Smart Control of Air Pollution

**Policy Briefs** from the **iSCAPE** project funded by the European Union's Horizon 2020 Research and Innovation Programme

# Improving air quality and climate with green infrastructure

Contents



## Key Take-Aways

This Policy Brief provides some compelling evidence in support of the adoption of green infrastructure in European cities, for improving urban air quality and reducing human exposure to air pollutants, as well as mitigating the impacts of climate change and thus contributing to a more sustainable urban environment.

Green infrastructure includes all types of vegetation, such as trees, hedges, green walls and green roofs.

Reported benefits in terms of reduced exposure to air pollution are substantial, and usually complemented by others of social (green spaces for the public) and/or economic nature (new job and business opportunities).

However, implementation of urban green infrastructure can result in its own disadvantages. For example, they could lead to direct emissions of pollen, fungal spores and biogenic volatile organic compounds (bVOCs) affecting the local air quality itself. Thus, an informed choice of the most appropriate species prior to deployment is of paramount importance.

It is also important to note that there is no "one size fits all" solution, and the outcomes of similar green infrastructures may vary considerably in different urban environments.

Other observed findings include, for example, the possible limited effect of low-height hedges at pedestrian height, and the strong dependency of results on wind direction and speed. In general, trees with larger crown distances and lower foliage densities are preferred for street canyon environments, but, as mentioned previously, an informed choice is paramount.



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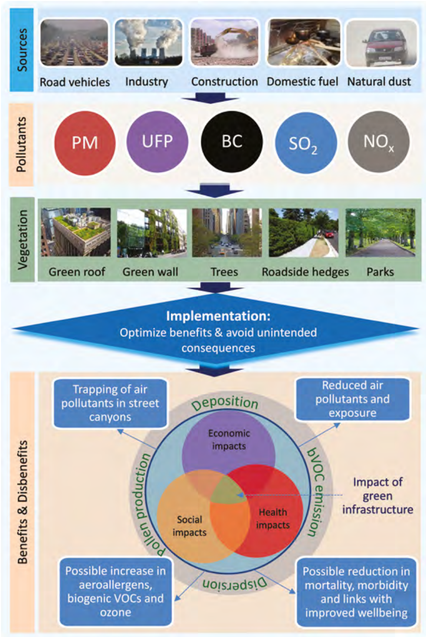


**Figure 1:** Conceptual diagram showing the linkages of air pollution sources, greening options, optimised benefits and unintended consequences. (Kumar et al., 2019)

## Building the Case

Due to urbanisation and population growth, it is well-known that air pollution in urban areas can be high and adversely impact both the built environment and human health. Common sources include: road vehicles, industry, construction, domestic fuels, and resuspended dust. The most common pollutants emitted are particulate matter (PM), ultrafine particles (UFP; less than 0.1 µm), black carbon (BC), sulphur dioxide ($SO_2$), and nitrogen oxides ($NO_x$).

**Green infrastructure** includes all types of urban vegetation, such as trees, roadside hedges, green walls and green roofs. **Trees** are widely employed as an environmental tool to improve urban outdoor climate. They are planted and managed as part of urban landscaping along streets, in **parks** and in other common accessible spaces. **Hedges** or hedgerows generally consist of adjacent shrub species or small trees, managed to form a barrier with leaf cover from ground level. They are usually planted along boundaries to serve as fencing or living boundary walls. Hedges are characterised as elongated vegetation of relatively low average height and low width compared to height. **Green walls and roofs** offer ways of incorporating vegetation on buildings and other grey infrastructure. Green walls are vegetated vertical surfaces where plants are attached to surfaces through various mechanisms, such as self-clinging climbers and self-supporting woody plants. Green roofs are vegetation planted on the roof of a building. Plants are cultivated on growth media isolated from the building, and consist of different vegetation types, from mosses to small trees, growing substrate, filter and drainage material, root barrier and insulation.

**Observed benefits** of green infrastructures include: alteration of regular dispersion patterns, less trapping of air pollutants in street canyons, reduced human exposure to pollution, and improved urban comfort and wellbeing. Additionally, a number of indirect socio-economic and health related impacts – a bit more challenging to assess and quantify – include new job and business opportunities for the solution providers, wider availability of green areas (alongside urban parks) for the general public, and a possible reduction in mortality/morbidity rates of the population living in cities.

Alongside the benefits, there may be some disadvantages of deploying green infrastructure, such as direct emissions of pollen, fungal spores and biogenic volatile organic compounds (bVOCs), thus adversely affecting air quality. Further, this may cause increases in aeroallergens and their deposition in urban environments. Thus, as shown in Figure 1 (from Kumar et al., 2019), the implementation of green infrastructure must consider the **optimisation of expected benefits** jointly with the **minimisation of unintended consequences**, and making an informed choice of plant species or cultivar prior to their deployment is very important. This includes the avoidance of invasive species, which may disrupt or damage existing ecosystems. The **advantages and disadvantages of deploying green infrastructure** are shown in Figures 1 and 2.

Trees interact with air pollution in a number of ways. For example, they can increase turbulence and dry deposition of air pollutants. However, in deep street canyons, planting trees will lead to a deterioration of air quality. The reason is that trees generally reduce the (already low) wind speed in street canyons and thus reduce the dispersion and dilution of air pollutants. Conversely, in open road conditions, hedges and/or trees can act as a barrier between the source (e.g. traffic) and the receptor (e.g. pedestrian), reducing far-side particle pollutant concentrations.

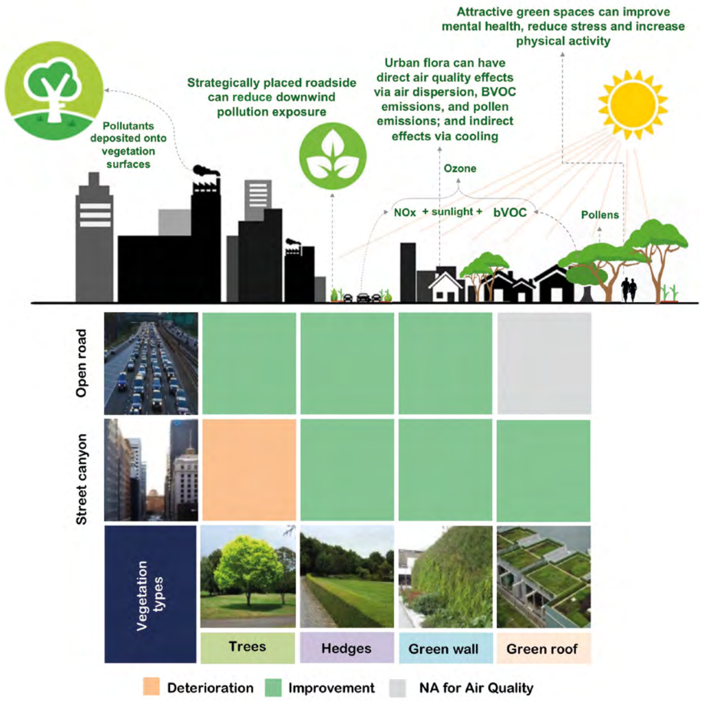


**Figure 2:** An overview of the relationship between air quality and green infrastructure with a matrix offering local-scale implementation impacts. (Adapted from Kumar et al., 2019, and Abhijith et al., 2017)

Green roofs help to: mitigate air and noise pollution, the urban heat island effect and energy consumption; manage runoff water; and enhance ecological preservation. In particular, green roofs lead to improved air quality when they are implemented in street canyons.

In summary, as shown in the last figure (from Abhijith et al., 2017), hedges and green walls lead to improved air quality when implemented in both street canyons and open road conditions.

**Multi-functionality** is one of the most powerful properties of green infrastructure, when designed and managed effectively. In fact, they are flexible and adaptable enough to enhance air quality, biodiversity, urban thermal comfort, and surface water management, thus improving health and wellbeing, urban design and social cohesion.

## Lessons to Share

As summarised in the previous sections, different types and forms of green infrastructure present a number of advantages and disadvantages for air quality, depending on the type of built environment in which they are deployed. Based on previous work in this area highlighted in the literature, the iSCAPE project investigated the impact of green infrastructure on air quality in six European cities (Bologna-IT, Bottrop-DE, Dublin-IE, Guildford-UK, Hasselt-BE and Vantaa-FI), thus providing further evidence of its efficacy in reducing air pollution.

**Figure 3:** Vantaa, Finland. © Jyri Moisio

For example, **simulations of the impact of green walls and green roofs** on air pollution and climate change mitigation were carried out in Vantaa (see Figure 3). Results showed that green walls and green roofs require little space, while hedges and trees require a substantial amount of space. They can support climate change adaptation by keeping the city cooler, while reducing carbon dioxide emissions.

However, the following limitations were also observed:

- High-resolution simulations regarding urban meteorology need large computing resources. This means that only specific examples can be simulated;
- Coarser resolution makes analysing longer time periods and larger domains possible. However, in Vantaa, urban areas are treated as "averaged" grid squares, each square having average values of the actual morphological factors (e.g. a fraction of roads, buildings, water, etc.). This may hide actual and even significant effects of any intervention.

Figure 4: Street canyon in the city of Bologna, Italy.

In relation to the **use of trees for the improvement of air pollution and thermal comfort in urban street canyons (see an example from Bologna in Figure 4)**, the project studies gave the following findings in the iSCAPE pilot cities:

- During the winter months no foliage is present on deciduous trees; therefore, the impact of trees on air pollution during this time is mostly limited to the deposition effect, which is not effective for gaseous pollutants;
- The introduction of trees in a street canyon may lead to strong decreases in pollutant concentrations in proximity to local hotspots and more uniform pollutant distributions in the street canyon. However, it may increase the concentrations of air pollutants in local single spots;
- Trees with larger crown distances and smaller foliage densities are recommended. In general, the absence of foliage on deciduous trees in the winter season leads to limited impact of trees on thermal comfort;
- The effect of trees on air flow and therefore on air pollution dispersion is strongly dependent on wind direction and wind speed;
- Trees may help to improve thermal comfort providing reductions of air temperature of about 1-2°C in the summer season. This impact also extends to larger neighbourhood areas.

Finally, **in relation to street-level interventions, such as the implementation of hedges and green walls, the following findings** were observed:

- The effect of low-height hedges, for example at pedestrian height, for air pollution mitigation was negligible. It also decreased with downstream distance from the hedge as the concentrations approached the urban background concentration;
- The air pollution mitigation effects of hedges were strongly wind direction-dependent with a maximum reduction in pollutant concentration during along-road wind conditions, followed by cross-road wind conditions;
- Deciduous hedges lose their leaves during the winter season, thus leading to increased porosity of the hedge. In general, dense hedges

show relatively large air pollution reductions with deciduous hedges likely to have lower air pollution reductions during the winter;

- Urban space is a scarce resource in many cities of Europe. This may limit the applicability of hedges for air pollution mitigation; however, the extent of this remains to be quantified;
- Improper selection of height, width and plant species of hedges may hamper the effective application of them for air pollution mitigation;
- Similar limitations as hedges were identified for trees in open-road conditions.

**"The iSCAPE project provided us with an opportunity to assess the effectiveness of passive control measures such as green infrastructures"**

**Prof Prashant Kumar from the University of Surrey (UK), on behalf of the iSCAPE project team.**

## Keywords to remember

| Air Pollution: | Green Infrastructure: | Urban Heat Island Effect: |
|---|---|---|
| Harmful emissions of particulate matter (PM), nitrogen oxides ($NO_x$), carbon monoxide (CO) and other volatile organic compounds (VOCs). Air pollution is particularly harmful for children, senior citizens and people with breathing related health issues. | As distinct from built or grey infrastructure, they usually include trees, roadside hedges, green walls, and green roofs. | An urban area that is significantly warmer than its surroundings due to the presence of human activities. The temperature difference is usually larger at night than during the day, and most apparent when winds are weak. Urban Thermal Comfort: As opposed to discomfort or heat stress, a particular condition of people living in cities, which is defined by the values of a set of environmental and state parameters, such as air and radiant temperatures, air velocity and humidity, as well as clothing insulation. |

## Read More

Information from the following key iSCAPE project deliverables have been used in the preparation of the current policy brief: **D1.2** 'Guidelines to Promote Passive Methods for Improving Urban Air Quality in Climate Change Scenarios' (October 2018), **D3.3** 'Report on Footprint of Passive Control Solutions' (October 2018), **D5.4** 'Strategic Portfolio Choice' (May 2019), **D6.3** 'Detailed Report based on Numerical Simulations of the Effects of Passive Control Solutions at the Urban Level'

(February 2019), **D6.5** 'Detailed Report of the Effect of Passive Control Solutions on Air Quality in the Future Climate Change Scenario (2050) in the Target Cities' (July 2019), **D7.2** 'Generalised Recommendations regarding Passive Control Systems for Improved Air Quality and Climate Change Mitigation' (November 2019), and 'Implementing Green Infrastructure for Air Pollution Abatement: General Recommendations for Management and Plant Species Selection' (Kumar, P., Abhijith, K.V., Barwise, Y., 2019).

All reports are available on the iSCAPE project website: www.iscapeproject.eu

## Other references:

Abhijith, K.V., Kumar, P., Gallagher, J., McNabola, A., Baldauf, R., Pilla, F., Broderick, B., Di Sabatino, S. and Pulvirenti, B., 2017. Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments – A review. Atmospheric Environment 162, 71-86.

Kumar, P., Druckman, A., Gallagher, J., Gatersleben, B., Allison, S., Eisenman, T.S., Hoang, U., Hama, S., Tiwari, A., Sharma, A. and Abhijith, K.V., et al., 2019. The nexus between air pollution, green infrastructure and human health. Environment International 133, 105181.

# Impressum

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## The iSCAPE project

iSCAPE aimed to reduce urban air pollution and the negative impacts of climate change by leveraging sustainable passive control systems, behavioural change initiatives and the Living Lab approach.

For more information: www.iscapeproject.eu.

**iSCAPE partners:**

University College Dublin

University of Bologna

University of Surrey

Finnish Meteorological Institute

Hasselt University

TU Dortmund University

JRC - Joint Research Centre - European Commission - Institute for Environment & Sustainability

Institute for Advanced Architecture of Catalonia - FabLab Barcelona

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Regional Agency for Prevention, Environment and Energy of Emilia-Romagna

European Network of Living Labs

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- **No. 3** **Effectiveness of travel behavioural change interventions**
- **No. 4** **Simulating change in urban air quality and climate conditions**
- **No. 5** **Urban strategies and interventions for planning healthier cities**
- **No. 6** **Improving air quality and climate with green infrastructure**
- **No. 7** **Air quality sensing and real time reporting in cities**
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