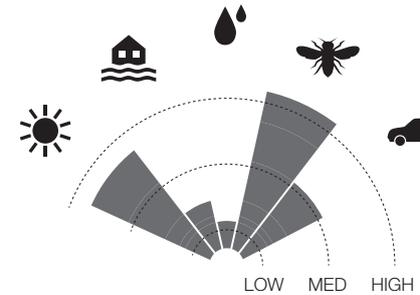




# green walls

1

As cities face increasing population density and shortage of space at ground level, vertical green landscapes, installed on ‘unused’ façades, are likely to become more prominent. Green walls improve air quality and acoustics while protecting buildings from thermal fluctuations and extreme weather. Maintenance costs for green walls, however, can be considerable; careful selection of plant species is key to managing expense. Low-cost solutions also include using existing structures for climbing plants.



📍 Calle Gran Via



1



Barcelona, Spain

## Vegitecture Supersized Green Wall

*Vegitecture*, developed by Capella Garcia Arquitectura, is a new concept in green wall design; a large-scale independent vertical infrastructure, separated from the original building. In Barcelona, a 21m high *Vegitecture* wall was implemented; its floors are connected through stairs and the structure features its own irrigation and fertiliser system while offering park-like urban spaces. As the wall runs independently from existing building structures, *Vegitecture* walls can enhance exposed, unused walls in dense urban areas. Like other forms of green walls, *Vegitecture* walls offer multiple benefits such as enhancing the cityscape, reducing greenhouse gases and improving air quality.

<http://popupcity.net/vegitecture-a-supersized-green-wall-in-barcelona/>



Reutlingen, Germany

## 'City Tree' Active Horticultural Display

The *City Tree* is a freestanding 'living display panel' consisting of 1,682 individual plant pots arranged in a vertical concrete grid. The plant pots can be configured to display a corporate logo or scannable QR code. The project aims to exchange sponsorship of *City Tree* units for corporate advertising. Each *City Tree* includes rainwater capture technology linked to moisture sensors, which automatically hydrate the plant beds as needed. The basis for each plant pod is a species of moss known for its ability to capture airborne particulates. As of 2015, a pilot installation is underway in the City of Reutlingen, Germany.

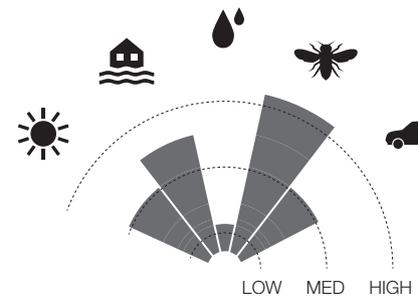
<http://greencitysolutions.de/#top>



## sustainable roofs

2

Roof space is underutilised in many cities; combining green roofs and solar technology can create vital synergies in dense urban areas. Roof vegetation can increase the efficiency of PV panels by reducing ambient temperatures. Sustainable roofs support water management, improve insulation and air quality, provide cooling, and create habitat for biodiversity. Sustainable roofs also provide heat and power to urban structures, bridging the gap between energy generation and consumption.



 Avenida Niceto Alcalá Zamora





Oslo, Norway

## 'Bee Highway'

Bee populations worldwide are declining due to environmental stressors, including urban development. In some areas up to 1/3 of native bee species are threatened with extinction. Restoring bee populations is an important issue, as 40% of the planet's food production requires bees for pollination.

Oslo is attempting to combat this problem through the development of *Bee Highway*, a network of rooftop flowerbeds and habitation spaces designed to provide rest and feeding spaces for Norwegian bee species.

<http://www.theguardian.com/environment/2015/jun/25/oslo-createsworlds-first-highway-to-protect-endangered-bees>



Various, Europe

## The Biosolar Roof Project

The *Biosolar Roof Project* aims to educate the construction industry towards undertaking an integrated approach to ecosystem services and sustainability. This is achieved by providing professional training and guidance on how to best install and maintain biosolar roofs, which combine solar power with green roofs. The project team examines ways to exploit the opportunities presented by the unique topography resulting from the presence of solar panels, including considerations of the panels' shading patterns as well as plants that can benefit from different light levels.

<http://www.biosolarroof.com/>

Madrid + Natural

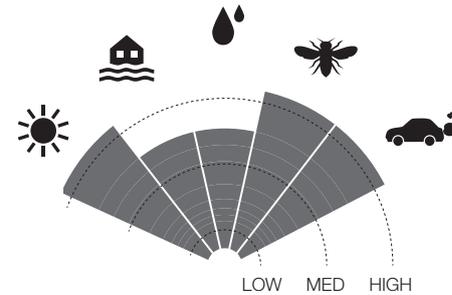
Buildings

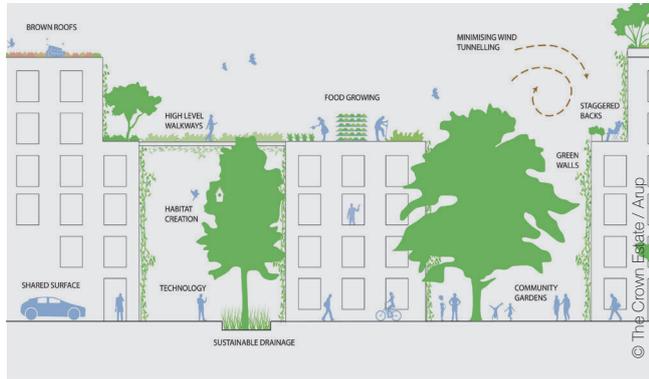


© Arup

## resilient development

Engaging businesses in devising resilient development strategies can become a vital strategy for cities looking to mitigate and adapt to climate change impacts. Involved businesses and local institutions can improve their social responsibility performance while promoting healthy districts and people's wellbeing. Strategies include voluntary investments, the creation of guidelines for green space development, and incentives for upgrading existing structures.





London, UK

## The Crown Estate Ecology Masterplan

The Crown Estate is working to establish a green corridor in London's West End throughout its property portfolio, connecting two major parks; Regent's Park and St James's Park. Adopting a long-term, estate-wide approach, an Ecology Masterplan has been prepared by Arup to guide the extensive installation of green infrastructure within The Crown Estate's central London portfolio. The initiative will provide valuable habitats for wildlife on and around the buildings, and improve the experience for people who live, work and visit the area. Expanding on the approach, The Crown Estate has created Wild West End; a partnership with local landholders to increase greening in the city.

<http://www.thecrownestate.co.uk/news-and-media/news/2015/londonproperty-owners-join-forces-to-launch-wild-west-end-ecology-initiative/>



Berlin, Germany

## Biotope Area Factor

Post-reunification Berlin was a city notably short on green space. As a result, the *Biotope Area Factor (BAF)* legislation was commissioned to make sure that future development would protect existing nature areas and expand green space. The regulation measures the proportion of green space included in any proposed project, ensuring that high-density development occurs hand-in-hand with quality of life and environmental considerations.

The *BAF* enables developers to use standard tables to plot the mandatory green space allowance in new projects while allowing a variety of compliant approaches.

[http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index\\_en.shtml](http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml)

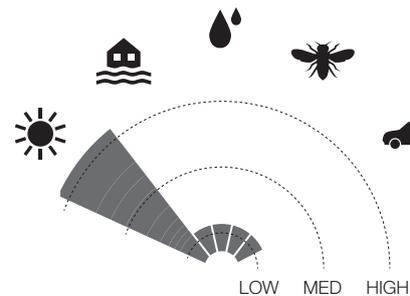


© Arup

## cooling roofs

4

Painting roofs white is a low-cost improvement that reduces energy consumption of buildings during hotter months. Flat roofs are often coated with dark materials that absorb solar energy, adding unwanted heat to the building. By painting roofs with white sun-reflecting paint or utilising materials such as light-toned gravel, solar gains can be significantly reduced. White roofs reflect up to 90% of received sunlight, which reduces the energy use of buildings and minimises urban heat island effect.



📍 Calle Fundadores  
(Manuel Becerra)



4



New York, US

## White Roof Project

New York's *White Roof Project* is a non-profit organisation promoting the benefits of coating dark roofs with solar reflective white paint. This modification decreases roof surface heat absorption (white roofs can reflect up to 90% of sunlight, compared to 20% for dark roofs) and can reduce cooling-related electricity usage by up to 40%. Local communities are encouraged to actively participate in making these simple changes. The project has painted over 100 roofs since 2010. Roof-repainting projects have included a 220,000-foot warehouse, a network of homeless shelters, and 20 cooperatively owned rooftops, called the Model Block, in a historic neighbourhood on the Lower East Side.

<http://www.whiteroofproject.org>



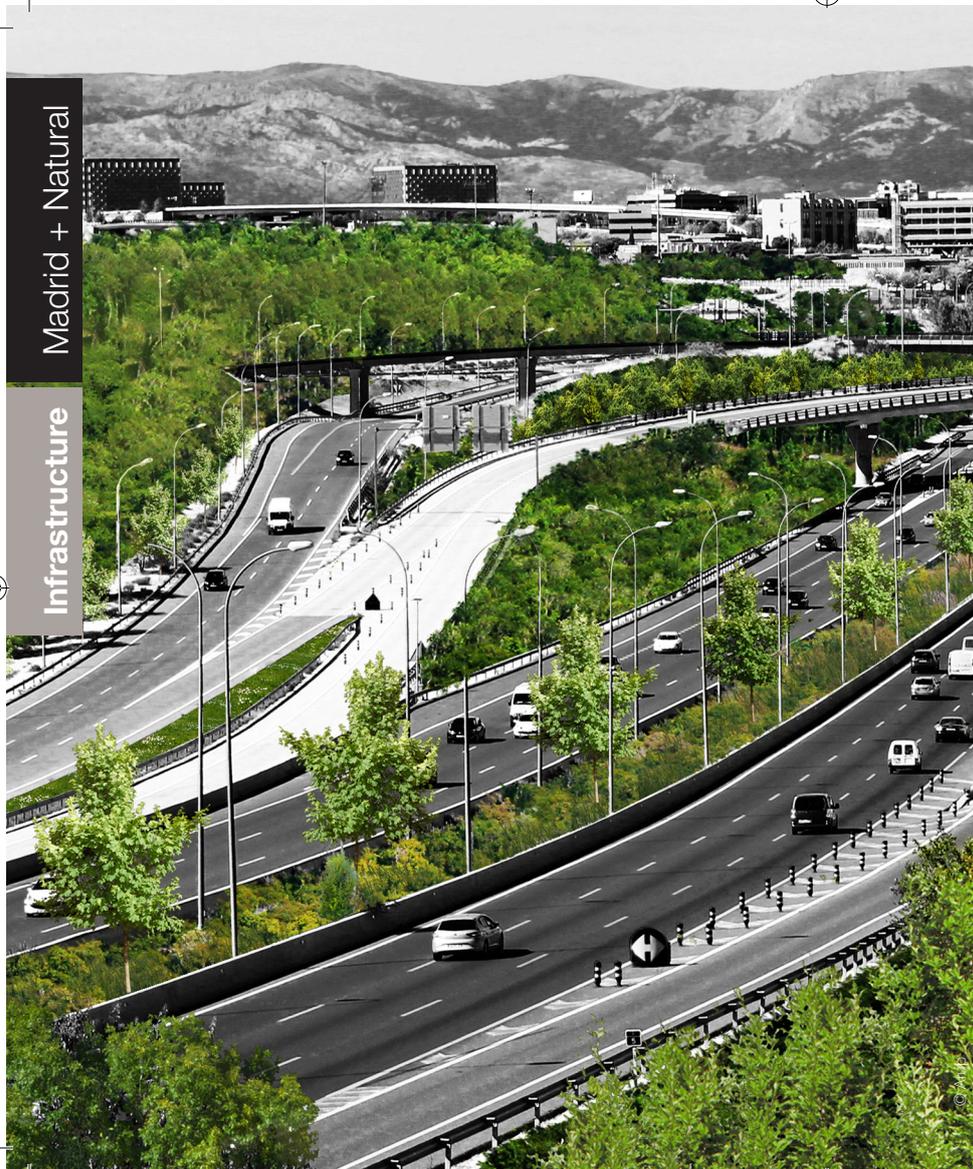
Woodbridge, Canada

## Earth Rangers Centre White Roof

The Earth Rangers Centre for Sustainable Technology is internationally recognised for its sustainable practices, including approaches to renewable energy and conservation. According to the centre, their building uses over 90% less energy than comparable buildings.

Part of the centre's sustainability strategy includes a 16,000 square foot white roof area. The applied thermoplastic polyolefin membrane also reflects sunlight into the building's skylights, reducing the need for artificial lighting. White roofs reduce surrounding temperatures, minimising local heat islands.

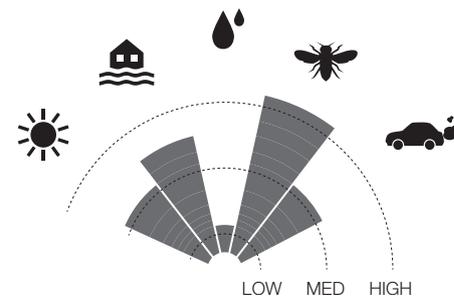
<http://www.ercshowcase.com/building-envelope/white-roof/>



## greening infrastructure

5

Greening of existing infrastructure provides natural habitats for wildlife and spaces for human enjoyment in increasingly dense cities. Transport links can be converted into linear parks, creating new nature areas. Empty spaces from infrastructure development can become pocket parks. Greening of obsolete infrastructure can enhance derelict spaces while improving air quality. Green bridges can provide similar benefits, in addition to offering pedestrian and wildlife crossings over waterways and roads.



📍 M40, Valdebebas,  
Calle Alberto de Palacio





London, UK

## Green Bridge Mile End Park

The regeneration design for East London's Mile End Park included a green bridge that links two previously divided areas into one large green space, forming a 90 acre linear green link. The refurbishment of the area provided valuable green space to a borough short of nature areas while improving local air quality. The green bridge is designed as a 25 metre wide landscape, comprising an array of mature trees. The span crosses a heavily used traffic route, providing safe pedestrian and cycle paths. The lower part of the bridge's structure also accommodates retail space, rent from which assists in the upkeep of the park.

<http://webarchive.nationalarchives.gov.uk/20110118095356/>; <http://www.cabe.org.uk/case-studies/mile-end-park>



Various, Germany

## Green Motorway Overpasses

As part of Germany's wildlife protection efforts, wildlife overpasses or green bridges have been built over 32 motorways, with 28 more in the planning or construction stages. Most of these bridges are specifically designed to reduce habitat fragmentation by creating safe passage over barriers for wildlife of all sizes, as well as for local residents and farm vehicles. Under the Nature Conservation Act and other environmental protection laws, road infrastructure projects, new and retrofit, require thorough environmental impact assessment before construction begins. These assessments examine impacts on air quality, noise levels, soil, hydrology and local flora and fauna.

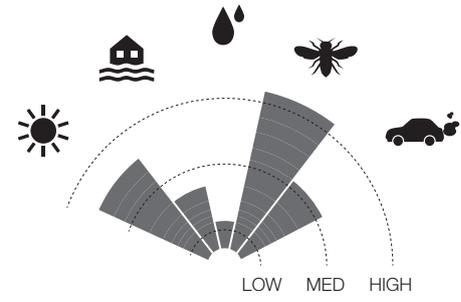
[https://www.environment.fhwa.dot.gov/ecosystemsgreeneroadsides/gr\\_summer02p3.asp](https://www.environment.fhwa.dot.gov/ecosystemsgreeneroadsides/gr_summer02p3.asp)



© Arup

# street greening

Increasing tree cover and green space is a key element of green networks, and can have positive effects on the economic and social quality of neighbourhoods. Trees provide shade and filter road pollution. Tree-lined streets can encourage people to seek alternative modes of transport and pursue healthier lifestyles. Street greening can lead to an increased sense of community belonging. Cities, for example, could incentivise community-led maintenance of planting in exchange for providing greenery.



Avenida del Mediterráneo





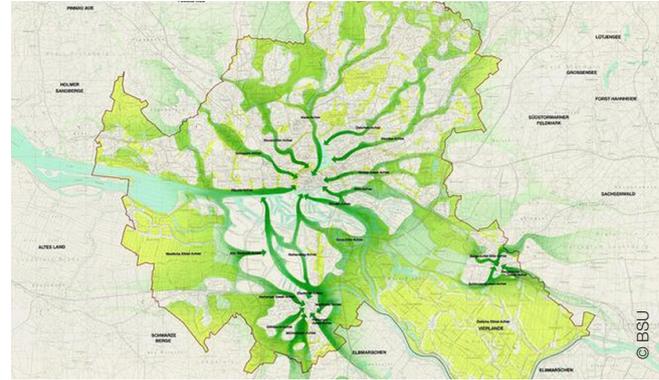
Melbourne, Australia

## Greening Melbourne's Laneways

The City of Melbourne has launched an initiative for residents and business owners to green its laneways with potted plants, climbing plants and green roofs. Residents and business owners are able to participate in laneway greening projects with little or no need for government permission and are able to seek funding in some cases.

The project reduces the possibility of flash floods by diverting runoff from laneways. The increased green cover filters pollution, adds a further layer of insulation to buildings, and increases the attractiveness of streets as well as the health and happiness of residents and passerby.

<https://www.melbourne.vic.gov.au/Sustainability/WhatCanIDo/Pages/GreeningLaneways.aspx>

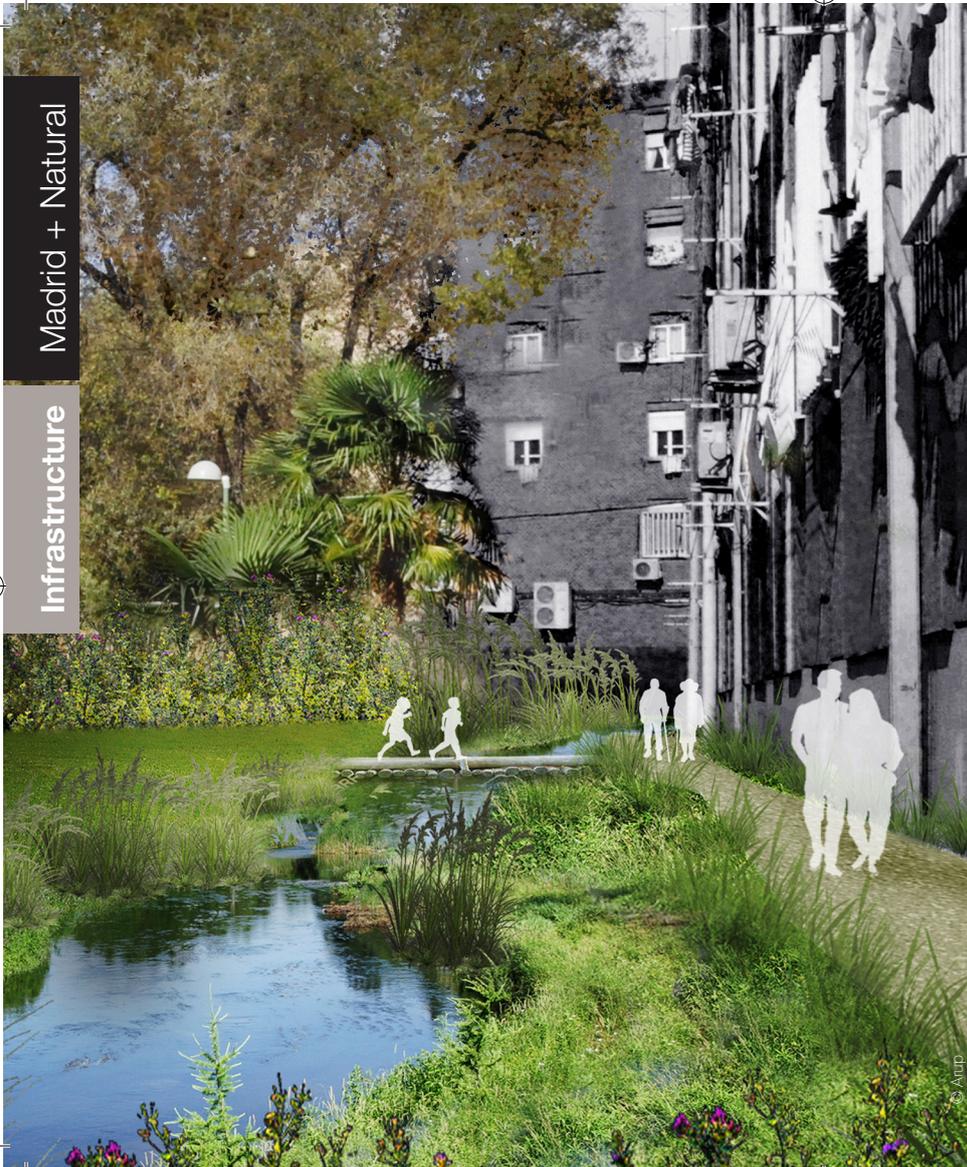


Hamburg, Germany

## Hamburg Green Power Strategic Plan

Hamburg has announced a plan to implement a city-wide network of green spaces by 2030, linking the city's outer ring with its dynamic centre through a series of walking- and cycling-friendly regenerated habitats. The changes are envisaged to be far more than aesthetic; such a widespread network of green spaces would allow Hamburg to better address impacts of climate change. The green network could at once provide flood mitigation for vulnerable spaces around Hamburg's vital ports, reduce urban heat island effects, improve air quality, and provide manifold public health benefits associated with urban greenery.

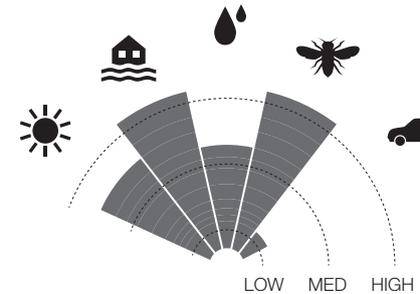
<http://www.hamburg.de/gruenes-netz/3939882/auf-gruenen-wegen-artikel/>



## river stream restoration

7

Over time, many cities have seen their water streams channelled and diverted from their natural courses and buried inside impermeable concrete beds to accommodate new developments and infrastructure. Re-meandering rivers and reducing their canalisation can facilitate the creation of a more balanced floodplain and the reestablishment of natural reed beds. This kind of habitat confers multiple benefits, including improved flood protection, increased biodiversity and wastewater management.



📍 Calle Nuestra Señora del Villar (La Elipa)





Singapore

## Kallang River Renaturalisation

Atelier Dreiseitl's conversion of a disused concrete channel into a sprawling natural park centred on the winding Kallang River in Singapore has created recreational opportunities as well as restoring wetland habitat for local species.

A bridge connects the park with nearby residences, encouraging residents to spend time surrounded by nature. The project won the Landscape of the Year award at the 2012 World Architecture Festival and has proven very popular with residents.

<http://www.dreiseitl.com/index.php?id=47&lang=en>



Seoul, South Korea

## Cheonggyecheon Stream Restoration

In 1958, the Cheonggyecheon River was entirely covered by a three-lane highway, creating one of the most congested and polluted areas in Seoul. In 2003, a radical redevelopment project completely transformed the area, providing a multilevel pedestrian walkway with abundant green spaces and significantly increasing the value of nearby real estate.

The restoration provides significant flood protection and reduces the urban heat island effect. Local air pollution has been reduced by 35% and biodiversity increased by 639%. The park is a popular destination for tourists and locals, drawing 64,000 visitors a day.

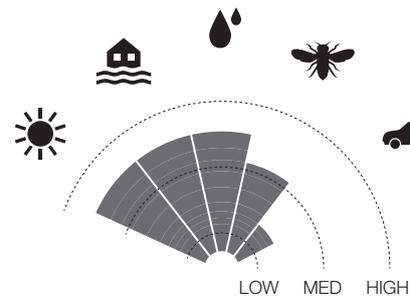
<http://landscapeperformance.org/case-study-briefs/cheonggyecheon-streamrestoration>



## permeable surfaces

8

Permeable paving and soft landscape areas will help to convert grey to green in future cities. This simple but vital technology can improve water absorption and slow rainwater run-off, and can be easily installed in interstitial spaces between buildings. More permeable surfaces will help cities to better cope with extreme weather events and increased sudden precipitation whilst having a positive visual impact. Cities could provide incentives to attract more private investment for this solution.




**Mercadillo de Hortaleza,**  
**Calle Santa Adela**





Concept design, no location

## Living Pavement Project

*Living Pavement* is a concept concerned with bringing more nature to the city, developed by Dutch designer Bennie Meek. The project aims to reimagine how we integrate nature in the city creating system that favour natural colonisation of spaces instead of relying on ornamental planting. The concept consists of a permeable, soil-bearing pavement that would encourage the growth of local flora, allowing urban dwellers to experience nature right at their doorstep.

Meek's permeable pavement design improves urban water drainage and if applied on a large scale, it could potentially improve the inner-city climate.

<http://popupcity.net/living-pavements-to-greenify-public-spaces/>



London, UK

## Derbyshire Street Pocket Park

The *Derbyshire Street Pocket Park* project used native plants and recycled materials to transform a dead-end street used for parking into a small park, improving the physical environment, increasing local drainage capacity and improving flood mitigation capacity.

The project employed Sustainable Drainage System (SuDS) components, including permeable paving, small scale green roofs on bike and bin shelters, attenuating planters, engineered tree pits, and an artificial swale. The pocket park processes all surface water on site, enabling disconnection from the local sewer system.

[http://www.susdrain.org/case-studies/case\\_studies/derbyshire\\_street\\_pocket\\_park\\_london\\_borough\\_tower\\_hamlets\\_1.html](http://www.susdrain.org/case-studies/case_studies/derbyshire_street_pocket_park_london_borough_tower_hamlets_1.html)

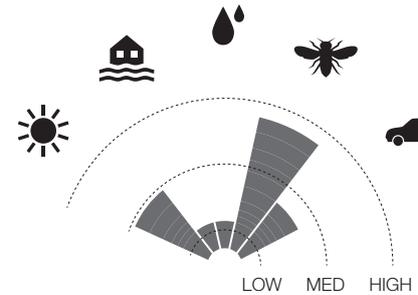


© Arup

## urban farming

9

As concerns rise over instability of the global food trade, and lack of space for agriculture, food production could become an integral element in cities. Urban farming can be implemented on rooftops and unused spaces between buildings, optimising the use of urban space. Growing crops can boost a sense of belonging, incentivise local food consumption and, by including schools and care homes, urban farming can provide educational and therapeutic benefits.



 Huerto Ladis,  
Villaverde Alto





Boston, US

## Urb.ag Urban Farming Assistance App

As urban agriculture becomes more popular, cities are increasing enforcement of current policies and rolling out new regulatory frameworks for oversight. The maze of regulations involved in starting an urban farm can be daunting to citizens; Urb.ag's app helps simplify the process.

Launched in 2014, the initial app version provides assistance for the Boston area. Users enter an address to discover what types of farming are permitted in that location, and the app outlines current policies and regulations, provides a list of permits that need to be filed, and offers contact information for relevant local agencies.

<http://urb.ag/>



London, UK

## Dalston Eastern Curve Garden

*Dalston Eastern Curve Garden* is a public garden space built in 2010 in East London, which repurposed a section of abandoned railway as part of an initiative promoted by the local council.

The garden is planted with a wide range of trees, such as birch, alder, hazel and wild cherry. Fruit trees, vegetables and herbs are looked after by volunteers, and provide a source of fresh food for the local community. The concept also includes multi-purpose facilities for use by visitors, including event spaces, a café and a workshop area.

<http://dalstongarden.org/>



Juniperus thurifera



Quercus ilex



Jacaranda mimosifolia



Ceratonia siliqua



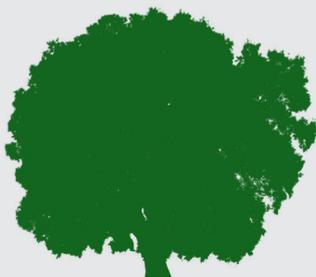
Ficus carica



Abies pinsapo



Pinus nigra



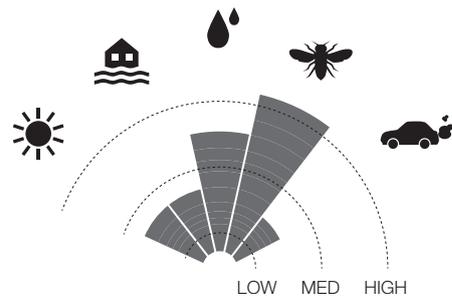
Quercus suber



Olea europea

## adaptive planting

Long-term approaches to the creation of green habitats are becoming more important, as our ecosystems increasingly need to withstand changing environmental conditions such as longer drought periods, hotter weather, or rarer but more intense rainfall. The selection of plants carries its own challenges, as ecosystem balance issues and potential allergy impact must be considered. Guidelines for future planting and plant combinations may become necessary as part of a city's climate change adaptation strategy.





Various, UK

## The Forestry Commission

The Forestry Commission, the government body responsible for the management of forests in England and Scotland, is planning for climate change through species selection. An analysis of existing tree stocks has been undertaken, designed to assess species' vulnerability to the likely effects of climate change, and current planting regimes are being adapted to ensure that England and Scotland's tree stocks remain consistent and resilient. Particular attention is being paid to urban forestry; the Forestry Commission has invested in research into the effects of climate change on trees, creating a database to assist in climate change resilient urban tree species selection.

<http://www.righttrees4cc.org.uk/>; <http://www.silvifuture.org.uk/>



Various, UK

## Trees in Hard Landscapes Guideline

An initiative of the Trees and Design Action Group, *Trees in Hard Landscapes: A Guide for Delivery* is a publication developed to support those involved in the design of the urban realm in their decision-making process. This paper highlights the importance of an integrated approach to urban planning to achieve a long-term harmonic coexistence of functional urban elements and plants.

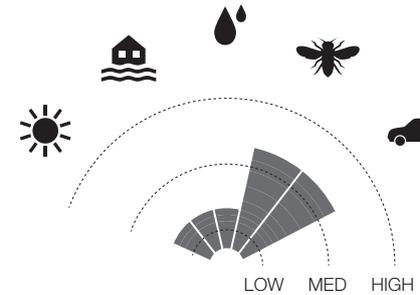
Highway engineers, developers and tree officers can benefit from the guidelines provided. They include principles on selection, plantation and maintenance of different tree species in diverse urban contexts.

[http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag\\_trees-in-hard-landscapes\\_september\\_2014\\_black-and-white.pdf](http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-hard-landscapes_september_2014_black-and-white.pdf)



## retrofitting derelict plots

Areas of social infrastructure, known as 'equipamientos', are often left unused and derelict due to demographic change and physical decay. Greening these pockets of land, in close consultation with local communities, can reinvigorate neighbourhoods by enabling social interaction, improving wellbeing and enhancing wildlife prosperity. Low-maintenance greening techniques and the involvement of local residents can help overcome maintenance challenges whilst strengthening a sense of ownership.





Philadelphia, US

## Greenworks Philadelphia

*Greenworks Philadelphia* is an initiative to unite the city government and its residents in transforming empty or underused urban land into publicly accessible green space. The initiative, designed to support Philadelphia's ambition to become the 'number one green city in America', aims to establish 500 acres of green coverage throughout the city. In neighbourhoods where vacant lots have been transformed into green spaces, research has found significant reductions in crime and stress, increased levels of physical exercise, and increased reporting of happiness among residents.

[http://www.phila.gov/green/PDFs/Greenworks2013ProgressReport\\_Web.pdf](http://www.phila.gov/green/PDFs/Greenworks2013ProgressReport_Web.pdf)



Santander, Spain

## Santander Pop-up Garden

The explanada de Gamazo is a promenade overlooking the bay of Santander. This area, once dedicated to maritime operations, has been transformed into a 'removable park'. This pop-up park was built to provide space for pedestrians and leisure activities while still accommodating large water sports events.

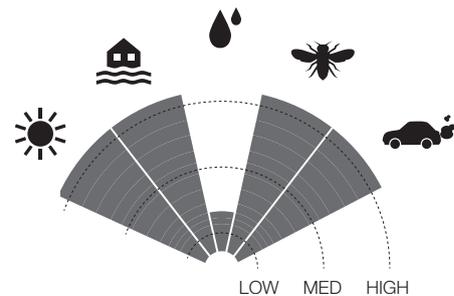
All of the park's features were designed and placed to enable change; they can be easily removed and stored before being returned to their positions at the end of an event. Installations include large paving slabs placed on rails, as well as floating modules containing small-scale plantations.

<http://www.eldiariomontanes.es/santander/201507/13/nuevo-parque-borde-20150712000303-v.html>



## urban forests

As a main component of green infrastructure, urban forests provide cooling, shade, water and air filtration, and stormwater management. Urban forests, especially when composed of local species, increase the diversity of local flora and fauna, preserve natural habitats, and can be used to provide natural compost. Urban forests provide communities with spaces in which to interact, keep healthy and escape from stress. In the future, more effective policies will be needed to protect or restore urban forests.



Estacionamiento,  
 Mercadillo de Hortaleza,  
 Calle Santa Adela





London, UK

## Bankside Urban Forest

London's *Bankside Urban Forest* was launched in 2007, with the goal of improving the streets and public spaces between the riverside and the borough of Elephant and Castle. The project aims to implement green streets which encourage cycling, walking and lower traffic speeds. The forest distributes the benefits of regeneration and makes Bankside a better place to live, work and visit. Multiple private and public institutions are working together to create this network of green connections. The project aims to demonstrate potential large-scale impacts resulting from weaving together a series of small landscape initiatives.

<http://www.betterbankside.co.uk/buf>; [http://publications.arup.com/Publications/C/Cities\\_Alive.aspx](http://publications.arup.com/Publications/C/Cities_Alive.aspx)



Pittsburgh, US

## Pittsburgh Urban Forest Masterplan

*Tree Pittsburgh*, an environmental non-profit organisation, together with an array of partners including the City of Pittsburgh, developed an Urban Forest Masterplan for the City of Pittsburgh.

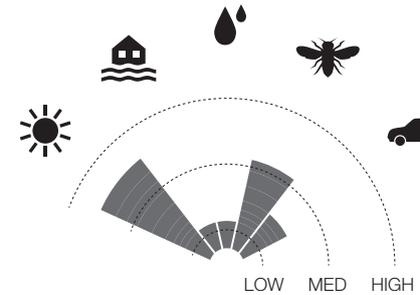
The plan provides a basis for managing, protecting and growing Pittsburgh's urban forest. Following a thorough evaluation of current trees, the initiative examines processes and measurements to increase the city's tree cover, with the aim of achieving 60% urban tree canopy cover within 20 years. Strategies focus on engaging all city stakeholders, from citizens to the public sector, in the protection and care of trees.

<http://treepittsburgh.org/urban-forest-master-plan>



## seasonal shading

When designing or retrofitting buildings and neighbourhoods, microclimate design should be taken into consideration to optimise buildings' energy efficiency and reduce energy costs. By using temporary shading sails, or structures supporting climbing plants, seasonal shading can help mitigate summer heat waves and make public space accessible during the hottest hours of the day. Similarly, by avoiding evergreen species, solar gain in winter can be maximised.



Plaza de Callao





Vigo, Spain

## Plaza del Pueblo Gallego

The demolition of the former building of El Pueblo Gallego, a historic newspaper, created a new bare space in Casco Vello, a central neighbourhood of Vigo, Spain. This created an opportunity for a multifunctional public square which could be used for community gatherings, public functions, concerts and plays.

The square integrates pockets of green at ground level, which develop onto a skeleton structure that supports climbing vines, creating a natural shading device. The net of plants filters light and cools the square, making it liveable during warm weather conditions.

<http://www.publicspace.org/en/works/g393-plaza-del-pueblo-gallego>



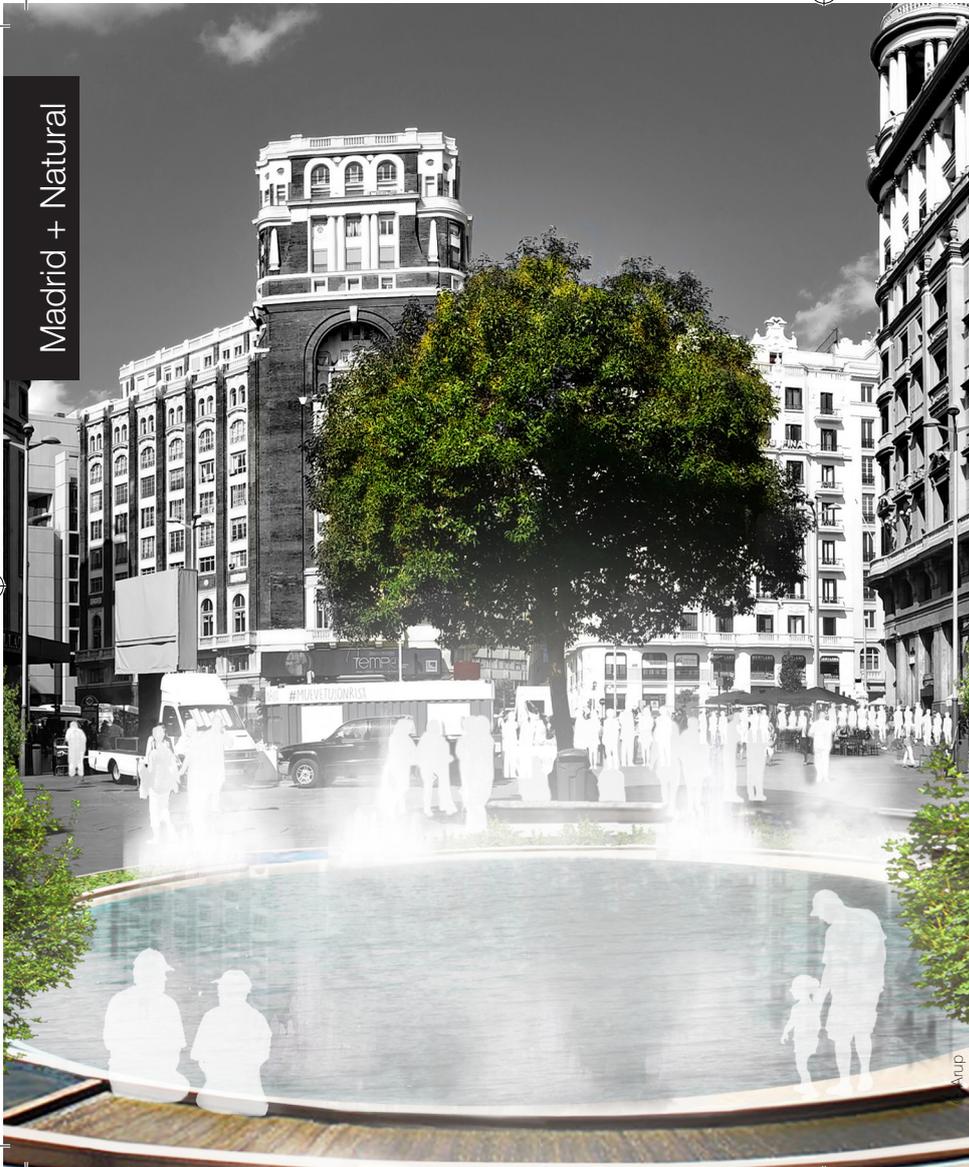
Vienna, Austria

## Kagome Sandpit

In response to a commission by the museum quarter for a temporary summer playground, PPAG Architects developed a unique sandpit enclosed in a living vegetated structure to provide essential shading to young urban dwellers playing in the museum's courtyard.

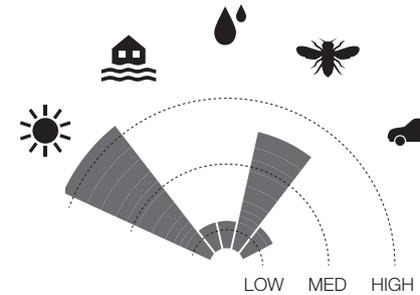
The structure, inspired by Japanese weaving techniques, is made of willow tree branches woven into a dome that grows a thicker layer of leaves as the weather gets warmer. The trees are rooted into soil bags underneath the sandpit, which provide nourishment to the plants throughout the whole season.

<http://inhabitat.com/japanese-inspired-woven-willow-kagome-sandpit-offers-natural-play-for-kids-in-vienna/>



# microclimates with water

The integration of water features into public realm design can provide a range of benefits, including a positive effect on local microclimates. Water can reduce local temperatures and mitigate the urban heat island effect. Fountains, mist, brooks and waterfalls can be used to create playgrounds and recreational spaces for urban residents. Best practice guidance will be needed for the use of water to create microclimates, considering energy consumption, water sourcing and maintenance, and use optimisation.



Plaza de Callao





Bradford, UK

## Bradford City Park

*Bradford City Park* is a flexible public space featuring a large 3600m<sup>2</sup> 'mirror pool' with over 100 illuminated fountains. The computer-controlled management system can alter the character of the square by changing the water level and actuating mist machines, fountains and laser lights. The square can be a fully filled basin, partially filled to reveal pedestrian paths, or be dried entirely to host large scale events. This potential for constant reinvention has made Bradford City Park a popular public space, attracting pedestrian traffic and new local businesses. The water feature is a symbol for Bradford's city regeneration, creating a focal point for further development and improvement of the city.

<http://www.visitbradford.com/thedms.aspx?dms=3&venue=2198372>



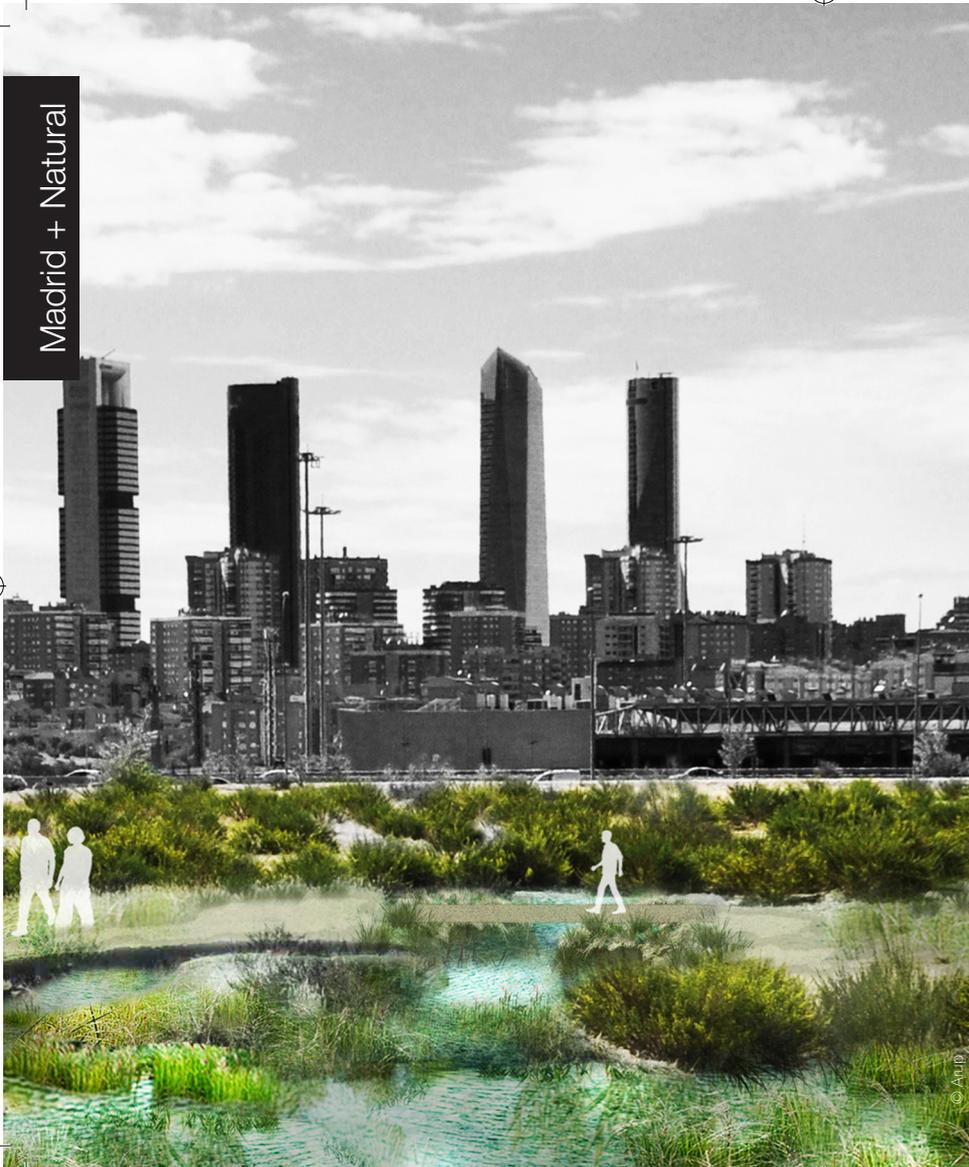
Tachikawa, Japan

## Showa Memorial Park Foggy Forest

Devised by Japanese Artist Fujiko Nakaya, *Foggy Forest* is a mist intervention within the Showa Park in Tachikawa. In this zone, cool clouds of mist hover above the undulating landscape, providing a cool atmosphere and a dramatic effect for visitors.

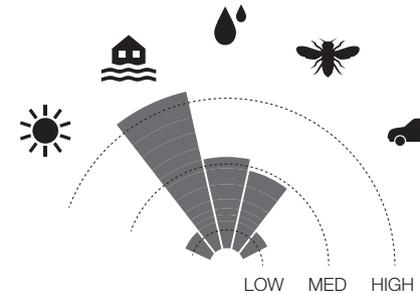
The fog is switched on during most of the day and evokes different reactions from visitors, from meditation to play. When the mist is deactivated, the park can be used as a unique play and leisure area. The fog feature waters the grass with little or no need for further soil irrigation.

<http://www.yokohamatriennale.jp/2008/en/artist/nakaya/>



## temporary flooding

Many cities are looking to redesign their water streams to make them more resilient in light of increasing extreme weather events due to climate change. Recreational green areas with permeable surfaces can be used as buffer zones for temporary flooding when needed. Spaces for temporary flooding should be included in city planning, especially when designing new developments in flood risk areas. The re-establishment of local riparian vegetation can help mitigate the impact of flood events.





Rotterdam, Netherlands

## Bentheplein Water Square

The City of Rotterdam is facing an increase in density and a subsequent lack of space for water storage, especially in its central areas. Climate change is also causing more intense rainfall, making water management particularly challenging. The 2012 refurbishment of Bentheplein square offered an opportunity to address this problem. When dry, the new square is an attractive, socially engaging space including a skate park and a basketball court. As rainfall becomes heavier and water volumes increase, the square's basin can retain up to 1.7 million litres of water, relieving sewage networks while helping to prevent floods.

<http://www.dutchwatersector.com/news-events/news/8841-new-innovativewater-square-combines-leisure-and-storm-water-storage-in.html>



Copenhagen, Denmark

## Cloudburst Project

The Copenhagen *Cloudburst Project* was developed as a reaction to 2011 floods in Copenhagen, which affected large areas of the city. The masterplan for 34 km<sup>2</sup> of central city districts, developed by Ramboll and Atelier Dreiseitl, focusses on improving flood management and water quality while working together with other vital city systems such as mobility and recreation. In this case, implementing blue-green infrastructure solutions was cheaper than rectifying the damage from flood events; for example, a single 2011 flood event cost £610m, as compared with the £410m cost of implementing sustainable drainage systems.

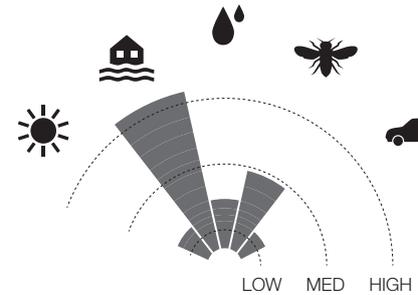
<http://www.ramboll.com/projects/germany/copenhagen-cloudburst>; <https://gloscape.files.wordpress.com/2015/05/cities-alive-sls-talk.pdf>



© Arup

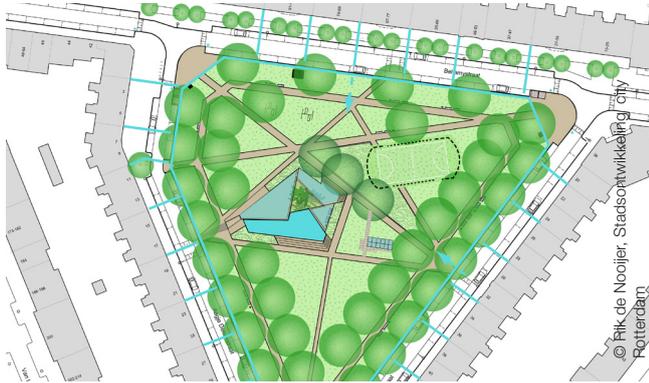
## sustainable drainage

Sustainable drainage systems implemented in urban environments, within streets and green spaces, assist cities to better cope with predicted extreme weather events. By simulating natural water filtration, sustainable drainage systems attenuate stormwater, facilitate water absorption from hard surfaces, and reduce pollution from water run-off. Filtered water can be reused for many purposes, from re-injection into aquifers to metro/underground sanitation.



M30, Centro Deportivo Municipal Cagigal





Rotterdam, Netherlands

## Green Water Square

The Spangen district in Rotterdam has almost no open water but a high proportion of paved surfaces within a dense urban environment. In order to build resilience to climate change, a series of well-vegetated water squares have been constructed in the district. The design of the central area of each square has been lowered and paved to act as a temporary buffer for rainwater. Surrounding paved surfaces connect to the central area; these supplementary storage areas can fill with rainwater to reduce the impact of rainfall and storms on the city. The square represents a creative and effective solution to deal with climate change, and provides an example that can be adapted to virtually any urban situation.

[http://publications.arup.com/Publications/C/Cities\\_Alive.aspx](http://publications.arup.com/Publications/C/Cities_Alive.aspx); <http://www.urbangreenbluegrids.com/projects/green-water-square-bellamyplein-rotterdamthe-netherlands/>



Normal, Illinois, US

## Uptown Water Circle

The *Uptown Water Circle* is a green water square that collects water run-off from the surrounding streets. The collected water is then stored and also purified in the circle. It also acts as a buffer for rainwater run-off into lower areas of the city. After passing through the filtration system, the water is used as a water feature within the circle, improving the local microclimate. Additionally, some of the filtered water is used to spray adjacent streets in order to reduce heat stress. While providing many environmental benefits, the square also acts as a showcase of sustainability for the neighbourhood and provides a 'playground' for children and adults alike.

<http://www.urbangreenbluegrids.com/projects/normals-uptown-water-circlewaterrotonde-in-normal-illinois-us/>

*“A study in New York states that asthma rates among children age four and five fell by a quarter for every extra 343 trees per square kilometre. The presence of street trees was linked with a 29% reduction in early childhood asthma.”*

—G. S. Lovasi, J. W. Quinn, K. M. Neckerman, M. S. Perzanowski, and A. Rundle. Children living in areas with more street trees have a lower prevalence of asthma (2008)



*“Residents in ‘high greenery’ environments were 3.3 times more likely to take frequent physical exercise than those in the lowest greenery category.”*

—Forestry Commission. The case for trees in development and the urban environment (2010)



*“Desk workers who can see a green environment from their desks experience 23% less time off sick than those that have an entirely urban view. Similarly, these workers also report greater job satisfaction.”*

—K. L. Wolf. Human dimensions of the urban forest. Urban nature benefits: psycho-social dimensions of people and plants (1998)



*“Trees and parks can reduce local air temperatures by 0.5 to 5°C resulting in cooler air that can lessen the need for air conditioning.”*

—United States Department of Agriculture, the Forest Service. Energy-saving potential of trees in Chicago (1994)

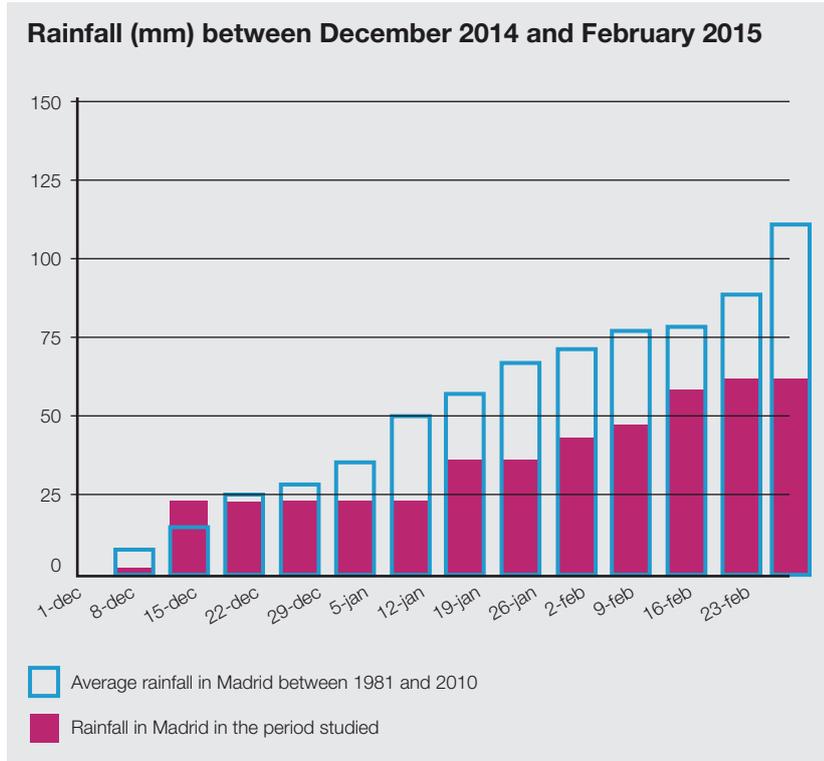


*“Cooling can be facilitated by even a small space – parks of only one or two hectares have been found to be two degrees cooler than surrounding areas.”*

—H. Upmanis. The park has its own climate. Swedish Building Research No.2 (2000)



# drop in rainfall

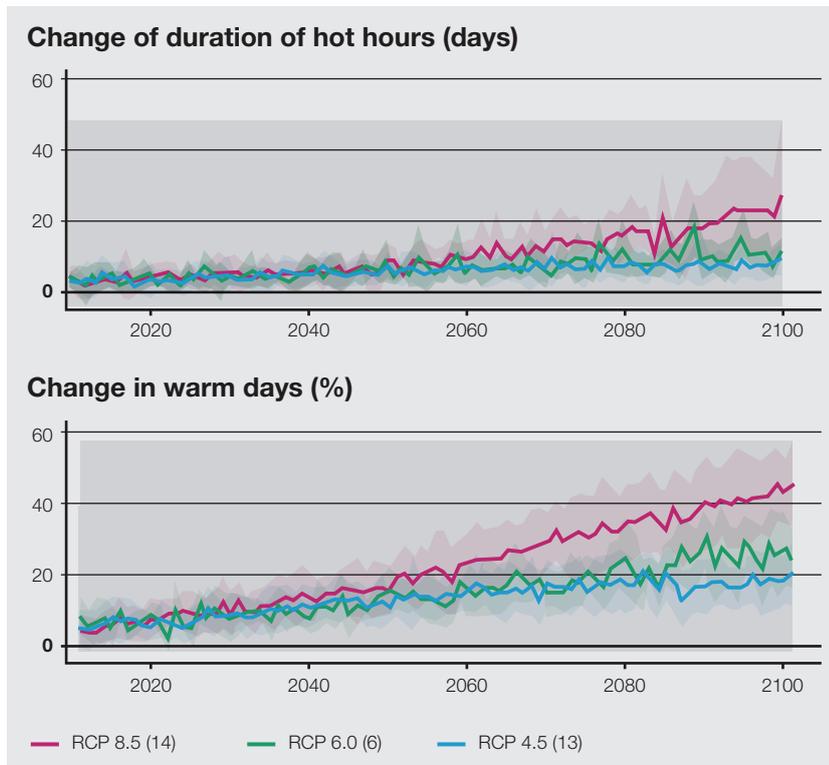


As the Earth heats up through global warming, cumulative rainfall increases. The distribution of rainfall, however, varies significantly. While some parts of the world are threatened by heavier rainfall, others are suffering longer drought periods. Although heavier storms are being registered in Madrid, overall, the city is starting to experience a significant reduction in average cumulative annual rainfall. Predictions point towards a rainfall reduction up to 100 mm above average data. This would account for a 25% reduced average cumulative precipitation and between 5 to 15 less rainy days by 2050.

Diagram source: Agencia Estatal de Meteorología



# heat island and heat waves

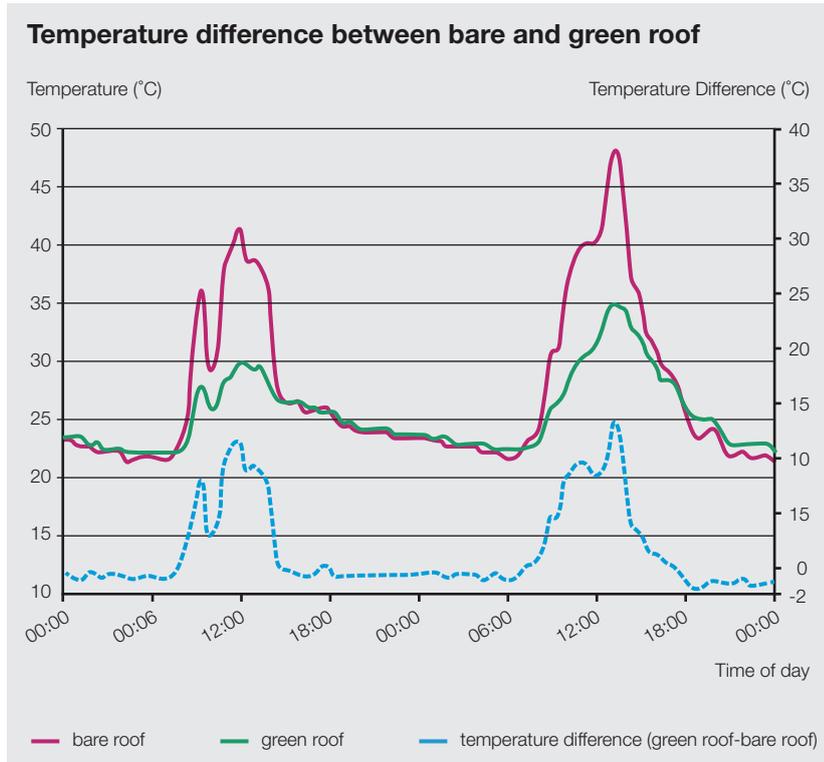


Periods of abnormally hot temperatures, and an increase in the duration of these periods, are among the first evidence of the effects of climate change in urban cores. These temperature phenomena can be linked to the evidence of urban heat island effects; as one of the major climate change impacts, this requires the inclusion of adaptive strategies aimed to control and alleviate extreme temperatures in cities. The results of the European Project ENSEMBLES, where different climate change scenarios for Madrid over the next 80 years have been assessed, show an increase in the number of abnormally hot days during summer, reaching 20% by 2050. This implies an increase in average high temperatures of up to 4°C.

Diagram source: Consorcio de Compensación de Seguros



# temperature regulation in green roof areas

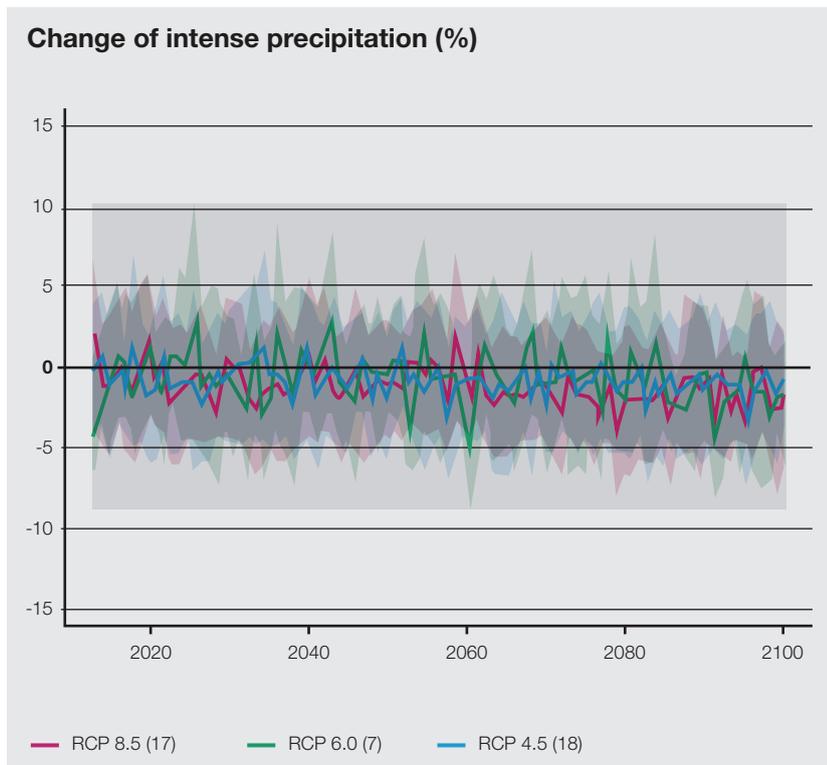


Green infrastructure elements such as green roofs, green walls and urban forests provide multiple regulating ecosystem services to the urban environment. These include stormwater management, heat island control, aesthetic value and improvement of air and water quality. Research in the field has demonstrated the potential of green roofs and urban forests as a strategy for adapting urban ecosystems to the impacts of climate change. Temperature reductions up to 4.5 °C over the summer were reported in areas of Madrid where these strategies have been implemented.

Diagram source: Retrofitting Housing with Lightweight Green Roof Technology in Sydney, Australia, and Rio de Janeiro, Brazil



# storm surges



Madrid is an area classified as a low flooding risk area in Spain. However, climate change predictions for the next 80 years forecast a continuous increase in the number of heavy storm events per year, which may also cause severe flooding events.

Flooding is the most frequent natural hazard, with a significant economic and environmental impact. Floods have been responsible for several fatalities in the city over the last 25 years. The Madrid flooding event of June 2015 involved two fatalities and an estimated economic cost of 10 million Euros, with more than 1,500 people filing property damage claims.

Diagram source: Consorcio de Compensación de Seguros



# energy saving potential from reduced temperatures

## Energy demand reduction achieved by the integration of green roofs and street greening. Energy demand profile for a peak hot day in Madrid



Reductions in ambient temperatures resulting from the inclusion of nature-based solutions in the urban environment have a direct impact on human comfort in the outdoor environment. Temperature profiles around buildings in urban environments where nature-based solutions have been implemented reported daily cooling energy demand reductions of up to 14% during the summer months, relative to areas without greenery. This demand reduction has a direct effect on required electricity production capacity, potentially allowing a larger contribution of clean energy to the grid while reducing the need for fossil fuel based electricity.

Diagram source: Effects of Green Roofs in urban microclimates during the summer



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