Living Roofs and Walls
from policy to practice

10 years of urban greening in London and beyond

SUPPORTED BY
MAYOR OF LONDON

Acknowledgments

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Cover photo: Goodman's Fields, Berkeley Homes North East

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Foreword

Shirley Rodrigues

Deputy Mayor of London,
Environment and Energy

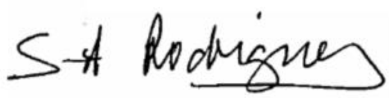
More and more people want to live in cities. They provide economic opportunities and are centres of culture and learning. With the right policies, planning and governance they can also be at the forefront of a more sustainable future.

London, like many other cities around the world, is growing. The Mayor is committed to ensuring that this growth has the potential to improve the health and quality of life of all Londoners, to reduce inequalities and to make the city a better place to live, work and visit - sustainable growth that works for everyone, using London's strengths to overcome its weaknesses.

I was privileged to be leading the Greater London Authority's Environment Team when the first green roof policy was included in the London Plan in 2008. In the intervening 10 years I have been delighted to witness the patchwork of green roofs and walls spreading across London's skyline, alongside the establishment of a world-class industry that is working towards the greening of London and other cities and which is, moreover, supporting our objectives on air quality, climate resilience and biodiversity.

Ten years later, and now as the Deputy Mayor for Environment and Energy, I want London to continue to be a pace-setter. The Mayor has made a commitment to make London the first National Park City and for more than half of London to be green by 2050. To make that a reality we must continue to green the built environment whilst ensuring the protection of our existing green spaces.

We have introduced an Urban Greening Factor into the London Plan to ensure that all new major development includes an element of greening which contributes to making the city healthier, wilder or more resilient. This is urban greening as infrastructure not as ornament, and it is essential if we want to create the sustainable cities of the future that we urgently need.



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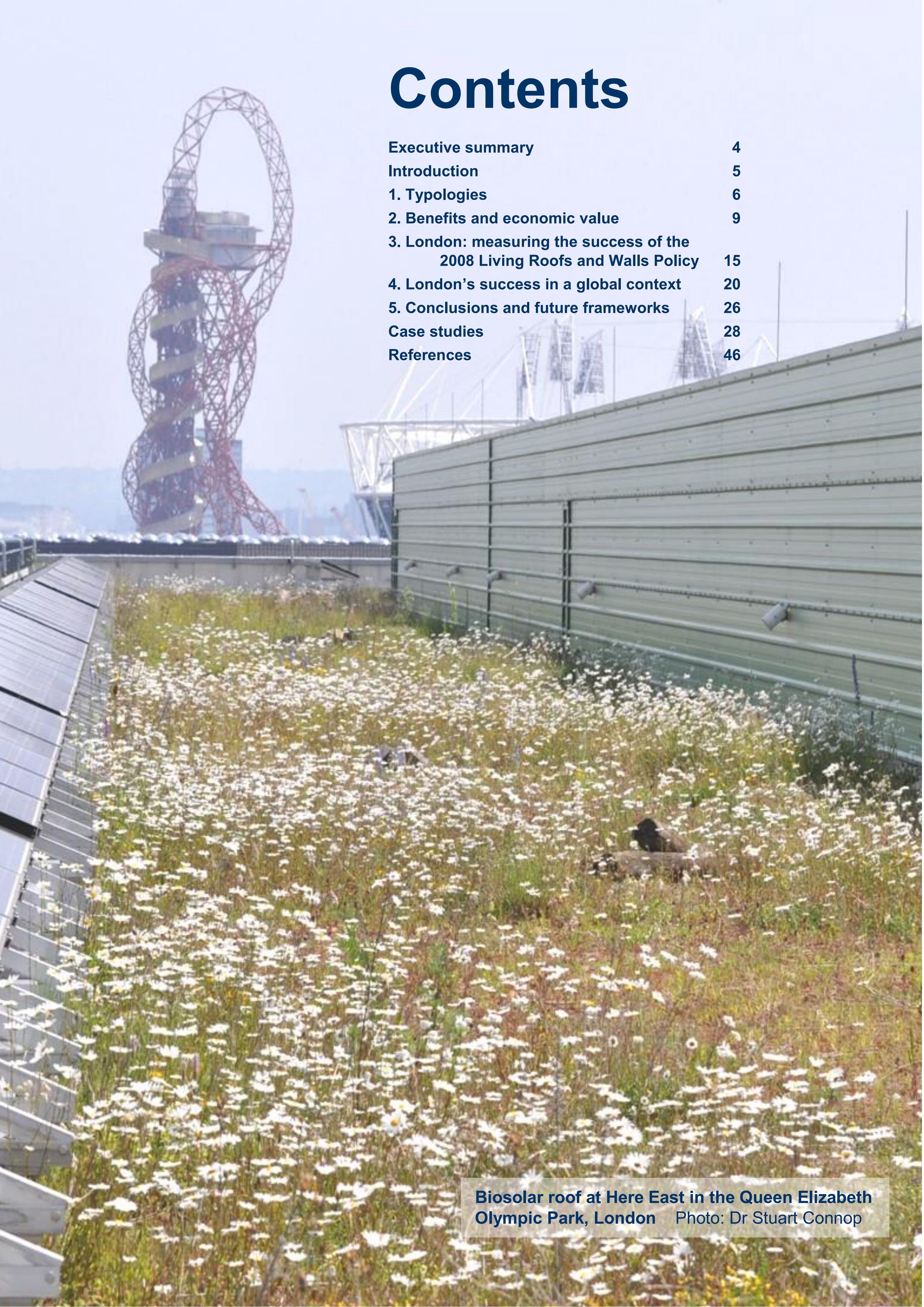


Biosolar roof at Here East in the Queen Elizabeth Olympic Park, London Photo: Dr Stuart Connop

Executive summary

This report is a summary of the progress that has been made in mainstreaming green roofs and walls as a response to the challenges facing cities now and in the future. It also updates information about the benefits of green roofs and walls and highlights policy development in London and elsewhere which aims to encourage more urban greening to ensure the urban environment becomes greener, healthier and more resilient to the impacts of climate change.

Green roofs (living roofs) and green walls (living walls) have, over the last decade, become the most obvious manifestation of urban greening in London. This has been driven by the ambitious and pioneering Living Roofs and Walls Policy which was first introduced into the London Plan in 2008 following the publication in that year of a technical report, Living Roofs and Walls, supporting the policy.

Since then, green roof and wall uptake in both large and small developments has increased annually across London. The main focus of activity has been in the inner London boroughs and in a few of the outer London boroughs where there is major regeneration. As a result:

- The total area of green roofs in the Greater London Area was 1.5 million m^2, which equates to $0.17m^2$ of green roof per inhabitant (2017 figures)
- In the Central Activity Zone (CAZ) green roofs covered $290,000m^2$, which equates to $1.26m^2$ of green roof per inhabitant (2017 figures). This is higher than many other cities in the world which are famed for their green roofs
- 42% of the total UK green roof market is in London (2016 figures)

This has been achieved without the subsidies or financial incentives that have been available in many other leading cities. Whilst some of those cities are recognised as global leaders in delivering green roofs and walls, London's progress, for the most part, has not been widely acknowledged.

This report shows that the London Living Roofs and Walls Policy has begun to transform the capital's roofscapes. The city is now regarded as a leader in urban greening, in terms of policy, planning and design, as well as in the overall amount of green roofs and walls being installed.

The 2008 technical report has influenced policymakers in other cities around the world and raised awareness of the benefits of green roofs and walls within the construction and property industry. Now many companies embrace their use as part of their own approach to delivering greener, healthier and more climate-resilient buildings and neighbourhoods.

The future is certain to be one in which the provision of green roofs and walls on new developments across the whole of London will continue to grow. The projected increase in population in London (and most other cities) will require more intensive use of developed sites and therefore a significant increase in the quantity of green roofs and walls.

However, urban greening policy and practice will need to develop further. It is imperative that new approaches, such as biosolar roofs (green roofs combined with photovoltaic arrays) and blue green roofs (green roofs that can store stormwater), become part of the standard range of urban greening measures planned, designed, managed and integrated into the wider green infrastructure network, to make the cities of the future more sustainable.

Introduction

Ten years have passed since the Greater London Authority published the technical report, Living Roofs and Walls, to inform new policy introduced into the London Plan of 2008 - the spatial planning framework for London. Much has changed during that time and much has been achieved.

The inclusion of a policy for green roofs and walls in the London Plan of 2008 was transformative. The policy stated that:

"The Mayor will, and boroughs should, expect major developments to incorporate living roofs and walls where feasible and reflect this principle in Local Development Framework policies."

At the time, policymakers were aware of the longstanding and widespread use of green roofs in Germany, Austria and Switzerland, and examples of green roofs were emerging in London. However, green roofs were still a relatively novel idea and the technology was new and somewhat controversial, while green walls were generally regarded as an expensive and unreliable ornament.

A decade later, the picture - as a result of this bold policy move - is very different. Architects, urban designers and planners are now familiar with both green roofs and walls and the development industry expects to be asked to include them in new developments.

Currently, there is more than 290,000m^2 of green roofs installed in central London, and 1.5 million m^2 across the whole of the Greater London Authority area. Green walls are now relatively commonplace and successful, with several large installations in prominent locations. There is also a thriving green roof and wall industry that delivers both small and very large-scale projects across the whole London area.

Extensive green roofs, Woodberry Down, north London Photo: Berkeley Homes North East

It is also the case that while the environmental, health and economic benefits of green roofs and walls were understood in 2008, there now exists a substantial body of evidence that is able to quantify these benefits. In section 2, this report sets out in detail the positive impact that green roofs and walls have on the urban environment especially in terms of biodiversity, sustainable water management, and general health and wellbeing.

A measure of the success of the London Plan is that London currently accounts for around 40% of all green roofs installed in the UK. This has been achieved primarily through the land-use planning process; unlike many other cities around the world, London does not provide financial incentives for their provision. In section 3, this report surveys the progress made across Greater London in the past 10 years. (Included at the end of the report is a series of case studies which represent the variety and breadth of provision now seen in the UK capital city.) Section 4 assesses the capital's achievement in a global context, looking at the various policies of cities around the world and the impact they have had on green roof and wall provision.

The report concludes by evaluating - in the light of the evidence collated and presented herein - how successful the 2008 Living Roofs and Walls Policy has been. It measures this success in relative terms against a global backdrop of green roof delivery, and uses the findings to set out its vision for how the greening of our urban spaces can continue to evolve and play an increasingly important part in greening our capital city and cities around the world.

1. Typologies

Whilst the general concept of a green roof or green wall has not changed in the past 10 years, innovations in design and technology have led to a number of variants to established systems and further advances in the ability of the construction industry to integrate vegetation into the built environment.

This is especially the case when green roofs are combined with other technologies such as photovoltaic arrays and blue roofs.

Definitions and descriptions of the various green roofs and walls are provided below.

Green roofs

A green roof (also known as a living roof or occasionally an eco-roof) is a roof or deck where vegetation or habitat for wildlife is deliberately established.

Although 'green' refers to vegetation, it is important to note that not all green roofs are uniformly green in colour. Different vegetation types, or features such as stones, sandy soils or dead wood added to create wildlife habitat, can result in a variety of colours and textures.

The German Landscape Research, Development and Construction Society (FLL), and the Green Roof Code of Practice in the UK, divides green roofs into two major categories: intensive and extensive. These terms refer to the intensity of maintenance required.

Intensive green roof, Embankment Place, central London Photo: Dusty Gedge

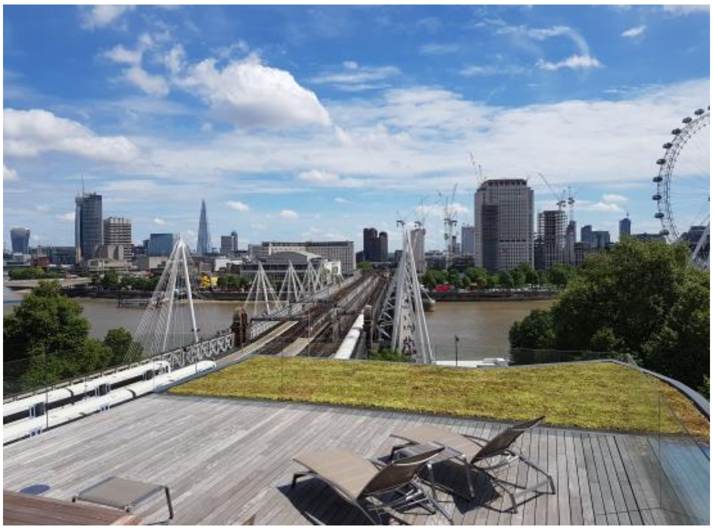
a) Intensive green roofs

Intensive green roofs are usually irrigated and receive several maintenance visits each year. Soils (artificial growing media usually known as substrates) are relatively deep on intensive green roofs (typically greater than 200mm). These green roofs are often referred to as roof gardens. The effect is generally a formal landscape such as a garden, park or parklet on a roof or podium. Where urban food growing is desired, intensive green roofs are usually necessary to provide sufficient soil volume.

Urban food growing on Nomura Bank, central London Photo: Dusty Gedge

b) Extensive green roofs

Extensive green roofs are usually vegetated with low-growing, drought-tolerant vegetation such as stonecrops (Sedum species) and dry meadow vegetation. They vary in depth between 40mm and 150mm. They are low maintenance, not usually irrigated (except during establishment) and have a relatively shallow build-up.



Sedum green roof, Charing Cross, central London Photo: Bridgman & Bridgman

Biodiverse green roofs

Biodiverse green roofs are designed to provide a particular native vegetation type or bespoke habitat for particular species of wildlife. As with most categories, there are examples that have the characteristics of both, known as *semi-intensive roofs*. These green roofs typically have deeper soils than extensive roofs, may or may not be irrigated and tend to have wider variety of plant types, including shrubs.

Extensive 'brown' biodiverse green roof, Bishopsgate, London Photo: Dusty Gedge

Biosolar roofs

A biosolar roof is one where an extensive roof is combined with photovoltaic (PV) arrays. The green roof substrate is used as the ballast required to support the frames to which the PVs are attached, resulting in benefits to both the green roof and the PV array.

Biosolar roof, Clapham Park, Lambeth, London Photo: Bauder

Recent research in the USA shows that the combination of these technologies results in greater efficiency of the PVs. This is because the efficiency of the PVs falls when they overheat, but this negative effect is reduced by the evaporative cooling provided by the green roof. There are now specific systems designed to ensure a seamless integration of the two technologies.

Blue green roofs

A blue roof is a roof that has been designed to store rainwater, thereby acting as a source-control feature in a sustainable drainage system. In their simplest form, blue roofs are not vegetated. However, blue green roofs consist of a green roof that overlies a void which is above the waterproofing. The blue component of the roof continues to act as a source-control feature but it also irrigates the green roof layer.

Blue green roof, Antwerp Photo: Vegetal ID

In recent years, these types of roofs have become 'smart', with sensors and software that allow the stored water to be discharged at slower rates than on normal green roofs, thus maintaining an irrigation reservoir. Alternatively, the void can be emptied in advance of heavy rain to maximise water storage. Blue green roofs can also be designed to create a wet biodiverse roof that combines habitat and amenity provision whilst storing rainwater.

Blue green roof, New Hythe, Kent Photo: Polypipe

Green walls

In the UK National Building Certification (NBS) the NBS4 divides green walls into three categories, as follows:

Green façades: these are the traditional green walls where climbing plants are rooted into the ground or into planter boxes. Climbing plants may be grown directly onto the building façade or be trained against wires or trellises. Green façades may take some time to establish; however, maintenance requirements are low and irrigation may not be necessary where plants are rooted into the ground.

Green wall, Finchley Road, north London
Photo: ANS Global

Living walls: these are proprietary systems, installed and maintained as a package. Textiles, plastics and metal (boxes and cages) are used to provide pockets or troughs that support plants. Some systems are substrate-based whilst others are soil-free with water held by mineral wool or foam. Living walls are usually irrigated, often with the use of pumps that are activated by timers or when sensors detect moisture levels below a certain threshold.

However, there are examples of passive living walls (or vertical rain gardens) where water wicks or seeps into planters from tanks that collect rainwater run-off from roofs.

Green wall, Ridgfield Photo: Scotscape

Bioactive façades: more recently, researchers have also begun to investigate these types of walls, where the intention is to produce building materials (often modified concrete) that have surfaces which are deliberately created to provide opportunities for self-supporting vegetation like algae and mosses - the aim being to create inexpensive, low maintenance green walls in locations where more heavily vegetated systems are not feasible.

Green wall, London Wall Place, central London
Photo: ANS Global

2. Benefits and economic value

When the technical report, *Living Roofs and Walls,* was published in 2008, many of the benefits had already been identified and described, largely as a result of work undertaken in Germany and Switzerland.

However, now that green roofs and walls have become widely adopted, a significant body of new evidence has been assembled that makes the case for urban greening even more compelling. This is summarised below with links for those who wish to dig deeper.

Empirical evidence is now available to quantify most benefits – evidence that is necessary for policymakers and decision-makers advocating and implementing municipal and city-wide policies, plans and projects.

In this brief review, the benefits are considered under the following categories:

- Surface water management
- Urban cooling
- Biodiversity
- Air quality
- Health and wellbeing
- Noise reduction
- Potential for carbon sequestration

Surface water management

Surface water flooding and sewer flooding caused by heavy rain is a significant problem in urban areas because of the prevalence of impermeable surfaces which prevent the infiltration of water into the soil.

Floodwater can overwhelm drains, pollute watercourses and flood streets, basements and tunnels, resulting in costly damage to property, delays and disruption to transport systems, and an increased risk of disease, all of which have an increasing economic impact as events become more frequent.

Surface water flooding in cities is predicted to become more frequent and more severe as a result of climate change. Therefore, it is essential that every opportunity is taken to reduce the problem, preferably as close as possible to where rain falls, as recommended by the Sustainable Drainage (SuDS) Management Train approach.

Green roofs are an ideal source-control, covering otherwise impermeable surfaces and absorbing and slowing down stormwater. They can reduce the volume and smooth out peak flows, whilst simultaneously removing some pollutants.

These benefits can be significant. Various German studies that date back to the 1980s have shown that typical extensive green roofs (between 60mm and 100mm deep) can intercept 50% of annual rainfall and that roof gardens, with much deeper soils – typically 500mm deep – can intercept up to 90%.[1]

A study in Pennsylvania found that a 89mm-deep green roof delayed the start of roof run-off by 5.7 hours and delayed the peak of run-off by 2 hours. It is important to note that the hydrological performance of green roofs does vary from season to season, from climate to climate and from site to site, and is affected by shade, aspect, slope and the composition of vegetation. However, it is generally the case that deeper substrates have a greater water-holding capacity than shallow ones.

Extensive green roofs retain more rainfall when they have had time to dry out. Run-off reductions therefore tend to be highest in summer, when rainfall is more sporadic. For example, for 32mm-deep green roofs in New York City, 70% of rainfall was retained in summer and only 28% in winter when soil moisture was higher.[2]

Light rainfall events (5mm or less) are normally completely absorbed by a green roof.[3] In the UK, 80mm-deep green roofs have been shown to retain 80% of the rainfall from events of 10mm or less, but this capacity falls as the rain becomes heavier.[4]

Where accurate predictions of performance are required, it is possible to create permanent voids under green roofs in order to store exactly quantified volumes of water.

Green walls can also contribute towards the reduction of stormwater run-off. The simplest approach is to create a rain garden at the foot of a wall of climbing plants; however, these may be limited by the amount of impermeable ground created.

A more complex approach, but one that can be based on a calculation of the water volumes held back from the drainage system is to harvest rainwater from rooftops and use the retained water to irrigate the green wall.

An even more sophisticated approach requires valves and control systems which are able to store and discharge at known volumes and rates, increasing storage capacity when storms are forecast.

This may be an important consideration in areas where increasing capacity in the piped drainage network might be unfeasible or too costly.

It is also possible to intimately integrate green walls with rainwater harvesting tanks, so that the vegetation is irrigated passively by wicking, without the need for pumps or pipes.

An example of such an installation - in effect a vertical rain garden fed with rainwater from a downpipe - can be seen near London's City Hall. This was one of the first examples of this approach, which was funded by Drain London and is near to London's City Hall.

Urban cooling

Green roofs and walls can reduce the temperature of a building's exterior, as well as the rooms within, by shade, insulation, albedo (reflectivity) and evapotranspirative cooling (the cooling which occurs when water is evaporated from leaves).

Insulation provided by green roofs and green walls can also reduce heat loss from a building in winter. These effects can, in turn, reduce energy consumption for cooling and heating.

The shading and cooling of buildings also reduces the urban heat island (UHI) effect. The UHI effect occurs in city centres where materials such as concrete, masonry and asphalt (which absorb solar heat and re-radiate it at night) predominate, and where waste heat is discharged from buildings, transport and infrastructure. As a result of these processes, the centres of large conurbations may be several degrees warmer than their rural hinterlands.

The UHI exacerbates heat stress and air pollution during hot weather, increasing mortality in the young and old, particularly affecting people with breathing conditions and cardiovascular disease. The health impacts of the UHI are becoming worse with climate change.

Thermal image showing the surface temperature of a green wall, central London Image: Gary Grant

There is evidence and modelling available to show how green infrastructure, particularly green roofs and walls, can reduce or eliminate the UHI effect, thereby improving comfort and saving lives.

The cooling effect of extensive green roofs is significant. For example, an analysis of an extensive green roof in Calabria, Italy, showed that the temperature of the underlying structure was on average 12°C cooler in summer compared to a conventional roof.

It has been observed in south-central Texas, that succulent-covered green roofs which were not irrigated reduced soil surface temperature by 18°C and the temperature immediately below the green roof was reduced by 27.5°C in hot and dry summer conditions when compared to conventional roofs.

Experiments in Adelaide, Australia, show that green roofs have the capacity to improve the surrounding microclimate with significant cooling effects in summer.

Researchers found the surface of experimental green roofs were between 2°C and 5°C cooler during the day (depending on substrate type and depth) and were generally cooler than the ambient air temperature.

These cooling effects could have city-wide impacts - for example, modelling indicates that a

50% coverage of green roofs across Constantine, Algeria, would decrease the ambient air temperature of the city by an average of 1.3°C.

Green walls are able to cool streets as well as buildings, thereby improving conditions for building occupants as well as pedestrians and cyclists on the street.

Green walls, either those using climbing plants or those made with plants grown in modules, shade buildings and may incorporate a useful insulating air gap and provide cooling by evapotranspiration.

Green walls are particularly useful when installed on walls with high exposure to sunlight and where space for large shade trees is limited. In hot, dry summers, green walls have been shown to reduce the temperature of the external building wall behind them by as much as 16°C.

South-facing green walls in Leida, Spain were found to be up to 32°C cooler than adjacent masonry walls. A comparison between a bare wall and green wall (consisting of Boston ivy growing on a trellis) found 34% energy savings in the building.

Densely planted green walls, also included in the study, saved 59% of energy. Combining green roofs with green walls can further increase cooling benefits.

Studies in Sydney and Rio de Janeiro comparing vegetated and non-vegetated experimental structures found that combining green roofs and green walls yielded better thermal performance for human thermal comfort than green roofs alone. In these studies, the maximum temperatures observed were 33°C for vegetated buildings, and 42°C in those without vegetation.

Biodiversity

Green roofs are usually relatively small in area and can be isolated and exposed to harsh conditions, which limits the number of species that can be supported. However, they do provide habitats that can be colonised by a range of plants and animals.

Many soil-dwelling creatures are absent from thin, hot and dry extensive green roofs. Habitats on buildings tend to be isolated from ground level habitats and the most important creatures associated with green roofs and green walls tend to be invertebrates (especially wild bees, beetles and spiders), birds and bats.

Research on extensive green roofs in Switzerland and London has shown that species diversity of invertebrates is influenced by the vegetation type, structure and diversity, setting, substrate depth and age, as well as the presence of features such as deadwood, stones, sand lenses and pools.

Avoiding sedum monocultures and planting drought-tolerant native wildflowers has been shown to boost biodiversity on extensive green roofs and Buglife, the invertebrate conservation charity, has published advice on how extensive green roofs can be modified to encourage invertebrates.

In London, the rare black redstart has benefited from the provision of biodiverse extensive green roofs as ‘stepping stones’ allowing this species to spread from the derelict sites of London’s Docklands into the rooftops of Central London.

Black redstart on a green roof, central London
Photo: Dusty Gedge

Air quality

Vegetation reduces air pollutants by filtering and capturing particulates (i.e. soot, which is produced mainly by diesel vehicles) and absorbing and breaking down gases (including nitrogen dioxide). Plants with finely branched, hairy or sticky leaves tend to be better at trapping particulates than those with large smooth leaves. Pollution trapped by vegetation can fall or be washed into soil, where microbes break it down.

The vegetation on both green roofs and green walls can make a contribution to reducing people's exposure to air pollution. Green walls in particular, offer the potential to reduce air pollution at street level.

Studies have found that vegetation in street canyons reduces nitrogen dioxide levels by 40% and particulates by 60%. The location of green roofs and walls is the most important factor to consider if air quality improvement is a key objective of urban greening.

Health and wellbeing

For many growing cities, a lack of accessible greenspace, poor air quality and urban heat islands is correlated with higher mortality and associated poor health.

The World Health Organisation has recognised the importance of green infrastructure for addressing many health problems in cities.

Green roofs have the potential to provide additional greenspace for people to relax and encounter nature. This is particularly important in the inner city or more densely developed areas, where conventional greenspace may not be nearby or easily accessible and where private gardens are less often provided.

Extensive green roofs, where access is normally only permitted for maintenance purposes, can still improve health and wellbeing by being overlooked or by improving the quality of the air and providing tranquillity through noise reduction.

It has been shown that exposure to nature, even looking at vegetation, promotes mental health. Other research has shown that 30 minutes or more exposure to nature each week reduces the likelihood of high blood pressure and depression.

A study of 150 students has shown that viewing green roofs can improve concentration levels by 6% whilst viewing bare concrete can reduce concentration levels by 8%.

St Thomas's Hospital: a public garden over a car park in central London Photo: Dusty Gedge

Green roofs and walls also improve air quality by intercepting pollutants that are known to cause allergies, as well as heart and respiratory conditions.

They can improve the liveability of otherwise barren built-up urban areas, thereby creating outdoor space where people can linger and interact with others. This, in turn, can foster social cohesion and strengthen communities. Green roofs can also be used to grow food (particularly herbs, fruit and vegetables) and it has been shown that activities associated with growing food for local consumption have a positive impact on mental health.

Urban food growing, Basinghall Avenue, central London Photo: Dusty Gedge

Noise reduction

Although vegetation brings about modest reductions in noise pollution, particularly for higher frequencies, high density growing media (soils and substrates) absorb sound well.

Performance does vary considerably (typically from 2dB for each 10mm of soil depth up to 100mm), with pore and particle size and saturation by water all affecting sound transmission. This means that green roofs (especially those with deeper substrates) and green walls with growing media held in modules, form excellent sound barriers.

Green roofs that are 100mm deep have been found to reduce noise by up to 10dB. A study of an 80mm thick modular green wall found that noise was reduced by 15dB.

Biodiverse 'brown' roof, central London
Photo: Dusty Gedge

Potential for carbon sequestration

Large quantities of carbon are stored in soils and vegetation as organic matter, and the ability of soils to become a net store of carbon is a well -established phenomenon. Intensive agriculture tends to result in the loss of soil carbon. However, extensive agriculture, restored forests and wetlands can absorb carbon.

There is a tendency for the growing media used in green roofs to be relatively shallow, which limits the available space to store carbon. However, there is evidence that modest quantities of carbon can be permanently stored in green roofs. In general, the deeper the growing medium the greater the potential to store carbon.

A typical figure for carbon sequestered by an extensive green roof (both below ground in substrate and above ground in perennial vegetation) is 375g of carbon per square metre.

Researchers are investigating the possibility of integrating charcoal and materials that chemically absorb carbon dioxide in green roofs in order to store carbon. Other research is also underway, looking at how the uptake of carbon dioxide in green roofs could be increased by inoculating mychorrizhal fungi.

The economic case

In most situations, green roofs and walls provide no direct revenue. The real estate or rental value of a building relates primarily to its use. Except when green roofs or walls provide space which can attract an access or rental charge, or produce commodities such as fruit or vegetables, there is no income directly attributable to urban greening.

The installation of a green roof or green wall is therefore usually considered in terms of the cost of construction and maintenance, rather than the economic value of the benefits they provide.

However, this position is now being challenged as we begin to account for the benefits of natural capital through disciplines such as natural capital accounting and economic valuation of ecosystem services, which start to reveal the economic value of the wider benefits provided by green infrastructure.

Many of the benefits provided are effectively public goods (such as resilience and public health) which deters investment decisions based on typical cost-benefit analysis as the investor does not often benefit directly from the investment.

This means that assessment of the economic benefits of urban greening needs to be considered through a wide range of different methods, depending on whether the benefit is public or private, direct or indirect, or whether or not there is a market for the services provided. New financing mechanisms are also required.

The simplest approach to the valuation of green roofs and walls is to undertake a cost benefit analysis of the lifecycle of the product and the direct benefits it provides, such as reduction in stormwater run-off - which might otherwise attract charges - or reductions in energy use, or extending the life of the roof's water-proofing layer by reducing its exposure to wear and tear and weathering.

This creates a total value for direct benefits and matches these against the costs of establishment and maintenance and allows for depreciation over a certain time span. A study in the US in 2008 found that a 75mm-deep extensive green roof (with a water retention capacity of 42.7 litres per square metre), operating for 40 years, would save US$9.06 per square metre in stormwater charges.

Another approach is to measure the reduction in surface water drainage fees. Looking at a number of cities in the US and assuming a 50% annual interception rate, researchers noted that an average annual fee of US$0.17 per square metre for impermeable surfaces, would be halved to US$0.08 per square metre per year by using green roofs.

The same study also noted that there would be city-wide stormwater management improvements by adopting green roofs that would reduce the need for capital expenditure on new grey infrastructure.

In addition to reductions in volume, the economic value of stormwater management with green roofs in Toronto has been estimated to be between C$1.73 and C$27.20 per square metre, owing to enhanced water quality and reduced erosion.

Across the whole of Toronto, if all flat roofs were greened, this would translate to savings of between C$41.8 million and C$118 million in avoided grey infrastructure costs.

Energy cost savings from green roofs and walls may come from reductions in heating and cooling. For example, in Turkey, it has been estimated that green roofs across a 10-hectare resort could save over US$2,000 per day.

Microclimate modelling suggests that installation of green roofs in Hong Kong could reduce air temperatures in a densely developed neighbourhood by between 0.65°C and 1.45°C.

The resulting reduction in the use of air conditioners would save between US$3.99 million and US$8.92 million per year.

A theoretical study of 35 hectares of green roofs in Michigan looked at removal of nitrogen oxides and estimated public health returns of between $158,720 and $601,930 per year. For removal of SO_2, NO_2 and PM10 by green roofs in an urban quarter of Hong Kong, savings of between US$0.75 million and US$1.15 million per year in avoided health costs have been estimated.

The phenomenon whereby property prices are elevated by proximity to green infrastructure is well established. For example, homes adjacent to parks are worth 20% more than similar homes elsewhere. Although the uplift in property values resulting from green roofs and green walls will be lower than this, it is likely that urban greening will contribute to an uplift in property values and/or rental income.

In 2011, the US General Services Administration estimated that green roofs boost property prices by US$130 per square metre across the USA and US$108 per square metre in Washington DC. The monetary value of the visual amenity of green roofs has been calculated by Canadian researchers to be $4.40 per square metre.

Hotel rooms with a view of a green roof cost $80 more each night than similar rooms without such a view. This equates to $29,000 per room per annum (assuming 100% occupancy rates).

With this brief review, we can see that the emerging costed benefits of improved stormwater management, improved insulation, summer cooling, pollution abatement, reduced health costs and increases in property value, when combined, produce a convincing economic argument for green roofs and green walls.

St Thomas's Hospital intensive green roof, central London Photo: Dusty Gedge

3. London: measuring the success of the 2008 Living Roofs and Walls Policy

The 2008 London Living Roofs and Walls Policy was developed specifically for the London context. Whilst many cities around the world have promoted urban greening (especially green roofs) through mandatory planning regulations or subsidies and incentives in various forms, London has no such direct delivery programmes. Green roofs and walls are promoted primarily through the land-use planning system.

The London Plan provides the strategic planning policy framework which in turn influences the policy frameworks developed by individual London boroughs in the Local Plans.

The London Plan of 2008 was reviewed and updated in 2011. In Chapter 5 of this version of the Plan, a new policy on urban greening (Policy 5.10) was introduced, in addition to a specific policy on green roofs (Policy 5.11).

The Living Roofs and Walls Policy marked a change by expanding the rationale for installing green roofs and also referencing green walls for the first time. Importantly, both the urban greening and green roof policies were set within the context of an overarching green infrastructure policy, Policy 2.18. The current London Plan, published in 2016, retains the policy framework of the 2011 London Plan.

Uptake of green roofs in London between 2008 to 2018

Using data collected up to and including 2017, this report is able to provide a comprehensive picture of the total number of green roofs in London for the first time. The data provides an insight into the success of the policy framework developed since 2008.

The data compares areas of intensive and extensive green roofs and there is information on the area of biosolar roofs, the number of green roofs installed in the Central Activity Zone and selected boroughs. Infographics are also available for all London boroughs online.

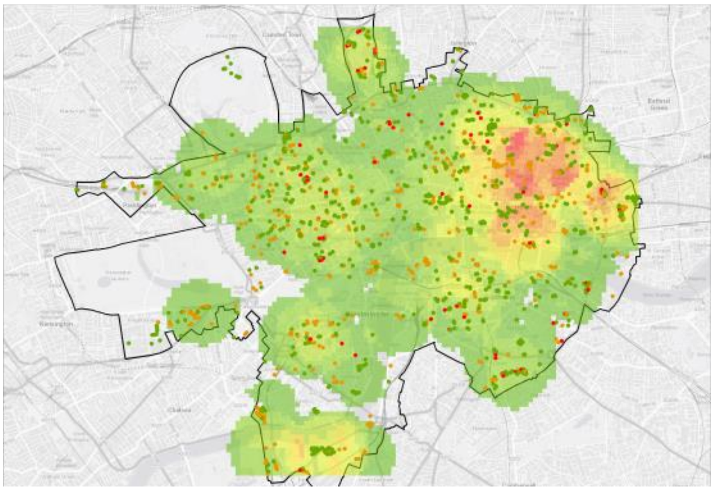
London's green roofs in 2010: the baseline

In 2010, just two years after the introduction of the policy promoting green roofs, there was an estimated total area of 715,000m^2 in London. The area of green roofs per inhabitant in London at that time was 0.08m^2. This per capita amount was equal to Copenhagen and more than that of Toronto.

Green roofs in London's Central Activity Zone (CAZ)

The CAZ is a specific planning zone in the centre of London. It is one of the world's most competitive business locations and a centre of culture, entertainment, tourism and heritage. The CAZ is an area which is continually undergoing extensive regeneration and renewal.

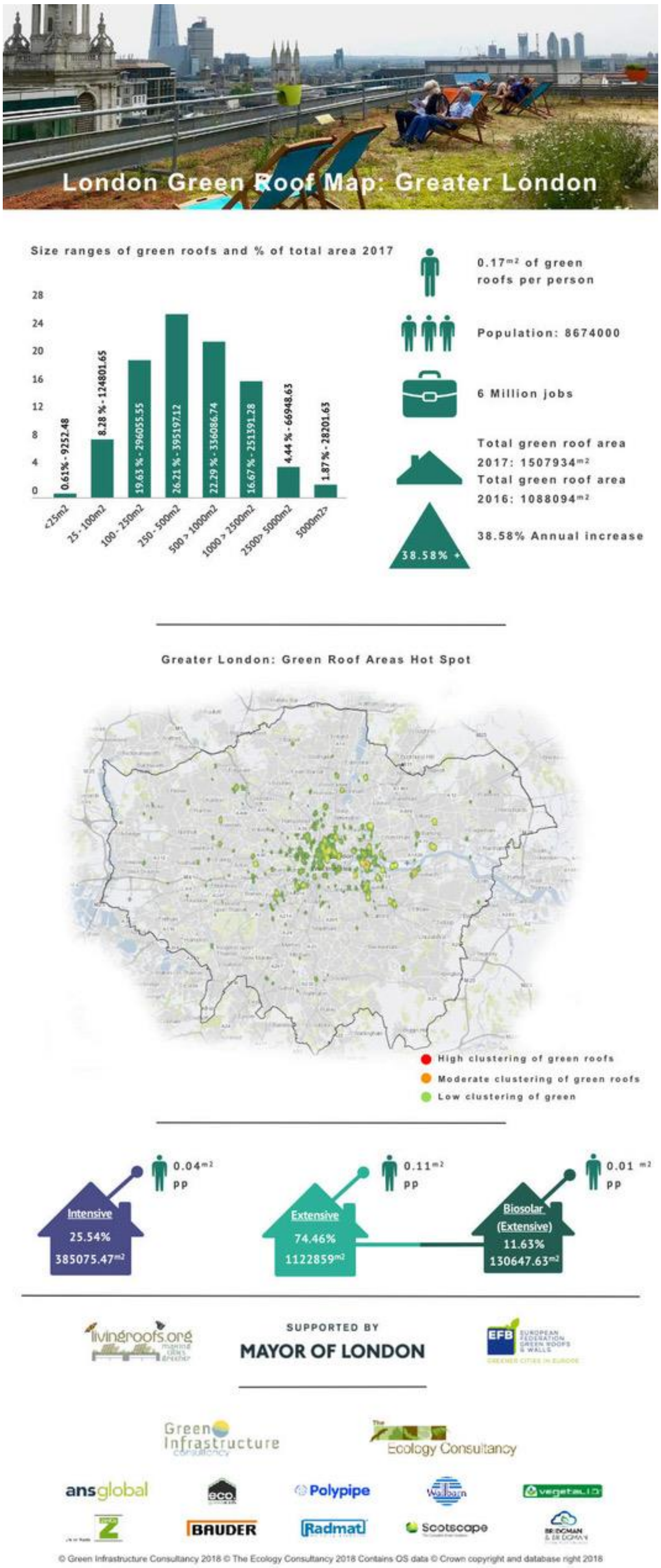
It was first mapped in 2014 for all green roofs installed up to that point in time. Although unpublished until now, the CAZ was also mapped in consecutive years up until the end of 2017. The area of green roofs in the CAZ has grown annually and has increased from a density of 0.89m^2 per inhabitant to 1.27m^2 per inhabitant.



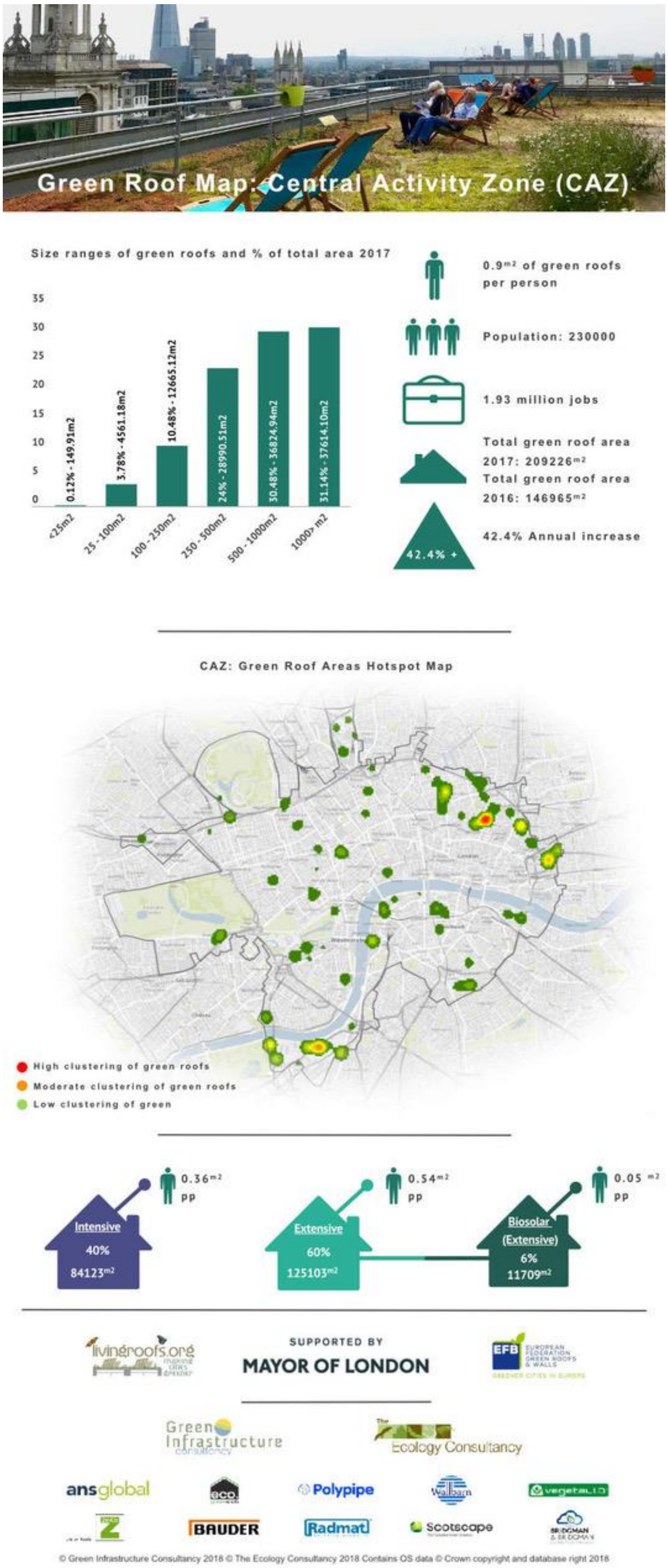
Green roof hotspots in the London Central Activity Zone (CAZ) Image: Green Infrastructure Consultancy and The Ecology Consultancy

Greater London Green Roof Map Infographics

||| Click on maps for downloadable pdf version |||



Greater London Green Roof Map Infographic
Image: The Green Infrastructure Consultancy and The Ecology Consultancy



London Central Activity Zone (CAZ) Green Roof Map Infographic Image: The Green Infrastructure Consultancy and The Ecology Consultancy

The Greater London Authority 2017 Green Roof Map

As of the end of 2017, the total green roof area in the Greater London Authority (GLA) area, mapped for this report, was just below 1,510,000m^2, giving a density of 0.17m^2 per inhabitant. When compared to the figure for 2010, both the total area and the density of green roofs has doubled.

Between 2016 and 2017, the data points to an increase of 31% of the total number of green roofs installed in the Greater London area. In common with many cities around the world, extensive green roofs (75%) make up the majority of green roofs installed compared to intensive green roofs (25%). Of the extensive green roofs, only 11% are biosolar roofs.

Of course, because of shading issues, not all roofs are suitable for photovoltaic panels. Yet, when comparing the figures for boroughs, there has been an overall increase in the number of green roofs being installed with solar panels, partly as a result of architects becoming more familiar with biosolar technology.

London's boroughs

The GLA is made up of 32 boroughs plus the City of London. The areas of green roofs per inhabitant in each borough are presented in the table below. The uptake and provision of green roofs varies considerably from borough to borough. This is partly because of the variation in policies for green roofs in each borough, but it

Inner London boroughs and councils	m^2/person
City of London	5.82
Tower Hamlets	0.55
Greenwich	0.43
Lewisham	0.42
Newham	0.38
Hackney	0.36
City of Westminster	0.33
Camden	0.32
Islington	0.26
Southwark	0.25
Wandsworth	0.22
Hammersmith and Fulham	0.21
Lambeth	0.21
Royal Borough of Kensington & Chelsea	0.05

Outer London boroughs and councils	m^2/person
Barking and Dagenham	0.24
Hillingdon	0.12
Barnet	0.11
Brent	0.1
Haringay	0.1
Hounslow	0.1
Sutton	0.08
Havering	0.07
Ealing	0.06
Waltham Forest	0.06
Croydon	0.05
Harrow	0.04
Enfield	0.04
Merton	0.03
Kingston-upon-Thames	0.03
Richmond-upon-Thames	0.03
Bexley	0.03
Bromley	0.02
Redbridge	0.01

London borough or council green roof area per inhabitant (2017) is also a reflection of different development patterns and the location of major regeneration zones. The boroughs with the largest and highest per capita green roof provision are mostly in inner London, except for the London Borough of Barking and Dagenham, which is an outer London borough.

Many of the larger developments delivering green roofs are located in these boroughs. Historically, these were the boroughs which adopted local planning provision for green roofs earlier than the outer London boroughs.

Some key insights about the performance of some London boroughs are provided below but more detailed information and individual infographics for each London borough is available at livingroofs.org.

The City of London

The City of London is unique in London as a district. It is a global centre of finance with more than 300,000 people commuting to work each day. However, it has a very small residential population, which means the area of green roof per person is very high at 5.5m^2 per inhabitant.

In 2011, the City of London produced a document to highlight case studies within the Square Mile. There are now many extensive green roofs in the City of London, most of which have been designed specifically for biodiversity. A good example is Wood Street (Case studies, p28). There is also an increase in the delivery of biosolar roofs in the City. The roof at Standard Chartered is just one example.

Intensive green roofs (or roof gardens) are being created on many buildings within the City. Whilst it is primarily the planning system that has driven the uptake on green roofs, developers and businesses have also recognised the potential benefits to staff of providing amenity space at roof level. The roof garden at Nomura Bank (Case studies, p28) overlooking the River Thames is one such example.

Another new approach in the City is to create publicly accessible rooftop gardens, the first of which recently opened at 120 Fenchurch Street.

The City of London saw an 11% increase in the area of green roofs from a total of 48,967m^2 in 2016 to 54,730m^2 in 2017. Extensive green roofs (including biosolar) increased by 17% whilst intensive green roof installations increased by 6%.

The London Borough of Tower Hamlets

The London Borough of Tower Hamlets is an inner London borough which lies immediately east of the City of London. It has the largest area of green roofs in the whole of Greater London and, aside from the City of London, also has the highest green roof area per inhabitant at 0.55m^2. With a total of 167,381m^2 of green roofs, Tower Hamlets saw an increase of 20% between 2016 and 2017.

Whilst the borough is home to many financial institutions (on the edge of the City and in the Canary Wharf area), the borough is mainly residential in character. Over the last 30 years, the area has undergone major redevelopment as the docklands and other brownfield sites within the borough have been transformed into new housing and businesses.

Like the City of London, Canary Wharf is also a major financial district which has seen extensive development in recent years. The Canary Wharf estate can be credited with pioneering the installation of green roofs in London.

Some of the first extensive green roofs in the capital were installed on buildings on the estate in the early 2000s, primarily as compensation for the loss of wildlife habitat that had developed on land that remained unused for many years prior to the regeneration of the former London docklands.

Extensive green roofs make up more than 60% of the borough's total green roof area. Not only does the borough have the largest area of green roofs of any local authority in London, it also has one of the largest areas of biosolar roofs at more than 11,000m^2, which equates to 7% of its total green roof area.

An excellent example of how green roofs are being delivered in the borough is Goodman's Fields, a development which is an innovative combination of semi-intensive green roofs designed with both people and biodiversity in mind. There are also more formal residential rooftop gardens. Many of the parks and gardens within the estate are now, in fact, intensive green roofs. Jubilee Gardens, for example, with an area of approximately 10,000m^2 is one of the largest green roofs in London and sits above the Jubilee Line station at Canary Wharf.

The London Borough of Barking and Dagenham

The only outer London borough with a significant number of green roofs is Barking and Dagenham. The borough has a total of 51,658m^2 of green roofs with 0.26m^2 per inhabitant.

This per capita figure is higher than the inner London boroughs of Wandsworth, Lambeth, Southwark, Hammersmith and Fulham and the Royal Borough of Kensington & Chelsea.

The borough has undergone extensive regeneration over the last 10 years and is also home to Barking Riverside which is one the largest redevelopment sites in the UK. With more than 25,000m^2 of green roofs installed this makes up nearly 50% of the total area of green roofs with in the borough.

The borough saw an increase of 64% in the area of green roofs between 2016 and 2017, from a total of 31,571m^2 to 51,658m^2 in 2017, the majority of which were within the Barking Riverside development.

The London Boroughs of Redbridge and Bromley

Redbridge in east London and Bromley in south-east London have the smallest areas of green roofs in London. This is primarily because both boroughs have extensive areas of green and open space and neither have any major regeneration projects within their boundaries.

Nevertheless, the London Borough of Redbridge included a specific policy on green roofs in its local plan published in 2018.

Large scale developments in London

Aside from the specific boroughs reviewed above, there are a large number of major developments across London which have delivered and will deliver green roofs (and to a certain extent green walls). Many of these developments are long-term projects and, over the next few years, more green roofs and green walls will be installed.

These include:

- Kidbrooke Village in the Royal Borough of Greenwich
- Nine Elms (including Battersea Power Station)
- Chobham Manor
- The International Quarter
- Elephant Park

There are also major new developments planned for all of London's Opportunity Areas such as Old Oak and Park Royal, and Old Kent Road which, will need to deliver wholescale urban greening. Such developments are embracing the need to provide green infrastructure for residents and the public at roof, wall and ground level.

The existing built environment

Despite the opportunities afforded by major regeneration and renewal, the biggest challenge for London remains the retrofitting of green roofs and walls in and on the existing building stock.

The original technical report, *Living Roofs and Walls*, estimated that nearly one third of existing roof space in Central London could be greened. Whilst many cities around the world have or have had incentives and subsidies to green up existing buildings, there is currently no such mechanism in London. Consequently, only a very small number of roofs and walls have been retrofitted with green roofs and walls over the years. Those that have been greened, such as Fortnum & Mason's, Rubens at the Palace Hotel and Selbourne Road (Case studies, p28), have been installed to address specific concerns (such as poor air quality or surface water flooding) and to demonstrate corporate social responsibility.

The development of fiscal mechanisms to stimulate retrofit on existing buildings could significantly increase both the area of green roofs in the capital and the environmental benefit to the capital as a whole.

4. London's success in a global context

The drive to make the world's urban spaces greener is a relatively recent phenomenon. Some cities, such as Linz in Austria, have had green roof policies for more than 40 years. However, the majority of cities around the world began developing urban greening policies and/or incentives only in the last 20 years. This makes London, which has had a policy in place for only 10 years, a relative newcomer on the urban greening stage.

This section provides a summary of the policies implemented by cities across the globe, followed by a league table of green roofs per capita, which details the achievements of these various policies. The league table is based on research undertaken for this report and as yet unpublished research by Humboldt University.

Setting London's achievements in a global context in this way reveals just how much the Greater London Authority has achieved in what is a relatively short period of time.

Europe

Austria, Germany and Switzerland

Most of the cities with a high density of green roofs are in Austria, Germany and Switzerland. This is not surprising considering they were the first to adopt policies and incentives for green roofs.

In **Germany**, building codes that encouraged green roofs were instigated in various cities in the late 1980s. Policies vary from city to city, but many include mandatory targets for green space (for example, in Berlin it is known as the Biotope factor) or reductions in stormwater fees if green roofs are installed (for, example in Munster, Munich and Cologne). In Stuttgart, there is a requirement for all new developments to have green roofs. The city also has a funding programme for greening measures which includes green roofs and walls. This programme pays up 50% of the cost up to a maximum of €10,000. In 2018, both Hamburg and Frankfurt launched similar incentive programmes.

These policies and incentives/subsidies are the reason that many German cities have high densities of green roofs. Even small towns such as Nürtingen (which has a population of 40,000 and a total area of green roofs of 60,000m^2) have relatively high densities of green roofs per inhabitant (1.5m^2 per inhabitant).

In **Switzerland**, Basel instigated a green roof policy in 1996. Under the Building and Construction Law, the city requires green roofs on all new developments with flat roofs. An amendment in 2002 also required green roofs to be designed to maximise biodiversity. The city provided financial incentive programmes during the periods 1996-1997 and 2005-2006 to increase the number of green roofs in the city.

In **Austria**, Linz was one of the first cities in the world to embrace green roofs by creating a policy in 1985. By 1989, the city was providing subsidies to encourage the uptake of green roofs. City building codes included an obligation for new buildings to have green roofs, reimbursing up to 5% (reduced from 30% in 2005) of the cost of installing a green roof as an incentive. This programme finally ended in 2016, but the delivery of green roofs is still very much part of the city's green space programme.

Intensive green roof, Berlin Photo: Dusty Gedge

The Netherlands

In the Netherlands, Rotterdam has led the way by setting ambitious targets for green roofs. In 2006, the city instigated policies for stormwater management which included the provision of green roofs.

By 2008, Rotterdam had also begun to provide incentives to increase the number of green roofs delivered. One of the long-term goals of these policy and incentive programmes is to increase the number of green roofs in the city to 600,000m^2 by 2025. In 2019, the total number of green roofs in Rotterdam is believed to be of the order of 267,500m^2, of which 160,000m^2 were financed by the city's subsidy programme.

Op Het Dak, semi-intensive green roof, Rotterdam Photo: Dusty Gedge

France

Although no French city is listed in our global league table, it is the only country in the world which, since 2016, has a national law that encourages green roofs.

The law is very specific and applies to all new commercial developments across France. It requires such developments to 'integrate green roofs or solar panels'**.** France also has a relatively mature green roof market. Around one million square metres of green roofs were installed in 2017 (Source: Vegetal ID/Adivet, 2019).

As is the case in the UK, the French market is currently focused on the area around the capital city, the Île de France region in which Paris lies. It currently accounts for approximately 30% of the entire market.

It is estimated that more than 300,000m^2 of green roofs were installed in the Île de France region in 2017 (Source: Vegetal ID/Adivet, 2019).

The city of Paris itself has set ambitious targets for creating new green spaces in its Climate Change Plan. These include specific targets of 100 hectares of green roofs and walls to be installed by 2020, through the Parisculteurs programme.

As of 2018, 75,000m^2 of green roofs and walls had been installed under this programme. However, as these are only the green roofs delivered via this particular programme, it is highly likely that the total area of green roofs installed across the city is considerably higher.

Scandinavia

The city of Malmö has been at the forefront of green roof development in Scandinavia. The first green roofs were installed in the Augustenborg district of Malmö in the early 2000s. It was also the first city in the region to embrace the use of a landscape planning tool (the Green Space Factor) to help support urban greening, especially in dense urban areas.

The planning tool was trialled in 2001 in a new residential development in the post-industrial regeneration area known as the Bo01 in the Western Harbour area of the city.

Extensive and semi-intensive green roof on the Emporium Hyllie, Malmö, Sweden Photo: Dusty Gedge

Elsewhere in Sweden, the capital Stockholm has embraced the Green Space Factor as a planning tool that 'contains the possibility of creating green roofs'. The tool is now a requirement for all property developers building on land owned by the city.

The only city in Scandinavia where green roofs are mandated is in the Danish capital, Copenhagen. Since 2010, the city has created green roof policies in local plans that require roofs with a pitch of less than 30° to be greened.

There are also incentives available for refurbishments of older roofs and exemptions owing to the structural integrity of buildings. However, even with this mandatory requirement the density of green roofs per inhabitant is currently relatively low at $0.07m^2$ per inhabitant.

Belgium

Prior to the financial crash of 2008/9, the Flemish government provided subsidies for green roofs. However, although the funding was withdrawn at that time, a few cities continued to provide subsidies from their own funds.

Since 2011, in Antwerp, stormwater management plans have been mandatory for new developments and major refurbishments as part of the planning process, with green roofs being one of the elements prescribed. Furthermore, over the last few years, the city is looking to improve how green roofs are delivered in the city.

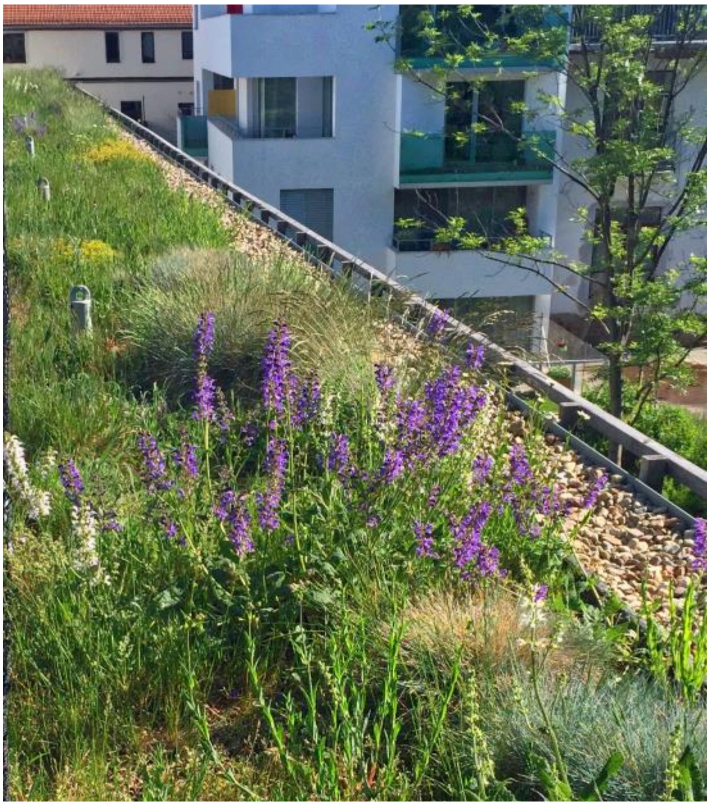
The Czech Republic

Of all the eastern European countries that are members of the European Federation of Green Roof and Wall Associations, it is the Czech Republic that is taking the lead when it comes to creating green roof policies. The recommendation for the uptake of green roofs is specifically stated in the strategy on adaptation to climate change in the Czech Republic in areas such as urban development, landscaping, ecosystem protection, rainwater run-off mitigation and more.

There are now policies in place in four cities in the Czech Republic that specifically target the uptake of green roofs. In addition, a national programme for 'green savings' was launched in 2017, under which green roofs are eligible for support. Those cities in the Czech Republic that are encouraging green roofs are:

- Prague, in its climate-change adaptation strategy, which aims to support the introduction of green roofs and walls and to develop funding mechanisms to increase uptake within the city
- Brno, which includes green roofs and walls within its strategy to reduce the negative impact of heatwaves and the urban heat island effect. Currently the city is looking at mechanisms to provide micro-grants to support the uptake of green roofs
- Pilsen promotes green roofs and walls and sustainable urban drainage to help mitigate the risk of flash floods, and to ameliorate the urban heat island effect.
- Ostrava is also looking to use green roofs to reduce the area of sealed surfaces in the city and to ameliorate the urban heat island effect. It is proposing to develop incentives to help achieve this.

As of 2017, $195,000m^2$ of green roofs had been installed in the Czech Republic, of which more than 75% were extensive. The total 2017 figure represents an increase of 50% from 2016.



Extensive green roof, Brno, Czech Republic
Photo: Dusty Gedge

North America

In 2009, Toronto - Canada's largest city - was the first local authority in North America to make green roofs mandatory. The green roof bylaw applies to all residential, commercial and industrial buildings with a floor area greater than 2,000m^2.

As of 1 January 2017, San Francisco's Better Roof Ordinance came into effect, the first mandatory green roof policy in the USA. The ordinance states that "between 15% and 30% of roof space on most new construction projects will incorporate solar, living roofs, or a combination of both".

San Francisco was followed by Denver in November 2017. The Denver ordinance requires "an amount of green space related to either the gross floor area, total roof area, or available roof area".

There are also many North American cities, which, although they do not have mandatory green roof policies, do have incentives to increase the area of green roofs within their administrative boundaries.

Extensive green roof, Washington, DC, USA.
Photo: Dusty Gedge

Until 2015, the leading North American city for roof greening was Washington DC. Mainly a result of its RiverSmart Rooftops programme, it had the highest density of green roofs per inhabitant of any North American city. In 2016, Toronto took over the mantle of the city in North America with the largest area of green roofs installed.

New York City has a programme which encourages green roofs, known as the Green Roof Property Tax Abatement. A mapping project undertaken in 2016 put the total area of green roofs in New York City at 242,811m^2 giving the city a density of 0.03m^2 green roofs per inhabitant, and accounting for 0.03% of the total land area.

Latin America

In Latin America there are two cities which have instigated green roof policies. Recife in Brazil enacted a green roof law in January 2015, while Cordoba in Argentina became the first Spanish speaking city in South America to instigate a green roof ordinance in 2016. This policy makes it mandatory to install green roofs on new developments in the central zones of the city.

Two environmental factors are the focus of the policy: reduction of the negative effects of the urban heat island and to improve the severe air pollution in the city centre. The policy is also backed up with an incentive. For new buildings, there is 50% financial support for residential and commercial buildings over 400m^2 and industrial buildings over 600m^2. There is also an incentive for those who voluntarily install green roofs and walls on existing buildings through 'stable tax benefits'.

Australia

Both Sydney and Melbourne have developed policies relating to green roofs and walls. Since 2014, Sydney has seen a 23% increase in the number of green roofs installed in the city. Melbourne city district has a relatively high density of green roofs at $0.36m^2$ per inhabitant, which places it above many of the North American and Asian frontrunner cities, as well as Copenhagen in Europe.

Intensive green roof, Sydney Photo: Matt Dillon

Melbourne has undertaken research to explore where and what kind of green roofs could be installed on existing buildings within the city district. Also, the city is halfway through the implementation of a green infrastructure action plan that focuses on green roofs, walls and façades. One of the targets is to double the area of green roofs and vertical greening by 2021.

Extensive green roofs, Melbourne
Photo: Melbourne City Council

Asia

Although Singapore is internationally recognised for its work on creating green spaces at roof level, the density of green roofs per inhabitant is relatively small compared to cities in Europe. Its Skyrise Greenery Programme aims to encourage the installation of green roofs and walls on existing residential and non-residential buildings.

Other cities in Asia have also been developing green roof policies, most notably Tokyo and Hong Kong.

League table: Global green roof area and density, 2015

The table below ranks cities in terms of square metres of green roof per inhabitant, which is in line with the World Health Organisation's urban health indicator of green space per urban inhabitant. This is a more appropriate metric when demonstrating how well cities are performing in terms of green roof provision. The figures reveal that while certain cities have an impressive total green roof area, the density - or sq m^2 per inhabitant - is actually relatively low. London's CAZ, on the other hand, has a total green roof area that is slightly below the average when compared with most other cities, but has a much greater square meterage per citizen.

	Population	Total area of green roofs (m^2)	Green roofs per capita (m^2/inhabitant)
Basel	175,131	1,000,000	5.71
Stuttgart	590,000	2,000,000	3.38
Linz	193,814	500,000	2.57
Munich	1,450,381	3,148,043	2.17
Vienna	1,714,000	2,560,000	1.49
Malmö	303,000	400,000	1.32
Hanover	522,686	638,500	1.22
London's CAZ	**230,000**	**205,000**	**1.21**
Düsseldorf	588,169	698,000	1.19
Berlin	3,600,000	4,000,000	1.11
Washington D.C.	681,170	254,470	0.37
Rotterdam	634,661	235,000	0.37
Amsterdam	813,562	300,000	0.36
Melbourne City	148,000	54,000	0.36
Portland	570,000	157,989	0.27
Chicago	2,700,000	508,130	0.19
Tokyo	13,184,161	1,345,250	0.10
Toronto	2,615,060	250,000	0.09
Singapore	5,100,000	468,000	0.09
Copenhagen	510,000	40,000	0.07

The figures have been collated from various cities and organisations and from work as yet unpublished by Humboldt University. Data collection methods vary. It should be noted that figures for London relate only to the Central Activity Zone as data for the Greater London area for 2015 are not available.

5. Conclusion and future frameworks

Across the globe, more and more cities are embracing green roofs and walls, alongside other urban greening interventions, to tackle a range of environmental issues. Whilst adapting to climate change and improving air quality are especially pressing concerns, there is also a need to address biodiversity loss. It is now widely accepted that a greener and wilder urban environment is critical to improving the health and wellbeing of the growing number of people living in cities.

This increasing uptake of green roofs and walls is encouraging. Urban greening policy and practice in many cities, with the necessary frameworks, has enabled forward-thinking planners, architects, developers, suppliers and contractors to develop, test and deliver green roofs and walls, so that the technology has moved from the unusual to the commonplace.

London's policy framework can be singled out in particular for creating a culture in which green roofs and walls are no longer a novelty. When viewed in the league table of cities and their green roof density (page 25), it is clear that this transformation has catapulted London to a position where it ranks alongside those cities which are most feted for their green roof provision. This is remarkable considering that London has had such a policy in place for only 10 years and that what has been achieved has been done so without subsidies or incentives.

The sheer range of green roofs and walls being delivered in London is also a significant part of the city's green roof and wall story as the case studies that follow this conclusion demonstrate. Extensive green roofs make up the vast majority of the total area of green roofs. Whilst most of these are designed specifically for biodiversity, over the past five years an increasing number of extensive green roofs are now generating sustainable energy with photovoltaic arrays, as well as delivering biodiversity.

A growing number of businesses and residential developments are also installing intensive green roofs. These are providing citizens and staff with much-needed access to greenspace at roof level.

The role of city authorities in improving the policy and practice of the future

Cities around the world are home to over half of the world's population and they continue to grow. London's population is expected to increase from 8.5 million to more than 11 million by 2040.

Cities are also the largest consumers of power, and are responsible for more than 80% of global carbon emissions, but they are also the places where more sustainable living can and must be promoted. Zero carbon and circular economy objectives are already embedded into city strategies, alongside initiatives to encourage more liveable cities which improve health, well-being and social cohesion.

Further greening of the built environment is acknowledged as an essential requirement for achieving the sustainable cities of the future. In A Green Future: Our 25 Year Plan to Improve the Environment, the UK Government recognises that the provision of more, and better quality, green infrastructure will make towns and cities attractive places to live and work and bring about key long-term improvements in people's health.

The European Commission has developed a research and innovation policy agenda on nature-based solutions and the European Environment Agency promotes the need for urban greening in Transforming Cities in a Changing Climate. At international level, initiatives such as the International Union for Conservation of Nature Urban Alliance and ICLEI's Cities with Nature aim to raise awareness of the value of greening urban areas.

The Urban Greening Factor

This added emphasis on urban greening requires further development in policy. These initiatives should encourage a more integrated approach, meaning that greening the urban environment should complement moves towards achieving healthy streets and a greener public realm that incorporates green infrastructure for sustainable drainage and improved air quality. Several city authorities have already responded by developing new policy instruments which aim to support a more considered approach to Integrating green infrastructure into the built environment. Based on a planning tool originally developed in Berlin to promote the protection and enhancement of landscape, wildlife habitats and green spaces, cities such as Malmö have included a Green Space Factor in their planning policy which sets out guidelines for how new developments should be greened.

This approach is being adopted by more cities as the imperative for urban greening increases. In London, the Green Space Factor has been translated into the Urban Greening Factor, which is integral to the updated Urban Greening Policy in the latest version of the London Plan.

Financing urban greening

In addition to progressing and evolving planning policy, there is growing interest in the development of policy and protocols relating to the financing of green infrastructure. Such financing models are emerging out of an increasing awareness of the natural capital benefits that are generated by urban greening.

The European Investment Bank’s Natural Capital Financing Facility (NCFF), for example, is a dedicated programme that can provide, amongst other things, long-term loan financing for urban greening projects to support public-private partnerships. These new models aim to move the greening of urban spaces beyond mandatory requirements to a position where the benefits that accrue to both public authority and commercial developer of including such projects - financial and otherwise - are fully recognised.

Green roofs and walls are now standard features in many cities around the world. They will continue to be a major contributor to the greening of the urban environment in the future. But to ensure the next step-change in provision, a more comprehensive approach to planning and financing urban greening must become mainstream. Accessible information on effective policies and approaches is key. This report and its findings will help to support that vital mainstreaming and information sharing process.

This report demonstrates that owing to the particular legal and regulatory framework of London, its ambitious policy has successfully delivered significant areas of green roofs and walls. This report should ensure that London is recognised as a global leader in this area and, alongside other pioneering cities, will continue to lead the way in what is a global transformation of the urban realm. In doing this our, cities will becoming greener and healthier for people, wildlife and the urban environment.

Case studies

Berkeley Group

Large intensive and extensive green roofs

Small-scale extensive green roofs

Green walls

Case Study

Goodman's Fields

Berkeley North East London

Comments

Right in the heart of London and on the edge of the City of London, this project demonstrates what can be achieved in the densest parts of a city. All roof spaces have been designed with both people and wildlife in mind. The green roofs provide amenity space for residents, as well as specific roofs designed primarily for biodiversity benefit. Berkeley North East London has installed varied and unusual substrates and rooftop beehives, among other features, proving that gardens on roofs do not have to be traditional, formal landscapes but innovative in look and innovative in delivering biodiversity at roof level in the heart of the city.

The green roofs at Goodman's Field have an innovative mix of substrates and planting schemes to help achieve biodiversity net gain. These include alpine, chalk and acid substrates with native perennials and grasses. There is also woodland planting using native hawthorn. A range of other features is included in the design including shade rocks for wildlife, pebble beds that collect rainwater (for attenuation and for wildlife), bird and solitary bee boxes. There are also four bee hives and a number of solar panels for renewable energy.

Contribution to net gain

The network of green roofs provides a habitat mosaic alongside the ground level and roof level residents' communal gardens. The planting chosen was designed to attract native and migrating species. This includes priority species targeted in the Tower Hamlets Biodiversity Action plan, such as rare native birds like the black redstart.

Maintenance

All roofs have been designed to allow safe and easy maintenance access, with clear walkways.

Berkeley Group

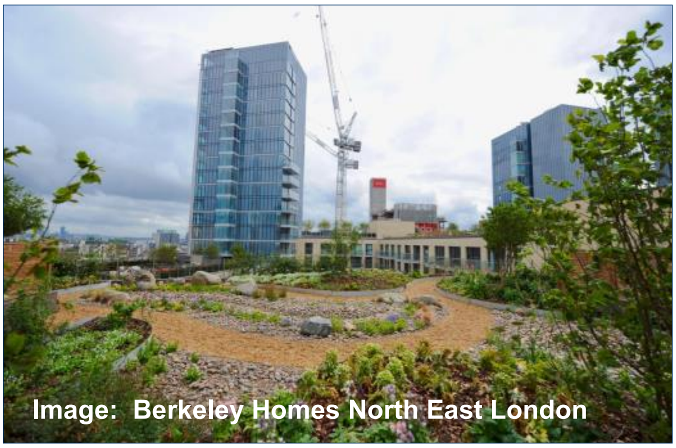


Image: Berkeley Homes North East London

Goodman's Fields Berkeley North East London	
Completed	2019
Size of development	2.83 hectares
Type of green roofs	Mix of biodiverse extensive, semi-intensive and intensive green roofs
Type of build	New development
Vegetation	A range of native, perennials, grasses and native woodland planting, specifically hawthorn
Location	Edge of the City of London

Developer's comments

It is hoped that the gardens will demonstrate what can be achieved in terms of biodiversity enhancement on new build developments in urban areas, and promote an 'outside the box' approach to habitat creation.

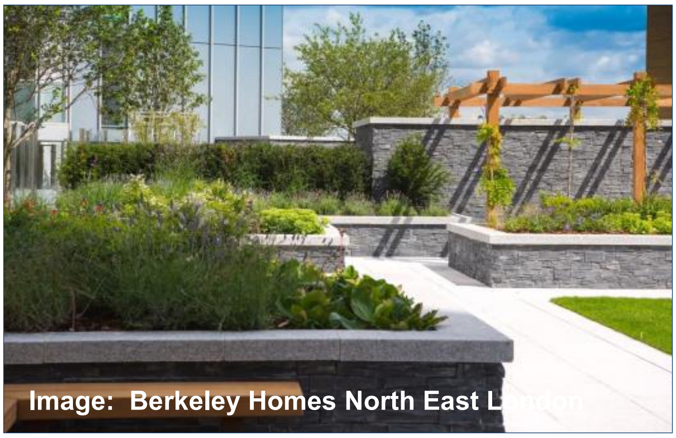


Image: Berkeley Homes North East London

Case Study
Woodberry Down
Berkeley North East London

Comments

Woodberry Down is a unique site with its links to the Woodberry Down Wetlands. Much of the site has been devoted to biodiversity enhancements and the design carefully considered to create a space for both people and nature to enjoy. The green roofs at Woodberry Down form part of an award-winning sustainable drainage system (highly commended at the CIRIA susdrain SuDS Awards 2018) which includes a network of swales and infiltration trenches at ground level, and a gentle slope towards the Woodberry Down Wetlands. More development on the site is planned, with further green roofs to be installed on buildings where appropriate.

The green roofs contribute towards net gain/ biodiversity enhancements, providing stepping stone habitats for species supported by the adjacent wetlands. The roofs increase habitat connectivity across the area - important as this is a large urban regeneration development.

Woodberry Down Berkeley North East London	
Size of development	25.8 hectares
Total area of roofs installed	4,700m^2
Area of intensive green roofs installed	None to date; however, intensive green roofs are being considered for phases currently in development
Total number of green roofs planned	All future phases will be designed in line with the Berkeley Group's Our Vision strategy which currently requires living roofs to be implemented on all suitable residential apartment roof spaces including semi-intensive and extensive
Reasons for installing / planning to install green roofs	Green roofs were set out in the initial masterplan and add to the character of the development. As part of the planning conditions it was agreed that there should be biodiverse, substrate-based extensive living roofs


Image: Berkeley Homes North East London

Berkeley Group

Case Study
Kidbrooke Village
Berkeley East Thames

Comments

Kidbrooke Village in the Royal Borough of Greenwich is one of several developments within the Berkeley Group's development portfolio. Whilst many of the buildings have been constructed and are inhabited, there are still more blocks to be added in the coming years. More green roofs are planned on some of these new buildings in the future.

Maintenance and monitoring

Maintenance is covered by the service charge. No specific monitoring is in place.

Developer's comments

There is a number of reasons for installing or planning to install biodiverse green roofs, including: planning requirements, corporate requirements; contribution to sustainable drainage strategies; and to enhance biodiversity.

Kidbrooke Village Berkeley East Thames	
Size of development	109 hectares
Total number of roofs installed	Approx. 20 in terms of blocks. If counting individual areas, it would be more
Number of extensive roofs	Majority of blocks will provide extensive biodiverse green roofs
Total number of roofs planned	12 currently planned (based on original consents, subject to change)
Location	South East London

Wider amenity benefits of the roofs

In terms of wider amenity benefits, the extensive biodiverse green roofs provide visual amenity for people in apartments at higher levels and the intensive green roofs provide amenity space for residents. Both also provide habitats for wildlife.


Image: Berkeley Homes East Thames

Case Study
IKEA, East Greenwich
Royal Borough of Greenwich


Image: Dusty Gedge


Image: Dusty Gedge

Comments

IKEA says its new store, awarded BREEAM Outstanding, is one of its most sustainable thanks to the addition of its fully accessible green roof. The green roof is one of the largest in the Royal Borough of Greenwich.

Installed by Bridgman & Bridgman LLP on a Bauder system, the green roof consists of areas of sedum blanket, wildflower turf and a biodiverse green section planted with a range of wildflowers for rare invertebrates. There are also small areas of more formal intensive green roofs.

The store opened in February 2019 and the roof itself will be open to the public in the near future, providing green space for the benefit of both people and wildlife.

IKEA, 55-57 Bugsby's Way	
Completed	2019
Type(s) of green roof	Intensive green roof
Type of build	New development
Vegetation	Extensive biodiverse green roof, sedum blankets, wildflower turf and small areas of intensive green roofs
Location	Millennium Leisure Park, East Greenwich
Area	4,000m^2
Contractor	Bridgman & Bridgman LLP
Green roof supplier	Bauder

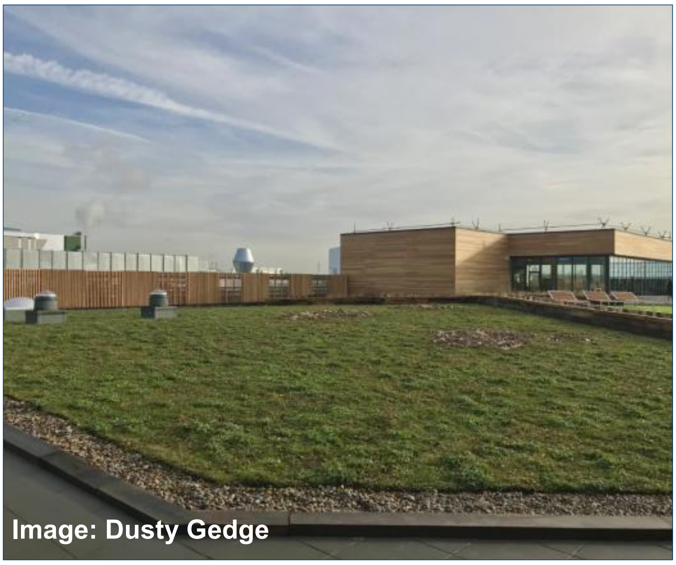


Image: Dusty Gedge

Image: Ian Hunter

Case Study
Thurston Road, Lewisham
South East London


Image: Dusty Gedge

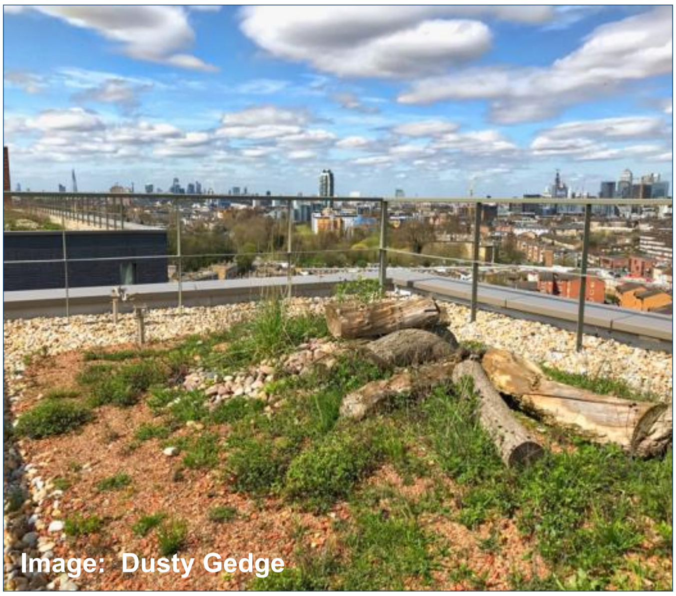


Image: Dusty Gedge

Comments

A development in central Lewisham owned by Chapter Lewisham, which provides student accommodation, includes two green roofs designed for biodiversity.

Installed by Bridgman & Bridgman LLP in 2016, the green roofs were planted with a wide range of wildflower plugs and also seeded with a species-rich wildflower mix.

The green roofs have been installed with a varied depth of substrate to create a diverse flora to meet the ecological design for biodiversity, as outlined in guidance on green roofs by Buglife – the invertebrate charity.

49 Thurston Road, Lewisham	
Completed	2016
Company	Chapter Lewisham (owner)
Type(s) of green roof	Extensive green roof designed for biodiversity
Type of build	New development
Vegetation	Wildflowers and features for biodiversity
Location	49 Thurston Road, Lewisham South London
Area	1,040m^2
Contractor	Bridgman & Bridgman LLP


Image: Dusty Gedge

Case Study
Clapham Park, Lambeth
South London


Image: Bauder


Image: Bauder

This new five-storey development with 21 dwellings replaced old social housing stock in Clapham Park, Lambeth. The green roof blends a biodiversity mix of 49 native wildflowers and PV solar arrays that generate 10% of the residents' electricity needs.

The Bauder biosolar green roof was implemented to meet National Planning Policy Framework Chapter 11: Conserving and enhancing the natural environment, and the London Plan 2011

- Policy 5.2 – Minimising Carbon Dioxide Emissions
- Policy 5.3 – Sustainable Design and Construction and Policy
- Policy 5.7 – Renewable Energy

The project is certified BREEAM Outstanding.

Clapham Park, Lambeth	
Completed	2017
Type(s) of green roof	Biosolar roof
Type of build	New development
Vegetation	Wildflowers
Location	Clapham Park, Lambeth, South London
Area	500m^2
Supplier	Bauder

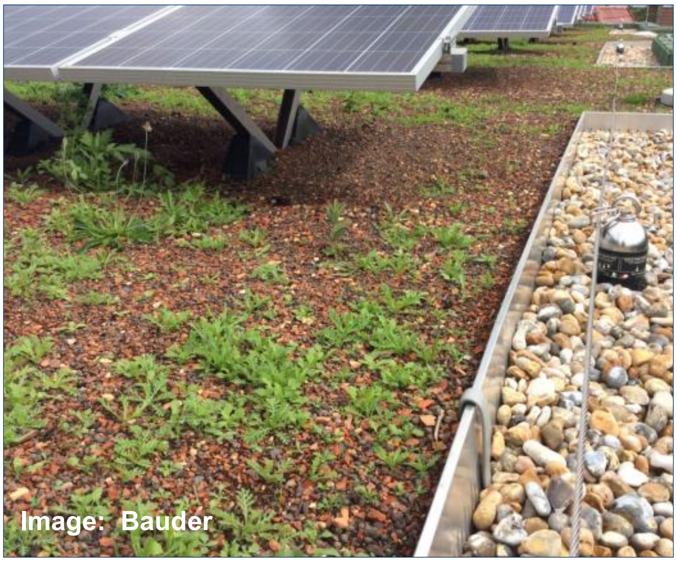


Image: Bauder


Image: Bauder

Case Study
Dickens Yard
Borough of Ealing

Comments

Dickens Yard is a new development close to Ealing Broadway station, on what was an old council car park.

The green roofs of this prestigious development, using ZinCo systems, consist of a single sedum blanket green roof and a series of intensive green roof gardens.

As most of the roof gardens sit above underground parking, these podium roofs require suitable drainage and stormwater management as part of the green roof system.

The planting on balconies and podiums ranges from trees to shrubs and perennials, including a series of dense hedges.

The roof gardens also include additional features, including benches and a pagoda to provide seating and shade for residents who use the garden.


Image: Kingston Landscape Group


Image: Kingston Landscape Group

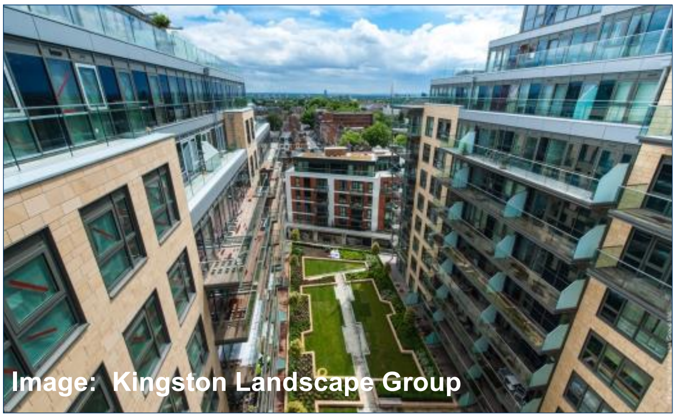


Image: Kingston Landscape Group

Dickens Yard New Broadway, Ealing	
Date completed	2017
Type(s) of green roofs	Intensive and extensive green roofs
Type of build	New development
Vegetation	Extensive green roof (sedum blanket), intensive green roofs on balconies and podiums (trees, shrubs and perennials)
Area	600m^2
Green roof supplier	ZinCo

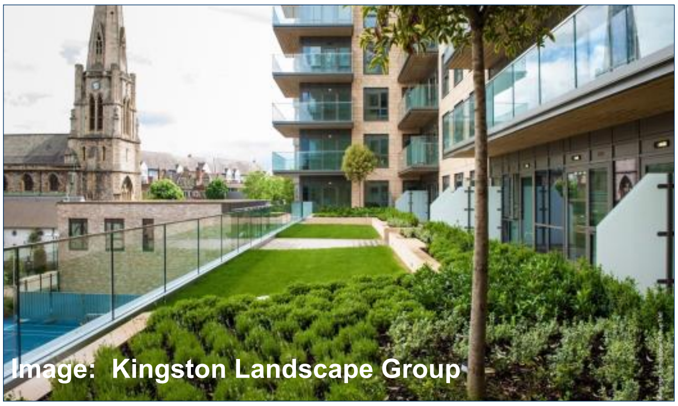


Image: Kingston Landscape Group


Image: Kingston Landscape Group

Case Study
College Road, Aylesford
Polypipe Building Services

Comments

Although this project is not in London, it is an important one as it demonstrates how blue and green roof systems can be successfully combined. A number of these projects have recently been installed in London and this approach is likely to increase over the coming years.

When Polypipe's offices in Aylesford, Kent, required renovations to the roof, the company decided to install a blue green roof which provided the opportunity for the design and development of a new, intelligent water management system.

Recognising that the health and survival of a green roof can be dependent upon unpredictable weather patterns and require ongoing maintenance, Polypipe worked to create a system which automatically:

- managed water supply rate for optimum soil moisture conditions
- ensured the green roof flourishes

Controlled and monitored remotely online via a smartphone, tablet, or computer, the Cloud Water Control System combines monitoring sensors, remote valve operation technologies and cloud computing software to provide adaptive irrigation. This combination of technologies creates the ideal conditions for plant life, whilst maximising water usage efficiency.

During high rainfall events, the system increases the amount of rainwater stored and, when at capacity, releases the excess water at a slower rate than is usual.


Image: Dusty Gedge

College Road, Aylesford, Kent	
Company	Polypipe Building Services
Completed	2018
Type(s) of green roof	Sedum green roof on a blue roof system
Type of build	Office renovation
Vegetation	Sedum blanket
Area	210m^2
System	Polypipe blue green roof system


Image: Dusty Gedge


Image: Dusty Gedge


Image: Dusty Gedge

Case Study

1 Angel Lane

City of London

Comments

1 Angel Lane opened in April 2011 and is home to Nomura International Plc.

The new development has two green roof areas.

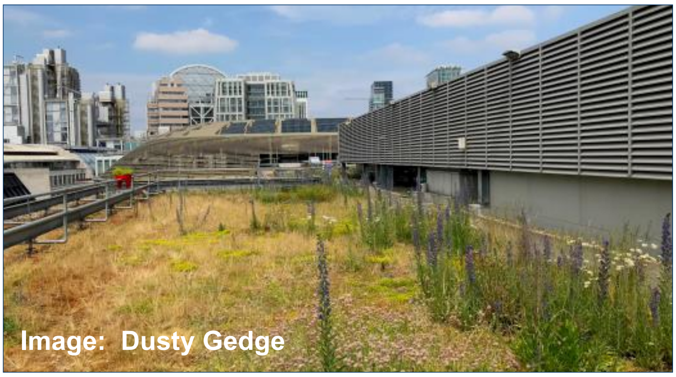
An intensive green roof accessible to staff consists of lawns, shrubs and perennials. The company also established a large area of this roof for urban food growing for staff.

On the upper roof, solar arrays are mounted on the sedum green roof. This roof is home to beehives, and the company has added wildflowers to support both the honey bees and other pollinators. In addition, rare green-winged orchids have colonised the roof.

Black redstarts are seen regularly on the upper roof.

1 Angel Lane, City of London	
Company	Nomura International Plc
Completed	2010
Type(s) of green roof	Intensive green roof/ extensive sedum blanket
Type of build	New development
Vegetation	Lawns, shrubs, perennials and food growing/sedum blanket
Location	1 Angel Lane, City of London
Area	4,000m^2

Case Study
1 Wood Street
City of London



Comments

This Eversheds Sutherland development was completed in 2008 with a sedum blanket roof. In 2009, extra substrate mounds and habitat features (logs, habitat wall) were added to the roof to increase its biodiversity value. Native wildflowers were seeded and planted along with spring bulbs.

Since 2014, the roof has been part of Open Square Weekend. Over 4,000 people visit the roof annually and experience its rich, varied habitat. Staff members also grow food and flowers. The honey from the beehives on the roof is used in the company's canteen.

The roof is also home to foraging and breeding black redstarts, and a wide range of invertebrates have been recorded on the roof.

1 Wood Street, City of London	
Completed	2008
Type(s) of green roof	Extensive green roof
Type of build	New development
Vegetation	Wildflowers, bulbs and sedums
Location	1 Wood Street, City of London
Area	1,400m^2
Designer	The Green Infrastructure Consultancy

Case Study
7 More London
Borough of Southwark


Image: Dusty Gedge

Comments

7 More London, home to PwC, is an example of a development with a series of green roofs on several levels. The building has three green roofs: an intensive green roof on the third floor which is accessible to staff; a biodiverse green roof which is seven storeys above street level and visible from office windows; and a small brown roof, which is located on the right top of the building.

The original extensive brown and green roofs were redesigned in 2012 by The Green Infrastructure Consultancy. The simple sedum roof and brown roof had areas of extra substrate added along with features which provide habitat for wildlife, including log piles and nesting walls for solitary bees. Native wildflower seeds and plants were sown and planted as well as spring bulbs.
The biodiverse and brown roofs now have a good range of invertebrate species and, in most years, a breeding pair of black redstarts makes use of the roofs for foraging.

This project demonstrates that staff amenity, both physical and visual, can be combined with delivering biodiversity. It is also a good example of how extensive green roofs can be improved ecologically with simple but effective interventions.

PwC, 7 More London	
Completed	2012
Type(s) of green roof	Extensive green roofs
Type of build	Retrofit project on existing green roofs
Vegetation	Wildflowers, bulbs and sedums
Area	Two roofs: 550m^2 and 116m^2
Designer	The Green Infrastructure Consultancy

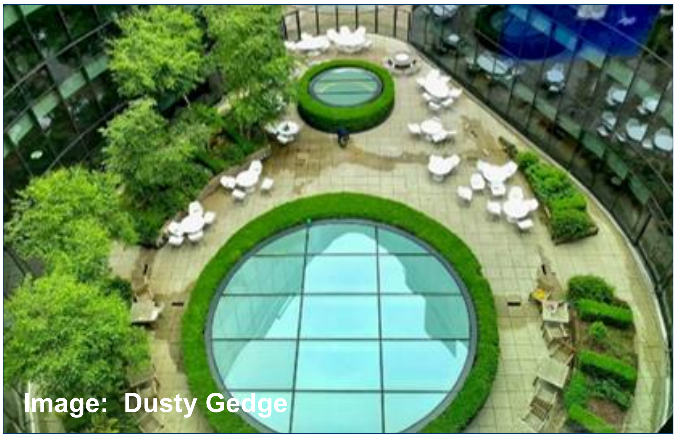


Image: Dusty Gedge

PwC, 7 More London	
Completed	2010
Type(s) of green roof	Intensive green roof
Type of build	New development
Vegetation	Trees, shrubs, ferns and perennials
Area	560m^2


Image: Dusty Gedge

Case Study
Fortnum & Mason
City of Westminster, London


Image: Alexander Bond


Image: Alexander Bond

Comments

Fortnum & Mason, working with Biophilic Designs, installed 200m^2 of biodiverse green roofs on 10 areas of existing exposed membrane roofs, using Vegetal iD pre-vegetated trays. The green roof system is pre-grown with a mix of perennials, sedums and mosses.

The driver for the project was to provide a range of benefits, including improved air quality, better energy efficiency for the building, and increased biodiversity.

The green roof will be monitored for 12 months to assess the amount of pollutants absorbed by the green roof areas.

Fortnum & Mason is keen to demonstrate the contribution that fitting green roofs on existing 'dead' roof space can make towards creating a greener, more climate-proof city.

Fortnum & Mason	
Completed	2018
Type(s) of green roof	Biodiverse green roof
Type of build	Retrofit project
Vegetation	Wildflowers and sedums
Location	Piccadilly, London
Area	200m^2
Supplier	Vegetal iD


Image: Alexander Bond

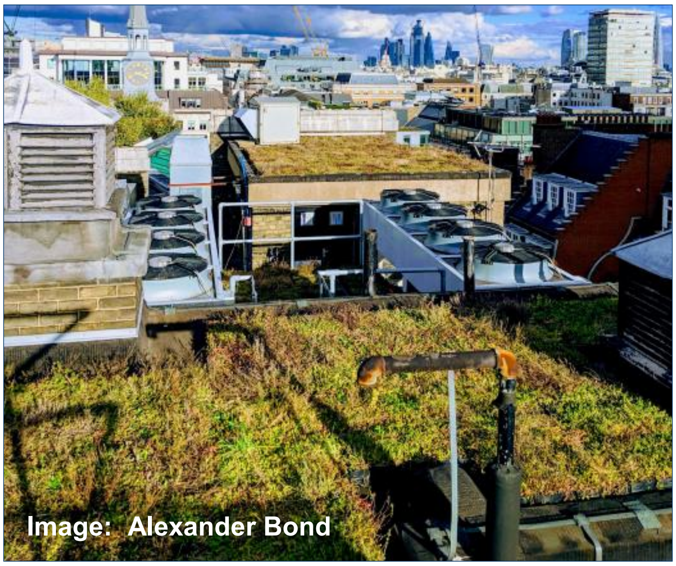


Image: Alexander Bond

Case Study
Sefton Road, Croydon
Private residence

Comments

This was a new-build single-storey extension at the back of a domestic property. The flat roof is overlooked by a bedroom, so the client did not want to look at exposed waterproofing membrane when viewing their garden.

Access to the back garden is via a pedestrian gate and alleyway. A roll-out system with such restricted access was not possible. The installer was a general builder without previous green roofing experience so a modular system was deemed the best solution.

The sedum was grown from seed in trays at Wallbarn's own nursery in Hampshire. The trays are harvested the day before delivery and contained 13 species of flowering sedum suitable for English and Northern European climates, specifically selected to attract bees and butterflies and encourage wildlife.

Individual trays were carried by hand through the house and passed through a window. Installation was completed in one day.


Image: Wallbarn

Sefton Road, Croydon	
Type of building	Private residence
Supplier	Wallbarn
Date completed	January 2018
Type(s) of green roofs	Extensive green roof
Type of build	Extension on existing property
Vegetation	Sedum green roof
Area	17m^2


Image: Wallbarn


Image: Wallbarn


Image: Wallbarn

Case Study
Cycle Shelters IKEA
Royal Borough of Greenwich


Image: Dusty Gedge

Image: Dusty Gedge

Comments

Whilst the main roof of IKEA is one of the largest green roofs in Greenwich, the store has provided seven cycle shelters with a green roof installed on each one. Small green roofs at street level are just as important as larger projects on buildings.

Green Roof Shelters has been delivering small-scale green roofs on cycle and bin shelters for over 10 years. Habitat features incorporated into the walls of the structures provide nesting for birds, bees and other insects. Native wildflowers and spring bulbs will create important foraging habitat.

Installed in February 2019, the small green roofs are in the early stage of establishing. Yet come the summer they will provide a welcome splash of colour visible from street level.

IKEA, 55-57 Bugsby's Way	
Completed	2019
Type(s) of green roof	Extensive green roof
Type of build	New development
Vegetation	Wildflowers, perennials and bulbs
Location	Millennium Leisure Park, East Greenwich
Area	$7.7m^2 \times 7 = 61m^2$
Designer	Green Roof Shelters


Image: Dusty Gedge


Image: Dusty Gedge

Case Study
2 London Wall
City of London

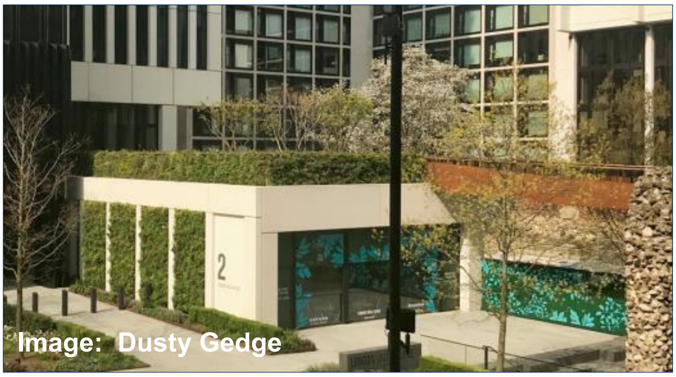


Image: Dusty Gedge


Image: Dusty Gedge

There are several living walls at 2 London Wall which were designed and installed by ANS Global. They are spread around the site with one main wall at street level and several others along the walkways of St Alphage Highwalk. The walls are part of a natural oasis in the heart of the City of London, which is constantly buzzing with workers from nearby offices.

The pre-grown system uses natural soil and was planted with a wide range of seasonal vegetation for year-round colour. The requirements for the wall included a desire to have a range of native plants to attract local wildlife. These include spring bulbs - crocuses, snowdrops, bluebells and daffodils. The plant palettes vary from wall to wall so as to respond to the challenges of aspect and the microclimate of each location.

2 London Wall	
Completed	2016
Type of green wall	Modular
Type of build	New development
Vegetation	A range of non-native and native species
Location	London Wall, City of London
Area	800m^2
Supplier	ANS Global

Image: Dusty Gedge

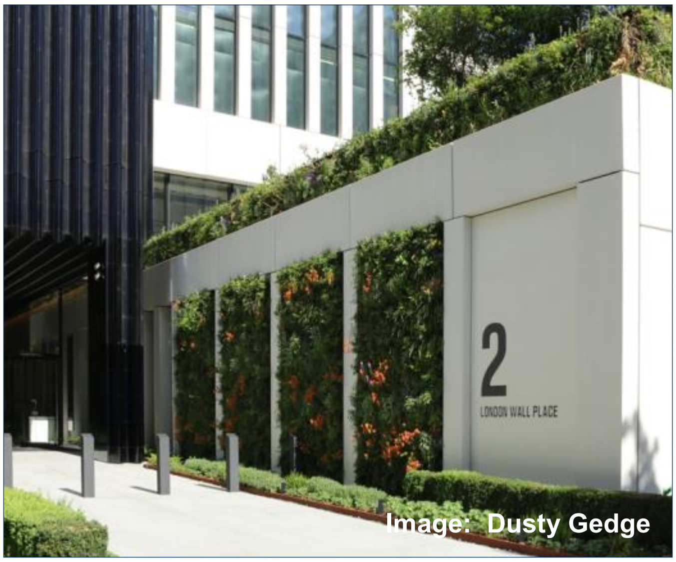


Image: Dusty Gedge

Case Study
Parliament Hill School
Borough of Camden

Comments

The Parliament Hill School green wall, supplied and installed by Scotscape, contains many native species to help support local biodiversity.

Hedera hedera, commonly known as ivy, is widely planted in the green wall. Ivy is especially important in autumn as the flowers are a vital late-season source of nectar for pollinators, particularly the solitary bee *Colletes hederae*.

Buxus sempervirens (the common box hedge) is also incorporated into the wall, and produces pollen and nectar for pollinators from March to May.

The densely planted structure also contributes to insulating the building and helps with air pollution amelioration.

The green walls, along with green roofs elsewhere on the building, were installed to meet planning requirements to support biodiversity and improve air quality.

Image: Scotscape

Parliament Hill School, Camden	
Date completed	2017
Type of green wall	Modular
Planting	Selection of native and non-native species
Location	Gospel Oak, Camden
Area	230m^2
Supplier/ Installer	Scotscape

Image: Scotscape

Case Study
Rubens at the Palace Hotel
Victoria


Image: Red Carnation Hotels

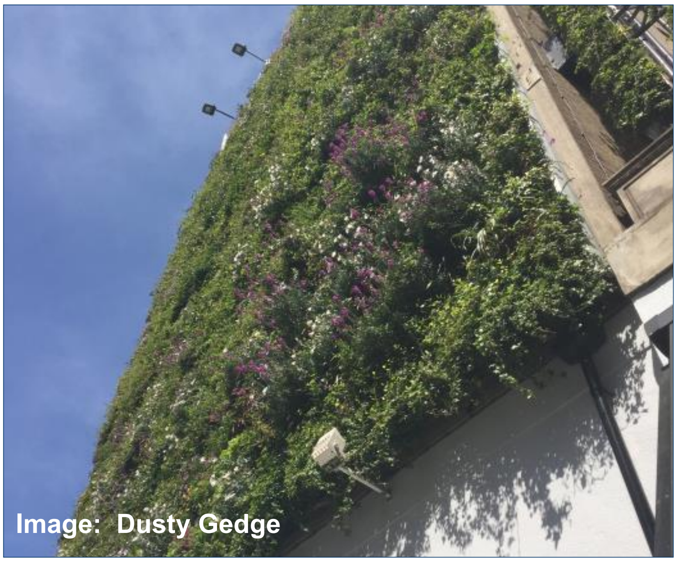

Image: Dusty Gedge

The potential of the blank walls of the Rubens at the Palace Hotel was identified as part of the Victoria Business Improvement District Green Infrastructure Audit, which was funded by the Mayor of London and designed by The Green Infrastructure Consultancy (GIC). GIC continues to provide technical support to the hotel.

The wall is irrigated with rainwater harvested from the hotel roof. The irrigation system is divided into 11 zones and is computer controlled. It is seasonally adjusted to ensure the correct amount of water gets to each part of the wall. The planting palette provides winter greenery, seasonal interest and flowers for pollinating insects.

The innovative middle section of planted 'louvres' allows light through to hotel rooms behind, whilst screening the hotel from noise and air pollution.

Rubens at the Palace Hotel	
Completed	2013
Type of green wall	Modular
Type of build	Retrofitted onto existing wall
Vegetation	Wide range of native and non-native species
Location	Victoria, Central London
Area	250m^2
Designers	The Green Infrastructure Consultancy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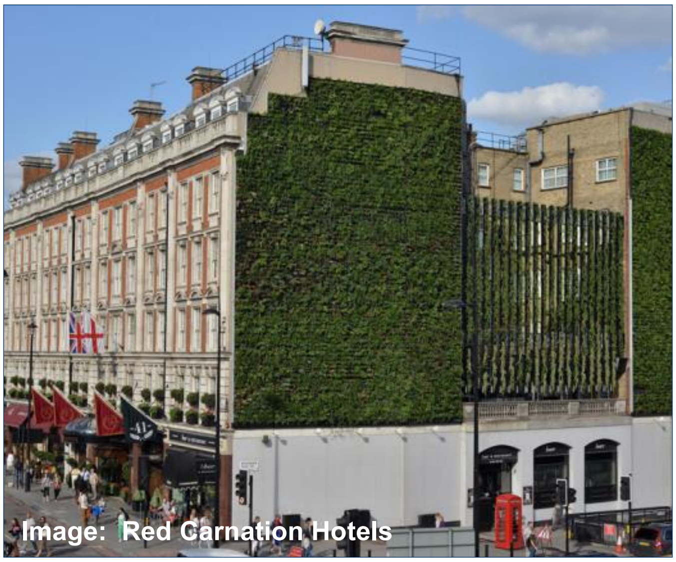
Image: Red Carnation Hotels

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2. Benefits and economic value (p9)

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