Green roofs

Green roofs (or vegetated roofs) are increasingly adopted for aesthetic purposes but also in the context of urban flood or heat wave reduction. They aim at compensating lost natural spaces due to soil sealing and are generally divided into two types: intensive and extensive green roofs.

Intensive green roofs have a deeper layer of substrates (up to 200 mm). This thick layer allows to plant different types from plants to shrubs or even trees. Intensive green roofs can become gardens or parks on the roof tops. Overall, this type may enable more diversity on roofs but also entail maintenance and heavy weight loads for the roof.

Extensive green roofs are more common as they are of a thinner layer of substrates (max. 150 mm) with low growing drought tolerant vegetation (e.g., succulents, mosses, perennials, and fobs). They require less maintenance and naturally are of lighter weight.

To enhance biodiversity, roofs can be designed with different local plant species, varying thicknesses of the substrate, or other structural elements such as trunks. Moreover, it should be aimed to connect the roofs with ground-level vegetation. Green roofs may also be combined with solar panels.

Overview

Type Hybrid

Approach Implementation

Hazard They can be implemented to reduce the risk on **Urban Flooding.**

Multi-hazard Their ability of reducing surface runoff can also prevent water from entering rivers or lakes which can attenuate **Fluvial Flooding**. Furthermore, the shading of the plants as well as their evaporation can mitigate **Heat waves**.

SDGs

Direct Benefits

Water harvesting

One of the main characteristics of green roofs is their rainwater harvesting ability. They can harvest up to 99 % of rainfall. In particular, their water retention capacity (l/m^2) can be calculated based on the substrate layer thickness (mm) and plant species/coverage (Catalano *et al.* (2018)):

Level 1: 80-100 mm; 40-50 l/m^2

Level 2: 100-120 mm; 50-60 l/m^2

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Level 3: 120-150 mm; 60-75 l/m^2

Level 4: 150-200 mm; 75-100 l/m^2

Level 5: 200-500 mm; 100-250 l/m^2

Level 6: >500 mm; >250 l/m^2

Co-benefits/ Disbenefits

Biodiversity

The popularity of green roofs is further ascribed to the idea that they are enhancing biodiversity as they are creating habitats for, for instance, insects. However, they need to be perfectly planned to enhance biodiversity as monocultures do not support a great diversity. To enhance biodiversity, green roofs can contain different substrate types, structural elements (e.g., branch piles, root trunks, sand, gravel, boulders), or areas for temporary ponds. Generally, they should mirror local habitats – meaning that local species should be used and structural elements typical for the area.

Temperature regulation

Green roofs can decrease temperatures through shading, evaporation, and transpiration.

Energy savings

Green roofs not only have a regulating effect on outdoor temperatures but also a cooling effect on indoor temperatures by up to 3.0°C in summers.

Air Quality

Air pollutants such as PM10 and NO2 can agglomerate on plant leaves and, therefore, have a positive effect on local air quality.

Ecosystem Disservices

With increased biodiversity, also unwanted species may reside on the buildings such as spiders or insects.

Economy

Construction costs of green roofs can be higher than of traditional roofs. However, in a long-term perspective, green roofs are found to be less costly.

They can be further combined with solar cell panels (photovoltaic panels) which can provide shade for some plants. It is recommended to grow low vegetation in front of the panel and higher growing plants behind and underneath to reduce maintenance.

Well-being

Intensive green roofs can be designed as gardens creating recreational spaces for homeowners, employees, or customers.

Property Prices

Green roofs are often increasing the attractiveness of houses. For instance, in Germany rental income was reported to be increased by 6-8%.

Carbon storage

The planted vegetation can sequester and store carbon. Nonetheless, the capacity depends on the vegetation type e.g., mosses were reported to absorb around 2.2 kg/m^2 CO2 per year.

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Costs	Costs of green roofs encompass: • Roof sealing costs which vary greatly between 3-21 €/m^2. • Costs of the green roof itself depend on the type of vegetation planted. The costs are estimated around 40-45 €/m^2. • Maintenance costs can be applicable. Depending on the vegetation type, they can be around 0.6 €/m^2 per year. However, it is mentioned that renovation costs (for conventional roofs), coming up around every 40-50 years, are not applicable.

NBS Related Policies	• EU Green Deal
	• EU Biodiversity Strategy for 2030
	• EU Green Infrastructure Strategy
	• National Standards & Norms:
	  ○ Austria: ÖNORM L 1131:2010 06 01
	  ○ Italy: UNI 11235:2015
	  ○ Malta: SM 3700:2017
	  ○ Netherlands: NTA 8292:2016
	  ○ Norway: NS 3840:2015
	  ○ Switzerland: SIA 312-SN 564312:2013

Funding Options	• European Green Deal • Life + • (Sub-)national funding schemes

Design Implementation

Scale	Microscale/single/scattered/local (1 m - 1 km)
Roof Type	Suitable for roofs with inclinations between 0-35° for extensive green roofs and for intensive green roofs only 0-5°. A minimum of 2° is recommended to avoid the implementation of additional water drainage systems.
Layers	Green roofs consist of different layers from bottom to top: • a vapor barrier and thermic insulation layer, • a waterproofing and root resistant membrane, • a drainage layer covered by a filter membrane, • and finally, on top the vegetation layer.
Plants	Generally, it is recommended to plant drought tolerant species to minimise irrigation but also to use local species, especially, species that may have been located on the site before the construction of the house. Overall, plants should be chosen based on the vegetation needs considering slope, sun exposure, and (micro-)climatic conditions. Suitable plants for extensive green roofs are mosses, sedum, and small shrubs. They can be combined with bricks and stone slabs, synthetic and organic fibre mats, or substrates up to 5 cm. Recommended plants for intensive green roofs with substrate fill up to 15 cm are lawn, perennials, and woody plants. For substrates in containers: perennials, woody plants, and mosses.

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Cautions	Consider building regulations and local fire regulations but also restrictions for wind (e.g., max 140 mph). Include a protective strip on the sides (between vegetation and roof structure).
Combination with other NSB	Green roofs may be combined with other rainwater harvesting measures to increase the reduction of flood risk.

NBS Suitability Mapping

(Below are the layers and specifications listed that were used for analysing the suitability of this Nature-based Solution for your area)

Buildings	Buildings [ESM, Corbane and Sabo, 2019]
Land Cover	Medium and high-density urban fabric, industrial areas [LUISA Base Map 2018, Batista and Pigaiani, 2021]
Imperviousness	> 50% [Imperviousness Density 2018, Copernicus Land Monitoring Service]

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References

Batista, F., Pigaiani, C. (2021) 'LUISA Base Map 2018. European Commission, Joint Research Centre (JRC)' [Dataset] PID: http://data.europa.eu/89h/51858b51-8f27-4006-bf82-53eba35a142c.

Catalano, C. *et al.* (2018) 'Some European green roof norms and guidelines through the lens of biodiversity: Do ecoregions and plant traits also matter?', *Ecological Engineering*, 115, pp. 15–26. doi: 10.1016/j.ecoleng.2018.01.006.

Connop, S. *et al.* (2013) *TURAS green roof design guidelines: Maximising ecosystem service provision through regional design for biodiversity*. London. Available at: https://repository.uel.ac.uk/download/732c7a85845dc994707938dbe16e7cf218a450a3f22c47f49f6ea356bf4aa7c9/4798249/Green_roof_design_final.pdf.

Copersnicus Land Monitoring Service (2018) 'Imperviousness Density 2018' [Dataset]. Available at: https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/status-maps/imperviousness-density-2018.

Corbane, Christina; Sabo, Filip (2019) 'European Settlement Map from Copernicus Very High Resolution data for reference year 2015', Public Release 2019. European Commission, Joint Research Centre (JRC) [Dataset] doi: 10.2905/8BD2B792-CC33-4C11-AFD1-B8DD60B44F3B PID: http://data.europa.eu/89h/8bd2b792-cc33-4c11-afd1-b8dd60b44f3b.

Dvorak, B. (2011) 'Comparative Analysis of Green Roof Guidelines and Standards In Europe and North America', *Journal of Green Building*, 6(2), pp. 170–191. doi: 10.3992/jgb.6.2.170.

FLL (2008) 'Richtlinie für die Planung, Ausführung und Pflege von Dachbegrünungen–Dachbegrünungsrichtlinie'. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau E.V. Bonn. Available at: https://shop.fll.de/de/dachbegruenungsrichtlinien-richtlinien-fuer-die-planung-bau-und-instandhaltungen-von-dachbegruenungen-2018-broschuere.html.

ISPRA (2012) 'Verde Pensile: prestazioni di sistema e valore ecologico. Manuali e Linee Guida 78.3/2012'. Istituto Superiore per la Protezione e la Ricerca Ambientale. Available at: https://www.isprambiente.gov.it/files/pubblicazioni/manuali-lineeguida/mlg-78.3-2012-verde-pensile.pdf.

Marvuglia, A., Koppelaar, R. and Rugani, B. (2020) 'The effect of green roofs on the reduction of mortality due to heatwaves: Results from the application of a spatial microsimulation model to four European cities', *Ecological Modelling*, 438, p. 109351. doi: 10.1016/j.ecolmodel.2020.109351.

NWRM (2015) 'Natural Water Retention Measures'. Available at: http://nwrm.eu.

Pfoser, N. and Dierks, F. (2019) *Green Roofs: Guidelines for Planning, Free and Hanseatic City of Hamburg*. Hamburg. Available at: https://www.hamburg.de/contentblob/13067550/723b4ee07403a9e706151892ac347c9f/data/d-guidelines.pdf.

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