9 Annex III: Adaptation Measures Technical Cards

This annex contains technical cards summarizing the characteristics of some key adaptation options. They are formatted for printing on glossy cards and complement the adaptation options descriptions on the online CLARITY Climate Information Service.

The Technical Cards provide end-users with a synthetic summary of most recurring adaptation measures to be integrated in building/open spaces design. This information is also integrated in the CSIS, and used to test the effect of adaptation strategies by modifying the land use layers in the study area according to the selected strategy, so that when the models are run, the effect of the adaptation option can be seen in the new results.

The scales included in the fact sheets were determined as follows:

- Adaptation target: derived from https://www.climateapp.nl/ [22]
- Performance parameters: derived by various literature sources and/or calculated and calibrated through validated software tools (e.g. ENVIMET, SOLWEIG), subsequently integrated in the CLARITY WP3 “Hazard - Local Effect” models. These are the main parameters used in the hazard/impact modelling workflow, determining the extent of potential “climate benefits” (as described in the fact sheet box) linked to the implementation of the adaptation measure/strategy. The choice of limiting the factsheets only to the key parameters of Albedo, Emissivity and Runoff is due to the fact that these are the only parameters that can be directly attributed to the land use type, while other key modelling parameters (e.g. SVF, Surface Temperature) strongly depend on further context conditions (e.g. urban morphology, solar radiation, etc.).
- Costs: derived by previous national research project conducted at UNINA (Metropolis -”Integrated and sustainable methods and technologies for resilience and safety in urban systems”) [27]. Originally calculated based on parametric costs for the Italian construction market, they have been extended to other EU countries by CLARITY WP5.
- Co-benefits: derived from diverse sources [23], [52], [53] and connected to each adaptation measure as found in literature, grouped into three main categories (environmental, social, economic) and homogenized into a qualitative scale, with a pure indicative purpose, since the scale is not used in the CSIS calculation. The purpose is mainly to inform end-users about the achievable “co-benefits” (as described in the fact sheet box), linked to each solution.
- The literature review and methodological approach has been developed with the support of A. Eggert (Aalborg University), during her 6 months internship at UNINA-PLINIVS (2019-2020), and included in her Master Degree thesis work [54].

Introduction

CLIMATIC BENEFITS

Climatic benefits concern the following two aspects:
(1) thermal conditions improvement and thermal comfort increase, through a surface temperature decrease and a urban heat island effect reduction, and (2) flood risks adaptation and mitigation, due to the rainfall increased and sea level rise.

CO-BENEFITS

Adaptation measures co-benefits are independent of their climatic benefits.
They can be described as additional effects to the direct reduction of climate impacts (global warming and sea level rise). Co-benefits can appear as relevant from an environmental, social and economic point of view, or as integrated and interdependent co-benefits.

PERFORMANCE PARAMETERS

Albedo
Albedo is the incident solar radiation fraction that is reflected. It therefore indicates the reflective power of a surface. Thus, the higher the albedo factor the more light is reflected.

Emissivity
It defines a material ability to emit thermal radiation. Surfaces with high emissivity factors remain cooler thanks to their rapid heat release ability.

Runoff
It correlates the amount of rain with the amount of surface run-off. This value is higher for low infiltration areas (pavement, steep slope) and lower for permeable and well-vegetated areas (soil, flat terrain).

Transmissivity
It defines the portion of solar radiation transmitted (measured e.g. under the canopy of trees) with respect to the actual values of the global radiation measured at the nearby open site. The value varies from 0 to 1, where the lower the value the higher the shading effect.

URBAN MICROCLIMATE THEORY

Since the temperature of a surface mainly depends on the characteristics of the its own material, indicators such as "albedo" and "emissivity" are of great importance.
Another important performance indicator is the "runoff factor".
Permeable materials, like green areas, increase rainfall infiltration into the substrate, decrease surface runoff, increase evapotranspiration and, therefore, reduce the "urban heat island" effect and the floods risk. In addition to the materials characteristics, shading is essential for increasing thermal comfort and reducing energy loads. This can be optimized through a careful vegetation configuration, in relation to the gray infrastructures like buildings. Vegetation, in particular, plays an important role in cooling surfaces through shading.

Legend

MEASURES CATEGORY (Datasheet colour)

Green infrastructures

Blue infrastructures

Functional-spatial constitution

Construction materials

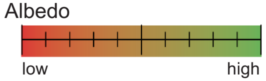
INFORMATION TYPOLOGIES (Datasheet side)

(A) TECHNICAL DESCRIPTION

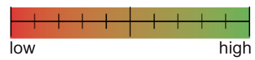
(B) CO-BENEFITS

PERFORMANCE PARAMETERS

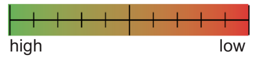
Albedo



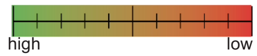
Emissivity



Runoff



Transmissivity



CO-BENEFITS CATEGORIES

Environmental

Air quality

GHG emissions

Water quality

Water recollection and security

Biodiversity

Landslides and Weathering

Social

health impacts

Public space access

Aesthetic value

Community inclusion

Economic

Employment and income generation

Savings

Innovation and investment

Property value

Ⓐ Green infrastructures
BIOSWALES

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

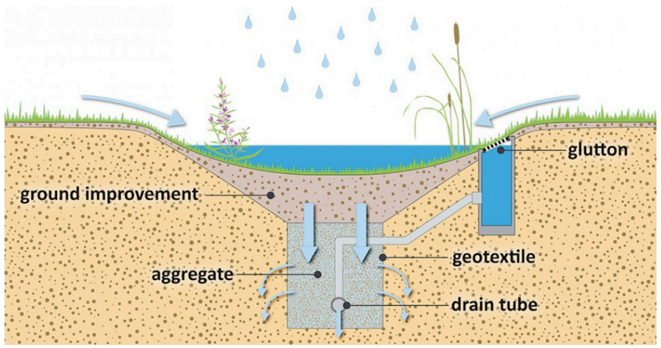
Emissivity
0.5 0.75 1

Runoff
0 0.5 1

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

A bioswale consists of a shallow trench or a small depression in the ground, with vegetation and porous bottom, made with natural materials such as plants, rocks and soil. In these systems, the water that flows from roofs and streets is not only channeled into the sewers but also conducted in the bioswale through gutters and/or ditches above ground. For most of the year, the bioswale remains dry, filling up with water only during heavy rainfall.

CLIMATE BENEFITS

Bioswales are an efficient instrument to improve the efficacy of waste water disposal in urban systems, by intercepting rainwater, filtering it and allowing its infiltration, thus reducing the overload of the sewage system. A properly designed Bioswale system minimizes overflow, improves the shallow waters and prevents the soil from drying up. Furthermore, Bioswales help to reduce the heat stress: this effect can be boosted by planting some carefully selected species, which help to reduce temperatures and consequently improve thermal comfort.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Bioswales improve rainwater quality by removing heavy metals and other pollutants, and improve air quality through carbon sequestration from green elements. Bioswales can provide a huge variety of flora by creating habitats for wild fauna, like birds and insects, thanks to differentiated types of grasses and vegetation

Bioswales have a positive impact on wellness and human health thanks to the reduction of the “heat island effect”; they can be used also as recreational areas open to public.

Vegetation and water increase the aesthetic and recreational value of urban places, improving life quality for local communities. Bioswales, having a relatively simple and rapid realization, can be considered a low cost technology. They represent a cheaper alternative to conventional rainwater management systems, like drainage basins. The volume reduction of polluted water filtered by bioswale reduces transport and rainwater treatment costs.

Ⓐ Green infrastructures
GREEN FACADES

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo
N/A

Emissivity
N/A

Run-off
N/A

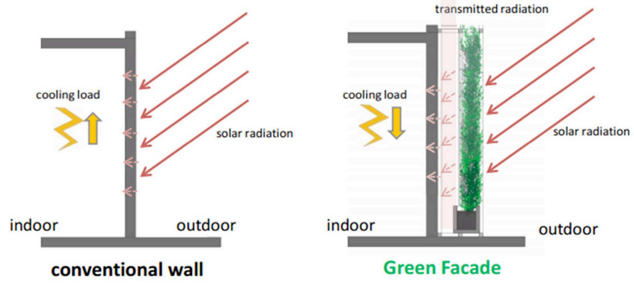
COSTS

Construction

€€€

Maintenance / Management

€€€



DESCRIPTION

The advantage of green façades in dense urban areas is that they occupy a small horizontal surface compared to urban green spaces, giving at the same time a lot of vertical surface of greenery, considering that a generic climbing plant is able to cover the façade of a five storey building in only few years. To propearly design green façade systems it is necessary to carefully assess the need for spaces for the root system in relation to the desired extension on the façade, providing enough space to allow the roots growing in a healthy way that guarantee resistance of plants especially in prolonged drought periods, limiting the consumption of water for irrigation. There are several types of green façade depending on plant type and needed support on building façades. It is necessary, to avoid structural damages, to conduct preventive inspections to check eventual problems, as melted grout or cracks, which must be repaired before realizing the green façade system.

CLIMATE BENEFITS

Vertical vegetation protects from direct solar radiation the external façades of buildings, reducing their overheating and facilitating the heat release during the night. Plants produce also water vapour trough evapotranspiration, promoting the cooling effect of surrounding areas. Vertical vegetation produces also a mitigating effect on maximum external temperatures, improving both indoor and outdoor thermal perceived comfort.

Ⓑ

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

Green façades, by capturing particulate matter and air pollutants, like CO_2, improve air quality. Green façades can also improve biodiversity, by giving habitat for birds and insects.

By protecting buildings facades by direct solar radiation, green facades give an insulating effect that increases internal thermal comfort and therefore it influences positively human health, reducing heat related disorders. Mitigating temperatures, both in autumn and winter, can help to save on energy costs that came from both heating and cooling. Evergreen climbing plants, like ivy, reduce building thermal dispersion during fall and winter periods. Vertical vegetation reduces also noise emissions and noise reflection from building façades.

Their aesthetic value improves the perceived quality of urban places and can contribute to increase the real estate value. Furthermore, if integrated with solutions for rainwater collection and reuse for irrigating the vegetation on the façade, they contribute to reduce water consumption..

Ⓐ Green infrastructures
EXTENSIVE GREEN ROOFS

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

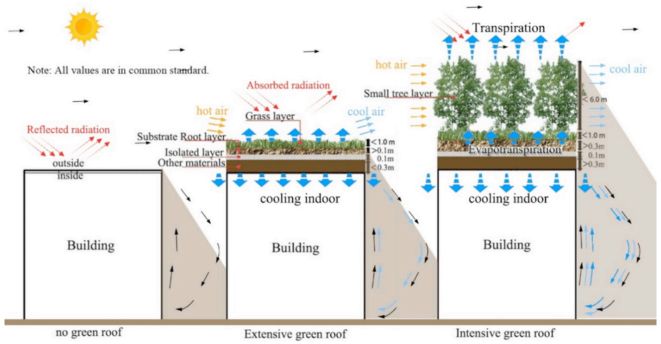
Emissivity
0.5 0.75 1

Runoff
0 0.5 1

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

Extensive green roofs can be partially or completely covered with vegetation. Usually, paved portions can be integrated to allow maintenance operations or for specific uses. Filtering and waterproofing layers below the terrain substrate should be continuous over the entire surface of the roof, and therefore installed both on green and paved portions. This intervention is ideal both for flat and sloped roofs, and it implies a limited structural overload because its vegetation is superficial, and the required terrain substrate thickness is about 15/20 cm. Extensive roofs are prevalently realized with perennial herbaceous plants and shrubs ground covers (sedum). Musk/sedum plants are very suitable for this purpose, because they have the capacity of storing a high quantity of water and surviving in long drought periods.

CLIMATE BENEFITS

Green roofs help to reduce the surrounding urban air temperature and to mitigate the urban heath island effect. Another advantage consists in rainwater drainage action, which is partially absorbed by the terrain and it is partially returned to natural cycle trough evapotranspiration, thus reducing the overload of sewage systems in case of extreme rain events.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Extensive green roofs ensure an excellent thermal control of underlying indoor spaces, reducing thermal dispersion in winter and, thanks to their high thermal inertia, improved attenuation and phase shift during summer. This implies a reduction of energy costs (mostly for indoor spaces situated at top floors). In case of partially covered roofs, attention should be given to the thermal properties of both green and paved sections, providing adequate solutions to avoid thermal bridges.

Green roofs improve air quality by capturing particulate matter and air pollutants, like CO_2, with positive impacts on human health, and they also encourage biodiversity, by giving habitat for birds and insects. Furthermore, green roofs have a big aesthetic relevance, because they improve the building appearance, and they contribute to increase the real estate value.

If integrated with solutions for rainwater collection and reuse for irrigating the vegetation on the roof, they contribute to reduce water consumption.

Note: Ecological and environmental benefits are generally increased with a higher depth of terrain substrate. For example, the increase of thermal insulation and rainwater absorption is more relevant in intensive green roofs thanks to the thicker layer of terrain (see "Intensive Green Roofs").

Ⓐ Green infrastructures
INTENSIVE GREEN ROOF

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

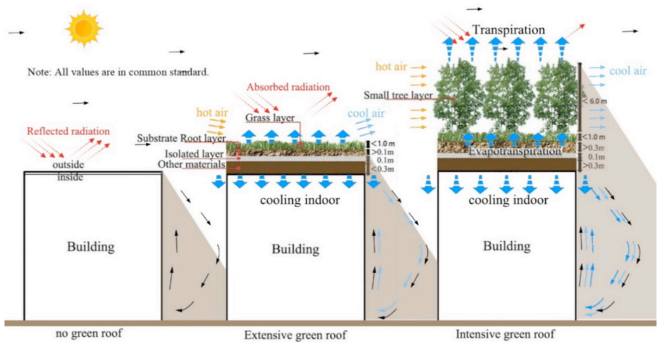
Emissivity
0.5 0.75 1

Runoff
0 0.5 1

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCPTION

Intensive green roofs can be partially or completely covered with vegetation. Usually, paved portions can be integrated to allow maintenance operations or for specific uses. Filtering and waterproofing layers below the terrain substrate should be continuous over the entire surface of the roof, and therefore installed both on green and paved portions. The solution is applicable to flat roofs capable with a load-bearing capacity of more than 150 kg/m2, because intensive roofs are characterized by a variety of vegation, unlike extensive roofs, which may also include little trees and shrubbery which require a thicker terrain substrate. The variety of plants usually require more maintenance compared to extensive roofs, and the integration of an irrigation system, like ordinary gardens, is generally advised

CLIMATE BENEFITS

Green roofs help to reduce the surrounding urban air temperature and to mitigate the urban heath island effect. Another advantage consists in rainwater drainage action, which is partially absorbed by the terrain and it is partially returned to natural cycle trough evapotranspiration, thus reducing the overload of sewage systems in case of extreme rain events.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Intensive green roofs ensure an optimal thermal control of underlying indoor spaces, reducing thermal dispersion in winter and, thanks to their high thermal inertia, improved attenuation and phase shift during summer. This implies a reduction of energy costs (mostly for indoor spaces situated at top floors). In case of partially covered roofs, attention should be given to the thermal properties of both green and paved sections, providing adequate solutions to avoid thermal bridges. Green roofs improve air quality by capturing particulate matter and air pollutants, like CO_2, with positive impacts on human health, and they also encourage biodiversity, by giving habitat for birds and insects.

Intensive green roofs offer also a space for recreational uses, as well as for urban gardening and agriculture, with positive social effects on the neighborhood community

Green If integrated with solutions for rainwater collection and reuse for irrigating the vegetation on the roof, they contribute to reduce water consumption. Furthermore, green roofs have a big aesthetic relevance, because they improve the building appearance, and they contribute to increase the real estate value. The use of intensive green roofs for urban agriculture can help to develop local green and circular production supply chains. Other impacts on job market linked with intensive green roofs concern the professional sectors linked by their design, realization and maintenance.

A Green infrastructures

LAWNS AND GREEN AREAS

A TECHNICAL DESCRIPTION

B CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissivity

0.5 0.75 1

Runoff

0 0.5 1

COSTS

Construction

€€€

Maintenance / Management

€€€

DESCRIPTION

Lawn Lawns and green areas are permeable surfaces that perform some important functions in an urban environment, such as heat and run-off control, space for recreational and sport uses, biodiversity hubs and carbon storage components. There are several typologies of lawn suitable for urban areas, such as: - rustic lawns, which ask for less maintenance and are mainly used for river/canal banks and floodable public places; - ornamental lawn, used in public and private gardens; - sports lawns, formed by species that allow a high trampling; - flowery lawns, formed by a mix of herbaceous flowering plants, annual or perennial. Depending on the types, they may or not require a regular irrigation and mowing. The use of spontaneous species and the support of symbiotic behaviours (between different plant types and/or fungi), when carefully designed, can greatly enhance the quality of green areas, reducing manteinance and irrigation costs, as well as providing improved resistance during droughts.

CLIMATE BENEFITS

The The main advantage of lawns consists in the reduction of surface run-off and the improvement of urban drainage, reducing flooding phenomena related to extreme rainfall. Furthermore, nearby buildings and public places, lawns perform an important role in microclimate thermal regulation. The surface temperature of a lawn can be 5°C lower than bare soil, and up to 15°C lower than asphalt. The efficacy from the thermal point of view of lawn surfaces is strictly linked to the ability to provide adequate evapotranspiration, therefore their use should be limited to urban spaces where irrigation systems are installed. Shrub species and aromatic plants with resistance characteristics suitable for the specific local climate can be integrated into green lawn areas to improve both their thermal regulation and surface drainage capacity, but require careful design that guarantees the suitability of the substrate and minimizes the need for maintenance and irrigation. Perennial urban lawns require only little maintenance throughout the year and are therefore less expensive than manicured parks.

B

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

Like all elements of green infrastructure, green areas also promote CO_2 sequestration and improve air quality. Urban lawns could be used in combination with selected flowers and plants in order to improve their appearance and support biodiversity in cities.

Green urban areas have an aesthetic and social value when used as recreational places for residents, encouraging social interactions that strengthen community cohesion. Furthermore, green urban areas have a significant positive impact on human health by fostering physical activities in open spaces.

Green areas, in addition to contributing to the reduction of the surface run-off and to the infiltration of rainwater, improve the quality for the non-drained component, thus reducing the load of the purification systems.

A

Green infrastructures

TREES

A TECHNICAL DESCRIPTION

B CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissivity

0.5 0.75 1

Transmissività

0 0.5 1

COSTS

Construction

€€€

Maintenance / Management

€€€

DESCRIPTION

The planting of trees within urban areas includes their integration in public parks, along roads, in squares and other open spaces (including private spaces). It is important that the location identified and the space intended for the root system is suitable for the tree to fully develop its crown. In addition, the type of tree should be chosen based on local climate features, taking into account the expected climate projections over a time horizon corresponding to the years needed for the complete maturation of the tree. Although trees improve air quality, dense foliage along busy roads can cause unwanted effects, as vehicle emissions tend to get trapped under the canopies. The right type of tree and the right shape of the crown in relation to the urban canyon geometry (and related wind channeling), road size and expected traffic load can help preventing the accumulation of pollutants. Furthermore, it is essential to provide adequate regular maintenance and protection cycles for the tree in order to guarantee its climatic benefits over time and prevent them from being a risk factor in the event of extreme events such as wind storms, which can cause trees with a weakened or not fully developed root system to collapse.

CLIMATE BENEFITS

The presence of trees in urban spaces reduces the impact of heat waves through shade and high levels of evapotranspiration which guarantee a cooling effect that improves outdoor thermal comfort. Trees are able to absorb and infiltrate a great amount of rainwater thanks to the presence of root systems, limiting the surface run-off in case of heavy rains and contributing to the stabilization of slopes, thus reducing the risk of flash floods and landslides

B

Co-benefits in total

Environmental

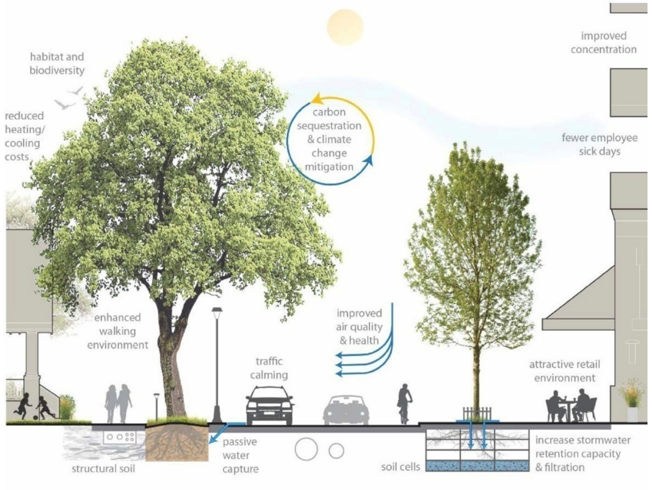
low high

Social

low high

Economic

low high



CO-BENEFITS

The filtering of rainwater through the roots system of trees allows to improve the quality of groundwater, acting as as natural water purification systems. The trees also improve air quality by capturing particulate matter and CO_2, increase biodiversity by offering living space to many species of birds and insects, reduce noise by creating absorbing barriers.

All these environmental factors, in turn, positively influence human health.

In addition, trees add an aesthetic value to the city. The trees that directly shade the buildings reduce the demand for energy for air conditioning, energy costs and the associated CO_2 emissions.

Ⓐ Green infrastructures
URBAN AGRICULTURE

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissività

0.5 0.75 1

Runoff

0 0.5 1

COSTS

Construction

€€€

Maintenance / Management

€€€

DESCRIPTION

Agricultural land differs from natural soil due to repeated tillage and various agronomic interventions. All types of crop, in general, affect the water cycle and promote environmental protection. The increase of agricultural production in cities can be promoted through the cultivation of bare soils and residual areas, as well as outdoor spaces of residential buildings. Crop types are closely related to local climatic conditions and therefore have to be carefully selected. The spatial configuration of urban land for agricultural use must also take into account the impact of urban activities in the surrounding areas (in particular vehicular pollution). Therefore, the cultivation of agricultural products intended for human consumption must be assessed based on the specific location in the city.

CLIMATE BENEFITS

The main advantage of urban agriculture is the reduction of surface run-off, ensuring a reduction in the risk of flooding in case of extreme precipitation events. Depending on the type of vegetation, the performance parameters may vary. The contribution to heat stress reduction can be relevant, but seasonality of cultivation types must be taken into account, preferring those growing during hot seasons.

Ⓑ

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

Urban agriculture offers high quality urban green spaces and preserves biodiversity by attracting birds and insects. Local food production reduces the consumption of fossil fuels and the greenhouse gas emissions associated with the transport, packaging and sale of food, thus contributing to the improvement of air quality in cities.

Agricultural areas integrated in community initiatives increase food awareness and promotes a healthier diets, with potential benefits for human health. In addition, by involving residents and providing a place for cooperation and knowledge sharing, urban agriculture strengthens community cohesion and inclusion, including positively affecting mental health diseases. Finally, urban agriculture fields contribute to the aesthetic value of the city.

Local cultivation allows saving on household expenses for food. The presence of local products and markets bring benefits in terms of job opportunities and stimulus to local circular economy. Specific interactions between urban agricultural systems and their different urban environments create opportunities for technical, social and organizational innovations. Urban agriculture can help increase the values of real estate in the surrounding areas.

Ⓐ

Construction materials

CANOPIES

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissivity

0.5 0.75 1

Transmissività

0 0.5 1

COSTS

Construction

€€€

Maintenance / Management

€€€

DESCRIPTION

Shading systems are integral part of physical configuration of many equipped public spaces. They can be installed as fixed or removable elements, designed for protect the underlying space from solar radiation and, if realized as waterproof canopies, from rain. The shadow quality, in terms of quantity of radiation transmitted is determined by the covering typology (e.g. continuous or discontinuos surface) and material. The upper surface should be designed with light color finishings, in order to reach adequate albedo values. The most used material include wood (with waterproof treatment), metals (steel or aluminium), glass (with optional selective treatment) and fabrics (acrylic and high resistance polyester) to meet not only structural but also aesthetic needs. In any case, the materials should preferably meet the requirements of lightness and flexibility. If not properly designed, they can however contribute to the trapping of heat and the overheating of the underlying area.

CLIMATE BENEFITS

The creation of shaded surfaces reduces the overheating of roads, pavements and green spaces, affecting the direct solar radiation, which is the main component of thermal stress conditions. If those surfaces are realized with waterproof materials and equipped with gutters connected to sustainable urban drainage systems, like green infrastructures and storage systems, they can help to reduce flooding phenomena in case of heavy rain.

Ⓑ

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

Shading systems, if integrated in public spaces can attract people, encouraging social interaction, commercial and recreational activities.

Canopies which directly shade buildings can reduce energy demand for cooling and related CO_2 emissions, especially for indoor spaces at groundfloor levels. Design innovations and the addition of functions (like recharge of electrical devices and vehicles, information systems and digital services, etc.) can bring economic benefits linked by new green and innovative supply chains.

Ⓐ Construction materials

GRASSED JOINT FLOORING

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissivity

0.5 0.75 1

Runoff

0 0.5 1

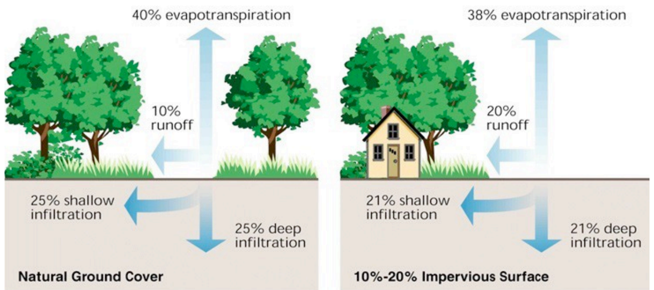
COSTS

Construction

€€€

Maintenance / Management

€€€



DESCRIPTION

Outdoor floors, made with tiles, slabs or blocks of various materials, may include the presence of grassy joints. The filling of the cavities, with openings of different number and size depending on the type, is composed of vegetable soil with spontaneous or cultivated herbaceous species. Depending on the type of substrate present under the pavement, the percentage of infiltration can even reach 100%. This type of flooring cannot support heavy loads, therefore it can only be used for pedestrian areas, parking lots or streets with a limited intensive use.

CLIMATE BENEFITS

The presence of grass increases the surface permeability and the ability to absorb and retain rainwater (this capacity is directly proportional to the percentage of plant surface compared to the total paved surface). Frequent maintenance is required to ensure greater absorption of rainwater. The evapotranspiration and emissivity components reduce the heat island effect, increasing the perceived thermal comfort.

Ⓑ

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

The soil-sealing reduction in urban areas slows down the surface run-off and allows rainwater to infiltrate the soil more easily, thus reducing the overload of sewer systems and the necessity of manholes maintenance.

The presence of green areas in urban paved spaces increases its aesthetic quality compared to asphalt or concrete sidewalks.

The higher initial construction costs of grassy joint pavements, compared to conventional ones, are justified by the potential savings due to the avoided construction of other more expensive rainwater collection/disposal systems.

A

Construction materials

REFLECTIVE SURFACES

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo*

0 0.5 1

Emissivity*

0.5 0.75 1

*dependent on degree of brightness of color

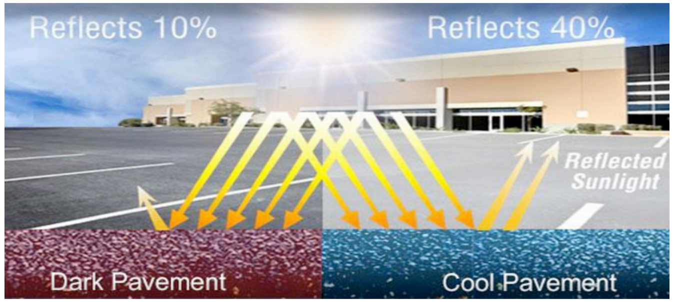
COSTS

Construction

€€€

Maintenance / Management

€€€



DESCRIPTION

Reflective surfaces are characterized by a high solar reflectance (albedo), obtained by using light colors (typically tending to white) or darker colors treated with special reflective pigments, which limit the increase in surface temperature when they are directly radiated. Furthermore, they are typically characterized by a high emissivity which determines during night a more favorable release of heat stored during the day, with effect on the reduction of the thermal flux release on environment. Reflective materials can be used for various types of external pavements or buildings façades, both as coatings and paints. Horizontal and vertical surfaces must be kept clean so that reflective properties are preserved over time.

CLIMATE BENEFITS

Since pavements occupy 30-40% of the urban area, reflective surfaces can play an important role in reducing heat island effect. These solutions have a positive influence on the surface temperature control, compared to asphalt, dark stone or cementitious materials that can reach surface temperatures up to 70 °C in the summer months. The high albedo can however cause glare phenomena, as well as conditions of thermal discomfort due to the reflection of the solar radiation at human height. The use of reflective pavements or building façades in areas characterized by high direct solar radiation thus must be carefully designed, favouring their use in dense building fabrics or by providing for the integration of appropriate trees and shading elements.

B

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

The cooling effect of reflective surfaces slows down surface chemical reactions and the consequent formation of smog on surfaces.

Used as external finishings of buildings, they slightly reduce the energy demand for cooling and the associated greenhouse gas emissions.

Ⓐ Construction materials
COOL ROOFS

Ⓐ TECHNICAL DESCRIPTION

Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo*

0 0.5 1

Emissivity*

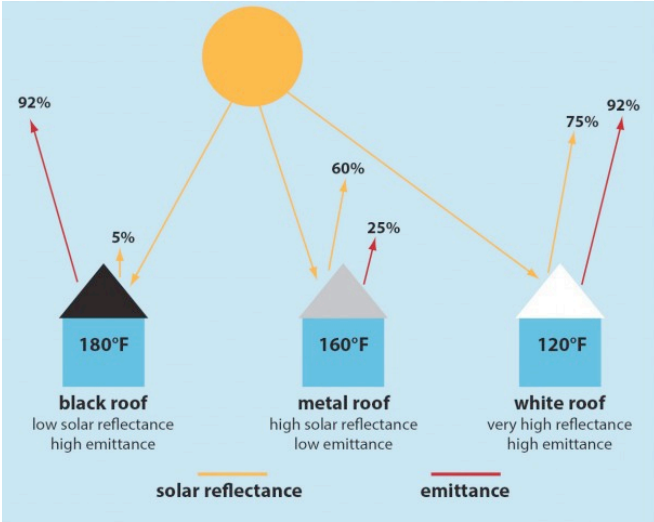
0.5 0.75 1

*for mineral reflex white

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

The cool roof is a roof characterized by a high ability to reflect the incident solar radiation (solar reflectance or albedo) and, at the same time, to emit thermal energy in the infrared spectrum (thermal emissivity). It is achieved by applying on the external surface of the roof paints or layers of surface coating, generally white or light grey materials.

CLIMATE BENEFITS

Cool roofs allow a reduction of the urban heat island effect, affecting the air temperature at different altitudes. On sunny summer days, traditional roofs can reach surface temperatures of about 80 °C while cool roofs usually do not exceed 50 °C.

Ⓑ

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

-

-

-

Construction materials

GREEN PERGOLAS

A TECHNICAL DESCRIPTION

B CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo

0 0.5 1

Emissivity

0.5 0.75 1

Transmissività

0 0.5 1

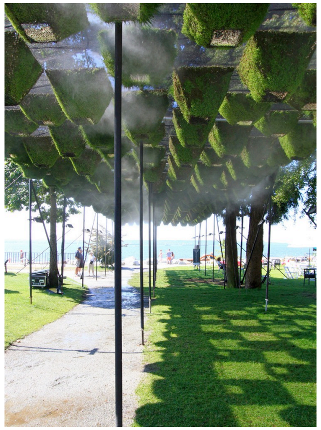
COSTS

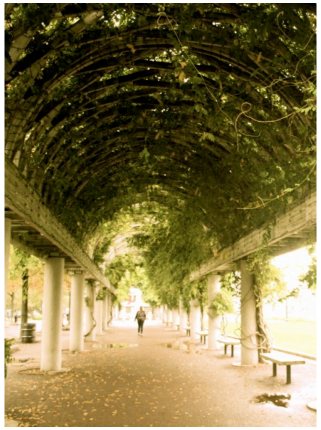
Construction

€€€

Maintenance / Management

€€€





DESCRIPTION

A green pergola combines the benefits of artificial shading systems, in terms of integration with buildings and urban equipment, with those linked to urban green. Plants must be selected based on the local climate and on the necessity of exposure to sunlight. The pergolas are designed and constructed in such a way as to protect the underlying areas from solar radiation during the central hours of the day, when the sun reaches its maximum height. A vertical wall can be associated with the horizontal green layer, in order to shield also towards morning or afternoon solar radiation (depending on location).

CLIMATE BENEFITS

Green pergolas guarantee excellent shading conditions, alongside the evapotranspiration component of vegetation, although with a lesser extent than trees and urban green areas. Compared to other artificial canopies, pergolas guarantee better conditions of thermal comfort during heat waves.

B

Co-benefits in total

Environmental

low high

Social

low high

Economic

low high

CO-BENEFITS

Green pergolas, by capturing CO_2 and the particulate present in the air, improve their quality. In addition, they can have a positive effect on urban biodiversity by offering living space for birds and insects.

Green pergolas increase the aesthetic value of the city and, consequently, improve the liveability and quality of life of the local communities.

Made in public spaces, they can attract people to gather, promoting social interaction and the development of commercial and recreational activities. The pergolas that directly shade the buildings reduce the demand for energy for cooling and the associated CO_2 emissions.

Construction materials
PERMEABLE CONCRETE

(A) TECHNICAL DESCRIPTION
(B) CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

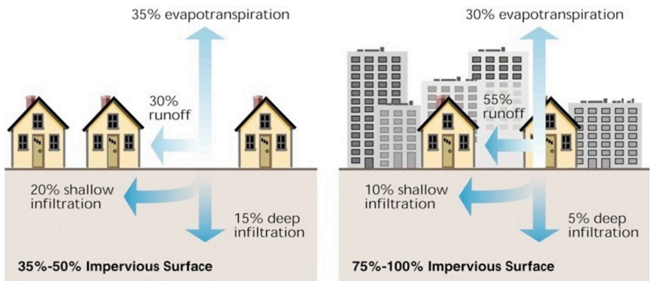
Emissivity
0.5 0.75 1

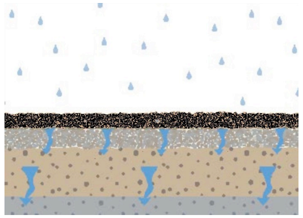
Runoff
0 0.5 1

COSTS

Construction
€€€

Maintenance / Management
€€€





DESCRIPTION

External continuous made with porous or permeable material (concrete, stabilized earth or other materials) allow water to infiltrate and can be used for parking lots, pedestrian walkways and cycling paths. However, permeable floors cannot be used for roads or parking areas subject to intensive use as they generally cannot support large loads, but also because of the risk of soil contamination due to the infiltration of particulates and other road pollutants.

CLIMATE BENEFITS

Porous or permeable continuous pavements have a good performance in terms of rainwater absorption, being characterized by low inflow values and, therefore, good water permeability (with percentages varying between 15% and 40%). Consequently, thanks to the high infiltration, they reduce the risk of flooding in case of extreme precipitation events.

(B)

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

-

-

The improved infiltration over large paved areas, by reducing the overload of sewer systems, contribute to lower their maintenance costs, including manholes. The higher initial construction costs of the permeable floors, compared to conventional ones, are justified by the potential savings due to the avoided construction of other more expensive rainwater collection/disposal systems.

Blue infrastructures

GUTTERS AND STORM DRAINS

(A) TECHNICAL DESCRIPTION
(B) CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

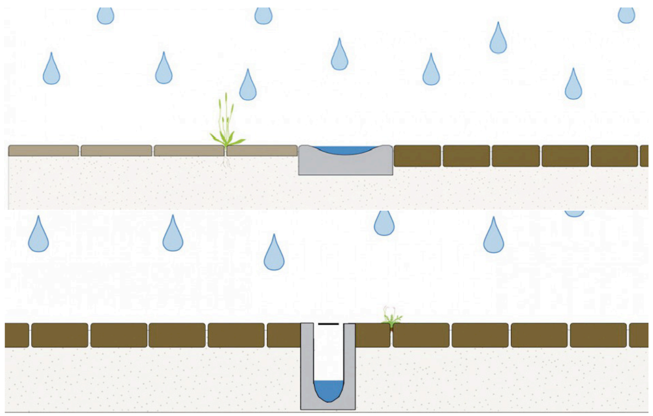
Emissivity
0.5 0.75 1

Runoff
N/A

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

Gutters and manholes are important elements of the urban drainage system, having the function of intercepting rainwater that flows on the horizontal surfaces of buildings and open spaces and conveying them into the sewerage network, using special infiltration systems. The main factor that determines surface flooding in case of extreme precipitation events is the obstruction of the manholes, due to lack of maintenance or design mistakes. Open canals connected to disposal systems, green areas, bioswales, flooded squares, rainwater collection systems and retention basins can be integrated into pedestrian areas to reduce the risk of flooding.

CLIMATE BENEFITS

By collecting and conveying rainwater, gutters, ditches and manholes reduce surface run-off, thus mitigating the risk of surface flooding in the surrounding areas. Open gutters/canals, connected to water recirculation systems, can be used during heat wave events to realize a network of small blue infrastructure artificially filled with water, which contributes to reduce outdoor thermal stress

(B)

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Through the drainage of surface water in retention areas or collection systems, the gutters facilitate the collection and reuse of rainwater, helping to ensure water safety.

In open canal systems, water can be visible and contribute to the aesthetic value of the neighborhood.

Open surface drainage systems are generally easier to clean and maintain than covered systems with consequent economic savings.

(A) Blue infrastructure

RAINWATER HARVESTING SYSTEMS

(A) TECHNICAL DESCRIPTION

(B) CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
N/A

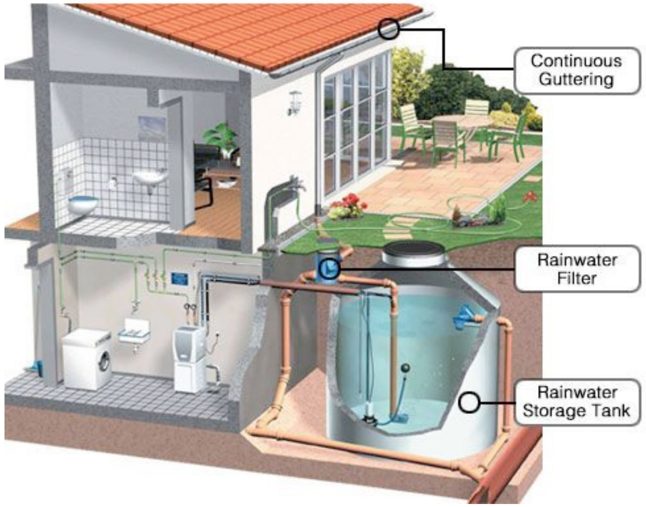
Emissività
N/A

Runoff
N/A

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

Rainwater collection, filtering, storage and reuse systems can be used for various purposes, including irrigation, cleaning of paved surfaces, toilet flushes and fire prevention systems. The simplest example of a rainwater collection system consists of storage tanks. In areas where dry periods alternate with extreme rainfall, excess water can be stored and used to refill aquifers through artificial techniques.

CLIMATE BENEFITS

The main function of rainwater harvesting system is to contribute to reducing flooding phenomena, limiting the overload of sewer system and increasing their disposal capacity during heavy rain events.

(B)

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Recycling and reusing rainwater for domestic or industrial purposes can significantly reduce water consumption, with relevant environmental benefits over large territories, and savings on utility bills.

-

The collection systems are based on simple and easily maintainable technologies. Installation costs are much lower than those of groundwater treatment (such as pumping and purification).

Ⓐ Blue infrastructure
RETENTION BASINS

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS

ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

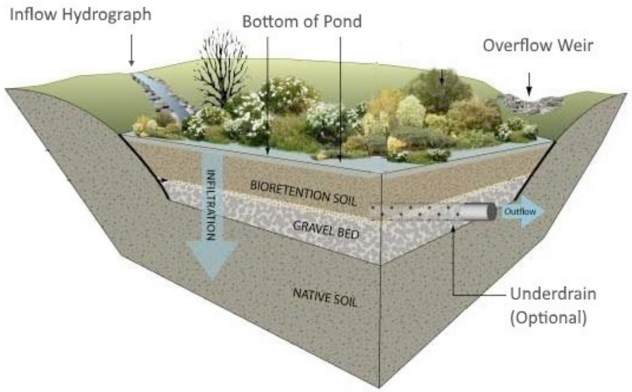
Emissivity
0.5 0.75 1

Runoff
0 0.5 1

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

Retention basins are water collection and storage areas configured as multifunctional vegetated spaces, created with a dual function: reducing the impact of flood events and conserving water for periods of drought. The accumulated water can be used for non-potable uses, such as irrigation, street cleaning, etc.

CLIMATE BENEFITS

The main function of the retention basins is to reduce the impact of floods in urban areas, collecting and storing rainwater in the event of heavy rains or floods. In the areas surrounding the retention basins, the temperature is significantly lower due to the presence of green areas and water, with a consequent increase in the perceived thermal comfort.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Retention basins facilitate the collection of water and reduce the overload of sewage systems during extreme precipitation events. They also allow a first purification of the water thanks to natural sedimentation, improving its quality, securing water availability in periods of shortage and seasonal stress, reducing the use of groundwater and limiting its potential depletion in periods of prolonged drought. Retention basins favour the growth of vegetation, absorbing CO_2 and humidifying the air, creating habitats for animals, with a positive impact on biodiversity.

Retention basins, thanks also to the presence of vegetation, allow the integration of public recreational functions. In general, blue and green infrastructures in cities increase aesthetic value and encourage citizens to use public space as a recreational area for social gatherings or other purposes, increasing social inclusion and interactio..

Retention basins therefore has potential positive effects on real estate values of the surrounding areas.

Note: For “dry” retention basins see also “Water Squares”.

Ⓐ Blue infrastructure
WATER SQUARES

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS

TARGETS ADAPTATING

Heat Wave

Pluvial Flooding

FluvialFlooding / StormSurge

PERFORMANCE PARAMETERS

Albedo
0 0.5 1

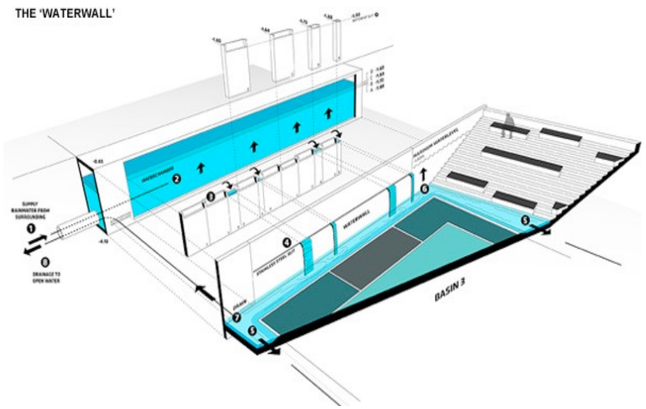
Emissivity
0.5 0.75 1

Runoff
N/A

COSTS

Construction
€€€

Maintenance / Management
€€€



DESCRIPTION

In densely built-up urban areas it is often difficult to find a space for the temporary collection of rainwater during extreme events. Water squares can be realized in areas with a high flood risk, and appear as public spaces which in most cases are “dry” and can be used like any other traditional public space, for play and leisure. Carefully designed, in periods of heavy rainfall, the square is flooded by conveying the waters from the surrounding surfaces, limiting the impact of extreme rainfall.

CLIMATE BENEFITS

The flooded squares work as retention and storage basins for rainwater within the city, reducing the impacts of extreme rainfall.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

Depending on the intensity of the rainfall, they can be more or less flooded, up to being used even during flood events.

Due to the need of realizing water squares at a lower level with respect to surrounding urban areas, and generally accessed with steps, they can perfectly host a number of recreational activities, such as theatre, sport and play, strengthening social inclusion and interaction.

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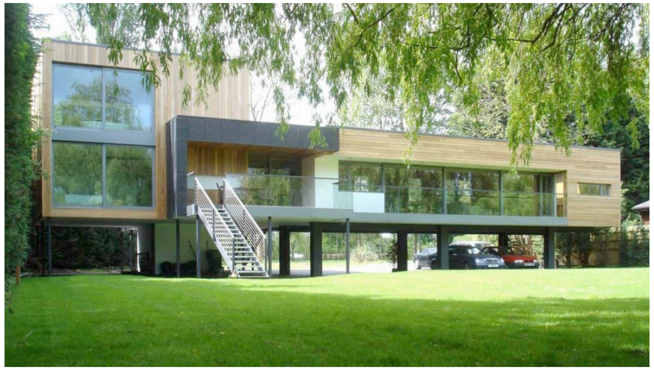
Functional-spatial constitution

PERMEABLE GROUND-FLOOR

Ⓐ TECHNICAL DESCRIPTION
Ⓑ CO-BENEFITS



ADAPTATION TARGETS

Heat Wave

Pluvial Flooding

Fluvial Flooding / Storm Surge

PERFORMANCE PARAMETERS

Albedo
N/A

Emissivity
N/A

Runoff
N/A

COSTS

Construction
€€€

Maintenance / Management
€€€

DESCRIPTION

Buildings with permeable ground floors allow water to flow along defined paths, possibly connected to collection or drainage systems, also promoting natural ventilation within dense urban areas. If built on pilotis, the buildings must be able to withstand water loads in the event of floods and local seismic risk conditions. The space intended to convey the water must be free of obstacles to avoid damage to the building during extrem precipitation events.

CLIMATE BENEFITS

By making the ground floors permeable, physical damage to buildings (structural or finishing elements) and people during flooding evnets can be reduced. The improved natural ventilation helps to mitigate the urban heat island effect even in the absence of wind. The presence of green or blue areas, as well as shaded areas carefully designed on the sides of the buildings, allows to promote cross-ventilation air exchanges, improving comfort conditions. If used as public spaces, open ground floors can be used as "cool spots" during heat waves.

Ⓑ

Co-benefits in total

Environmental
low high

Social
low high

Economic
low high

CO-BENEFITS

The openings on the ground floors of the buildings, especially if integrated into a network of pedestrian or cycling paths and green and blue infrastructures, favour the passage of some animals, preserving biodiversity. Furthermore, the improved ventilation reduces the concentration of air pollutants.

The greater pedestrian and cycling permeability increase the quality of public spaces and favours the development of commercial, cultural and recreational activities.

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