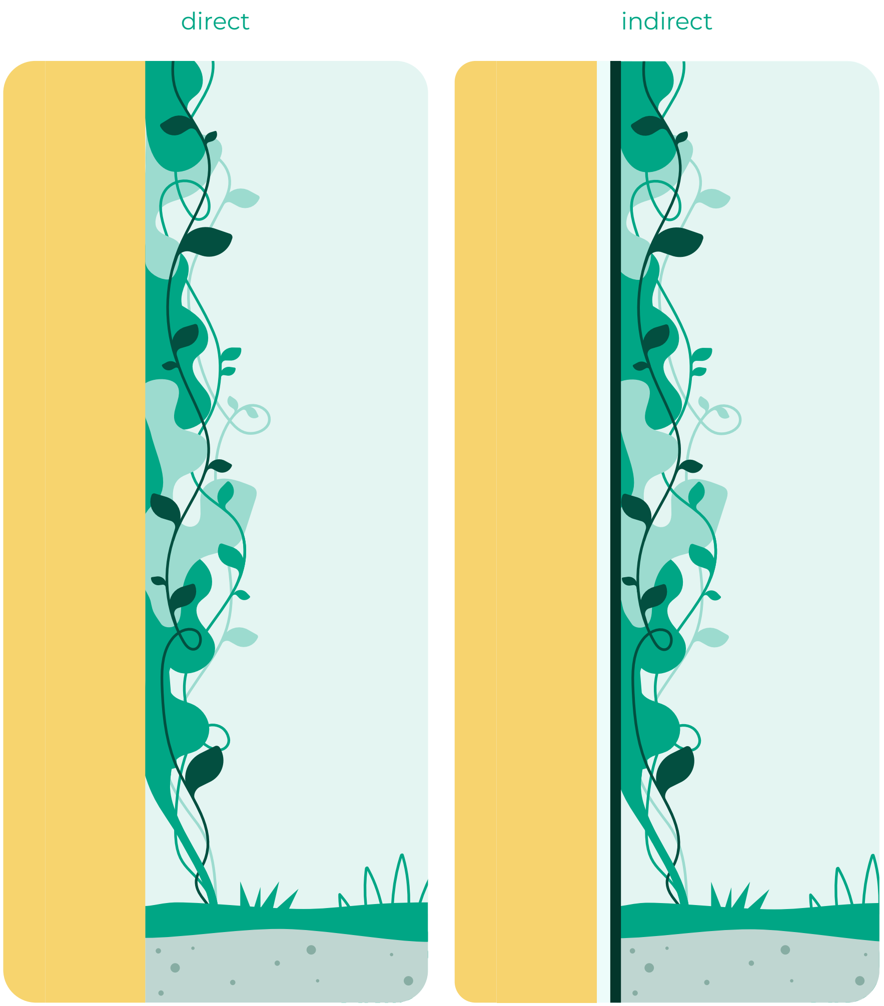
Living walls can be installed **indoors or outdoors**, as freestanding structures or attached to existing walls, and in various sizes. **Regular maintenance** is required, including pruning, replacing individual plants or entire panels, and checking the irrigation system to ensure proper functioning.

application scale: **building**

GREEN FAÇADE



water
SNOB
NBS



A Green Façade is a vertical garden where **climbing plants are planted at the base of a building** and supported by a **structure attached to the façade**. Depending on climatic conditions and plant species, these plants require watering during establishment and **ongoing irrigation** throughout the year. Green Façades contribute to **renaturalisation**, offering a range of environmental functions and benefits.

Climbing green walls, a type of green wall, are key components of **urban renaturalisation**. They deliver a range of ecosystem services after building's construction, including **aesthetic enhancement**, **mitigation of the urban heat island effect**, and **promotion of biodiversity**. Vertical vegetation protects building walls from direct solar radiation, while the process of evapotranspiration releases water vapour, further enhancing the **cooling effect** in the surrounding area. Additionally, green walls **improve air quality** by helping to remediate pollution. One of the key advantages is their **space efficiency**, as they offer extensive vertical greenery without occupying much ground space—a valuable feature in densely built urban environments.

These green walls rely on the use of climbing plants that grow up the vertical face of the host wall, either **anchored directly to the wall surface** or with the aid of a **support system** made of nets, cables or trellises. The plant cladding can be regarded as an additional cladding to the wall, not completely integrated into it. Green façades have their growth medium only at the base, either in a container or a ground bed. Regular irrigation may be required depending on the climatic conditions and plants specie. The selection of plants is limited to **climbing or decumbent species**, which are the only ones that can guarantee the covering of the wall perimeter over time without the need for plant foliage to be close to the root systems.

For green façades, **maintenance** is generally **minimal** to pruning once or twice a year or depending on the growth rate of the plant species and the space available and periodic checks of the irrigation system.

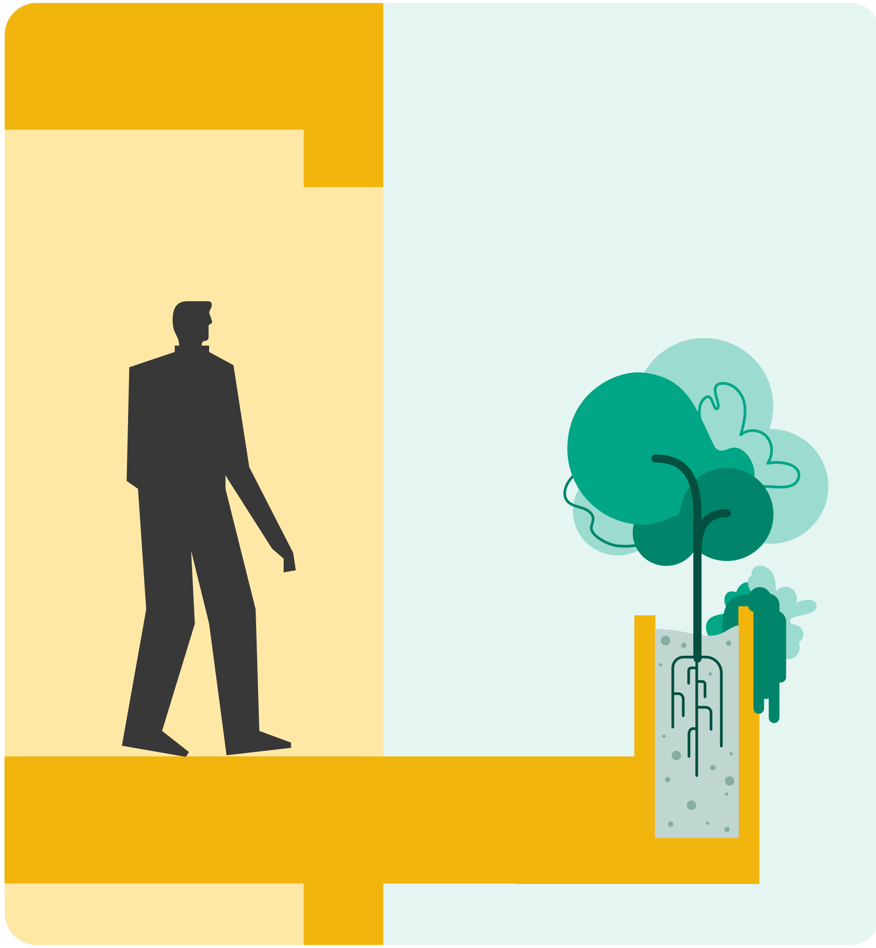
application scale:
building

GREEN BALCONY

water
SNOB
NBS

water quantity | water quality | water provision | urban biodiversity

aesthetic | cooling | recreation

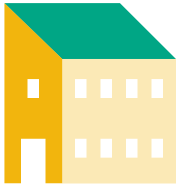


The greenery of balconies refers to the **greening of a building** through the strategic placement of vegetation on its balconies to provide **shading** and **cooling**. This greeing can be achieved with various types of plants, such as **bushes**, **small trees**, **climbing plants**, or **hanging plants**. These plants require temporary watering during establishment and **regular irrigation** throughout the seasons to thrive.

The greenery on balconies and terraces is often valued primarily for its **aesthetic appeal**, influenced by plant selection and an understanding of flowering cycles. However, the greenery of balconies and terraces, even in limited spaces, can produce interesting effects in terms of **mitigating summer temperatures** inside the premises and representing a **filter against the entry of atmospheric pollutants**. Additionally, it creates microhabitats for insects and birds fostering **urban biodiversity**, while also serving as a **sound barrier** by absorbing and deflecting noise from urban activities. By making efficient use of available vertical and horizontal surfaces, green balconies and terraces not only enhance the visual appeal of urban spaces but also contribute to environmental sustainability.

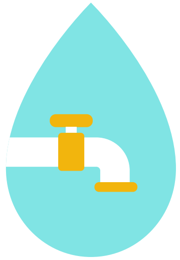
Balconies and terraces are in fact able to host a **wide variety of plant species**, such as shrubby, trailing or climbing plant species that can produce an effective protective screen from direct sunlight, especially for south-facing areas. For the shielding effect against solar radiation and, at the same time, air pollution to be effective, it is essential that the selected plants develop a large leaf area. Perennial and deciduous leaf species provide the most significant results.

Trees and climbing plants often require **structural supports**, and the weight load on terraces and balconies must be carefully assessed. This includes considering both the **weight of the pots** and the **vegetation**, especially when fully saturated with **water**. Given that water requirements can be considerable, it is beneficial to establish irrigation systems that, where possible, utilise rainwater or greywater.

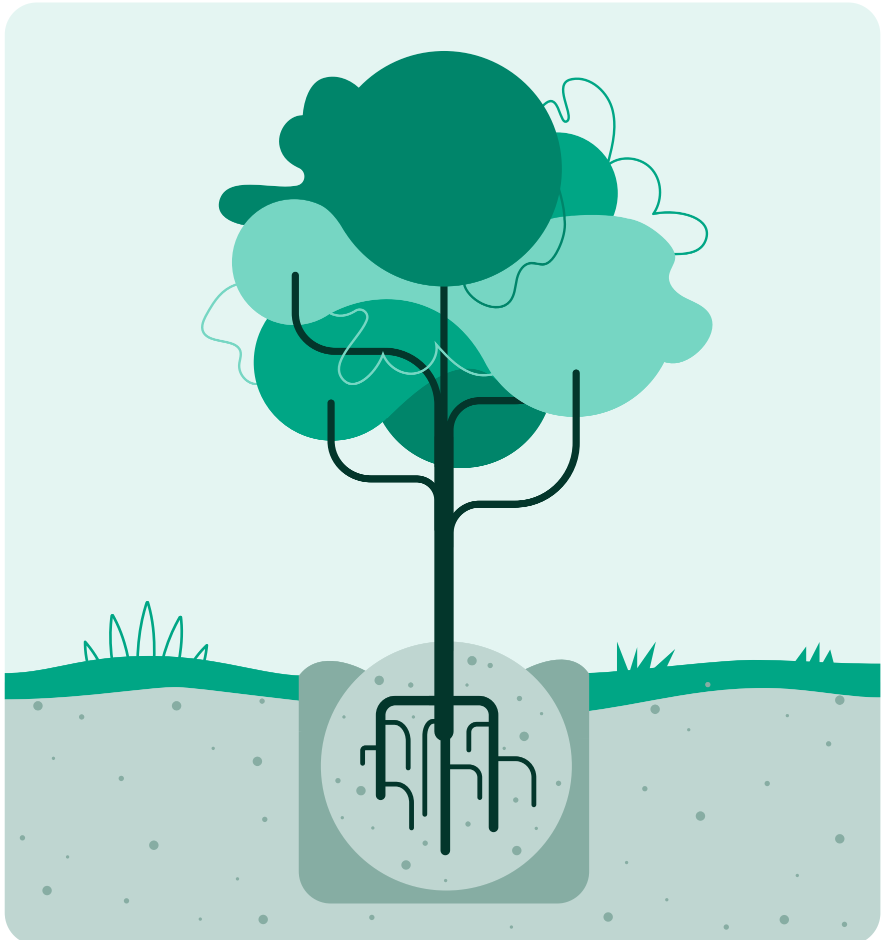


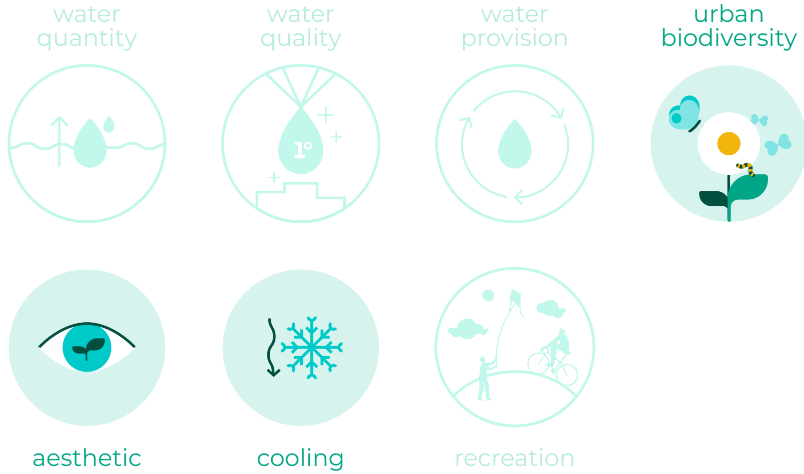
application scale:
building

URBAN TREES



water
SNOB
NBS





Urban trees are typically defined as those **planted along city streets** and in **public squares**, but they can also be arranged **individually**, in **rows**, or within **wooded areas**, contributing significantly to both visual appeal and environmental benefits. During their establishment phase, they require **temporary watering**, while irrigation may be necessary in extreme weather conditions.

Urban trees planted **along city streets**, including roads in residential neighbourhoods, major traffic arteries, and public squares play a very important role from an **aesthetic** point of view, and also provide a number of ecosystem services in terms of **air pollution remediation**, **heat island mitigation** and **biodiversity** enhancement.

The planting of trees along streets or in squares, when carefully designed, includes **permeable surfaces around the trunks**. These surfaces help regulate rainfall runoff, reducing the risk of flooding during heavy rainfall. Urban trees offer significant **benefits for biodiversity** by creating habitats for birds, insects, and small mammals, as well as providing food for pollinators. They also enhance ecological connectivity by acting as green corridors that link fragmented habitats, allowing species to move and thrive. Tree canopies can produce **air cooling** through shade and process of evapotranspiration releases water vapour, further enhancing the cooling effect in the surrounding area. To maximise these functions, a careful choice of species and varieties is essential. Also important are the positioning of tree individuals, their maintenance and, first and foremost, pruning techniques. Careful design of urban trees is important, to be evaluated on a case-by-case basis, to optimise the benefits.

application scale:
urban

Maintenance of urban trees is generally **minimal**, mainly consisting of regular pruning to remove dead or diseased branches, maintain the tree's structure, and prevent hazards like falling limbs. Typically, they only require irrigation during their first few years, with additional watering considered only in extreme weather conditions.

GREEN PERGOLA

water
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NBS

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water quantity

water quality

water provision

urban biodiversity

aesthetic

cooling

recreation

Green pergolas are **pathways** featuring **supporting structures** designed for **shrubs** and **climbing plants** that create **shaded areas**. These areas provide protection from excessive sunlight and, to some extent, from car exhaust and noise. The plants require watering during their establishment phase and may need **regular irrigation** throughout the year, depending on climatic conditions.

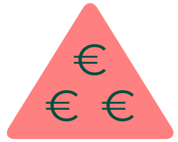
Pergolas offer an interesting alternative, particularly for streets and open spaces that are very sunny in hot weather and experience intense pedestrian traffic, where planting may not be feasible due to technical or management constraints. They help **mitigate the urban heat island effect** by providing shade and reducing direct sunlight. Additionally, pergolas **support urban biodiversity** by providing habitats for insects and birds, while also **improving air quality** and enhancing the **aesthetic value** of the urban landscape.

Pergolas can be **free-standing** or **attached to a building wall** and are typically constructed from wood or simple or wrought iron. The placement of these structures requires the installation of plinths at predetermined (though flexible) distances at street or pedestrian level. Vegetation can be planted directly **in the ground or in containers** made from masonry or synthetic materials. Structures may be:

— **self-supporting**: the structure is supported or anchored to the ground or floor by uprights supporting beams;

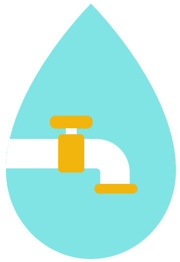
— **semi-supporting**: the structure is leaning against a wall on one or more sides; at these points the beams are fixed directly into the wall, while on the other sides they are supported by uprights.

During the growing season, the plants require water from an irrigation system, with additional watering needed throughout the year depending on climatic conditions. The installation of the structures is relatively simple, but particular attention must be paid to the design and implementation of the irrigation system, which must include numerous connection points. It must be ensured that the pergola is stable and robust enough to withstand the action of the wind and the weight of the covering (climbing plants).

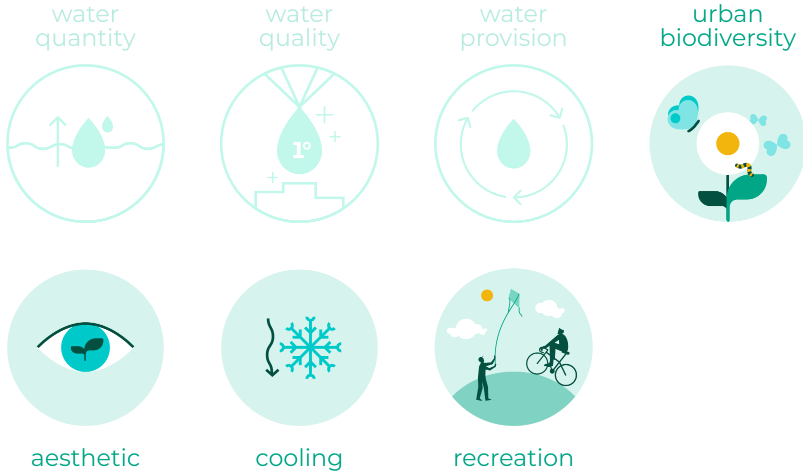


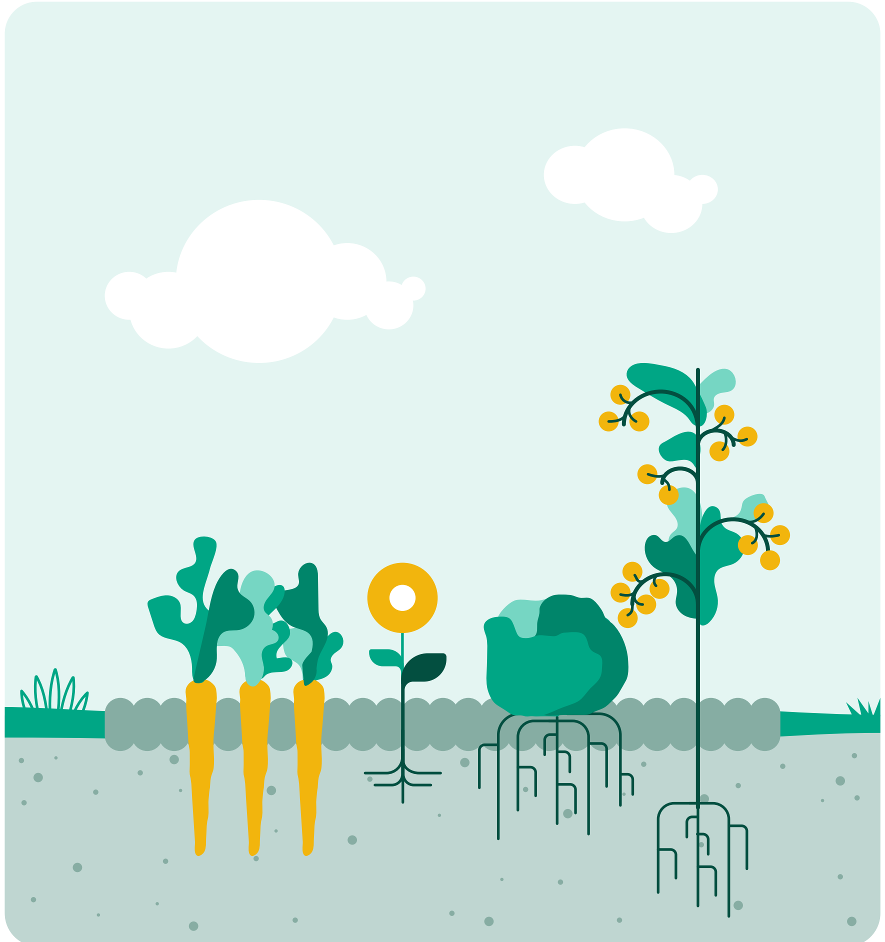
application scale:
urban

URBAN VEGETABLE GARDEN



water SNOB NBS





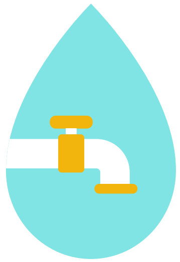
Urban vegetable gardens consist of abandoned or unused green areas in public or private spaces that are transformed into **shared gardens managed by citizens** or local organisations **for growing vegetables, herbs and flowers**. Urban vegetable gardens help promote environmental sustainability, food self-sufficiency and a **sense of community**. Urban gardens need **regular irrigation** through the year.

Urban horticulture plays a sociocultural, environmental, recreational, educational and therapeutic role. Urban vegetable gardens contribute to **biodiversity** by creating habitats, supporting pollinators, increasing **plant diversity**, improving **soil health**, and acting as **green networks within cities**. They offer a practical and impactful way to enhance urban ecosystems. At the same time, urban gardens are an agricultural activity with potentially high environmental impacts due to the significant inputs required to sustain production. Therefore, particular care must be taken to preserve soil fertility, manage water resources efficiently, protect crops from environmental factors and pathogens, and minimise the use of chemicals.

Abandoned or unused green areas in public or private spaces appear to be the most suitable for enhancing the multifunctional role of urban gardens. Urban vegetable garden spaces can be bought, rented or leased, or the garden can be included in a public park project. Horticulture in urban areas can be practised on or above ground, including flat roofs, one of the most numerous spaces available within cities. Urban vegetable garden characterised by **above-ground systems** are becoming increasingly popular in urban areas. These systems can be divided into two main categories, according to the management of excess water resulting from irrigation: a **'closed-loop'** system refers to a setup where drained water is reused for subsequent irrigation (more water-efficient) whereas an '**open-loop'** system discards the drained water (cheaper and easier to manage).

application scale:
urban

URBAN PARK / GREEN AREA



water
SNOB
NBS

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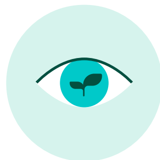
water quantity

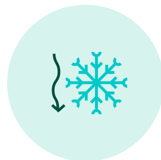
water quality

water provision

urban biodiversity



aesthetic



cooling

recreation

Urban parks or green areas are portions of the urban territory dedicated to **green spaces available to citizens for recreation and relax**, characterised by the presence of lawns, trees, bushes and ornamental plants, and may include facilities such as footpaths, cycle paths, benches and more. They require watering for plant establishment and generally need **regular irrigation** throughout the year.

Urban parks or green areas are public green spaces where **diverse plant structures** coexist alongside human-designed land management features to ensure maximum attractiveness and usability. They can serve as a strategy for **revitalising underutilised spaces**, transforming them into valuable resources that enhance both the **environmental quality of urban areas** and the physical, mental, and social **well-being of residents**.

application scale:
urban

By integrating **naturalistic solutions** with a focus on **social engagement**, urban parks can become focal points for neighbourhood life, promoting both **community interaction** and **environmental sustainability**. These parks vary in size, from small green spaces nestled between buildings (pocket parks) to expansive peri-urban parks located near city centres.

Depending on their scale, urban parks **influence local climate conditions** by creating temperature gradients between built-up and vegetated areas. This effect generates **airflows** that help **remove heat and atmospheric pollutants** from the city while **stabilising humidity levels**. Parks also play a crucial role in supporting biodiversity by providing habitats for wildlife, fostering plant diversity, and forming **green corridors** that connect fragmented urban ecosystems. Furthermore, in areas with a rougher morphology, the presence of parks can have a **function in intercepting precipitation** and, in the presence of significant meteorological events, mitigating surface runoff.

The maintenance of urban parks includes **regular mowing**, **pruning**, **pest control**, and **infrastructure upkeep** to ensure safety, functionality, and aesthetic appeal. Depending on the park's type, location, climatic conditions, and plant selection, irrigation may be necessary to sustain vegetation.

ARTIFICIAL POND / WETLAND

water
SNOB
NBS

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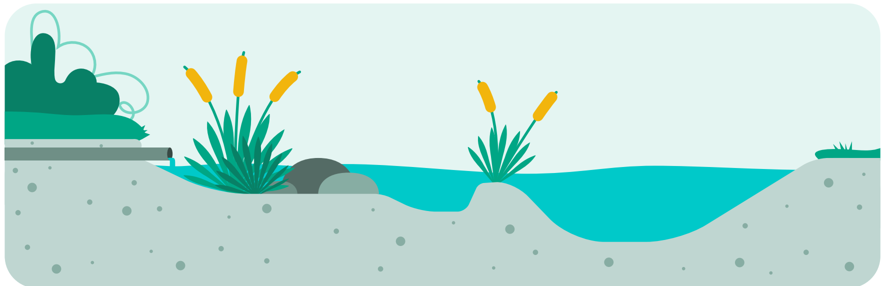

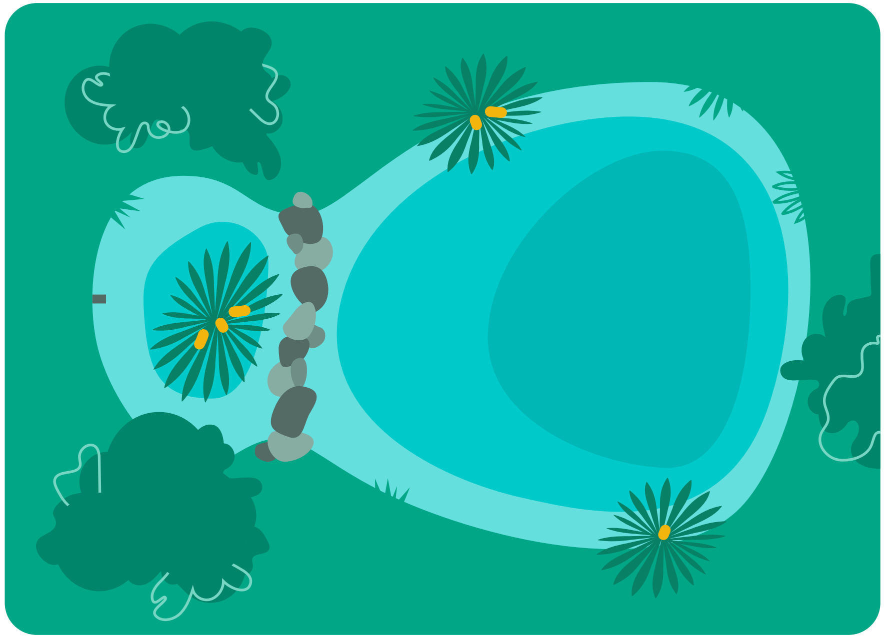

water quantity | water quality | water provision | urban biodiversity

aesthetic | cooling | recreation

Ponds and wetlands are **basins with a permanent sheet of water** supplied with water from the aqueduct or wells. They can have areas at **different depths**, so that **different plant species** can be planted, and biodiversity can be increased. Typically designed for **new development areas**, ponds and wetlands can be easily integrated into usable public spaces, such as parks.

Ponds and wetlands are basins that contain a **permanent water layer**, sustained through regular replenishment from the aqueduct or nearby wells. The term “ponds” typically refers to areas where deeper open water predominates, while “wetlands” describe shallower, vegetated areas. These features enhance urban environments by providing **recreational spaces** for activities such as walking and birdwatching, improving **aesthetic appeal**, offering **cooling effects** through evaporation, and supporting **urban biodiversity** by creating habitats for plants, insects, birds, and aquatic life.

The design should provide for **natural shapes**, adaptable to the specific topography and soil conditions on the site, as well as its orientation, appearance and proximity to other landscape features, buildings, etc. In the case of very extensive ponds or wetlands, **they can be divided into several sub-basins** to facilitate management and maintenance operations. It is advisable to provide for wetland areas **different depths** to maximise biodiversity, by planting different plant species, with **helophytes** in shallow areas (maximum 40 cm in dry periods) and **hydrophytes** in deeper areas (typically 1 m). It is important, especially for wetlands that have a shallower water depth, to **estimate a water balance** in order to verify that the inputs are sufficient to compensate for evapotranspiration, so as to prevent the risk of periods without water or with excessively stagnant water, which can encourage the proliferation of insects. Maintenance involves **regular cleaning**, **water quality monitoring**, **vegetation management**, and **infrastructure upkeep** to ensure functionality, aesthetic appeal, and ecological health.

application scale:
urban

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WATER SMART NBS

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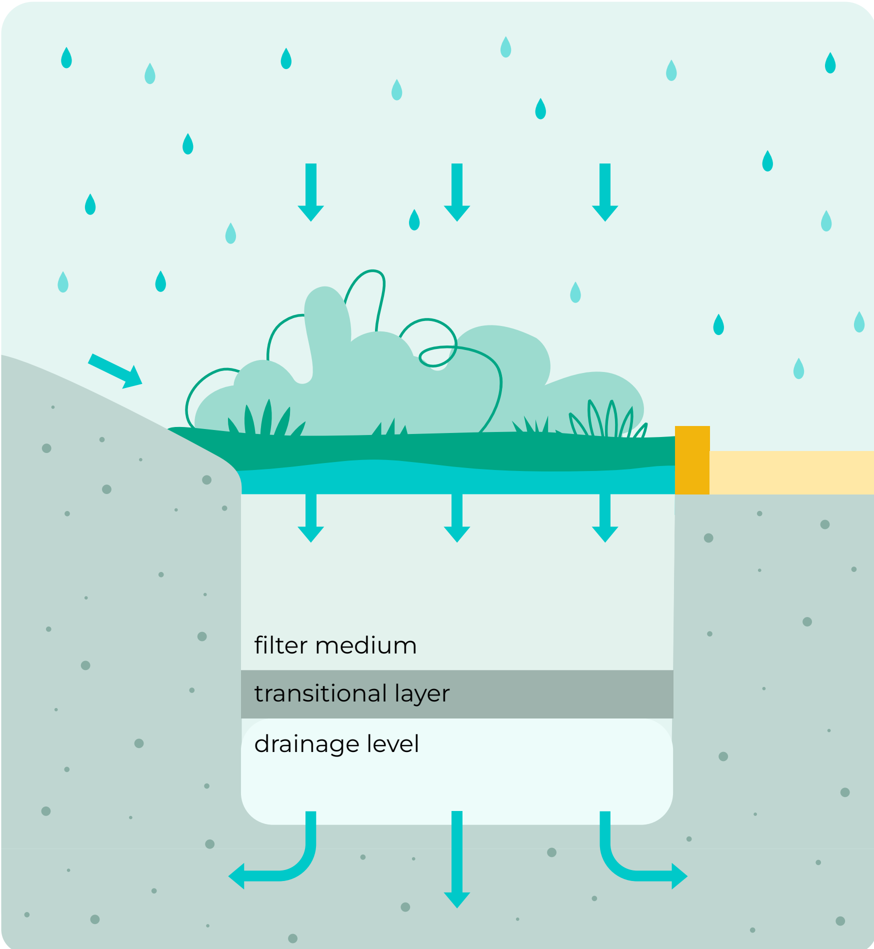
BIORE-TENTION AREA

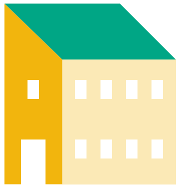


Bioretention areas are slight depressions in the soil covered with greenery, aimed at **collecting and treating rainwater** drained from surrounding impermeable surfaces **by filtering and removing pollutants**. Treated rainwater can either infiltrate in the soil below or be discharged in the sewer system. In addition to managing stormwater effectively, bioretention areas **enhance urban greenery and support biodiversity**.

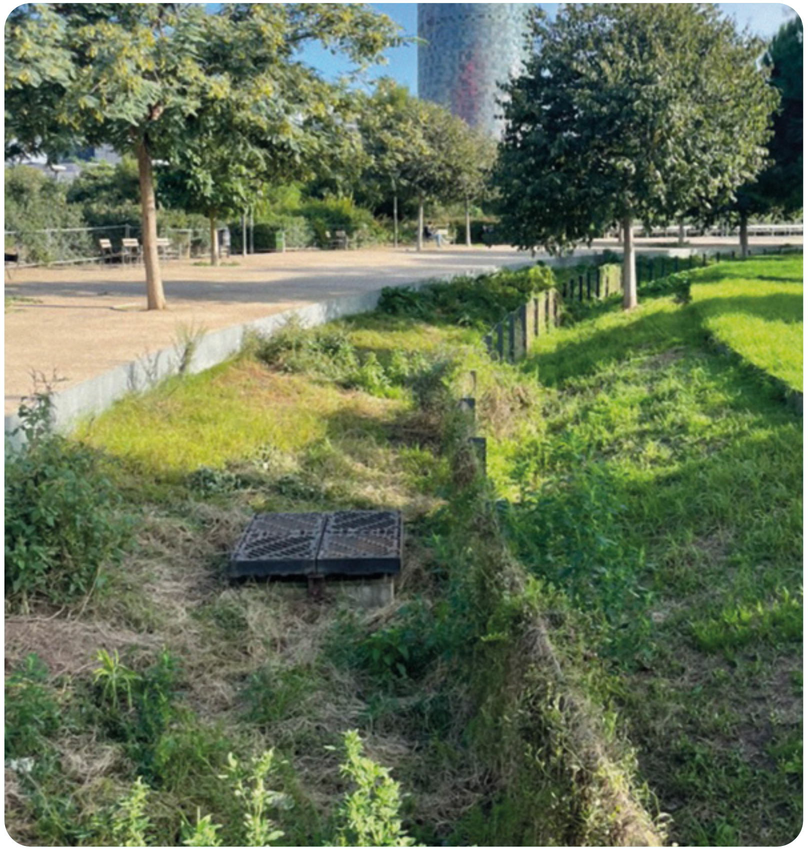
Bioretention areas allow **completely natural filtering** and **treatment of the water** collected with excellent removal of the main pollutants carried by rainwater runoff. Moreover, bioretention areas also have a beneficial effect in terms of **reducing hydraulic risk**, **increasing biodiversity**, as well as being used as an element of **urban design**. They contribute to **cooling** by promoting **evapotranspiration** from plants and moist soil, reducing ambient temperatures in urban environments.

Runoff from surrounding impermeable surfaces, such as roads, parking lots, and rooftops is conveyed via surface runoff to the vegetated bioretention area. The grass-covered strip performs a **filtering action** of the coarser material and slows down the runoff velocity. In the forebay area, there is a **temporary accumulation** and further deposition of transported material. The **layer of organic material** performs an **initial filtration** of the rainwater and encourages the growth of microorganisms that provide degradation of the transported organic matter. The **vegetative soil layer** acts as a **filtration system**; the clay particles in the soil provide sites for the adsorption of pollutants. Vegetation ensures soil stability and participates in the retention of pollutants. The **bioretention area** can be contained by a **layer of geotextile** and allow the water to infiltrate into the underlying soil, or **it can be sealed** and the water discharged into the sewer via a drainage pipe.

Maintenance includes **regular removal of debris**, **weeding**, **mulching**, **inspecting and cleaning** inflow/outflow structures, ensuring proper **plant health**, and **monitoring soil permeability**.



application scale:
building



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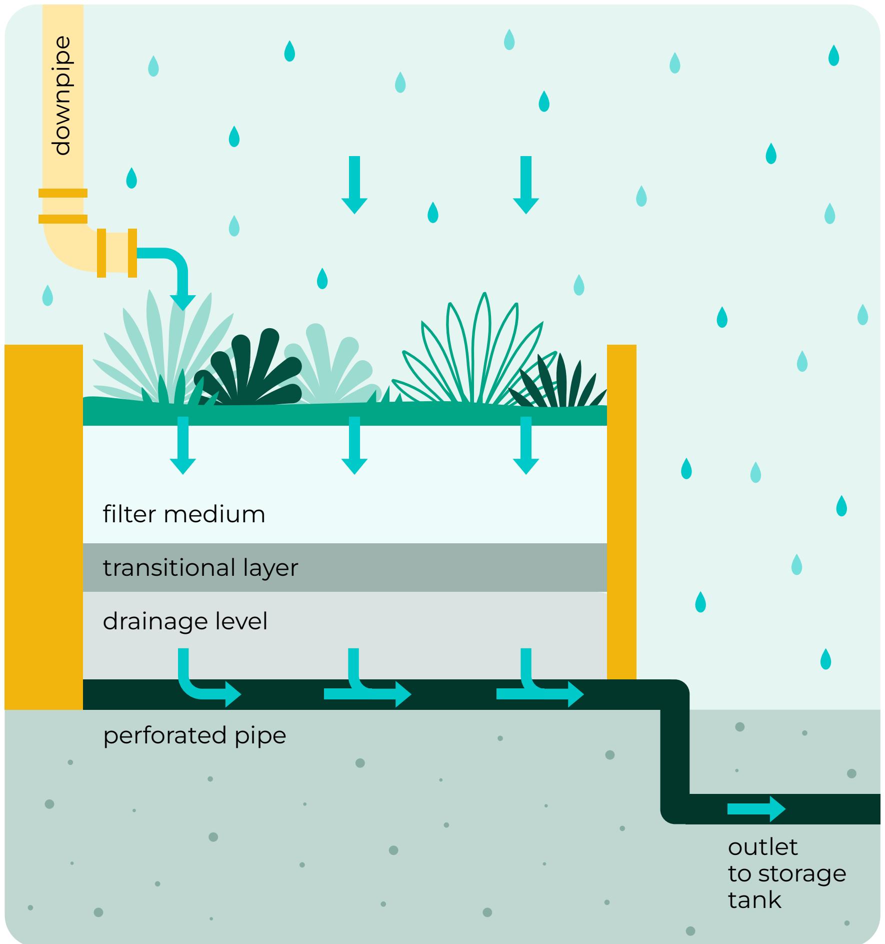
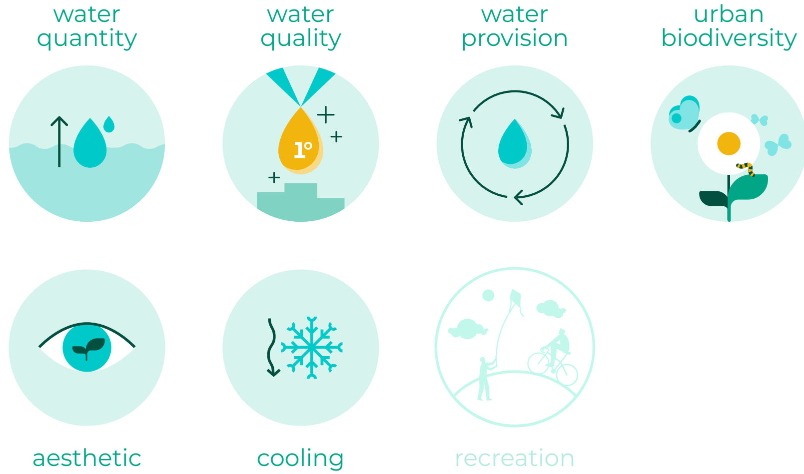
RAIN GARDEN



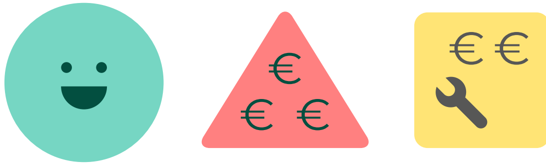


Rain gardens are slight depressions in the soil filled with vegetation, designed to **collect and treat rainwater** drained from surrounding impermeable surfaces by filtering and removing pollutants. The treated water is then directed into a connected **storage tank**, where it can be **collected and reused** for purposes like **irrigation or non-potable water needs** reducing reliance on municipal water supplies.

Rain gardens are smaller bioretention areas serving a single dwelling or building, with the aim of **harvesting treated rainwater for reuse**. Rain gardens usually **receive runoff from building roofs via downpipes**, and they allow completely **natural filtering and treatment of the water** collected with excellent removal of the main pollutants carried by rainwater runoff. Moreover, rain gardens also have a beneficial effect in terms of **reducing hydraulic risk**, **increasing biodiversity**, as well as being used as an **element of urban design**. They contribute to **cooling** by promoting **evapotranspiration** from plants and moist soil, reducing ambient temperatures.

The grass-covered strip performs a **filtering action** of the coarser material and slows down the runoff velocity. In the forebay area, if present, there is a temporary accumulation and further deposition of transported material. The layer of organic material performs an initial filtration of the rainwater and encourages the growth of **microorganisms** that provide degradation of the transported organic matter. The vegetative soil layer acts as a filtration system; the clay particles in the soil provide sites for the **adsorption of pollutants**. Vegetation ensures **soil stability** and participates in the **retention of pollutants**. Rain gardens are **sealed**, at the bottom there is a drainage pipe to channel the filtered water to the **storage tank**. The collected water can then be **used for non-potable purposes**, such as irrigation, filling toilet cisterns, etc.

Maintenance includes **regular debris removal**, **ensuring plant health**, **inspecting and cleaning** inflow/outflow structures and storage tanks, and **monitoring soil permeability**.



application scale:
urban

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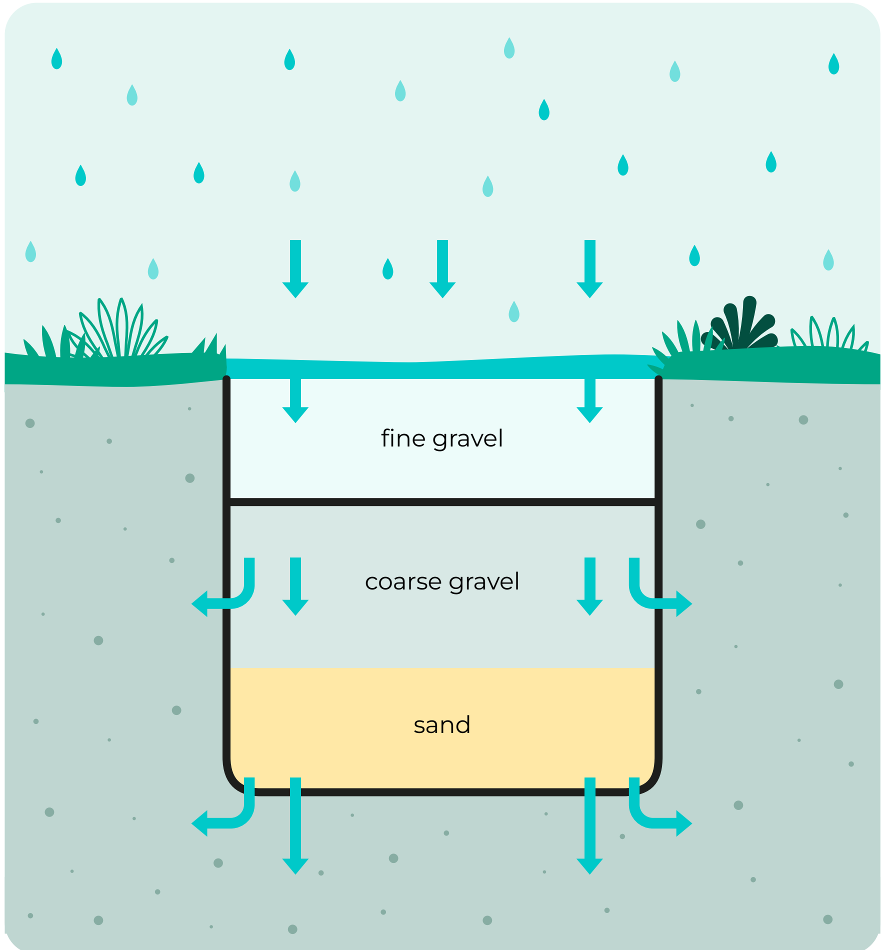
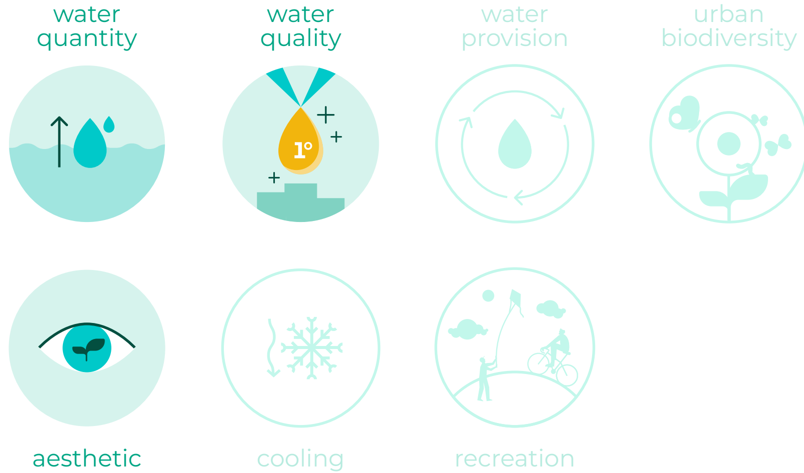
INFILTRA-TION TRENCH

water SMART NBS





Infiltrating trenches are **excavated structures**, filled with **permeable gravelly and sandy materials**, designed to facilitate runoff infiltration through their top surface and filtration into the subsoil through their sides and bottom. These systems effectively **reduce surface runoff**, **minimize flood risks**, and **ease pressure on urban drainage**. They also improve water quality by **filtering pollutants**.

Infiltration trenches are designed to **facilitate the absorption of runoff** through their top surface, allowing filtered water to percolate into the subsoil through the sides and bottom. They effectively **remove a wide range of pollutants** from rainwater through **absorption**, **precipitation**, **filtration**, and **chemical and bacterial degradation mechanisms**.

These trenches serve as **effective stormwater management solutions** by **reducing surface runoff**, **minimizing flood risks**, and **easing the burden on urban drainage systems**. By filtering sediments and pollutants, they also **improve water quality** before the water reaches natural bodies or groundwater reserves. Additionally, when integrated into urban landscapes, **infiltration trenches can provide aesthetic benefits**. Incorporating vegetation, such as grasses or native plants, around the trenches allows them to integrate seamlessly into parks, green spaces, or streetscapes.

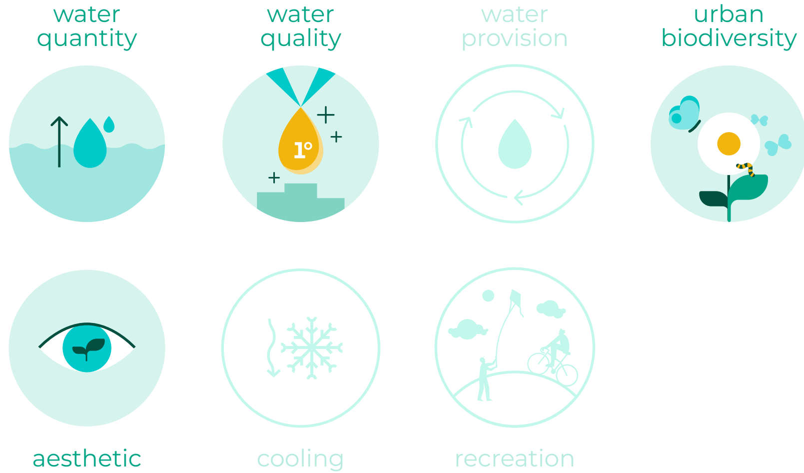
Structurally, infiltration trenches consist of excavated trenches filled with **highly permeable natural gravel** and sandy inert material. Infiltrated water is transported along the trench either through the backfill material or via a drainage pipe placed at the trench's base. To prevent clogging, the trench is completely covered with layers of non-woven fabric. The trench is sized to ensure complete drainage of filtered water into the underlying soil within 12 to 24 hours after rainfall, depending on site-specific soil conditions. This process also **supports groundwater recharge** and helps maintain the local water balance.

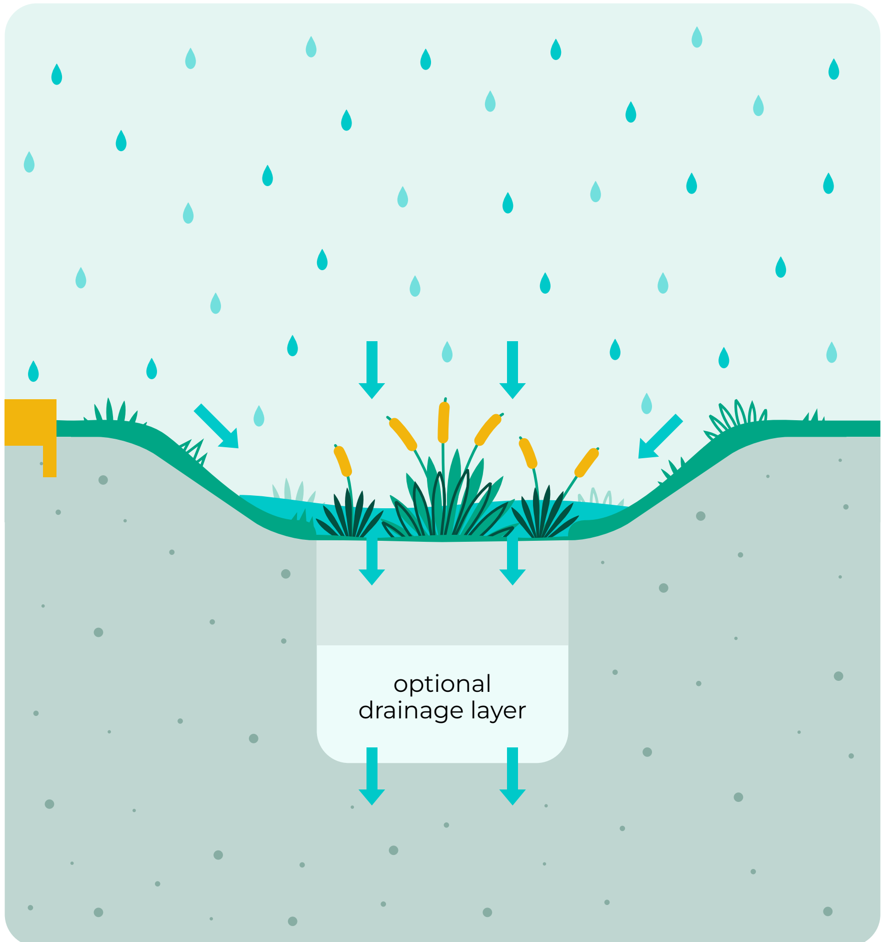
Maintenance involves **periodic removal of debris** and **inspection for clogging** to ensure continued functionality and **aesthetic appeal**.

application scale:
urban

VEGETATED SWALE

water SMART NBS





Vegetated swales are designed to **manage a quantity of runoff from a large impermeable area** as car parks or roads. They absorb, store and convey surface water runoff, as well as **remove pollutants and sediment** as the water flows through the vegetation and soil layer. The choice of vegetation is variable, but rooted native plants are common and preferred.

Vegetated swales can be wet or dry and appear as **open, shallow, trapezoidal or parabolic-shaped linear swales**. The banks are grassed or vegetated with **flood- and erosion-resistant plants**. Within the vegetated swales, water runoff is attenuated, causing it to flow at a lower, controlled speed. It functions primarily as a **filtering medium** and **removes pollutants** by capturing the flow of rainwater. **Dry swales** primarily facilitate infiltration and conveyance, while **wet swales** function as permanent water features, offering enhanced treatment and ecological benefits. Their wide application is a significant contribution to **local stormwater management and control**.

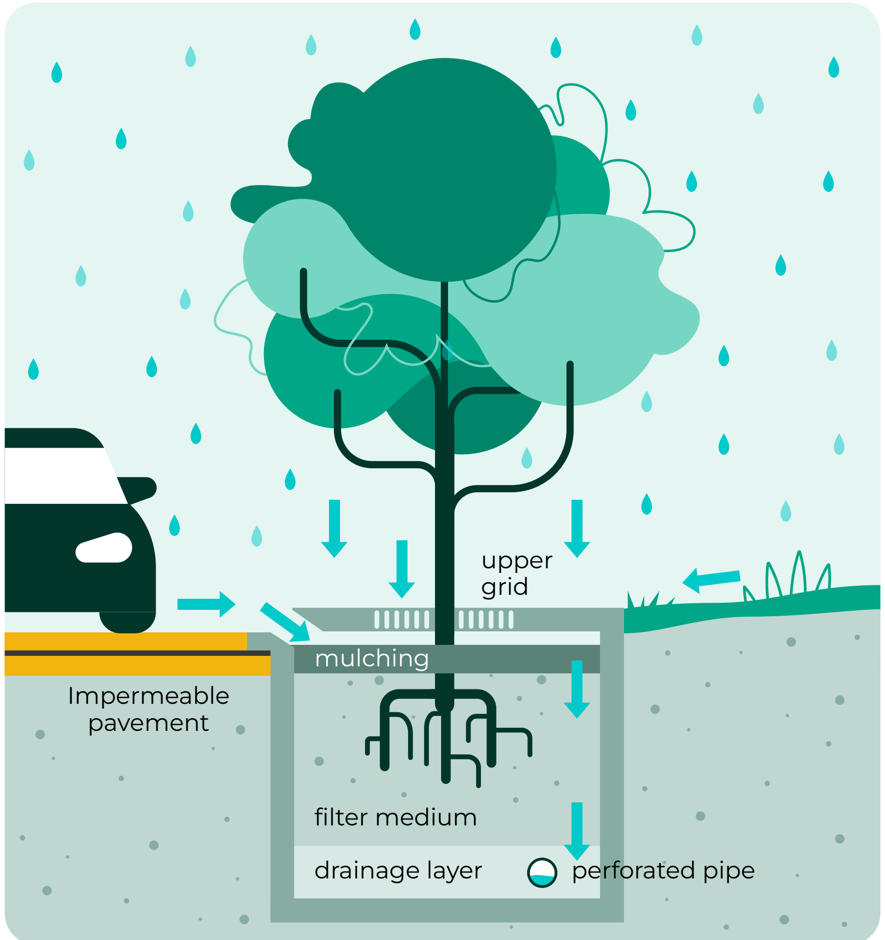
The water flowing through it along its length moves slowly through the grass, which slows and filters surface water flows, allowing some of the water to infiltrate into the subsoil and exerting a lamination effect with a consequent reduction in water velocity. Water that is temporarily stored in the swale is eventually released into a storage or drainage system.

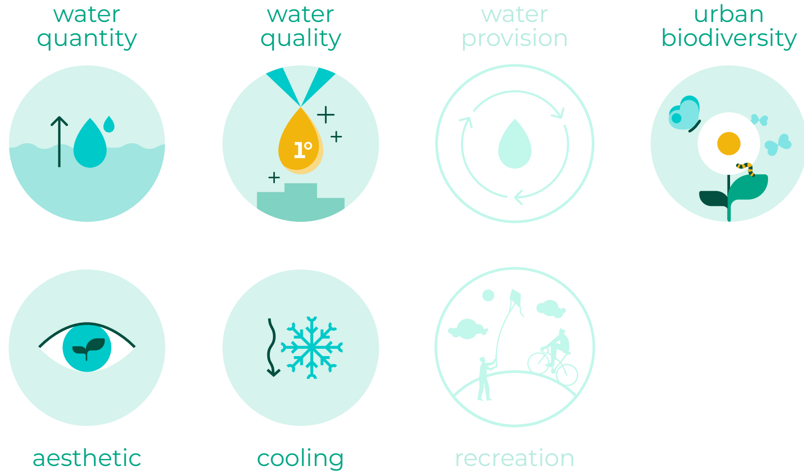
Vegetated swales can replace classic sewer pipes, enabling rainwater to be conveyed without the use of storm drains, kerbs or manholes. They are typically used to **direct rainwater to other SuDS** (**Sustainable Drainage Systems**) components such as bioretention areas, detention basins, or ponds and wetlands. However, an overflow pipe is typically included to manage intense rain events.

Maintenance of vegetated swales includes **regular removal of debris**, **mowing or pruning vegetation**, **inspecting for erosion**, and **ensuring proper water flow**.

application scale:
urban

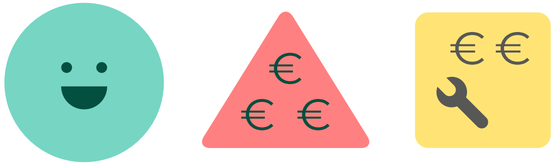
TREE BOXES





Tree filter boxes are **compact biofiltration systems** made up of a **box**, **soil**, and a **tree or plant**. They naturally filter stormwater, **removing pollutants** as water passes through the soil and root zone. These systems combine **stormwater management** to the benefits of trees in urban environments, such as **reducing heat islands**, **improving air quality**, **enhancing aesthetics**, and **supporting biodiversity**.

Tree boxes consist of **underground boxes** made of, for example, precast concrete structures, and can be closed or open-bottomed chambers depending on whether or not the water can infiltrate the soil. The soil inside is composed of a **special mixture of substrates and filter materials** specially formulated to filter the water it receives. Tree or shrub species are grafted into the soil, preferably indigenous, that can withstand stressful conditions, resulting from alternating periods of rainfall and thus soil wetting, and periods of drought. The filling medium must be both **capable of draining the rainwater** and guarantee a **sufficient supply of nutrients** to the tree.



application scale:
urban

The tree box filter system allows the **removal of pollutants in the rainwater**, filtering it before release into the sewer system or underground. These vegetated filter systems are designed to drain the accumulated water, after the weather event, in no more than 48 hours, to avoid compromising the health of the tree. The choice of trees depends on both technical (adaptability to dry/wet conditions) and aesthetic/ landscape/fruitive components and must always be supported by a landscape architect or agronomist.

Tree filter boxes offer multiple advantages such as **reducing urban heat islands**, **improving air quality**, and **enhancing the aesthetic appeal of urban spaces**. They also support **biodiversity** and contribute to greener, more sustainable cities by integrating nature-based solutions into urban infrastructure.

Much of the maintenance of these solutions concerns the **state of health of the tree**, so it does not differ from **ordinary maintenance work** for urban trees.

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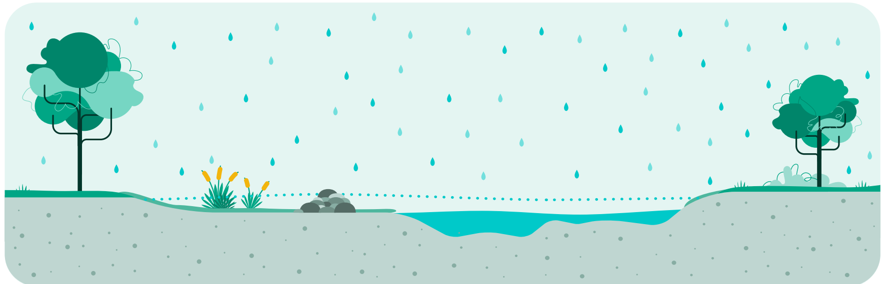
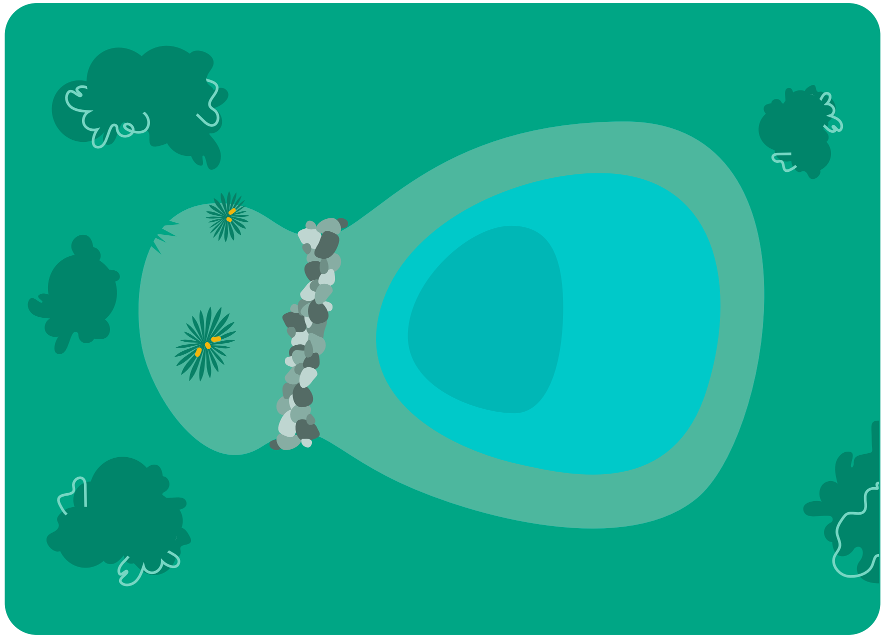
DETENTION BASIN

water SMART NBS





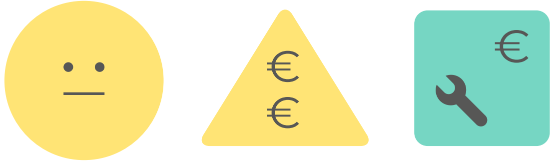
Detention basins are **slightly depressed areas** in the ground or pavement designed to **temporarily hold and regulate the release of stormwater runoff**. These basins, typically featuring a permeable bottom, **remain dry most of the time** and may or may not be vegetated. Used for **flood mitigation**, **erosion control**, and **water quality management**, they help regulate water flow during and after rainfall events.

The purpose of detention basins is to **temporarily receive and retain rainwater during and after storm events**, gradually releasing it over 24–48 hours through filtration systems that prevent debris from entering downstream waterways. They serve both to **control surface water runoff** and to **allow sedimentation of suspended solids** in the first flush, requiring careful sizing to fulfil both functions. Essentially, they act as **stormwater detention tanks**, integrated into the urban fabric with a multifunctional approach.

When incorporated into urban environments, detention basins provide additional benefits such as **recreational spaces**, **aesthetic enhancement**, and **habitat creation for biodiversity**. Typically unsealed to promote natural infiltration, they are only waterproofed in areas with high groundwater vulnerability. Their runoff treatment capacity can be enhanced by adding small basins or wetlands at their outlets, which further **filter pollutants** and support **ecological functions**.

Detention basins are often vegetated with grass, but introducing diverse plant species can enhance landscape value, stabilize banks, and support local ecosystems, significantly **increasing biodiversity benefits**. A minimum of 100 mm of soil is required for vegetated basins to ensure both functionality and environmental integration.

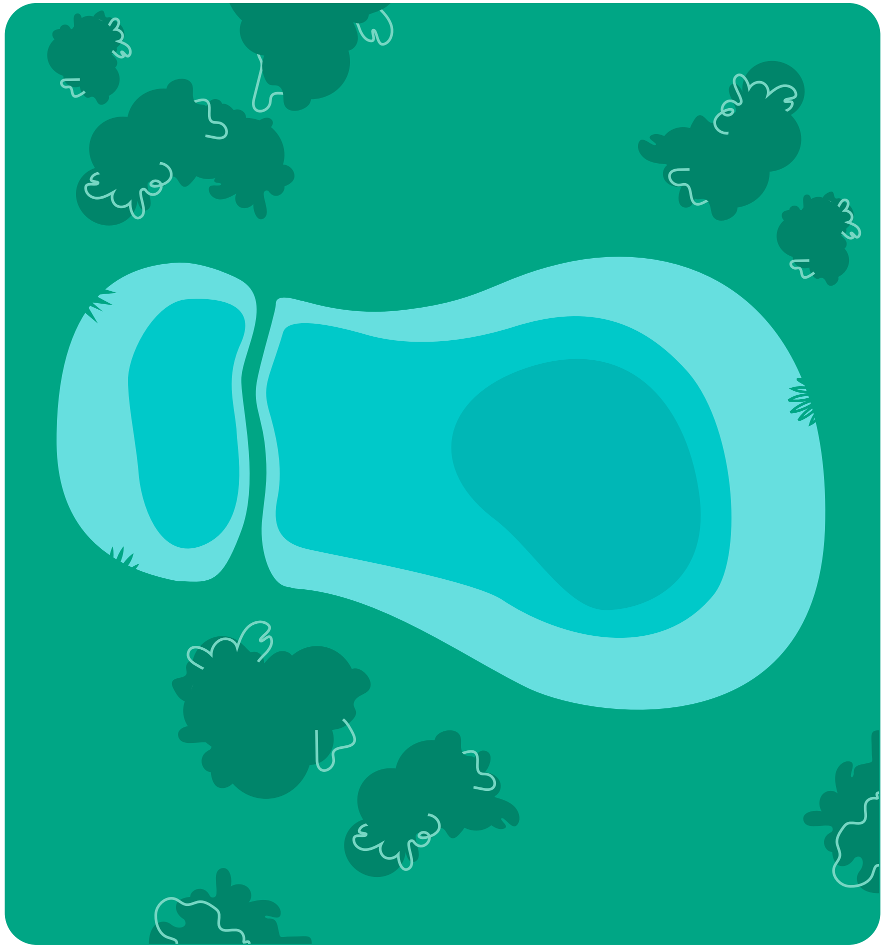
There are two main types: **dry detention basins**, which remain empty between storms, and **wet detention basins**, which maintain a permanent water level—each serving specific urban and ecological needs. These systems not only manage stormwater but also contribute to greener, more resilient cities by seamlessly integrating infrastructure with nature.



application scale:
urban

STORAGE POND

water SMART NBS

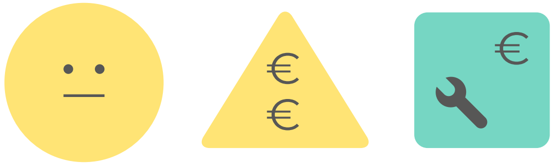


Storage ponds are **deep basins** with a **permanent water level**, designed to **collect and retain rainwater** during rainfall events. By temporarily storing excess water, they help **reduce flood risk** and allow for controlled release or **reuse for non-potable purposes**, such as irrigation. These systems play a key role in **mitigating runoff** and promoting the **sustainable use of water resources**.

Storage ponds are designed to **collect and store runoff water**, primarily to provide a reliable **supply water for other uses**, such as irrigation of public green spaces or street cleaning. They are a versatile and cost-effective solution for addressing both agricultural and urban water challenges while delivering environmental and social benefits.

In urban settings, storage ponds play a crucial role in **urban water management**. They help **mitigate flooding** by temporarily holding excess rainwater during heavy storms, **alleviating pressure on drainage systems** and r**educing infrastructure damage**. By capturing and storing rainwater, they reduce the demand for potable water resources, supporting **sustainable urban water management** and resilience. They also **improve water quality** by allowing sediments and pollutants to settle before reuse or discharge. In addition, storage ponds can be integrated into urban landscapes as multifunctional features, providing **aesthetic value** and **recreational opportunities** for communities. Moreover, storage ponds **enhance urban biodiversity**, creating habitats for aquatic and terrestrial species while **improving green spaces and ecological balance**.

As water loss in storage ponds can occur through infiltration, to mitigate this, they can be constructed in **clay-rich soils**, which naturally reduce permeability, or lined with impermeable membranes in highly permeable areas. Additionally, storage ponds can be strategically designed by leveraging natural slopes, with dams or dikes built at the lowest points to maximize water storage capacity.



application scale:
urban

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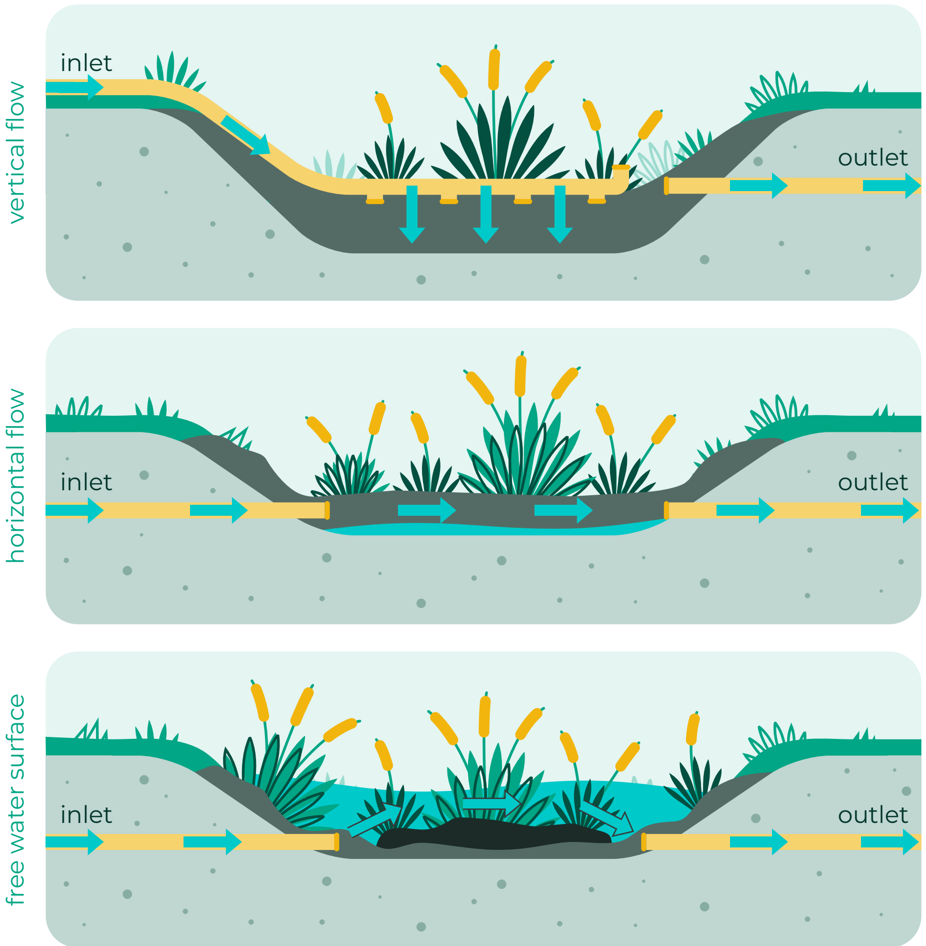
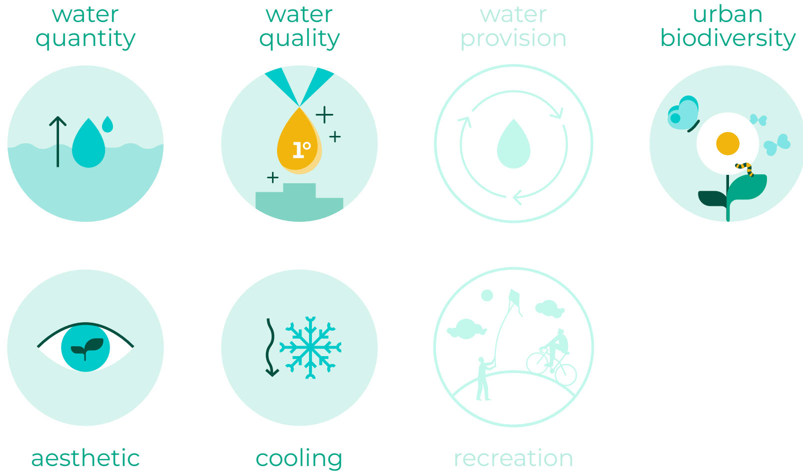
TREATMENT WETLANDS

water SMART NBS





Treatment wetlands are systems designed for the **treatment of wastewater**, they consist of an **excavation filled with inert material** or with free surface water through which wastewater flows, planted with appropriate vegetation. They are particularly valued for their **low operational and maintenance costs**, energy efficiency, and ability to integrate seamlessly into natural landscapes.

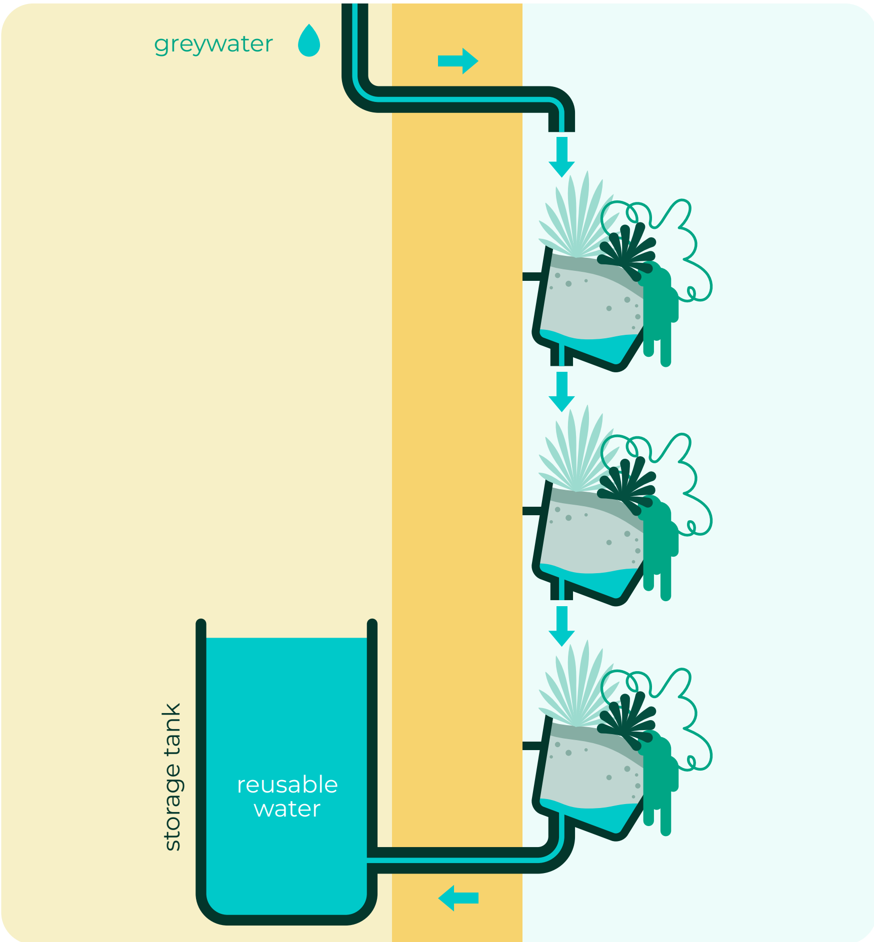
Treatment wetlands are **natural treatment technologies** that efficiently treat many **different types of polluted water**. They mimic the self-treating capacity of natural wetlands by exploiting complex biochemical, physical and physiological treatment processes. **Surface flow wetlands** (or Free Water Surface wetlands) consist of densely vegetated units where water flows above the media bed. **Subsurface flow wetlands**, in contrast, operate below the surface within impermeable tanks filled with inert materials (gravel or sand, without soil), allowing macrophyte roots (typically Phragmites australis) to develop. **Subsurface flow systems** consist of impermeable tanks filled with inert material (gravel or sand, no soil), within which the roots of emerging macrophytes are allowed to develop. **The water flow is constantly below the surface**, ensuring high treatment efficiencies and the absence of odour diffusion.

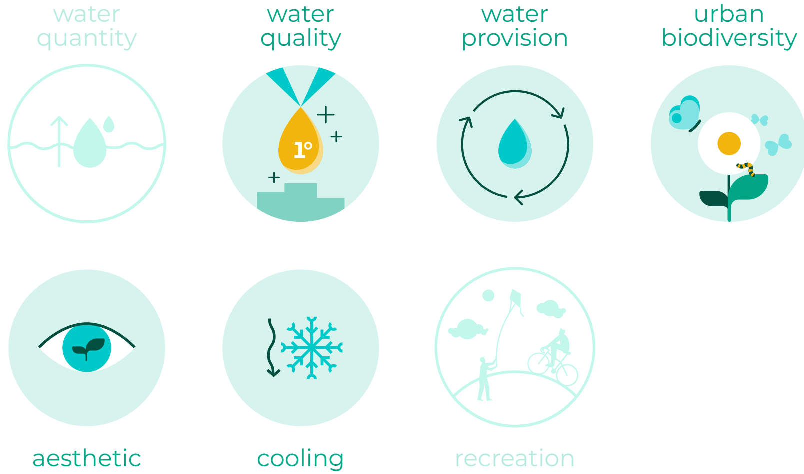
Treatment wetlands are among **the most widely adopted techniques for treating grey water for reuse** and overflows from combined sewers. The shape of treatment wetlands can be chosen on a case-by-case basis, so that the system can be pleasantly inserted as an element that does not compromise the aesthetics of the surrounding landscape.

In urban settings, they can be integrated into urban planning as **green infrastructure**, providing both **water treatment** and additional **ecological and social benefits**. They can be incorporated into parks, green roofs, or along riverbanks, where they not only treat polluted runoff but also **enhance biodiversity** by creating habitats for wildlife. They help **mitigate the urban heat island effect** by introducing vegetation and water bodies into built environments, improving local microclimates.

WATER RECYCLING LIVING WALL

water SMART NBS





Water recycling living walls are green walls repurposed to reproduce **constructed wetland processes to treat and reuse greywater**. They consist of modules composed of rows of pots filled with a suitable medium and vegetated with selected plants. The greywater is treated by **flowing vertically** into the filling medium, passing from one pot to the pot below, and is then collected by gutters.

Water recycling living walls are **green walls designed to mimic constructed wetland processes for greywater treatment and reuse**. Their installation enhances the visual appeal of vertical surfaces, making them particularly suitable for cities by combining water recovery benefits with urban renaturalisation.

These systems consist of **modular units** with rows of pots filled with a **selected medium** and planted with suitable vegetation, which can be chosen to enhance biodiversity. The container elements are typically made from plastic or resin pots, each with its own irrigation and anchoring system for attachment to a building's facade or ornamental walls. Fabric and panel-based systems are not ideal for greywater treatment due to limitations in substrate volume, hygiene, and water recovery. The materials used, the chosen filling medium, and the potential for saturation in planter boxes depend on the maximum weight load allowed by the supporting structure.

In operation, **greywater flows vertically** through the filling medium, passing from one pot to the next, and is **collected by gutters**. The treated water is then conveyed to a **storage tank** for **reuse in non-potable applications** such as irrigation or toilet flushing. Because these systems can be suspended and occupy minimal horizontal space, they are well-suited for cities.

In addition to water recycling, these living walls offer multiple benefits including **heat mitigation**, **building insulation**, increased **urban biodiversity**, and the **remediation of air and water pollutants**.

application scale:
building

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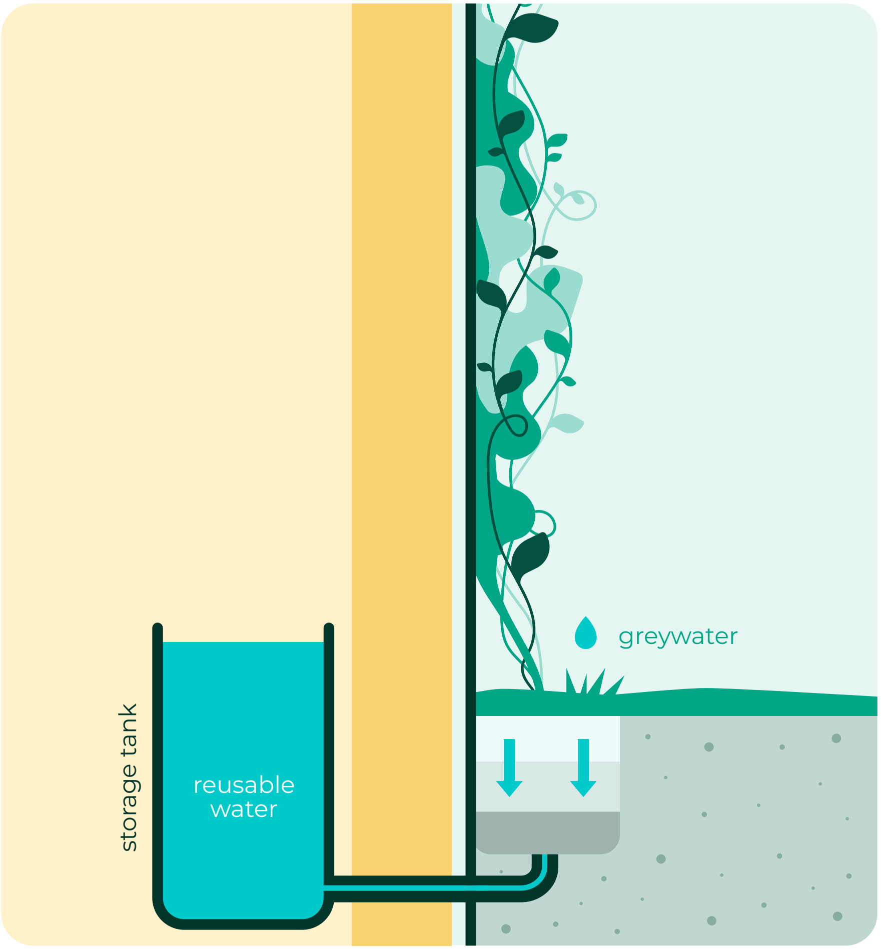
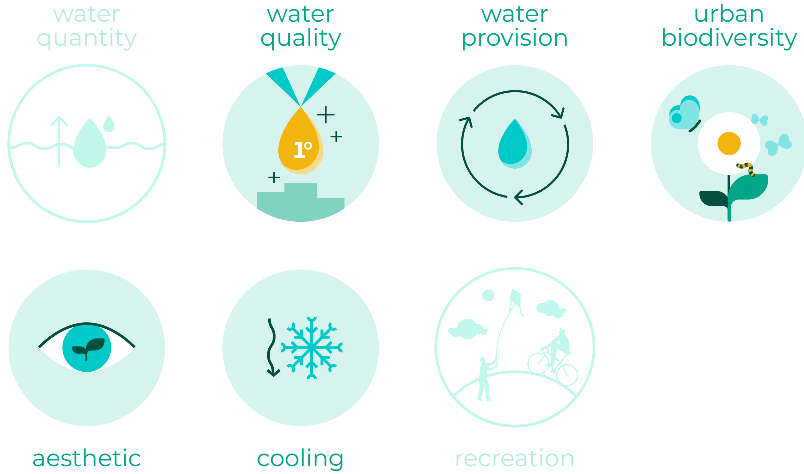
WATER RECYCLING GREEN FAÇADE

water SMART NBS





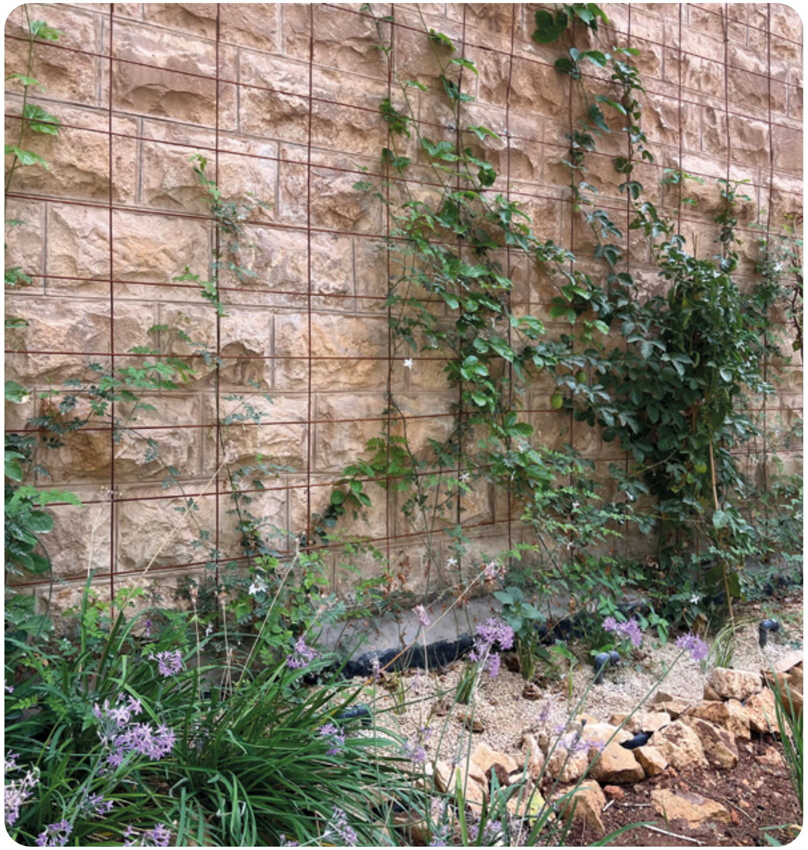
Water recycling green façades are **vertical gardens** featuring **climbing plants** rooted at the base of a building wall. They are repurposed to mimic constructed wetland processes for the **treatment and reuse of greywater**. These systems consist of trenches planted with suitable vegetation and filled with a **specialised medium**, functioning as a vertical flow constructed wetland.

Water recycling green façades are innovative systems that function as **vertical flow constructed wetlands**, designed to treat greywater while enhancing urban aesthetics and sustainability. They consist of trenches filled with a **specialized filtering medium**, through which greywater flows from the top, percolates downward, and is collected at the bottom by drainage pipes. These trenches are planted with **carefully selected vegetation**, including climbing plants that grow vertically to cover the wall surface, either directly anchored to the wall or supported by structures like nets, cables, or trellises. The treated water is then stored in tanks and **reused for non-potable purposes**, such as irrigation or toilet flushing.

A key advantage of water recycling green façades is their **minimal horizontal footprint**, making them ideal for dense urban environments. They are a cornerstone of **urban renaturalisation**, providing not only water recycling but also a range of ecosystem services. These include **heat mitigation** through evaporative cooling, **building insulation**, and enhanced **urban biodiversity** by creating habitats for plants and pollinators. Additionally, green façades **improve air quality** by capturing pollutants and particulate matter, contributing to healthier urban environments.

This system is a low-cost, innovative approach for water treatment that combines the functionality of constructed wetlands with the aesthetic appeal of vertical gardens. **Maintenance is minimal**, typically involving pruning once or twice a year, along with monitoring water quality.

application scale:
building



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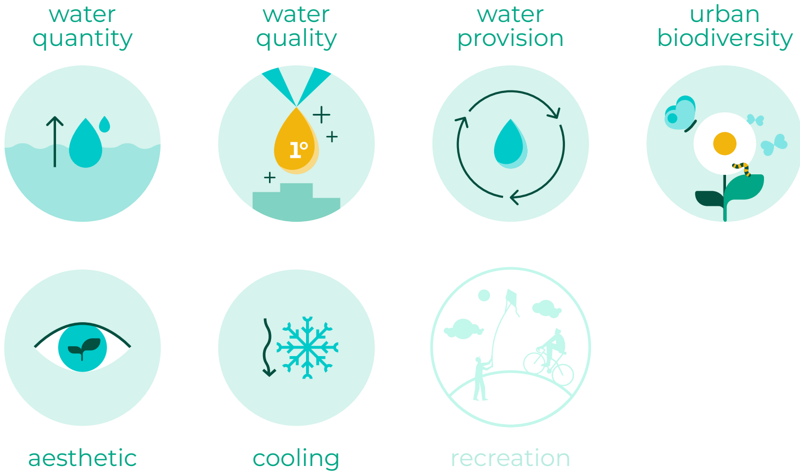
ROOFTOP TREATMENT WETLAND

water SMART NBS



Rooftop treatment wetlands are **green roofs retrofitted to replicate constructed wetland processes for greywater treatment**, combining the benefits of both treatment wetlands and green roofs. Various bed compositions and designs are possible depending on the building structure and climatic conditions, among other factors.

Rooftop treatment wetlands are green roofs retrofitted to reproduce constructed wetland processes to **treat and reuse greywater**. These systems combine the benefits of treatment wetlands, such as **efficient water purification through natural processes**, with those of green roofs, including **thermal insulation** and **urban greening**.

Designed with various bed compositions and configurations (e.g., horizontal or vertical flow systems filled with lightweight, selected-grain materials), rooftop treatment wetlands can be tailored to suit different building structures and climatic conditions. A major advantage is their **minimal land use**, as they are built on rooftops, making them ideal for space-constrained urban areas. However, they require **buildings with high load-bearing capacity** to support the additional weight.

In urban environments, rooftop treatment wetlands offer numerous benefits. They provide **building insulation**, reducing energy consumption for heating and cooling, and help **mitigate the urban heat island effect**. By introducing vegetation and water features, they enhance **urban biodiversity**, offering habitats for birds, insects, and other wildlife. Additionally, they **improve air quality** by capturing pollutants and particulate matter, and aid in stormwater management by retaining rainwater in vegetation and soil, promoting rainwater conservation. **The treated water can be reused for non-potable purposes**, such as irrigation or toilet flushing, promoting water efficiency and reducing demand on municipal water supplies.

application scale:
building

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