PRIFYSGOL ABERYSTWYTH UNIVERSITY

Building greening for urban wellbeing

What to think about when specifying on-building green infrastructure

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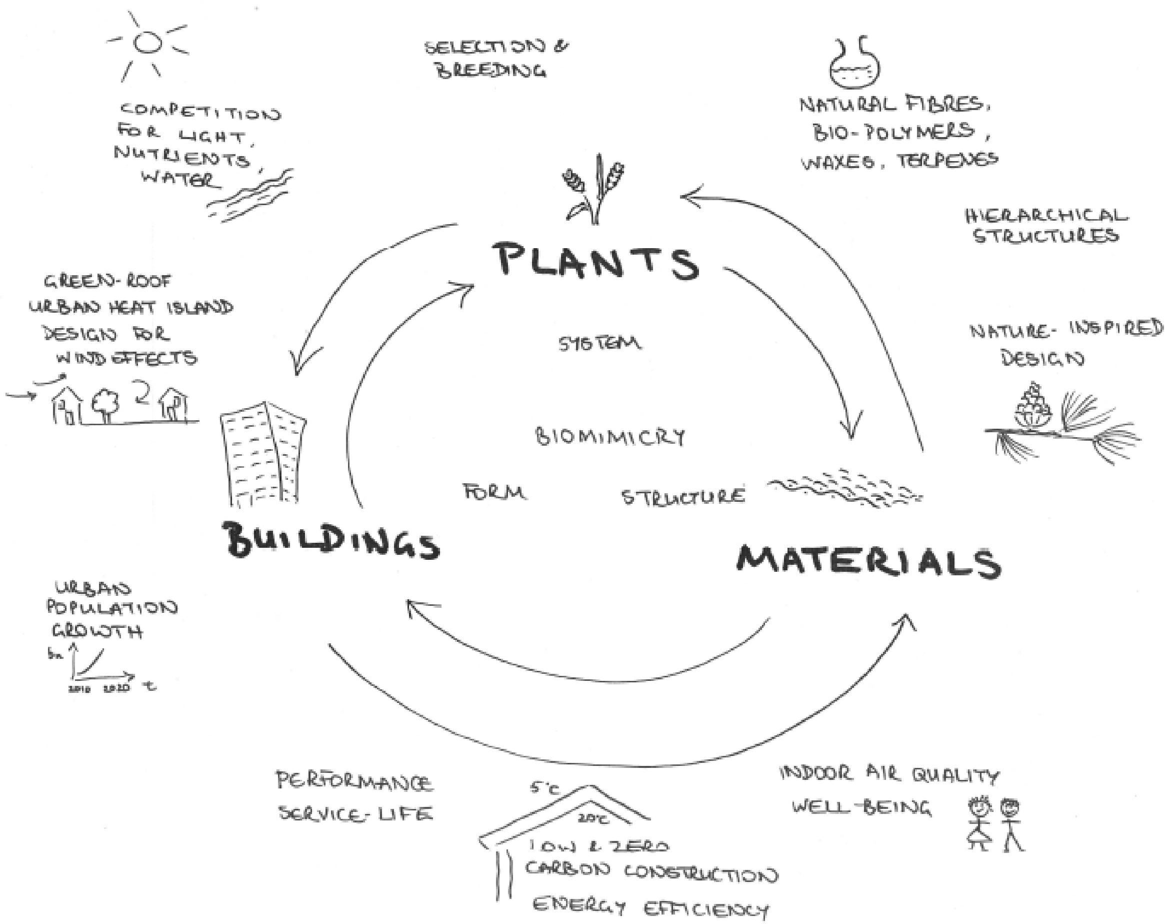

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Global Market

Green roof market worth approx. $7bn

Green wall market approx. $700M

Green roofs in the UK

- Annual growth of 17.1%
- Increase of 17.4% in GR area in LCAZ
- Extensive green roof market baseline worth £26.2M
- London installs 42% of GR currently due to planning policy
- GR being incorporated into more planning policies across other urban regions

The UK Green Roof Market – First Assessment (2017)

- 3.7M m^2 in UK versus 86M m^2 in Germany (2014)
- 80-85% Extensive (Hungary is only nation installing more intensive roofs (65%)
- €28M in UK vs. €245M in Germany

(EFB European Green Roof Market Report, 2015)

- UK Climate change risk assessment evidence report identifies green roofs as an indicator of climate change (Kovats & Osborn, 2016)

- CCC recognises that green roofs can play an important role in climate change mitigation (CCC, 2017)

- Green Infrastructure for Sustainable Urban Living conference suggests that green wall market is also growing, with numerous new companies entering the market in 2016/17
- Suffering from a lack of understanding regarding installation and maintenance
- No UK figures available

Types of green roof

British Horse Society ©Sky Garden Ltd

©Zinco green roofs

MSM Cambridge ©Sky Garden Ltd

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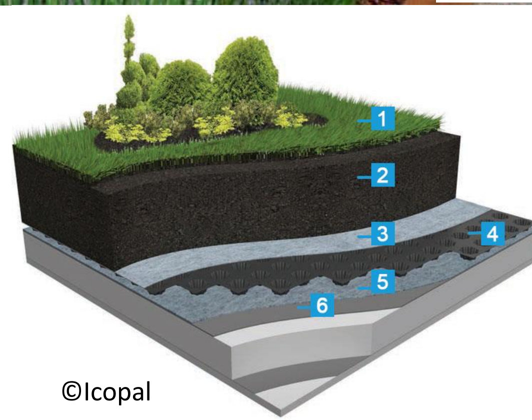

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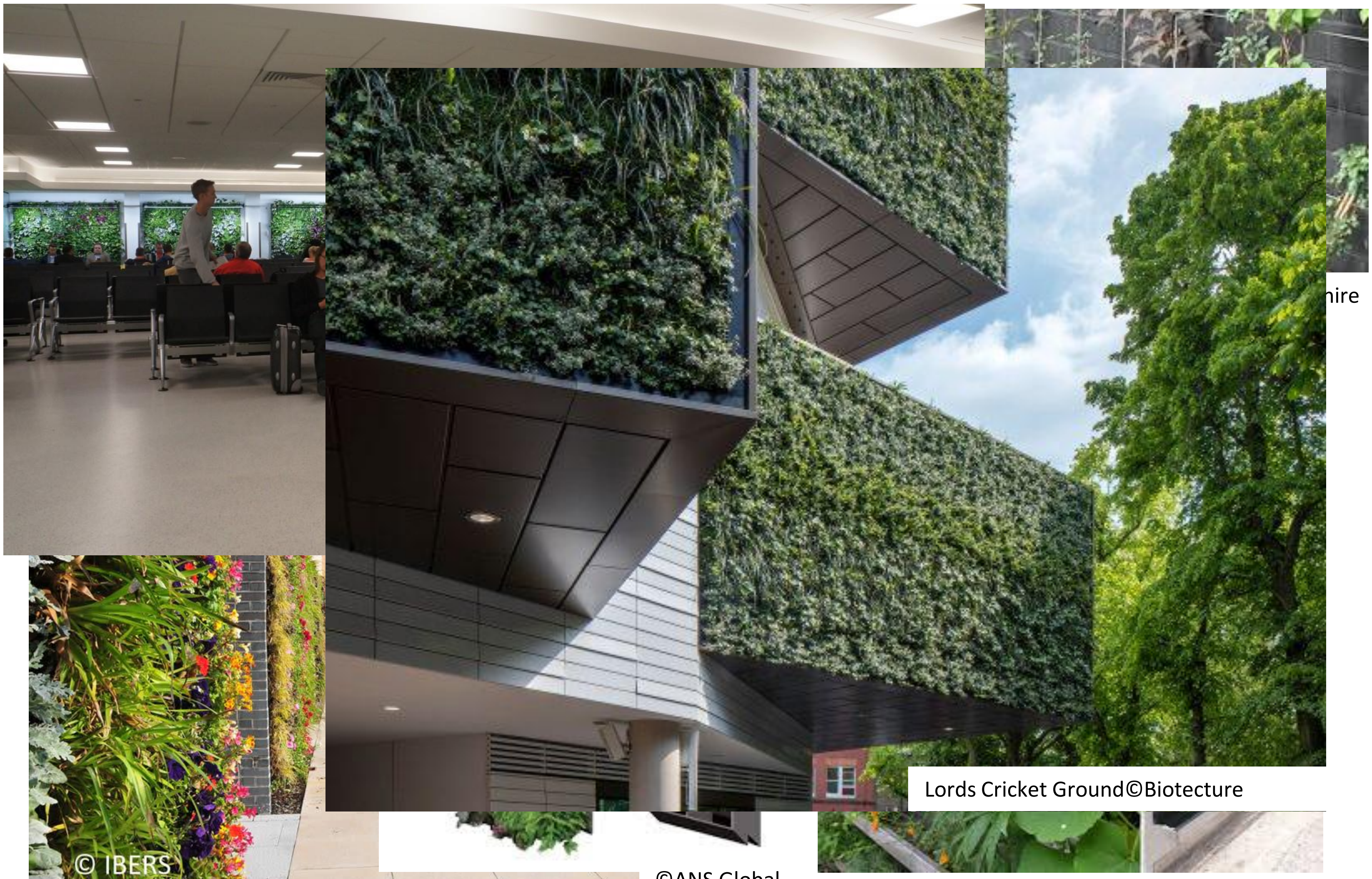
Extensive — Intensive

- ✚ Depth of soil/substrate (and weight)
- ✚ Use by people
- ✚ Diversity of vegetation forms
- ✚ More like a garden and less like a roof

Types of green wall



hire

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Manual

Automated

- Use of hydroponics/drip irrigation/fertigation
- Use of monitoring equipment e.g. sensors
- Integration of additional tech e.g. zeolite filters
- External aftercare/maintenance/remote control
- Diversity of vegetation forms
- Less like a garden, more like a machine

Ultimately, building greening comes down to a fundamental balance

Justify → **Cost vs. Value** ← Maximise

Internalised	Externalised
Weight loading	Environmental enhancement
Installation	Aesthetic quality
Materials	Habitat creation
Maintenance	Sustainability criteria
Consultants	Health and Wellbeing

Does building greening make people healthier?


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Thermal Comfort– Cooling the atmosphere (indoor and outdoor) to reduce the impact of heat waves

Energy Use/ Building thermoregulation – Applying an external layer to regulate internal temperature and energy use

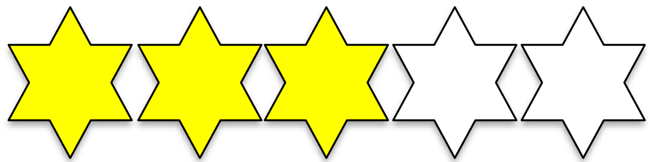
Indoor Environment – Improving air quality, improving hygrothermal conditions, noise

Outdoor Air pollution – Trapping pollutants in canopy or substrate, removal by absorption or engineered solutions

Mental health – Visual stimulation, aesthetic quality and evolutionary preferences

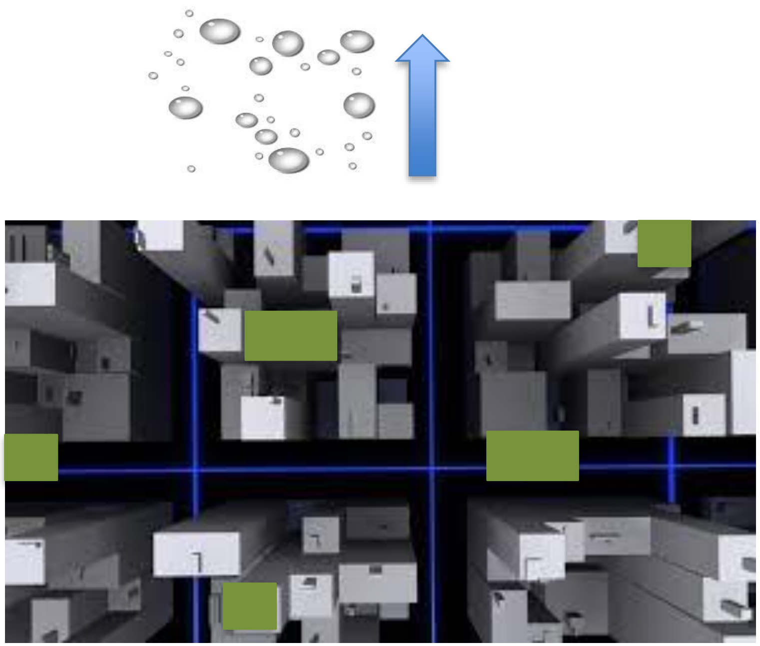
Thermal comfort

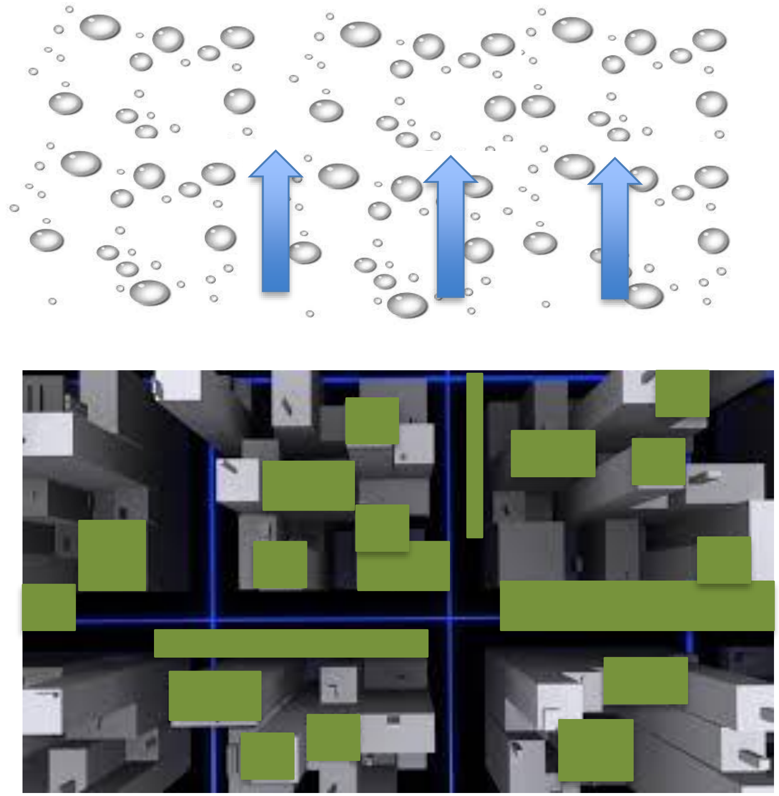
Principle effect: Evapotranspiration (Evaporation +Transpiration) leads to atmospheric cooling.



- \+ Fundamentally determined by the availability of moisture (and wind flow). (Vegetation cover, precipitation, irrigation, humidity)
- \+ Vegetation replaces sensible heating with latent heating and reduces the Bowen ratio
- \+ Urban parks an average of 1°C cooler during day (can be up to 4°C on selected nights) (Bowler et al., 2010)
- \+ Vegetation modifies surface roughness and wind flow altering convective heat exchange

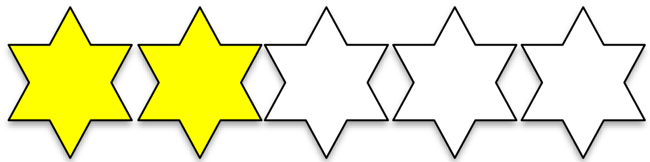
- − Minimum size of $0.05km^2$ ($50,000m^2$ or 5 hectares) to have cooling effect
- − Relevant at town/city scale or for large green spaces
- − Heterogeneity leads to best effects on heat loss
- − Not yet any evidence for network of smaller spaces owing to necessary fetch





Indoor Thermal comfort

Principle effect: Evapotranspiration (Evaporation +Transpiration) leads to atmospheric cooling.

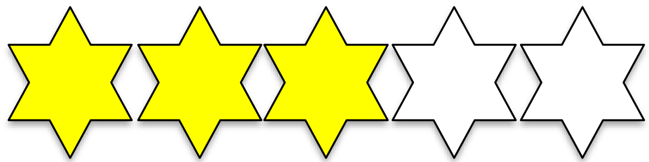


- ✚ Still fundamentally determined by the availability of moisture (and air flow). (Vegetation cover, irrigation, humidity)
- ✚ Active systems incorporating fans have been designed e.g. Naava smart wall
- ✚ Positive effect on thermal comfort in controlled studies throughout a range of seasons and temperatures
- ✚ Depending on amount, can reduce energy consumption

- ▬ Large number of plants required to have cooling effect
- ▬ Highly influenced by building use patterns and local maintenance
- ▬ Needs to be matched to air conditioning/heating regimes which relies on constancy
- ▬ Expensive to install and maintain, even at the level of pot plants for large spaces

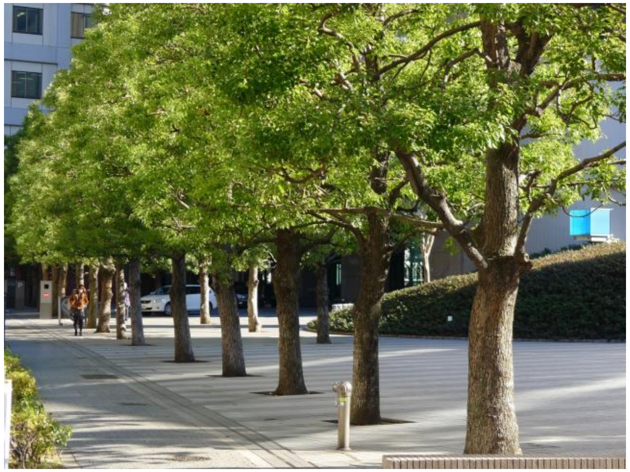
Building Thermoregulation

Principle effect: Insulation / shading provided to building envelope results in more stable internal temperatures



+ Shading potential is considerable, and can be a cost effective mitigation measure (Gupta & Gregg, 2012)
+ Rural vegetation reflects 15-25% of shortwave radiation (Armson et al., 2012)
+ Effectiveness driven by leaf size, crown area and LAI (Santamouris, 2014)
+ Insulation benefits are evident, but negligible relative to other options
+ Plant albedo values higher than grey surfaces creating more stable roof temperature

– Plant selection must be matched to heat gain needs (i.e. vegetation when you want shading/insulation in summer, no vegetation when you want sensible heat gain
– Other highly effective engineered solutions (e.g. better insulation/shading)
– Plants grown on a building have the potential to be invasive for poor masonry
– Cost effectiveness of high maintenance options
– Suitable for certain building orientations and aspects, less relevant for N/W aspect





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0 ←——→ 100

Bitumen
0.03-0.18

Coloured paint
0.15 – 0.35

Grass
0.4 – 0.5

White paint/Cool
0.9

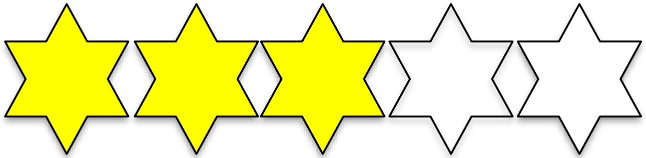
Solar Reflectance

(Solar Reflectance + Thermal Emittance = SRI)

Global effects of cool roofs could be in order of saving 150 Gtn CO_2. Or taking every car off the road for 50 yrs (Akbari et al. 2012). **Large overestimate? – but the point is well made!**

Sound Insulation

Principle effect: Green walls provide a physical noise barrier and/or sound insulation

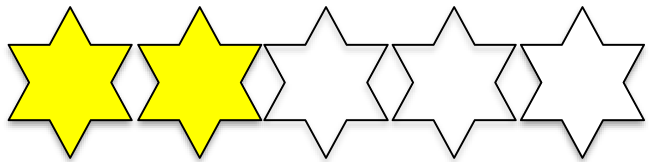


- + Effective at reducing sound reduction index (15db) when used as a physical barrier
- + Sound absorption co-efficient of 0.4 (Azkorra et al., 2015)
- + Can be used to screen significant noise sources e.g. construction sites
- + Provides some acoustic insulation for buildings (Perez et al., 2016)
- + Can be used to provide a source of pleasant sounds e.g. bird song, wind through leaves (Irvine et al., 2009)

- − Dependant on building users and behaviour (i.e. opening a window)
- − More effective in large landscape iterations (e.g. shelterbelt)
- − How much of the effect can be attributed to the actual vegetation?
- − Transience of noise source

Indoor Air Quality

Principle effect: Plants absorb/trap harmful air pollutants and ‘clean’ the air

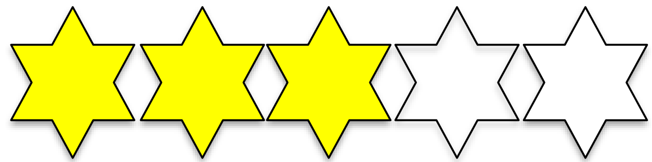


- + Active green walls products available that include either absorbents or a rhizosphere (e.g. Naava, Agrosci Aerogation, Junglefly, (Torpy et al., 2016
- + Some harmful chemicals e.g. Formaldehyde, Benzene, Xylene, Ammonia, Trichloroethylene, some VOCs, Acetone are removed by house plants (Kapoor, 2017)
- + Plants absorb CO_2 during the day
- + Leaves traps PM_{10} / $PM_{2.5}$ to varying degrees based on physiology

- − Dependant on building users and behaviour (i.e. opening a window)
- − Dependant on a large number of plants in the average sized home (10-20 per room?)
- − Plants are a source of VOCs as well as a sink. May increase UFP concentrations.
- − Plants emit CO_2 and consume O_2 at night
- − Studies based on small scale, controlled chamber experiments, not real living scenarios

Outdoor Air Pollution

Principle effect: Principle effect: Greenery acts as either a barrier to, or sink/source of pollutants



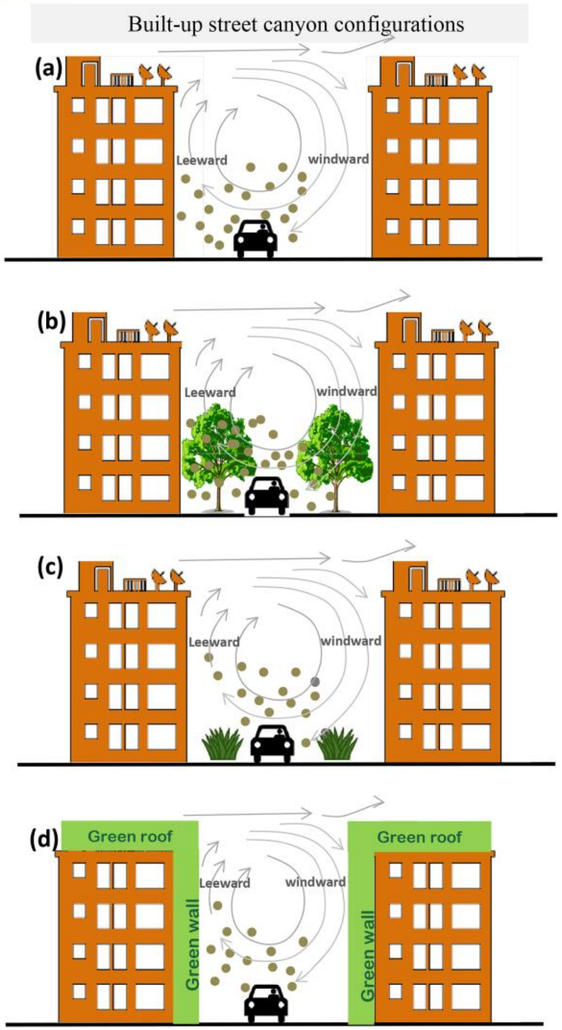
+ Plants trap particulate matter $PM_{2.5}$ and PM_{10} which is harmful to health
+ E.g. Tree cover of West Midlands estimated to reduce PM_{10} by 4% (McDonald et al., 2007)
+ Related to canopy density and leaf traits e.g. waxiness, hairiness etc.
+ Plants can absorb some pollutants e.g. NOx, SO_2, substrate can be a sink for heavy metal deposition and pollutants, and is preferable to surface dust for water quality
+ Substrate can neutralise localised acid rain
+ Effective as a physical barrier for people on foot

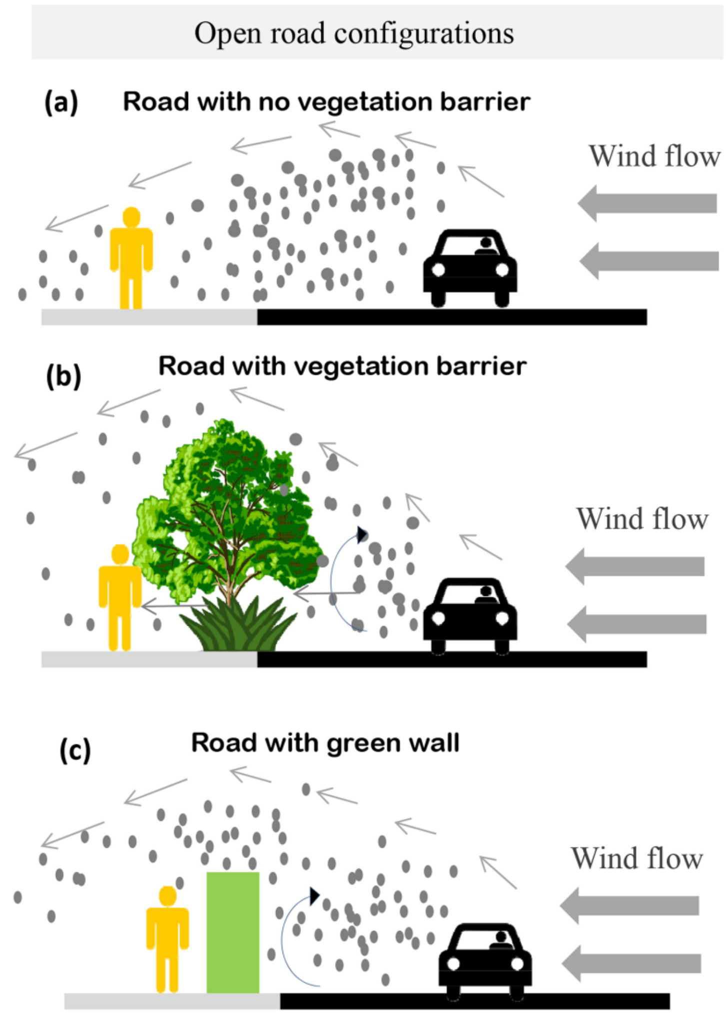
– Depending on atmospheric deposition rates, green roofs can become a source of pollution in the longer term, particularly metals e.g. Pb, Cr, Cd, Cu and Zn.

– Fertilisation will create a source of water contamination for N, P & K

– Highly dependant on soil depth, type, age, and weather conditions (e.g. wind direction)

– Dependant on urban geometry

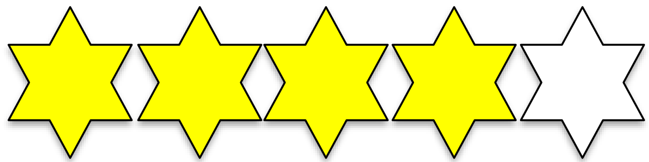




Reproduced from Abhijith et al., 2017

Mental Wellbeing

Principle effect: Visual/aesthetic qualities of transforming grey-green has positive psychological effects



+ Link between wellbeing a green space exists (e.g. Takano et al., 2002, deVries et al., 2003)
+ Well managed greenery increases sense of community attachment (e.g. Kuo et al., 1998)
+ Viewing greenery ameliorates attention fatigue and stress (Ulrich et al., 1983, 1991)
+ Natural superior to urban for attention function and emotional state (Hartig et al., 2003)
+ Effects have been replicated in hospital patients, school children, office workers etc.
+ Trichromatic vision provides evolutionary advantage, green central wavelength (biophilia)

- No direct evidence of biophilia (or biophobia) hypotheses, but strong logical reasoning
- Benefits may be highly subjective and individualised
- May impact small number of people depending on site
- Highly depending on perceived aesthetic quality – i.e hydroponic green wall vs. wildflower green roof – may affect urban style/aesthetic

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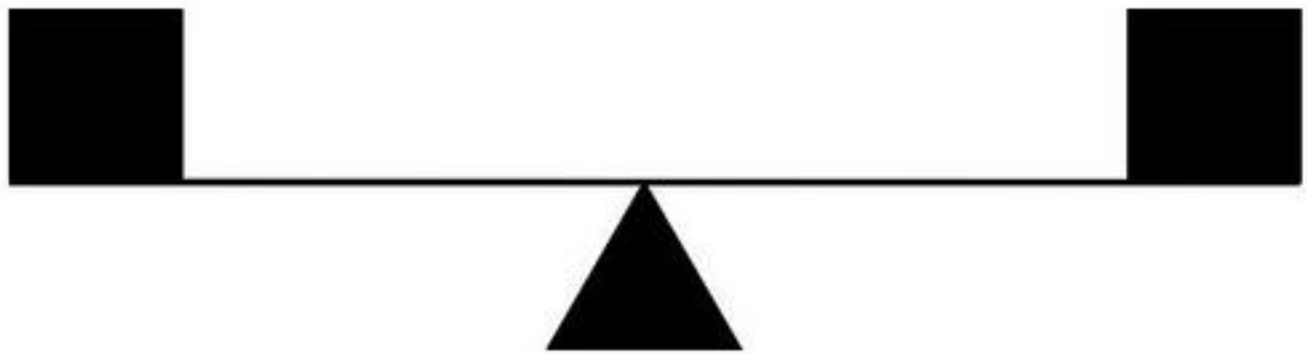
Take home messages

- Local conditions (rainfall, wind, temperature, pollution levels etc.) – What problems are you trying to solve?
- Realistic benefits of the intended system (not all green roofs/walls are created equal, nor should they be) – Can you solve those problems in a meaningful way?
- Maintenance is **ALWAYS** part of the deal – it's a garden on a roof – Who will take care of it?
- Appropriate plants for the desired benefits, think about seasonality, density, diversity and care needs.
- Where is it? – Orientation, aspect, proximity to human activities and visibility are crucial to achieving success.
- Don't believe the hype - multiple benefits are not guaranteed – What are the benefits that are important?



Thank you.

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