Environmental benefits

Air pollution tends to be highest in deprived urban areas, and particulate air pollution (PM_{10}) is a major health issue in cities around the world. Motor vehicle exhaust emissions are responsible for a substantial proportion of urban particulates and their reduction presents the largest challenge to improving the air quality. Exposure to high air pollution can cause and exacerbate respiratory problems, heart disease and cancer. Green infrastructure can reduce exposure in two ways.

- Vegetation can reduce air pollution directly by trapping and removing fine particulate matter and indirectly by reducing air temperatures. The strength of the effect depends on multiple factors, such as the weather, the pollution concentration, and the type and quality of vegetation.
- Urban transport infrastructure often results in the funnelling of pedestrians along major roads, where the concentration of air pollution is highest. Green corridors across cities can reduce pedestrian exposure to pollution by providing alternative routes.

Living walls can trap dust and other pollutants from both the air and rainfall on the leaves of plants, though during sustained periods of dry weather plants may reach a saturation point, after which particulate capture is likely to become less efficient. Varying the type, location and density of plants within a living wall can increase the opportunities for particulate capture. Creating texture across the wall by using a variety of plants increases the air turbulence in and around the vegetation, which has been shown to increase the rate of particulate deposition. The particulate capture ability of different plant species depends on the size, shape and surface texture of the leaves:

- Hairy, rough and/or ridged leaves are effective in trapping particles
- Waxy leaves are also effective in trapping particles
- Plants that attract aphids could be appropriate for inclusion as the sticky secretion of aphids deposited on leaves will retain particles
- Evergreen vegetation offers a year-round particulate-trapping surface
- Plants with smaller leaves have greater density of foliage and branches. The adsorption capability of plants is positively related with the leaf area index (leaf area/surface area, m^2/m^2).

In 2011 a 180 m^2 living wall was erected at the entrance to the Edgware Road underground station, London, funded by the Department of Transport Clean Air Fund. The planting design (Figure 3) intentionally created a variety of textures across the wall to interrupt air flow and encourage particle deposition. The wall contains 14,000 plants of 15 different species which were planted in a matrix format with the same plants repeated at different heights within the wall to enable comparison of PM_{10} capture rates [5]. A study found a great disparity in the relative ability of different species. Plants with small leaves which are hairy, waxy or deep-veined were found to be more efficient than those with smooth and supple leaves. *Convolvulus cneorum* performed far better than any other species, followed by *Stachys byzantina*; *Hedera helix* was the worst performing species. Over the three month monitoring period, the total PM_{10} capture was calculated to be 515 g [6].

Figure 5: Edgware Road living wall, London
Source: https://www.flickr.com/photos/zoer/8106439891

Another study involved free standing living walls at the Warren School in Dagenham, London, which is situated close to a busy road. A 15 metre living wall runs parallel to the road, and another living wall is situated at a 45° angle to it. The study looked at the effectiveness of five species (*Stachys byzantina*, *Carex testacea*, *Convolvulus cneorum*, *Lavandula angustifolia* and *Geranium* sp.) planted at three different heights (30 mm, 75 mm and 120 mm) at attenuating PM_{10}. A comparison was also made between the two wall types and a nearby natural hedge. In parallel, the effect of the walls and hedge on nitrogen dioxide levels were also measured. All five species were found to capture particulate matter, but at low levels, which may have been due to high levels of precipitation recorded during the monitoring period. No significant difference was found in particulate capture between species or at different heights. However, the plants on the angled wall captured significantly more PM_{10} compared with the wall running parallel to the road. Previous studies have shown that wind flows around dense barriers are complex and this may have influenced the outcomes of this trial. The natural hedge assimilated a significant amount of nitrogen dioxide compared to the walls [7].

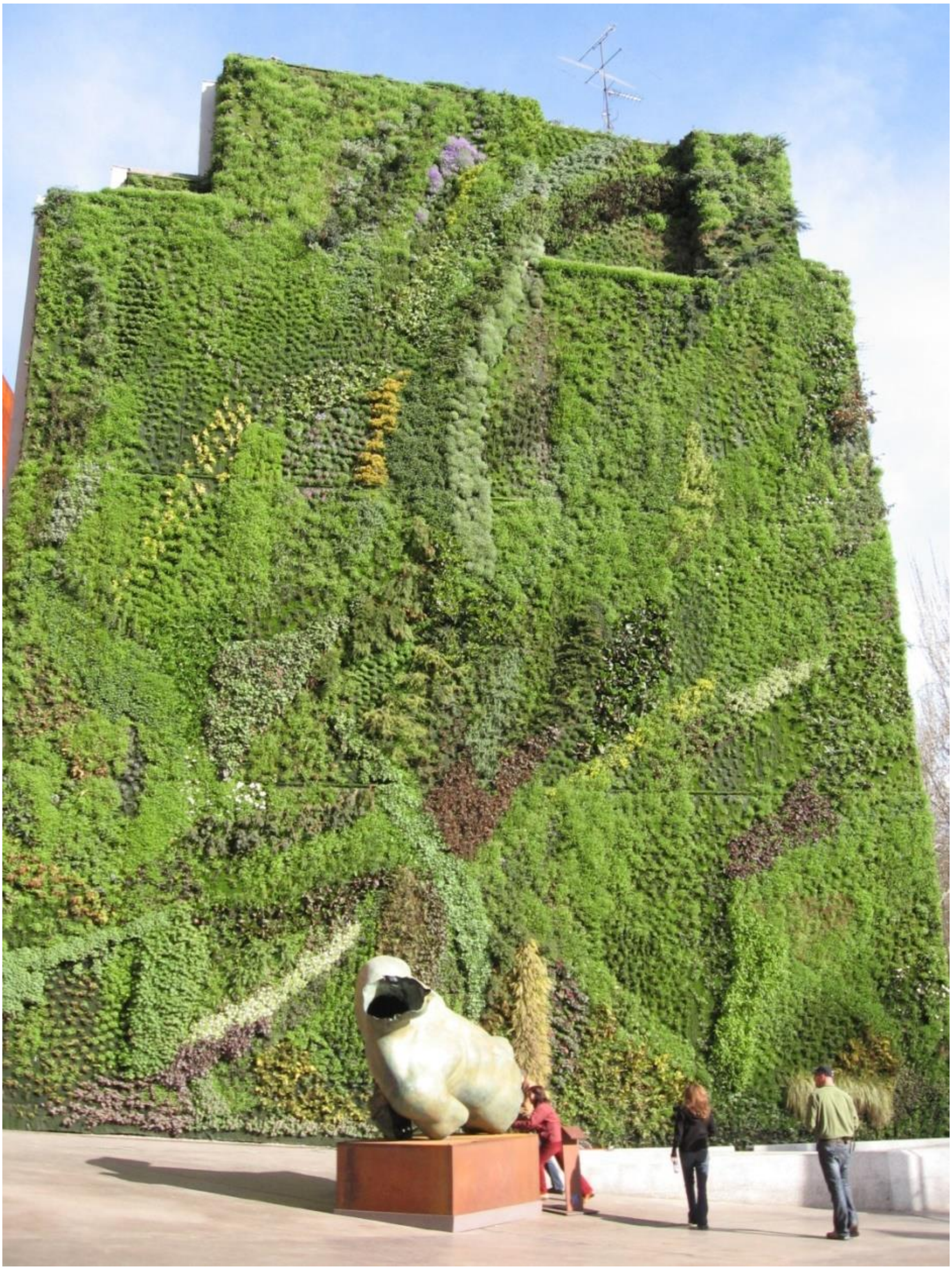

Figure 6: Living wall near the CaixaForum, Madrid, designed by Patrick Blanc
Source: **https://upload.wikimedia.org/wikipedia/commons/d/dd/CaixaForum_Madrid_1.jpg**

Living walls also have a role to play in the attenuation of **noise pollution**. While the hard surfaces of urban areas tend to reflect sound rather than absorb it, living walls can absorb sound: the vegetated surface will block high frequency sounds, and when constructed with a substrate or growing medium support they can also block low-frequency noises. Experimental studies have shown that even a thin layer of vegetation (20–30 cm) is able to absorb 1 dB of traffic noise, and 3 dB of pink noise.

Green infrastructure can **lower air temperatures** through the evaporation of water from vegetation and by providing shading. Urban areas often experience elevated temperatures compared with the surrounding countryside, because of extensive heat absorbing surfaces, such as concrete and tarmac, concentrated heat production and impeded air flow. This is known as the 'urban heat island effect'.

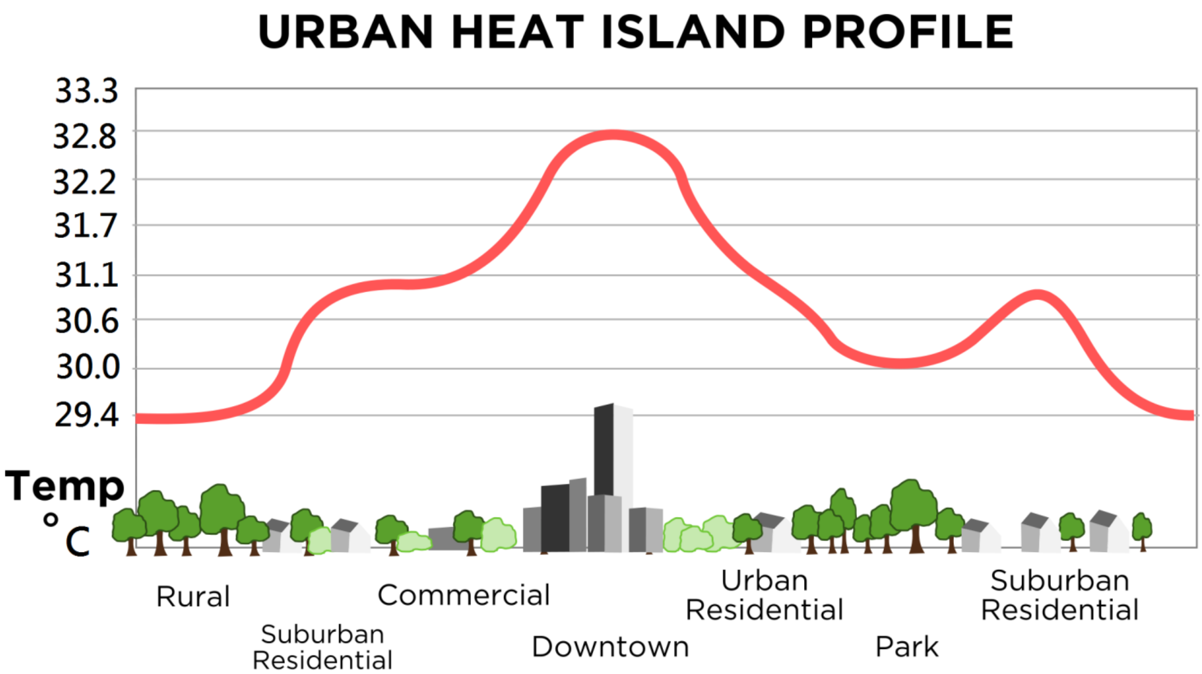

Figure 7: Urban heat island profile
Source: https://commons.wikimedia.org/wiki/File:Urban_heat_island_(Celsius).png

For example, the centre of London is on average 5°C warmer than surrounding rural areas. Heat waves during the summer pose significant health risks to urban populations either directly from the heat or from increased air pollution. During the 2003 heat wave, a temperature difference between urban and rural areas of up to 10°C was recorded for London and estimates suggest that 40% of the 600 excess deaths (the number of actual deaths minus the number of expected deaths) in London were due to the urban heat island effect. Climate change projections suggest that by 2050 such summer temperatures will be common.

Living walls can help reduce the urban heat island effect through the interception of both light and heat radiation which would otherwise be largely absorbed and converted to heat by the building surfaces and then radiated back into the surrounding streetscape. By providing shading from the sun, living walls can therefore significantly reduce the external temperature of a building. The effectiveness of this cooling effect is related primarily to the total area shaded and evapotranspiration effects of the vegetation, rather than the thickness of the living wall. Diurnal temperature fluctuations at the wall surface can be reduced from between 10°C and 60°C to between 5°C and 30°C. Other potential benefits of living walls include 'bioshading' – reducing sunlight penetration through windows. With strategic placement, the plants in living walls can also create enough turbulence to break vertical airflow, which slows and cools down the air.

Increasing plant species diversity and increasing the range of vegetation in cities can significantly increase other forms of **biodiversity**. Living walls can potentially provide a food source for invertebrates on which, in turn, other invertebrates and birds may feed. They also provide breeding and nesting habitat for invertebrates, birds and possibly bats, and are ideal for including artificial animal breeding structures such as nest boxes or bat roosting boxes. Careful choice of species and the orientation of the wall will increase the potential of a living wall to harbour other forms of wildlife. For example, ivy (*Hedera helix*) is a valuable food source for innumerable invertebrates which feed on its leaves, flowers and nectar, and, being evergreen, it also provides valuable over-wintering and hibernation habitat. In addition a living wall can be part of an overall city greening strategy linking ground level open space with street trees, water courses and living roofs.

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