

ON YOUR ROOF — GET SET — GREEN!

GREEN ROOF STRATEGY FOR HAMBURG

GREEN ROOFS

GUIDELINES FOR PLANNING

www.hamburg.de/gruendach
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Hamburg

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Vision: Green roofs for Hamburg



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GREEN ROOF STRATEGY FOR HAMBURG

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Preface

Hamburg not only wants to build more apartments in the urbanisation zone, but also to develop the "city in new places". In order to ensure residential and living quality in the long term, this process must by all means be accompanied by the development of new open spaces of high quality for recreation and the support of urban flora and fauna. At the same time, the effects of climate change (heat and heavy rainfall events, storms, increased risk of flooding) call for increased retention of rainwater and controlled discharge into the sewer system. While increasing urban densification stands in the way of the overdue unsealing of ground surfaces, shallow-pitched roofs will in the future assume a key role in creating new inner-city green spaces.
With its focus on knowledge, planning and action, this brochure substantiates and supports the City of Hamburg's green roof strategy in the realms of financial incentive, dialogue, regulation and science. The brochure offers assistance with questions about green roofs and offers supporting argumentation regarding binding urban land-use planning and building permit procedures. It is intended for actors in administrative agencies, but also for architects and property developers such as housing cooperatives and investors. It concerns the roof areas of buildings and parts of buildings as well as open outdoor spaces above subterranean structures in development zones in accord with the Federal Land Utilisation Ordinance (BauNVO).



STARTING POINT AND OPPORTUNITIES

Knowledge

High-quality built environments create spaces for living and working, and for education, art and commerce – thereby enriching urban life and the cityscape. On the loss side, construction brings about a reduction in the ecological performance of the built-upon ground, such as water absorption, evaporative cooling, plants with their oxygen production, CO2 reduction and particulate binding. Buildings generate climate burdens that impact the entire city: flat roof materials are exposed to the sun – they age prematurely due to ultraviolet radiation and rapid temperature changes. Their heat storage fosters stable heat islands and hinders urban night-time cooling ("heat island effect"). Sustainable ecological contributions to the urban climate and rainwater retention are lacking. Green roofs take the opposite approach: Green roofs have high potential for improving the surroundings. They promise a wide variety of benefits for the city. Chief among them are urban development and open space planning qualities, water management arguments, contributions to climate protection and aspects of nature conservation. At the same time, real estate owners stand to benefit directly from possibilities for building optimisation, such as material protection / material economy, the reduction of energy needs and appreciation in the value of their property.

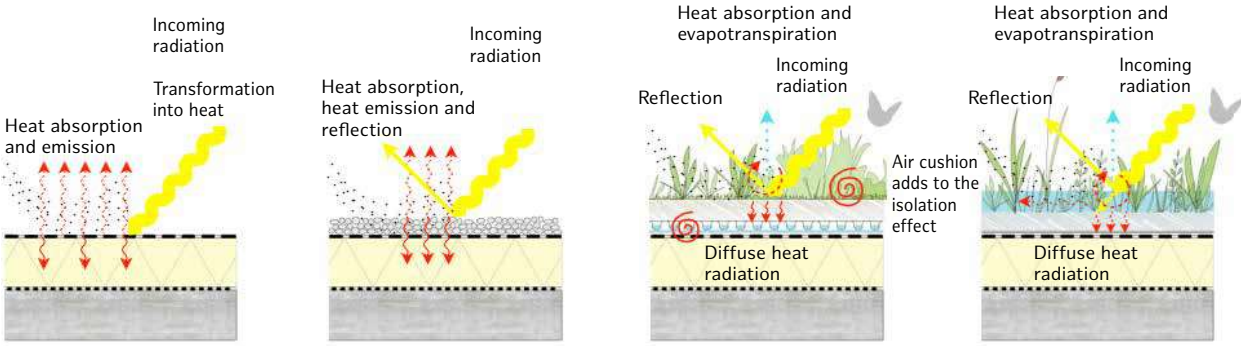
On this complex of related themes, the chapter "Knowledge" spells out performance factors in detail, presents cost comparisons and illustrates opportunities for improving and upgrading our private and urban surroundings.



■ BENEFITS FOR CITIZENS

Improved surroundings

Green roofs enrich the visual urban experience from varied perspectives. Especially in the urban mix of high-rise buildings and lower properties, the dismal view out over a multitude of utilitarian flat roofs is fundamentally improved by rooftop greening. The living and working environment is enhanced visually, climatically, acoustically and thus also socially. Day-care centres and schools can bring to fruition urgently needed playgrounds and sports areas without additional land consumption and without traffic hazards. Covered underground parking levels enrich the cityscape and everyday life as tree-covered neighbourhood squares. Thus green islands can even be created in highly dense areas. As an attractive crowning element, even a high-lying green roof enhances the address and its surroundings. Utilitarian roof areas are transformed into natural gardens of encounter and recreation. The additional urban greenery is accompanied by climatic benefits, such as cooling via shading and evaporation, air purification via the adsorption and washing out of fine particulates, oxygenation of the air, and carbon fixation by the plants via photosynthesis. The city as a whole benefits from the rainfall absorption of green roofs, their evaporation capacity and the delayed, reduced discharge of excess water into the sewers. Greening measures for buildings prepare the way for the return of urban fauna. With new food sources and living spaces, they fulfil a "stepping-stone function" between the natural areas located in and around the city. The individual criteria are shown in the adjoining table.



Influence of green roofs on the microclimate. Improvement of the microclimate via rooftop greening.

Performance factors for improved surroundings **Note: The numbers in brackets [...] refer to the literature, scientific studies and expert reports on which the text is based. The list of references is found on page 43.**	
Urban development and open space planning grounds	
Upgrading of buildings and open space	• Improvement of the residential environment (enhancement of the address, greater attractiveness, corporate identity, psychological/medical/social benefits) [see 29; 36]
Design diversity	• Visual and space-defining possibilities of use [24] • Diversity of greening forms, wide selection of plants with varied surface appearances, colours of foliage, flowers, and possibly fruits, foliage and flowering phases [24]
Amenability	• Design diversity / natural element in the urban environment, decrease of urban heat build-up / cooling effect, privacy screening and wind protection, noise reduction, improvement of the air quality [24]
Noise reduction	• Reduction of environmental noise by up to 6 dB(A) via sound absorption and sound diffusion from rooftop greening, depending on frequency (Hz), traffic speed, green roof assembly, foliage condition, substrate moisture, layer height, roof pitch and orientation [6; 19; 21; 35; 37]
Water management aspects	
Stormwater retention	• Water retention capacity up to 99% (dependent on substrate composition and substrate thickness / water accumulation height) [24, p. 152]. Commensurate relief for the municipal sewer system. • Reduces discharge peaks: Runoff coefficient **(Cs)** as per DIN 1986-100 (issued 12/2016): intensive greening = **0.1** assembly thickness > 50 cm; **0.2** > 25 cm; **0.3** > 15 cm / extensive greening = **0.4** assembly thickness > 10 cm; **0.5** < 10 cm (for comparison: gravel fills = **0.8** / waterproofing sheet = **1.0**)
Regulates urban precipitation	• Reduces weather extremes (heavy rainfall events and droughts) through local rainwater retention and evaporation [24, pp. 151–153; 31]
Contribution to climate protection and climate adaptation	
Ambient cooling	• Reduces the local air temperature (compared to non-green roofs) of up to 17 °C (extensive) and 18.5 °C (intensive) and of the local air temperature by 1.7 °C [24, pp. 178–179], depending on building height, initial humidity and meteorological conditions. • Cooling via evaporation and shading (influences the microclimate): 20–40 % transpiration, 40–80 % reflection and absorption of solar radiation [24, p. 112]
Evaporation capacity	• Evaporation of 200 l/m² in a growing season (planters as rooftop garden greening) [1]. Evaporation of 62–67 % of the annual precipitation [12].
Reduces of air pollution	carbon storage, oxygen production, particulate binding and metabolisation of air pollutants • Improvement of the air quality within a street canyon (PM10 concentration / NO2 concentration) [26] • A green roof is deemed a carbon sink (–83 g C m-2 year-1) [32] • Dust and fine particulates “clump up” (agglomerate) on the leaves to form “non-respirable” particles. These are then removed together with the foliage when the leaves fall later in the year. [23; 34]. • Mosses absorb about 2.2 kg/m² CO2 per year (equivalent to the CO2 efficiency of intensive grassland) [11]
Nature conservation aspects	
Contribution to urban greenery	• Hamburg has set itself the goal of greening a total roof area of 1,000,000 m² (in the decade from 2014 to 2024) [13] – additional usable urban area with ecological value
Minimisation of intrusion	• Green roofs as compensation for urban soil sealing
“Stepping stones”/ biotope network	• Links expanded and improved food sources and living spaces for animals with the natural areas close to the city [4; 15; 39]
Biodiversity	• Dependent on the varied degree of coverage and variety of vegetation as well as the resulting individual quantity and density of fauna, greening form, location / urban situation, size of the area, place of refuge (soil, water, wind, temperature and nutrient conditions) and age of the habitat (maturation period) [22; 39]



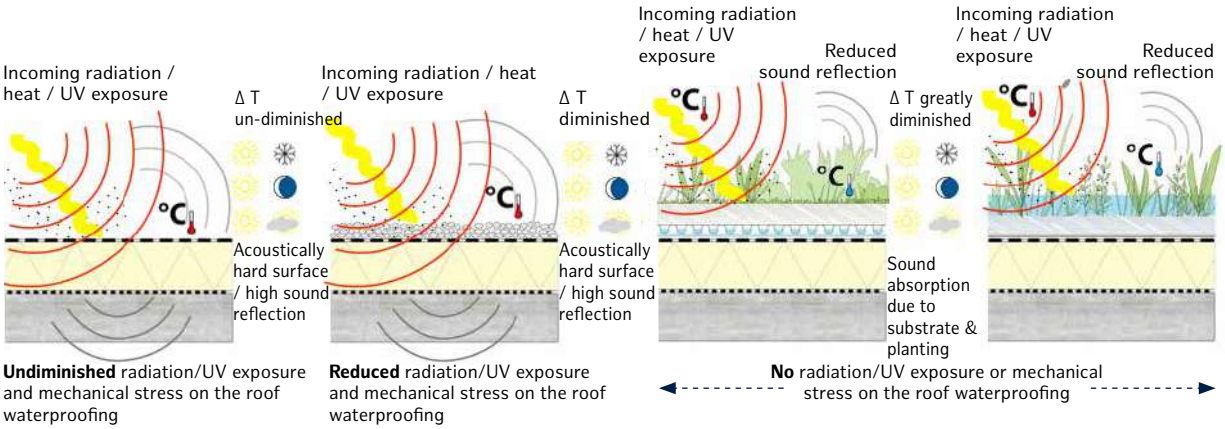
ADVANTAGES FOR THE OWNER

Building optimisation

In addition to the function, design and appropriateness of costs, significant factors include the values of resource consumption for production, operation and removal. The contribution to climate protection becomes an important target value and a benchmark for the efficiency of the means employed. With clearly positive climatic effects and high utility value, greening measures for buildings have firmly established their place in the process of making design and planning decisions.

The contribution made by building greening to a responsible-minded approach to energy – through passive regulation of the cooling and heating of the building envelope, for example, or seasonal control of active solar heat recovery or the performance optimisation of photovoltaics through the use of natural ambient cooling – opens up a wide range of applications. Chemical effects, rapid temperature changes, mechanical stresses and ultraviolet radiation are the sources of aging in roofing materials, causing them to become brittle and ultimately fail. Protection against all these adverse effects and against the heavy hailstorms that are becoming increasingly frequent is provided by an expertly designed and executed green roof assembly. It buffers the temperature difference at the roof waterproofing at all times of year, thus reducing heating and cooling loads accordingly. Green roofs compensate for visual deficits, create acceptance and also contribute to reducing noise, improving air quality and deterring excessive heat. Direct access to a roof garden is a sought-after quality and unique selling point of high value for inner-city commercial and residential areas. With an appropriate intensity of greenery, the many possibilities range from relaxation gardens and playgrounds to the cultivation of ornamental and useful plants.

Data for building optimisation by means of rooftop greening are given in the adjoining table.



Increased service life of the roof waterproofing due to reduced solar radiation / UV exposure plus hail protection. Cooling capacity, heat retention, noise reduction, particulate binding

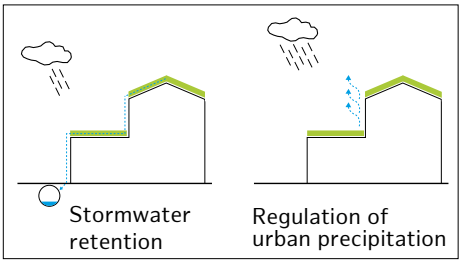
Performance factors for building optimisation **Note: The numbers in brackets [...] refer to the literature, scientific studies and expert reports on which the text is based. The list of references is found on page 43.**	
Material protection and economy	
Pollutants / contaminants	• Green roofs protect the surface of the roof waterproofing from thermal stresses resulting from concentrated dust deposits and from chemical stresses [3; 24]
Effects of weather	• Protection of the roof waterproofing against temperature extremes and against storm and hail damage [34]
Prolongation of service life	• In addition to reducing temperature fluctuations caused by solar radiation and material properties, the ageing of materials from UV radiation is reduced and the roof cladding is thus protected. It can be assumed that the material service life will be prolonged by 10–20 years [8; 14].
Reduces energy demand / improves performance	
Cooling capacity	• Cooling via evapotranspiration and shading at green roofs with an ambient temperature of approx. 30 °C [7; 28]. Increased effect with irrigation. • Reduced summer heat build-up as a result of rooftop greening (temperature amplitude of bitumen roof: 50 °C / green roof: 10 °C) [33]. Extensive green roofs (10–15 cm substrate thickness) decrease the heat transfer by 30–60 % compared to a gravel roof [17]. • In the summer months, conversion of 58 % of the radiation balance into evaporative cooling by means of extensive green roofs (vs. 5 % for non-green roofs) [31, pp. 481–487; 33, p. 16]. • Performance improvement of 4–5 % for roof-mounted photovoltaic systems with module cooling (PV/green roof vs. PV/bitumen roof) [38]. • Energy cost savings by means of process cooling (water-filled roof) [24, pp. 130–131]
Heat retention	• Extensive green roofs (10–15 cm thickness) increase the insulating performance of the roof assembly in winter by 3–10 % (compared to gravel-covered roof assembly)[17; 28]. Insulating effect dependent on vegetation thickness and density, substrate layer, moisture penetration [28] and insulation standard [16]. • Additional thermal resistance (R) of 0.14 to 0.40 m²K/W (substrate height 10 cm, saturated with water). Equivalent: approx. 6–16 mm of conventional insulation of the heat conductivity group (WLG) 040. [17] • High buffering factor: Measurements of heat transfer (W/m²) of extensive/intensive green roofs compared to roofs covered with gravel, bitumen or sheet metal panels [28]
Appreciation in value	
Expansion of usable space	• Additional green spaces for private, shared or public activities: such as recreation, play and exercise, cultivation of fruits and vegetables • Increase in the property value due to heightened environmental quality / gain in rentable s pace [3, p. 18]
Noise reduction	• Reduces noise passage by 5–46 dB(A) via sound absorption and sound diffusion by the rooftop greening, dependent on frequency (Hz), substrate moisture, layer height, green roof assembly, foliage condition, roof pitch and orientation [6; 19; 21; 24; 35; 37]
Acceptance/demand	• High demand-driven interest due to environmental quality / range of open spaces despite urban density [3, p. 18]
Corporate Identity	• Unique selling proposition, building identity/confidence with natural elements, address enhancement, media effectiveness / long-distance impact

SUMMARY OF THE ARGUMENTS

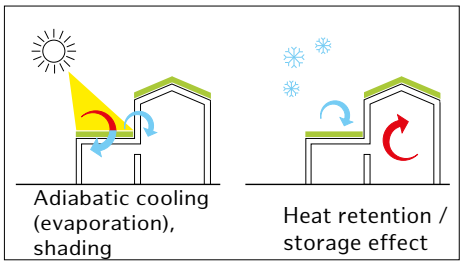
The graphics to the right summarise the substantial potential for green roofs and illustrate their supporting effect in relation to the key needs of buildings and our urban surroundings. Measures are presented and savings and profit systems are examined in terms of their ability to respond to specific needs. Water management aspects concern both the retention of rainwater within the green roof assembly through delayed, reduced discharge to the sewers and the influence that the amount of evaporation from the green roofs has on the formation of new precipitation. Compensation of the ambient temperature in summer by means of evaporative cooling, which results in reduced storm damage and fewer urban heat islands, is a positive accompanying effect and aids in adapting to climate change.

Grounds pertaining to urban design and open space planning are met with increased acceptance due to the design quality and possess improved amenity values. An additional effect is a reduction of noise pollution thanks to the sound absorption of the greenery. An essential aspect benefitting nature conservation is the newly created habitat for flora and fauna. The primary potentials of building greening reside in building cooling and component protection. The greening of buildings markedly assists in meeting the demands for heat, cooling, fresh air, light, water, electricity and material economy. Together with the performance potentials and possible solutions, integrating building greening into the planning processes of future construction projects clearly has exceptional importance; it must be done in a timely manner and in a more interdisciplinary way. In individual cases it is necessary to verify whether buildings are within an area governed by social preservation regulations, are recognised or otherwise listed as historical monuments, or subject to other urban design requirements.

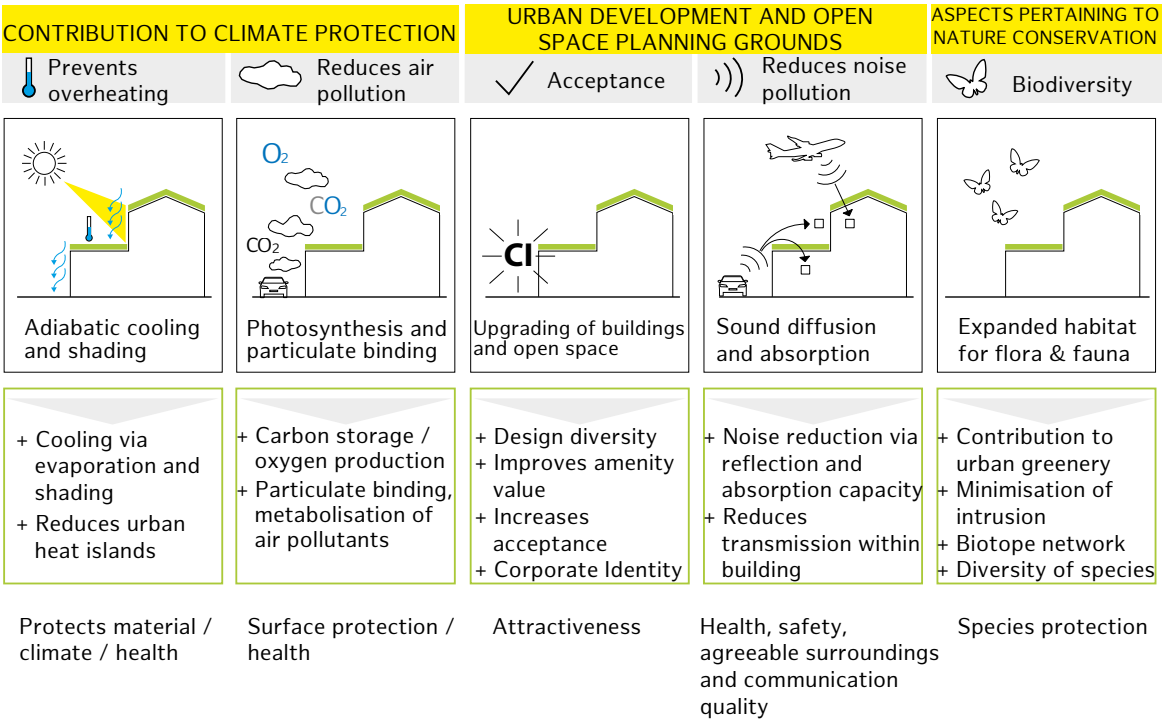
IMPROVED SURROUNDINGS

NEED	WATER MANAGEMENT ASPECTS Water management
MEASURE	 Stormwater retention Regulation of urban precipitation
IMPACT OF GREEN ROOFS	+ Water retained by reducing the runoff coefficient + Prevents overflooding of the sewer system + Reduces sealed surfaces + Increases the evaporation rate + Ambient cooling
SAVINGS / GAINS	Reduced storm water fee Fewer heavy rainfall events / less storm and hail damage, sewer relief

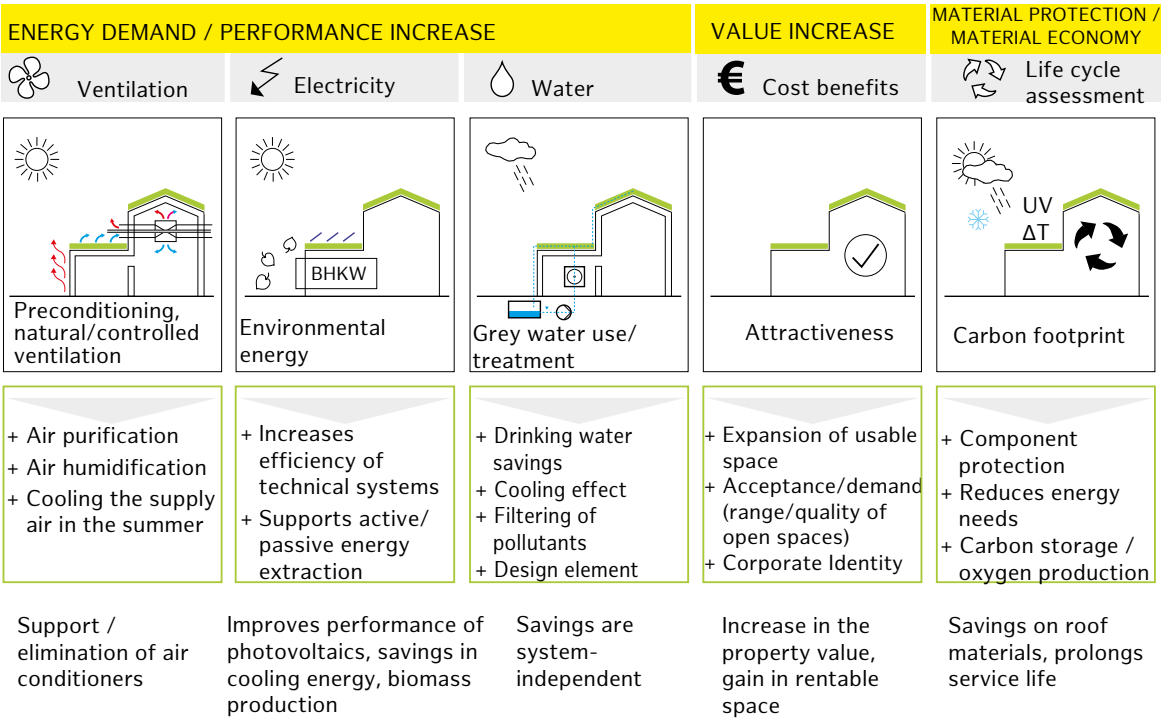
BUILDING OPTIMISATION

NEED	REDUCTION °C Temperature
MEASURE	 Adiabatic cooling (evaporation), shading Heat retention / storage effect
IMPACT OF GREEN ROOFS	+ Heat build-up at roof / in interior space is prevented through shading / evaporation performance of the plants + Reduces heat losses from the building envelope + Less wind load + Less humidity
SAVINGS / GAINS	Savings in cooling costs Reduces heat transfer

Measures for improving the surroundings in an urban context. Depiction of the impacts and savings/gains attained with green roofs [24, p. 161].



Measures for building optimisation – Depiction of the impacts and savings attained with green roofs [24, pp. 146–147]



COST COMPARISON

Green roofs offer cost/benefit advantages for the city and for the owner of the greened building. These are mainly based on ecological benefits, protective effects for the building envelope and greater amenity value.

An economic life cycle assessment is effective for evaluating the resource utilisation of a greening project. The life cycle phases of relevance here include the planning phase, manufacturing phase (choice of materials, production, transport), construction phase (delivery, site facilities, assembly), utilisation phase (costs for operation, care and maintenance), and renewal phase (partial renewal, total renewal, possibly alteration) as well as the removal and disposal phase (continued use, recycling, energy recovery, landfill). [20]

In the analysis of nine green roofs in the Hanseatic city (see graphic on p. 13), their investment and maintenance costs were surveyed and their economic benefits and impact are demonstrated. The results of the study show: The larger a green roof is, the lower the green roof costs are per square metre of roof area. [3, p. 14] The investment in green roofs is all the more worthwhile the earlier and more consistently the topic is introduced into the planning. The overall average for the costs of creating a (green) roof amount to about 1.3% of a building's total construction costs. For multi-storey residential buildings, this share of the costs can be as little as 0.4% of the total construction costs, which shows the positive influence that multi-storey construction has on the average green roof costs per unit of useable area. In terms of life-cycle costs, black roofs and green roofs cost about the same over a period of 40 years. [3, p. 5]

The construction costs of extensive green roofs – apportioned to the respective vegetation area – range from 40 to 45 €/m² of roof area. According to experts, with sufficiently good planning no relevant additional costs can be discerned in conjunction with structural engineering, parapet heights or the construction process. Additional structure-related costs for extensive green roofs are at most 3–4 €/m², while an increase in parapet height is not necessarily required, and if it is, the costs are approx. 6.50–8.50 €/m². As a rule, no other costs are incurred during the course of construction.

In order to avoid unnecessary costs, it is expedient to contact different companies and to obtain several quotations (possibly also with regard to different manufacturer systems and building materials). [3, p. 22] Cost optimisation should be taken into account beginning at the planning stage (functionality, synergy effects).

Indices (3, p. 11)

For the purposes of economically evaluating Hamburg's green roofs, the following indices were used:

- **Useable floor area (UFA):** Partial area of the net internal area (NIA) that serves the essential purpose of the building, according to DIN 277 (2016) – Areas and Volumes of Buildings (Building Construction). Expressed in m².
- **Building costs:** Sum of the costs of all the positions for construction of the entire building. Costs that result as the sum of cost groups 300 (Building – Structures) and 400 (Building – Technical Systems) according to DIN 276-1 – Building Costs (Building Construction). Expressed in €.
- **Roof costs:** Sum of the costs of all the positions for construction of the entire roof – including roof greening. This corresponds to cost group 360 (Roofs) according to DIN 276-1 (2008) – Building Costs (Building Construction). Expressed in €.
- **Green roof costs:** This refers to the sum of the costs for green roofs (including initial care – excluding root-resistant waterproofing). These costs can be part of cost group 360 (Roofs) or cost group 500 (Outdoor Facilities) in accordance with DIN 276-1 (2008) – Building Costs (Building Construction). Expressed in €.
- All costs are gross, including VAT.

Under nature conservation law, green roofs are included in the balance as a mitigation measure for the intervention and compensation scheme. In this way, intrusions into a site's ecological values can be partially compensated directly on site, and the need for expensive compensatory measures elsewhere can be reduced.

Representative greening of buildings bring about increased acceptance by users and an increase in property value through additional usable outdoor areas. The use of green roofs for leisure and recreation also offers the potential to generate additional income from rental/leasing or sale. According to an estimate by TÜV SÜD, properties with an intensive green roof enjoy an added financial value of 6–8% more rental income. [3, p. 18]

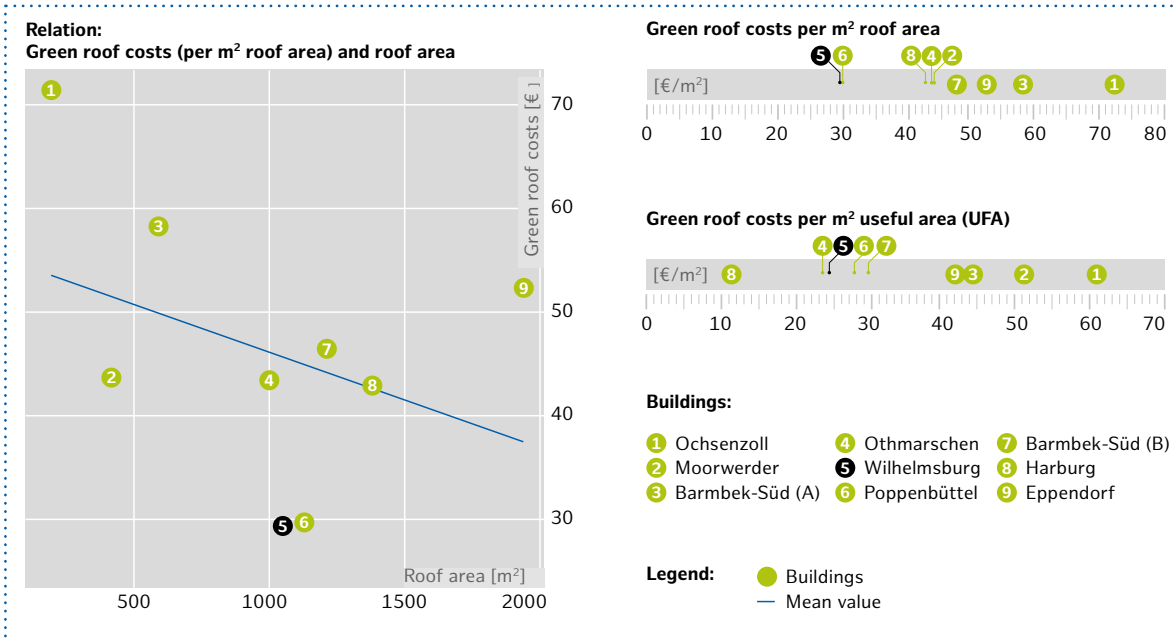
Green roofs can achieve operating cost savings by cutting yearly storm water fees per m² of green roof in half. In addition, there are savings in heating costs thanks to the insulating effect and a reduction in cooling costs thanks to evaporative cooling by the greenery in the summer. Protecting the roof waterproofing against weather influences, temperature extremes and UV radiation, as well as protection it from mechanical stress, has a positive effect on the service life.

In combination with photovoltaic systems, the evaporative cooling by the greenery reduces the ambient temperature, which yields a corresponding increase in the efficiency of the modules and thus shortens the amortisation period of the investment.

For DGNB certification of sustainable construction, green roofs are counted as a positive factor. In the case of renovation or an individual measure to upgrade energy efficiency, green roofs may also be eligible for financial support within the scope of programmes offered by the KfW bank.

The economic values for improving the working and living environment, upgrading the building architecture, improving the microclimate, introducing airborne sound insulation, binding and filtering air pollutants and promoting biodiversity are also relevant, but cannot be accounted for in connection with construction costs.

A tabular overview illustrating the economic life cycle cost analysis on the basis of average values of real costs over a period of 40 years, along with a corresponding graphic representation (comparison of black roof vs. green roof), are presented on the following page.

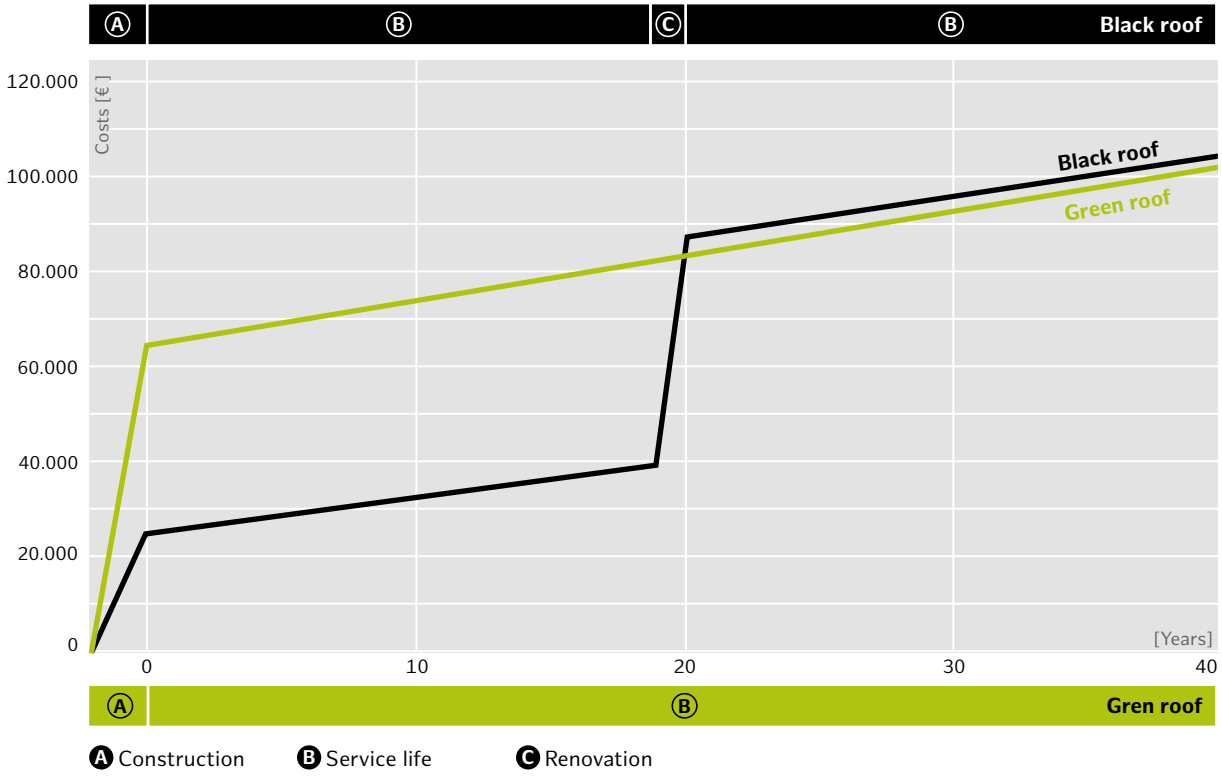


Green roof costs in relation to roof area and to useable floor area [3, p. 15]

TYPE OF COST	GREEN ROOF (1.000 m²)	BLACK ROOF (1.000 m²)
1. One-time costs		
Construction costs	65.000	24.000
Green roof costs (€/m²) (1)	41	
Sealing costs (€/m²) (2)	24	24
Renovation after 20 years (€) (3)	0	43.347
Sum of one-time costs	**65.000**	**67.347**
2. Running costs (over 40 years)		
Maintenance care (per year: green roof 0.60 €/m², bitumen roof 0.25 €/m²)(3)	24.102	10.043
Rain water charge (€)	14.235	28.470
Sum of running costs (€)	**38.337**	**38.513**
Total sum of a 40-year cycle (€)	**103.337**	**105.859**
Difference in cost compared to green roof (€)		**+ 2.522**
Total sum of a 40-year cycle (€/m²)	**103**	**106**
Difference in cost compared to green roof (€/m²)		**+ 3**

(1) (1) Average value of buildings 4, 6, 7, 8 Fig. 3 / (2) Average value of real costs, in order to obtain the same basis /
(3) Interest rate: 3% per year

Economic life cycle assessment [3, p. 17]



Graphic depiction of the life cycle assessment over 40 years [3, p. 17]



Planning

The design of green flat roofs involves a wide range of possible solutions. When consideration is taken of the intended use, the local architectural and climatic conditions and the personal options for care and maintenance, a group of realistic alternatives emerges, providing the framework for individual design intents and the financing requirements. As described in the previous chapter, the implementation of occupied green roofs has a positive impact in many respects on the qualities of the environment and the added value of the property, so that it – generally more than the built floor space itself – can be assessed as an ecologically and economically well-founded investment in the future.

For further development to be successful in this regard, the preconditions must be taken into account in a timely manner: Since success depends on numerous factors, early collaboration is advisable with the structural engineer, the building services engineer, the garden and landscape architect and the responsible district administration as well as the sanctioning authority, in order to be in a position to present a well-conceived concept. This will facilitate the building permit procedure and, where applicable, enables financial relief in return for overall climatic benefit for the city. This interdisciplinary groundwork yields the final range of solutions as the basis for further action.

The following pages present information about local conditions, greening forms, plant use and construction criteria as well as sustenance criteria. The essential features are summarised in a way that allows comparison of the different greening forms, thus serving as parameters for decision-making about construction and vegetation.

LOCAL CONDITIONS

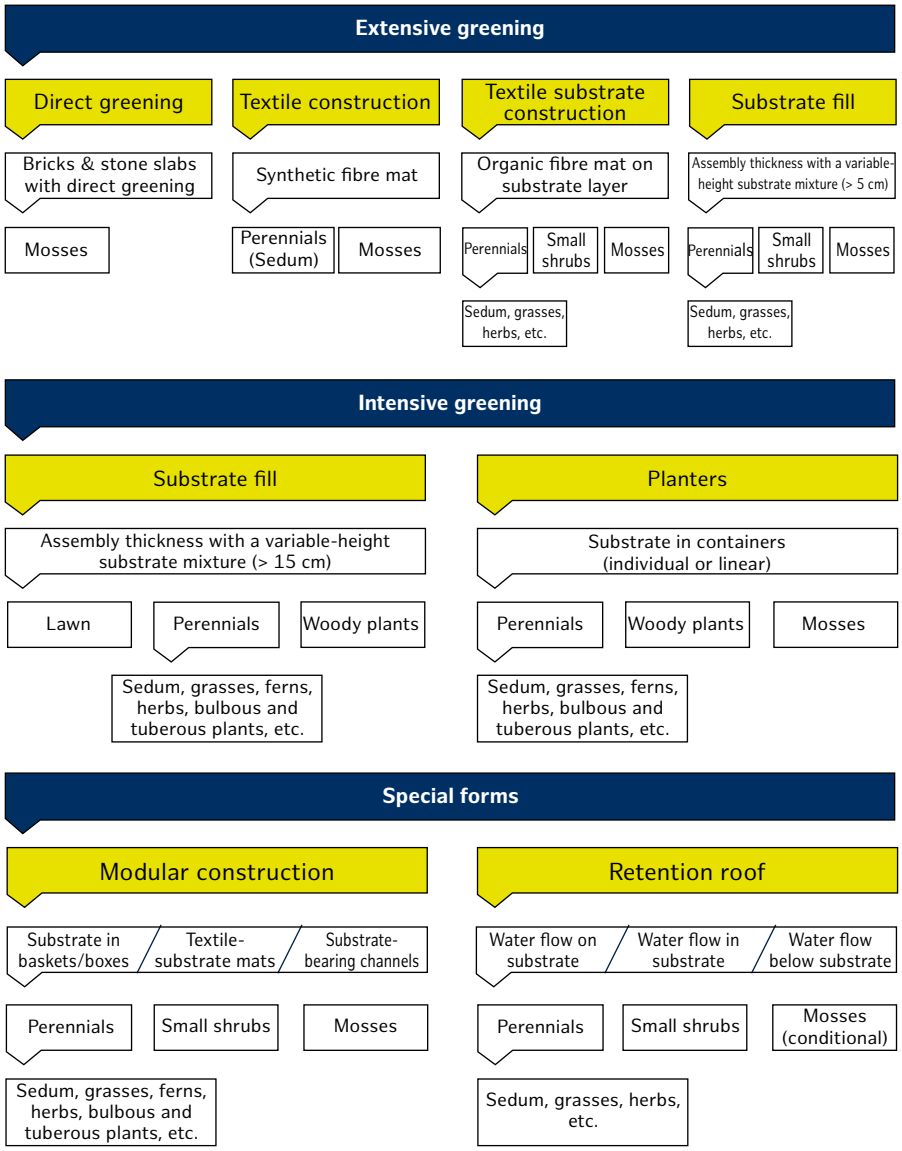
The list of criteria below is intended as an aid for the early recognition and inclusion of positional and incidental (also subsequent) adverse effects. In addition to the conceptual objectives of a roof greening project, the greening measure is also influenced by external planning in the immediate vicinity. The aim of this list is to be able, during the course of implementation, to incorporate helpful countermeasures that could otherwise only be retrofitted after completion at considerable expense or not at all.

With the great variety of building situations and their greening possibilities, this compilation of local conditions for the planning and realisation of green roofs for buildings cannot be exhaustive. The specific circumstances may mean that individual steps prove to be unnecessary or further steps may be necessary.

Elevation (above sea level)	
Climate zone (winter hardiness)	
Orientation (N-S-E-W)	
Average annual temperature cycle (lowest/highest temperatures)	
Average duration of sunshine (total radiation)	
Regional precipitation amounts during the year	
Predominant wind direction and strength	
Permanently free-standing building or expectation of future additions	
Periodic shading from surrounding buildings	
Periodic shading from nearby or planned vegetation (e.g. trees)	
Plant location in the rain shadow of vertical building elements or other buildings	
Superstructures that impact the green roof (e.g. sun shading, roof overhangs, balconies)	
Monument protection or valuable historical building fabric (existing)	
State of preservation, need for structural renovation of the roof, expected renovation intervals	
Support of the local fauna (e.g. availability of habitat and food for insects/birds)	
Wind turbulence or deflection, formation of wind vortices	
Periodic sunlight reflection from neighbouring bright wall surfaces, incl. glass or mirrored facades or glass roofs/solar roofs	
Selection of the appropriate greening form and suitable range of plants dependent on how the roof is used (e.g. accessible areas, solar energy harvesting with coverage/shading)	
Location and design of any necessary restrictions to unwanted growth propagation (e.g. under windows, at adjacent walls, at areas actively used for harvesting solar energy)	
Heating up of dark wall surfaces, particularly metal facades and dark plaster layers on thermal insulation	
Structural testing of load-bearing building parts, coordination of the greening form (extensive/intensive) and plant selection (e.g. for trees)	
Clarification of how the roof can be accessed for maintenance/service (stair, lift). Provision of areas for maintenance equipment and scaffolding: location for cherry picker or scissor lift and storage location for material deliveries.	
Mains water connection / rain water storage (e.g. cistern). Clarification of suitability for irrigation.	
Possibility of frost-free installation of an irrigation system, if potentially with nutrient dosing system.	
Possibility of draining excess water below the greening level. If necessary, coordination with municipal drainage.	
Energy supply: Equipment for care and maintenance, clarification of the cabling / routing of utility lines	
Consideration of supply and exhaust air and exhaust gas or steam outlets	
Consideration of additional installations (e.g. fall protection, lightning protection, wiring)	
Inclusion in the impact/compensation calculation	
Observance of the advice in DGUV Information 202-023 concerning the problem of presumed risk to young children in places where toxic plant constituents may be accessible (e.g. outdoor spaces in kindergartens/ hospitals, playgrounds).	
Miscellaneous (e.g. impacts of climate change or peculiarities of regional climate)	

FORMS OF ROOF GREENING

Once the local conditions have been clarified and one's own objectives for design and use have been developed, an extensive range of technical variations is available for planning and implementation (see figure below), as summarised and described here. The term "extensive greening" encompasses not only the frequently constructed type of green roofs on substrate fills but also alternative applications: textile system that eliminates the weight of a substrate (for use on existing lightweight roofs) and a system (currently undergoing research) of direct greening on growth-promoting slabs. [24, p. 63]. Classic intensive greening is supplemented by planters. These are used where continuous greening is not desired. Special forms offer applications for modular interim plantings or as retention roofs for process cooling and/or process water clarification.



Nature-based forms of vegetation that are largely self-maintaining and self-propagating. Can be produced and maintained with little effort. [24, p. 56]

Comparable (in use and design diversity) with outdoor spaces directly on the ground. The plant selection places high demands on the composition of layers. Can be maintained permanently only through intensive care and regular supply of water and nutrients. [24, p. 57]

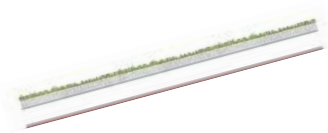
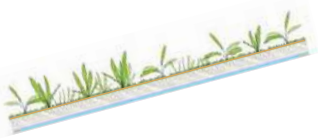
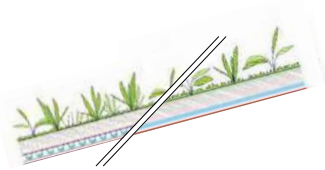
Modular construction: for immediate greening and/or interim solutions. Retention roofs: Green roofs with a structural composition designed to retain as much rainwater as possible. [24, p. 57]

DECISION PARAMETERS

The following tabular overview summarises the constructive and vegetation-related criteria for prevailing construction methods for the greening of flat and pitched roofs. In addition, the criteria for design and economics are compared, as are the ecological potentials of the systems.

Constructive and vegetation-related decision parameters [24, P. 72–73]

Extensive greening

Direct greening	Textile construction	Textile substrate construction	Substrate fill 5–15 cm
			
Mosses, lichens	Mosses	Perennials (sedum, grasses, herbs, etc.), small shrubs, mosses	Perennials (sedum, grasses, herbs, etc.), Small shrubs, mosses
• Directly greened bricks / stone slabs with surface texture that promotes greening	• Synthetic fibre mat	• Organic fibre mat on substrate layer	• Assembly thickness with a variable-height substrate mixture

ESTABLISHED

Design criteria

- Coverage effect: medium to long term, immediately with pre-culture
- Coverage effect: short to medium term, immediately with pre-culture
- Coverage effect:
- Design latitude: minimal
- Design latitude: moderate

Construction design

- Greening of flat or steep roof (0–35°, max. 85° conditionally)
- Greening of flat or steep roof (0–35°, max. 45° conditionally)
- Weight dependent on backing materials and substructure
- Weight ~20kg/m², saturated with water
- Weight ~30–90kg/m², saturated with water
- Weight ~50–190kg/m², saturated with water
- Water supply system site-related / as needed
- Water supply, drainage and dewatering provided. Water supply system
- Relevant for building authorities, structural calculations required; non-rusting components
- Possibly relevant for building authorities & static proof required; non-rusting components
- Relevant for building authorities, structural proof required, supporting components: with
- Storm-proof construction, substrate anchorage
- Roof assembly requires protection from moisture and root penetration

Suitable roof constructions

- Single layer, uninsulated (conditional) / Double layer, uninsulated, ventilated (conditional) / Single layer, insulated, unventilated – warm roof
- Single layer, insulated, unventilated (inverted roof – no vapour barrier layers or standing water!) Single layer, insulated

Economic criteria

- Investment cost: low to high
- Investment cost: low
- Investment cost: moderate
- Alternative: ballast (slabs or gravel)
- Alternative: ballast
- Effort for care: low
- Effort for care: low to moderate
- Service and maintenance effort: low to high
- Service and maintenance effort: low to moderate

Ecological potentials

- Cooling / insulating effect: year-round relevance as an energy source
- Possible diversity of species on site: low
- Possible diversity of species on site: moderate
- Immediate microclimatic relevance with pre-culture
- Microclimatic
- Water retention / discharge delay: low
- Water retention / discharge delay: low to moderate
- Water retention / discharge delay: moderate

Intensive greening

Substrate fill >15 cm



Grass, perennials (incl. sedum, grasses, herbs), bulbous and tuberous plants), woody plants (trees, contingent on substrate thickness >80cm)

- Assembly thickness with a variable-height substrate mixture > 15 cm

Planters



Perennials (also including grasses, ferns; bulbous and tuberous plants under certain conditions), woody plants (trees under certain conditions), mosses

- Substrate in containers (individual or linear)

Special forms

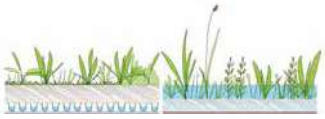
Modular construction



Perennials (incl. sedum, also grasses and ferns), small shrubs, mosses

- Substrate in individual basket/box elements
- Mat systems
- Substrate-bearing channel systems

Retention roofs



Perennials (incl. sedum, grasses, herbs), small shrubs, mosses under certain conditions

- Regulated water flow on substrate
- Regulated water flow in substrate
- Regulated water flow under substrate

GREENING FORMS

medium term	Coverage effect: short term, immediately with pre-culture		
Design latitude: ample			Design latitude: moderate to great
Greening of flat or flat-pitched roof (0–5°)	Green flat roof (0–5°)	Greening of flat or steep roof (0–20°, max. 85° conditionally)	Greening of flat or flat-pitched roof (0–5°, max. 15° conditionally)
Weight ~190–680 kg/m², saturated with water	Weight dependent on container and plant selection	Weight ~50 kg/m², saturated with water	Weight ~50–210 kg/m², saturated with water
site-related / as needed.	Drainage. Water supply system site-related / as needed.	Drainage. Water supply system site-related / as needed.	Water pump circulation / drainage may be necessary
corrosion protection or rust-proof material	Structural calculations may be required; rust-proof anchors	Relevant for building authorities, structural proof required, rust-proof components	
and planting (wind pressure/suction)			
			Roof assembly requires protection from moisture and root penetration
ensure high-quality vapour barrier! (conditional) / Double-layer, insulated, ventilated – cold roof, observe load capacity! (conditional)			
unventilated with supplemental insulation (no vapour-barrier layers or areas of standing water!) Ensure ventilation around/beneath planters!			
Investment cost: moderate to high			
(slabs or gravel); Structural protection		Alternative: ballast (slabs or gravel); Structural protection	Cooling, grey water clarification, structural protection
Effort for care: moderate to high		Effort for care: low to high	Effort for care: moderate to high
Service and maintenance effort: high	Service and maintenance effort: moderate to high		
Relevance: medium-term		Cooling / insulating effect: year-round relevance as an energy source	Cooling energie: year-round relevance as an energy source
Possible diversity of species on site: ample			
	Immediate microclimatic relevance with pre-culture		
Water retention / discharge delay: moderate to high	Water retention / discharge delay: low to moderate	Water retention / discharge delay: moderate	Water retention / discharge delay: high

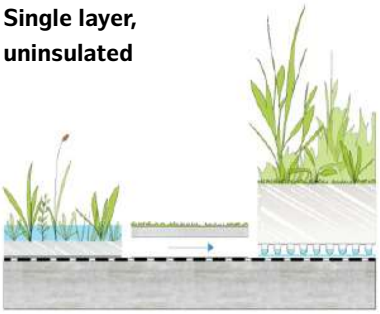


Construction Criteria

The overview shows the variability of common roof construction principles in connection with suitable greening techniques. The green roof assembly depends on the construction and loading capacity of the planned roof construction.

The remarks concerning the respective construction variants must be observed. The individual greening examples are explained on pages 18–19 (Constructive and vegetation-related decision parameters).

Single layer, uninsulated



Solid structure
In-situ concrete or precast with waterproofing
All greening techniques possible.
Observe load capacity!

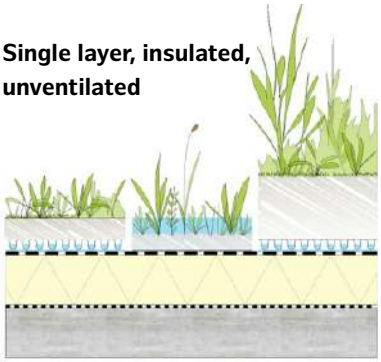


Steel frame construction
Metal (trapezoidal metal deck, corrugated metal, slabs)
All greening techniques possible on separate waterproofing.
Observe load capacity!



Wood frame construction
Sheathing/boards with waterproofing
All "lightweight" greening techniques possible.
Observe load capacity!

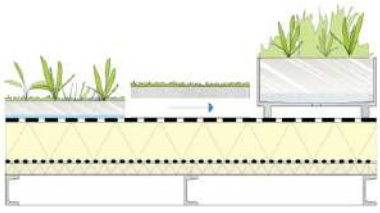
Single layer, insulated, unventilated



Solid structure with vapour barrier, insulated, waterproofing
All greening techniques possible on pressure-resistant insulation. Pay attention to vapour barrier!
Observe load capacity!

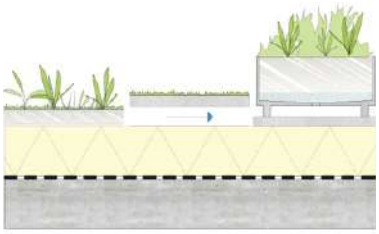


Wood frame construction with vapour barrier, insulated, waterproofing
All "lightweight" greening techniques possible on pressure-resistant insulation. Pay attention to vapour barrier! Observe load capacity!



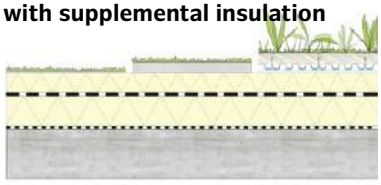
Steel frame construction with trapezoidal metal deck and vapour barrier, insulated, waterproofing
All greening techniques possible on pressure-resistant insulation. Pay attention to vapour barrier! Observe load capacity!

Single layer, insulated, unventilated, Inverted roof



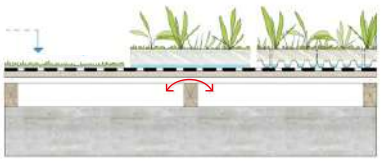
Solid structure with perimeter insulation on waterproofing
No greening techniques with vapour barrier or areas of standing water!
Pressure-resistant insulation!
Observe load capacity!
Alternative: stone slabs or gravel for planar greening

Single layer, insulated, unventilated with supplemental insulation with supplemental insulation



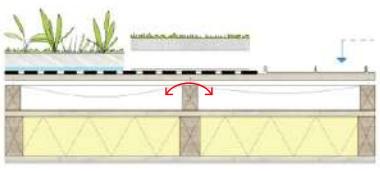
Solid structure with vapour barrier, insulated and waterproofed. With supplemental with perimeter insulation.
No greening techniques with vapour barrier or areas of standing water! Pressure-resistant insulation!
Observe load capacity!
Alternative: stone slabs or gravel for planar greening

Double-layer, uninsulated, ventilated

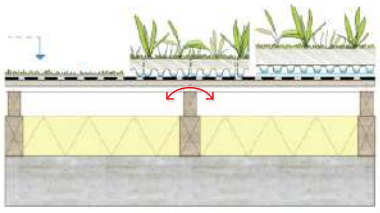


Solid structure with sloped wood superstructure plus waterproofing
All greening techniques possible.
Observe load capacity!

Double-layer, insulated, ventilated



Rafter roof with sheathing, underlining and previous roofing (e.g. zinc sheeting)
All "lightweight" greening techniques possible on a separate base course for waterproofing.
Observe load capacity!



Solid structure with sloped wood superstructure plus waterproofing
All "lightweight" greening techniques possible.
Observe load capacity!

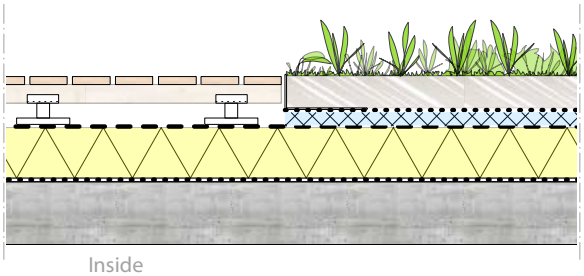


ENABLING THE USE OF THE ROOF AREA

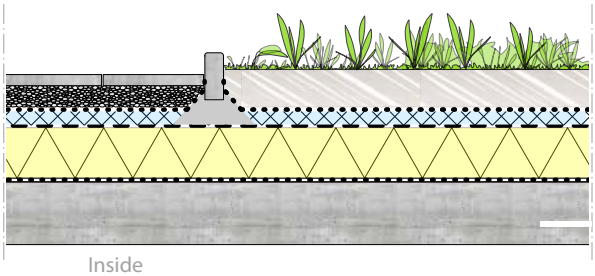
Especially in dense urban situations, quiet and relaxing open spaces with amenable surroundings are becoming increasingly rare – the pressure to exploit high-priced plots of land leads to contrary developments. This makes the potential of unused flat roofs as substitutes for urban open spaces – be they green roof gardens, playgrounds or café terraces with verdant surroundings – all the more valuable. Green roofs provide a range of benefits, from added amenities for commercial properties or valuable additional private space for dwellings to the possibility of cultivating food crops. They offer a view out over city life or secluded space surrounded by their own green walls – such as vine-covered pergolas. Valuable utility benefit is a good basis for ensuring maintenance and care.

The use of green roofs may consist mainly of paved paths and terraces. If the entire surface area of the green roof will be utilised, suitably resilient grass areas are required. Barriers are required to protect against falls over the edge or through elements like skylights wherever people will be using the roof. The regulations for barrier-free construction must also be observed: DIN 18040-1, DIN 18040-2 and (for public areas) DIN 18040-3. [9, p. 26]

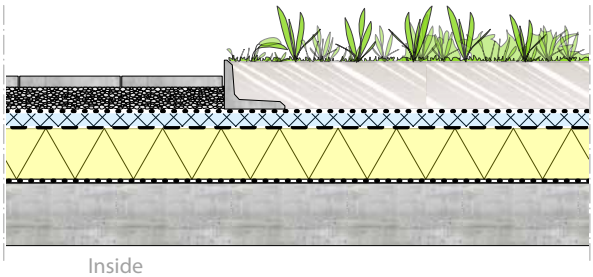
The objectives for the sustainability of outdoor facilities apply to usable roof areas. This comprises the planning, the execution of the construction work and the maintenance. Technical, functional, socio-cultural, economic and ecological aspects of the assessment system for sustainable building must be taken into account. [27]



Juncture between pedestal-mounted wood decking and planting [adapted from: 16, p. 53]



Juncture between slab paving on gravel bedding and planting (flush transition) [adapted from: 16, p. 53]



AJuncture between slab paving on gravel bedding and planting (different heights, with L-shaped blocks) [adapted from: 16, p. 53]

The City of Hamburg has issued a brochure about its open space quality campaign: *Mehr Stadt in der Stadt: Gemeinsam zu mehr Freiraumqualität in Hamburg* [2]



Constructional considerations regarding use are specified in DIN EN 1991-1-1, DIN 18531-1, DIN 18195-1 and, as far as relevant, in the ZVDH/HDB "Fachregel für Dächer mit Abdichtungen" [Technical rules for roofs with waterproofing]. [9, p. 26]

For structural calculations and determination of the imposed (live) loads as a function of the use categories according to DIN EN 1991-1-1, the intended use must be communicated to the engineering professional.
Changes of use for the green roof shall be taken into account. [9, p. 26] Prerequisites for safe use are year-round hazard-free accessibility/walkability (proof of loading capacity, traffic safety / fall protection), fire protection and compliance with regulations under neighbour law. The scope of use, contribution to maintenance costs and responsibility for care must be clarified.

☐ TRAFFIC SAFETY

In order to ensure safe use, proof of traffic safety is to be furnished. Supplements to HBauO § 19(1)(4); traffic safety, as per FLL p. 30: Planning and tendering are based on the requirements derived from accident prevention regulations and protective measures, such as fall protection and fall-through protection for construction and maintenance work. Other applicable regulations: BG regulations BGV C 22 "Unfallverhütungsvorschrift Bauarbeiten" [Accident prevention regulations for construction work] plus BGW C 22 DA "Durchführungsanweisungen Bauarbeiten" [Instructions for implementation of construction works] and the accident prevention regulation of the Gartenbau-Berufsgenossenschaft VSG 4.2 "Gartenbau, Obstbau und Parkanlagen".
Rope protection in accordance with DIN EN 795 or DIN EN 795 A1 must be provided for subsequent care and maintenance work. Appropriate attachment points are to be provided by the client.
If the roof waterproofing has already been completed, it is recommended that attachment points for the installation be affixed in a manner that avoids penetration of the roof membrane (e.g. attachment to load-bearing vertical elements or with safety systems held by a superimposed load). [9, p. 30]

☐ MONUMENT PROTECTION

For the rooftop greening of buildings that are registered on the list of historical monuments or recognised as such, prior approval under monument protection law is required on a case-by-case basis. [9, p. 18] The green roof's compatibility with the monument protection objectives and scope must be ascertained. The building facades must be preserved unchanged. If the green roof assembly cannot be placed behind an existing parapet (not visible from off the property), it must be set back far enough from the edge of the roof that the building elevations remain unchanged. The protected building fabric's structural suitability to support additional loads (green roof structure / water retention) and

safety components (fall protection) must be demonstrated for approval.

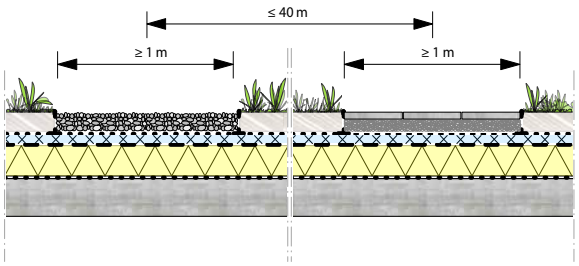
FIRE SAFETY REQUIREMENTS

For the containment of surface fires involving dry vegetation, DIN 4102-7 applies. The requirements formulated for extensive green roofs differ from those for intensive green roofs. Measures for intensive green roofs require fewer expenditures because – since they are irrigated, maintained and have a thicker substrate layer – they are considered a reduced risk.

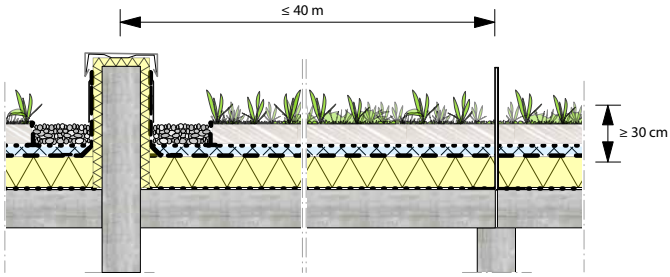
Under § 30(4)(2) about green roofs, the fire protection interpretations (Brandschutztechnische Auslegungen, BTA) issued by the building inspection service (Bauprüfdienst, BPD) of the Free and Hanseatic City of Hamburg provide clarification of the applicable regulations of the HBauO pertaining to fire protection: For extensive green roofs, sufficient resistance to flying sparks and radiant heat is presumed if a roof substrate layer at least 3 cm thick with a maximum of 20 per cent by weight of organic components is present. Where this is not the case, or where vegetation mats made of synthetic fibres have been installed, individual verification in accordance with DIN 4102 Part 7 must be carried out at a 15° inclination, in a dry state without vegetation. A further prerequisite is that fire barrier walls, fire walls or walls that are permissible instead of fire walls extend at least 30 cm above the green roof (measured from top of substrate layer). If the aforementioned walls do not have to extend above the roof, it is sufficient to provide a 30 cm high upstand of non-combustible building materials or a 100 cm wide strip of massive slabs (building material class A) or a layer of coarse gravel at least 5 cm thick.

In front of openings in the roof surface (roof windows, skylights) and in front of walls with openings, a strip at least 50 cm wide must be paved with solid slabs or covered with a layer of coarse gravel at least 5 cm thick, unless the sill of the wall opening is more than 0.8 m above the top of the substrate.

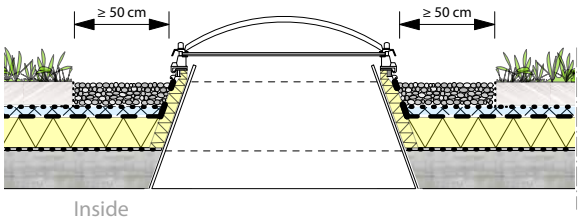
In front of roof hatches, an area of at least 1 m x 1 m must be paved with solid slabs or covered with a layer of coarse gravel at least 5 cm thick. In the case of a series of adjoining gable-fronted buildings, a strip at least 100 cm wide (measured horizontally) adjoining the eaves is to be kept permanently free of vegetation and provided with a non-combustible roof covering.



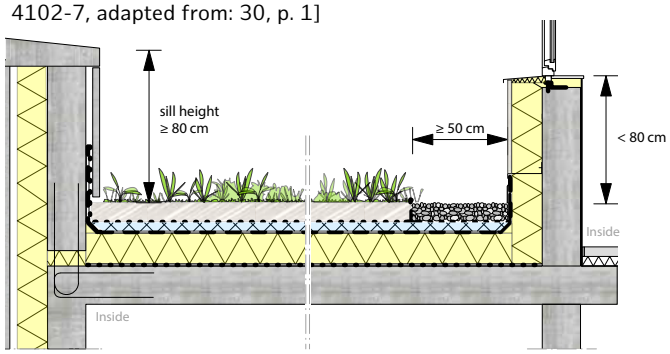
Bands of gravel or concrete pavers at least every 40 m [DIN 4102-7, adapted from: 30, p. 2]



Alternatively, ascending walls that extend above the roof, at max. spacing of 40 m, made of building materials complying with DIN 4102 Class A (non-combustible) [DIN 4102-7, adapted from: 30, p. 1]

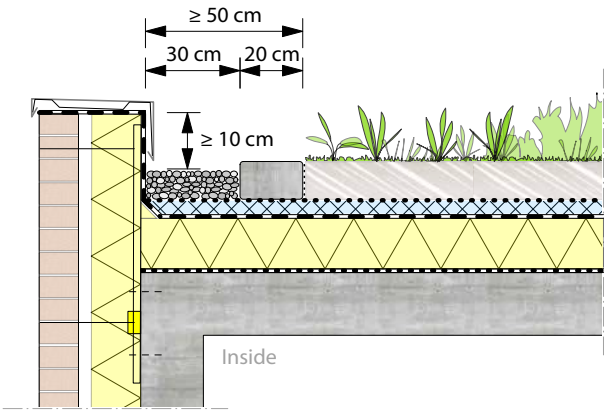


Protective strips around roof openings [DIN 4102-7, adapted from: 30, p. 2]

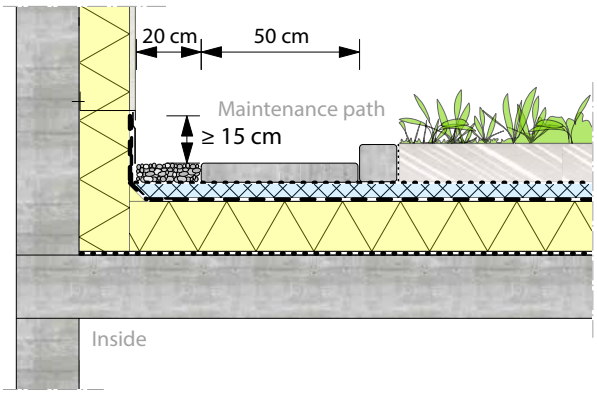


Gravel strips in front of ascending walls with windowsill heights < 80 cm [DIN 4102-7, adapted from: 30, p. 2]

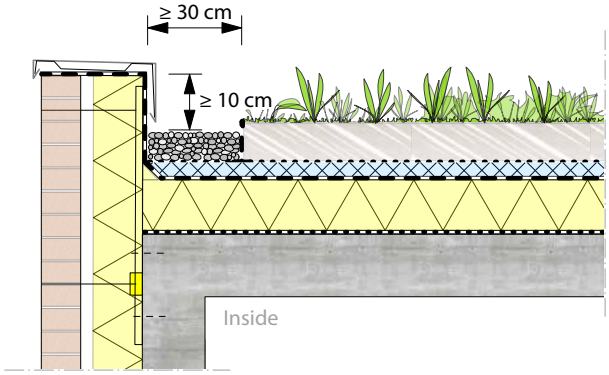
PROTECTIVE STRIPS



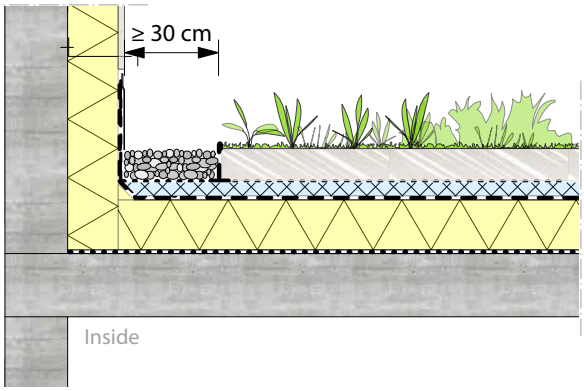
Clearance strip of gravel and concrete kerb. Vertical waterproofing protected by removable metal flashing.
[adapted from: 18, pp. 71, 125]



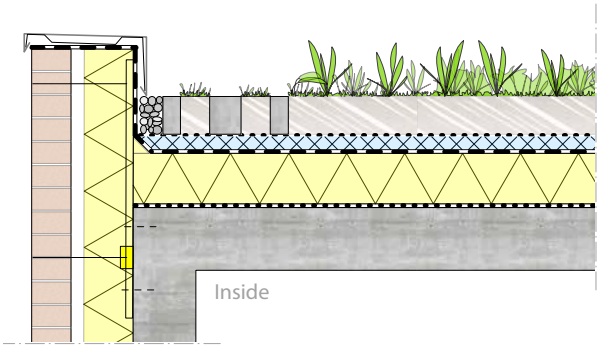
Protective strip at juncture between roof and ascending wall, also satisfies fire protection requirements. Waterproofing protected by metal flashing.
[adapted from: 18, pp. 71, 127]



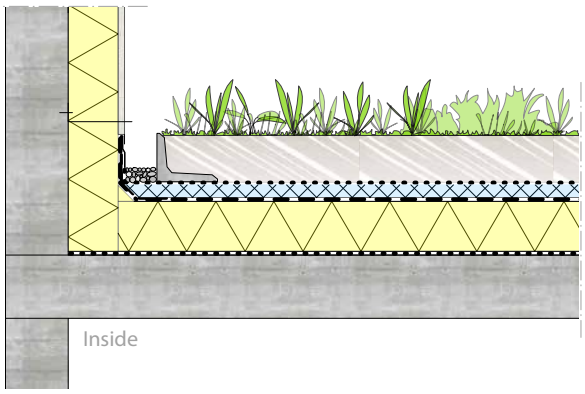
Solution with edging of perforated stainless-steel angled plate (instead of concrete kerb).
[adapted from: 18, p. 125]



To prevent root invasion, provide adequate protective strip with increased waterproofing. Waterproofing fastened with metal flashing. [adapted from: 16, p. 52]



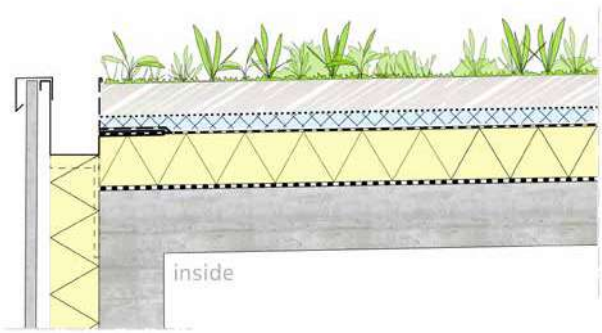
Grass paving blocks provide increased superimposed load at the roof perimeter. Gravel strips for dimensional tolerances and temperature fluctuations.
[adapted from: 16, p. 52]



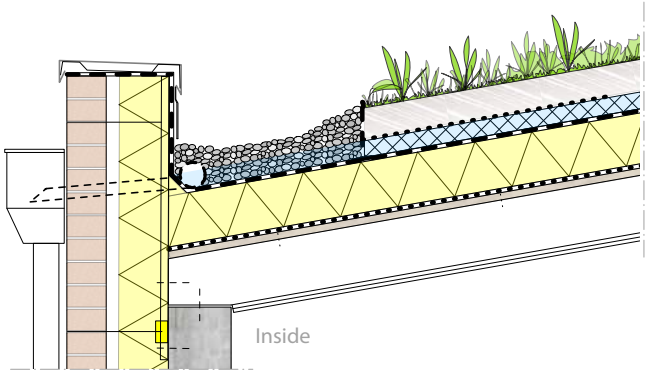
Minimal juncture height. Recessed vegetation edged with metal profile or L-shaped blocks.
[adapted from: 16, p. 53]

Considerable natural forces act on green roofs and their peripheral areas as well as on technical equipment installed there. Materials and connections have to withstand not only temperature fluctuations over the course of the seasons, but also spontaneous temperature changes. Adequate allowance must be made for the dilatation (flexibility) of joints, edging and materials cut to size.

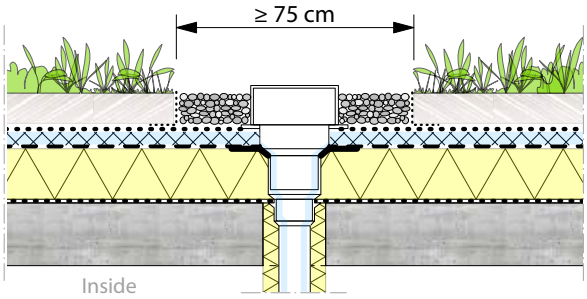
The edges and joints of waterproofing must reliably preclude root invasion. The protective strip can be installed horizontally, or it can be created vertically by carrying the waterproofing upright. The entire surface of the waterproofing must be protected against UV and thermal stress. Sensitive areas where the planting adjoins functional components such as roof drains, roof edges and drainage gutters or valleys must be cleaned and maintained at all times. As shown in the depicted concept sections, storm-proof edges of sufficient width (with maintenance path if needed) are well suited to preventing neglect and allowing easy inspection of such connection areas. Special fire protection requirements apply to green roofs that are atop high-rise buildings or adjoin the facades of high-rise buildings. According to subparagraph 3.5 of the "Anforderungen an den Bau und Betrieb von Hochhäusern" [Requirements for the construction and operation of high-rise buildings] issued by Hamburg's Bauprüfdienst [Building inspection service] (BPD 01/2008), roof components must, as a basic principle, always consist of non-combustible building materials. Deviations from this are permitted if, in front of the vertical high-rise facade or parts of a facade, a 50 cm wide strip of non-combustible material (massive slabs of building material class A or a layer of coarse gravel at least 5 cm thick) is applied. Plants with a high proportion of essential oils (e.g. pines) are ruled out for rooftop greening of high-rise roofs. A roof plan with details of the planting and a care and maintenance concept that explains any necessary pruning and irrigation measures along with other necessary care and maintenance measures must be submitted as part of the procedure for obtaining a building permit.



Aesthetically minimised edging. Precautions against substrate dispersal due to turbulence from wind forces is needed (e.g. textile substrate construction).



Substrate boundary and formation of edge gutter with drainage, incl. connection to downpipe, for a low-pitched roof. [adapted from: 19, p. 117]



Vegetation-free protective strip around a roof drain with inspection shaft. [adapted from: 18, p. 71]

Good engineering practice – guidelines and standards:

- Fachregel für Abdichtungen – Flachdachrichtlinie [Flat roof directive] (2016)
- DIN 18531, Roof waterproofing, Planning principles (1991)
- DIN 18195, Parts 1 to 10, Waterproofing of buildings
- Green Roof Guidelines – Guidelines for the planning, construction and maintenance of green roofs (FLL 2018)
- DIN 4102, Part 7, Fire behaviour of building materials and building components, Roofing / DIN V ENV 1187, Test methods for external fire exposure to roofs
- Model ordinance "Brandverhalten begrünter Dächer" [Fire behaviour of green roofs], ARGEBAU, June 1989
- HBauO – Hamburgische Bauordnung [Hamburg building code] § 30 Dächer [Roofs]
- VStättVO – Versammlungsstättenverordnung [Public assembly ordinance] § 4

NATURE CONSERVATION AND ECOLOGY

(climate, water, biodiversity)

§ 9(3)(4) of the BNatSchG [Federal Nature Conservation Act] formulates requirements and measures for the implementation of the concrete objectives of nature conservation and landscape management. § 4(3)(1) of the HmbBNatSchAG [Hamburg law on the implementation of the Federal Nature Conservation Act] enables the Free and Hanseatic City of Hamburg (FHH) to formulate relevant stipulations in development plans. These serve in particular the biotope network, biotope cross-linking, the development of diversity, the distinctiveness and beauty of nature and landscape, the protection of air and climate, improvement of the recreational value of nature and landscape and the preservation and development of open spaces in populated areas. A green roof is suited as a mitigation or compensation measure for impacts to the objects of nature conservation if it implements the following components of biodiversity:

- Appropriate substrate selection, surface modulation for the greening objective and species richness
- Vegetation-free areas (e.g. lenses of sand or loam, gravel beds, crushed stone surfaces)
- Refuge for ground animals (substrate mounds, woody plants, higher planting beds)
- Inclusion in the planting concept of fodder plants for insects and birds
- Introduction of dead wood (heaps of branches, rootstocks, tree slices)
- Use of windproof and waterproof nesting aids for birds and insects
- Placement of water elements, possibly with suitable flora (e.g. water troughs, ponds) [9, pp. 58–59]

These components of biodiversity are suitable for ecological upgrades to green roofs on existing buildings and for green roofs on new buildings. The goal is to increase the availability of habitat and



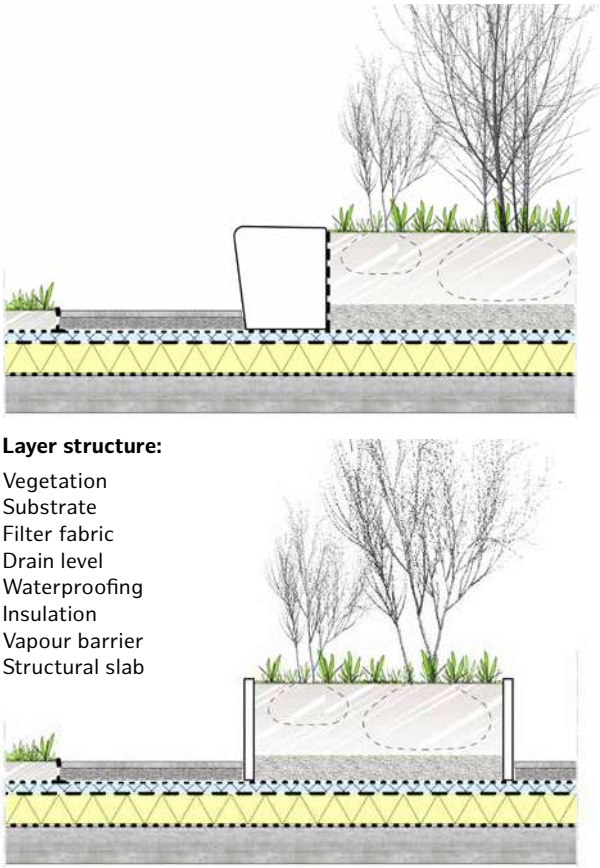




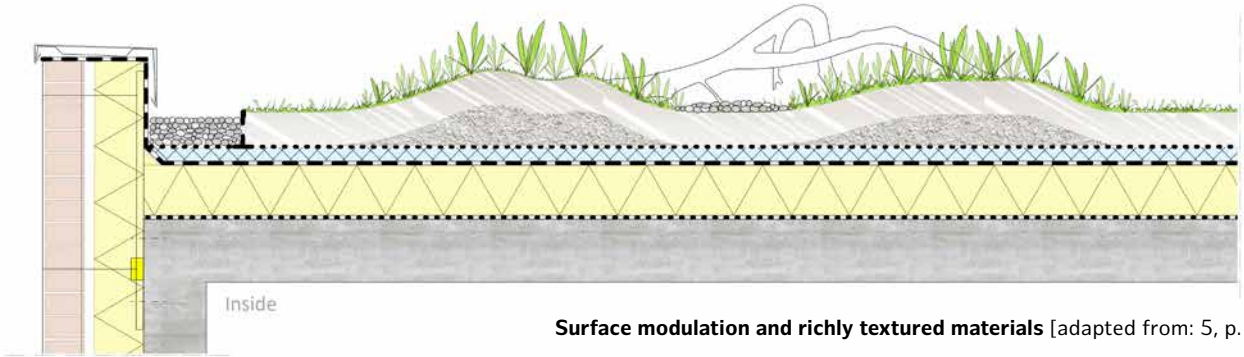
suitable food in order to increase the biodiversity. A detailed implementation plan is to be drawn up, when possible with the involvement of biologists. With regard to the local flora and fauna, the integration of additional measures may be necessary. [9, p. 59]

As a contribution to the diversity of species and according to the degree to which the green roof is to be credited for mitigation or compensation, the use of plant material suitable for the site and/or local seed may be required. [9 pp. 18, 58, 81]
The use of biocide-free materials for the creation of green roofs is important in regard to the precipitation water discharged from green roofs into bodies of water (groundwater and surface water).

If a green roof project is also to focus on the living conditions of wildlife such as bees, butterflies, beetles and birds, useful information can be obtained from the German Wildlife Foundation, Christoph-Probst-Weg 4 in 20251 Hamburg.



Differences in substrate levels at built-in planters and edging [adapted from: 18, p. 119]



Surface modulation and richly textured materials [adapted from: 5, p. 5]



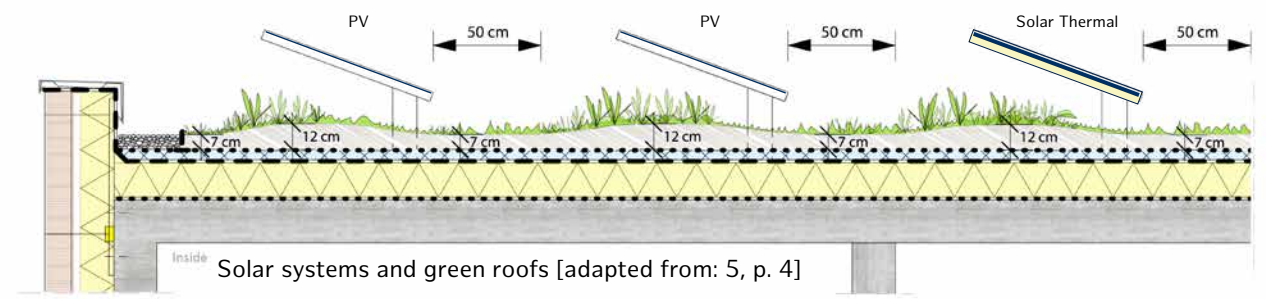
TECHNICAL EQUIPMENT

The aim is to limit the space required for building services equipment as much as possible on green roofs. So as to not unnecessarily restrict the vegetation area, equipment for solar energy harvesting (photovoltaic / solar thermal energy) can be integrated into an extensive green roof by installing it on raised supports. Plant growth can be controlled contingent upon the type and height of the substrate.

In order to avoid shade resulting from plant growth near solar equipment, the expected height of plants in front of all energy-active faces of PV panels is regulated by installing less substrate (max. height 7 cm). Low-growing species with no or short flower heads are suitable for planting here. The substrate height beneath and behind the panels is increased (12 cm) to support a greater diversity of species at the location, thus usually strengthening the plant growth. In this way, the expenditures for care and maintenance of green roofs can be more economical. [5]

Space-consuming ventilation equipment with vegetation-free intake and exhaust areas in front can be avoided by selecting units with vertical towers for outside air and exhaust air.

Emissions from combustion processes contain acids and herbicides, the exhaust gases displace the atmospheric oxygen, and their toxic substances – dissolved in precipitation and humidity – accumulate on the plant substance and can damage its metabolism and genetic material.
Thermal stresses also have an effect that ranges from disruptive to detrimental: At ventilation and air-conditioning equipment, the escape of warm and cold air and the occurrence of air currents can cause damage to plants from frost and insufficient water. Exhaust gases such as SO2 that escape from chimneys and flues can cause direct damage to vegetation, especially to wintergreen and evergreen plants. Therefore, in areas affected by warm air, air currents and exhaust gases, particular care must therefore be taken to check whether and, if so, which vegetation is suitable.
[see 9, p. 41]



Solar systems and green roofs [adapted from: 5, p. 4]



SUSTENANCE CRITERIA

Intact green roofs promote the objective of a building upgrade, be it for the purpose of design, economy and/or ecology. Professional execution and reliable care and maintenance are the prerequisites for the long-term viability of green roofs and thereby help to compensate for the urban greening deficit.

☐ SUBSTRATE REQUIREMENTS [cf. 25, p. 19]

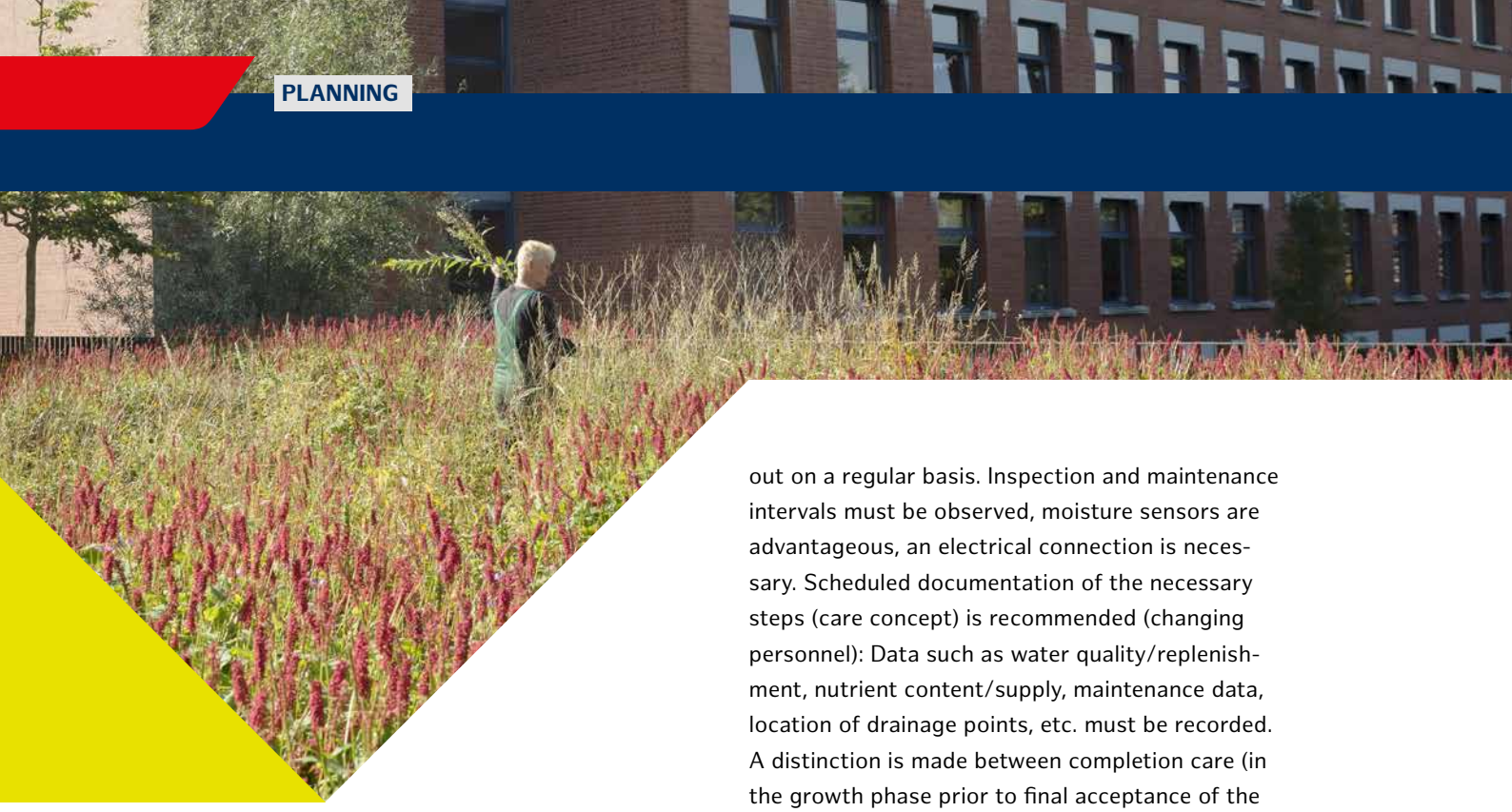
The quality of the substrate is crucial to determining the success of the green roof. Essential criteria are:

- High form stabilit
- Few organic components
- Low weight (dry condition)
- High continuous water storage capacity
- Sufficient air capacity when saturated
- Good absorption of nutrients
- Good resistance to pH-value shifts (e.g. against acid rain)
- Free of pests, pathogens and seed contamination
- Low fines content (to avoid hardening / sludge formation)

☐ IRRIGATION AND DRAINAGE

Every type of green roof requires proper irrigation and drainage, which must be taken into account early on in the planning process. Such early planning is particularly needed to ensure the drainage of excess water from flat roofs. While irrigation systems for extensive green roofs are generally only used during the initial growth phase, they are indispensable for intensive green roofs at all times. The absorption capacity of the substrate and the retention capacity of the drainage layer fulfil the function of a compensating water reservoir for both greening forms. An irrigation option should generally be provided for dry periods, even for extensive green roofs. Waterlogging should be avoided. [10]

Analogous to § 62 of the Hamburgische Bauordnung (HBauO, Genehmigungsverfahren mit Konzentrationswirkung [Approval procedure with concentration effect]) and the discharge approvals in accordance with § 11a of the Hamburgisches Abwassergesetz [Hamburg waste water act] (HmbAbwG) and/or the permission issued under water law in accordance with the Wasserhaushaltsgesetz [Federal Water Act] (WHG) § 10 (for direct discharge), the quality standards for the materials used, as defined under building law, as well as the legal requirements of the City of Hamburg for waste water with regard to the indirect and direct discharge of roof run-off and drainage water must be fulfilled. [see 9, p. 18 / www.hamburg.de/regenwasserableitung/]. Due to the continued growth of the city and the corresponding increase in the sealing of ground surfaces, heavy rainfall events can in some cases no longer be taken up by the public sewer system. [www.hamburg.de/regenwasserableitung/] The retention of precipitation and the delayed water run-off in conjunction with water consumption and transpiration by plants are, from an ecological and economic viewpoint, therefore the main beneficial impacts of green roofs. [see 9, p. 53]



The following problems should be prevented by careful planning, execution and maintenance:

- Oversaturation or dehydration of substrate
- Injury to the plants caused by snow or frost/ice days [see 25, p. 33]
- Pressure losses due to line lengths or supply height
- Fine material deposits in pipes and outlets (sintering)
- Cistern water: fines filter necessary
- Cistern water: prevent the introduction of chemicals (growth inhibitors / biocides) from e.g. roof waterproofing or facade paints.

The frequency and intensity of irrigation depend on the following factors [see 25, p. 33]:

- Evaporation intensity, wind strength, wind direction, exposure (e.g. peripheral location)
- Water storage capacity of the substrate or the substrate substitute
- Tolerance of waterlogging and drought resistance of the plants
- Water and nutrient requirements of the plant

Supplemental irrigation is possible via drip or spray hoses.

☐ CARE AND MAINTENANCE

For the purposes of care and maintenance, an early planning criterion is to permanently ensure year-round accessibility to all portions of the greened areas. Plant inspections should be carried out on a regular basis. Inspection and maintenance intervals must be observed, moisture sensors are advantageous, an electrical connection is necessary. Scheduled documentation of the necessary steps (care concept) is recommended (changing personnel): Data such as water quality/replenishment, nutrient content/supply, maintenance data, location of drainage points, etc. must be recorded. A distinction is made between completion care (in the growth phase prior to final acceptance of the property) and development care (on-going maintenance measures after successful roof greening). [9] The development care of extensive green roofs comprises two inspection rounds per year. This care includes, among other things, removal of foreign growth, reseeding/replanting and the inspection and cleaning of irrigation and drainage facilities. [9]

The effort needed for the care of intensive green roofs is comparable to that of intensive green gardens. The care and maintenance must be carried out with consideration for fauna settled on the roof, especially in regard to nest-building.

☐ QUALITY ASSURANCE

For intensive green roofs, a condition suitable for acceptance as per DIN 18916 or DIN 18917 must be ascertained. For extensive green roofs, the criteria of the current FLL Green Roof Guidelines apply in addition to or deviating from DIN 18916 and DIN 18917 as well as in addition to or deviating from ATV DIN 18320.

Infrared and aerial photographs of the Free and Hanseatic City of Hamburg make it possible for the approving authority to monitor the green roofs (e.g. vitality, degree of coverage).

The criteria dealt with in excerpts in this chapter are based on the FLL Green Roof Guidelines, which serves in total as the basis for planning, executing and maintaining green roofs.



PREREQUISITES AND CONSTRAINTS

Action

This brochure on green roofs explains the ecological opportunities, construction options and legal aspects of executing the work. At all times it takes into account the effects of climate change and the challenges of maintaining living quality in a vigorously growing city. The diversity and added value of exemplary green roofs on new buildings can trigger comparable initiatives for existing buildings to create a more attractive urban living and working environment with ecological and climatic benefits.

The following summary is intended to unify the stipulations and grounds for green roofs in development plans for Hamburg,

thereby offering assistance to planners and all institutions active in the real estate sector as well as ordinary citizens. The chapter “Action” describes the prerequisites and constraints pertaining to the legal framework, the construction and the vegetation.

The aim is to supplement and strengthen Hamburg’s “green roof strategy”.



Action

DEVELOPMENT PLAN STIPULATIONS

By encouraging rooftop greening, the City of Hamburg intends to counteract the number of hot summer days and nights, mitigate the effects of heavy rainfall events, ecologically compensate for the consequences of increasing surface sealing in the city and create space for recreation and leisure.

This chapter contains stipulations and substantiations taken from development plans and is organised as follows:

01	Application scenarios	S. 32
02	Roof slope	S. 33
03	Area values / dimensions	S. 34
04	Type and height of substrate fill	S. 35
05	Vegetation selection	S. 36
06	Types of use	S. 37
07	Supplemental comments / effects	S. 38
	Rainwater retention / waste-water law	S. 38
	Combination with technical systems	S. 40
	Air pollutants	S. 40
	Noise	S. 40
	Hygiene	S. 40
10	Legal basis	S. 41

01 APPLICATION SCENARIOS

Preliminary notes

In principle, green roofs for buildings can be established in all development zones in accordance with the BauNVO [Federal Land Utilisation Ordinance]. Furthermore, according to the BauGB [Federal Building Code], the designation of green roofs is generally also possible for physical structures in other areas, such as areas for community use, areas for sports and games, and green spaces.

The principle of proportionality is to be observed in all stipulations. In each individual case, a specific explanation must be given as to why the particular stipulation is suitable, necessary and appropriate (i.e. not excessively expensive) for achieving the specified objective. If less costly green roofs are equally suitable to achieve the intended objective, the stipulation is unnecessary and therefore unlawful.

The following examples of stipulations and substantiations are arranged here according to the various individual aspects of the green roof specifications. Examples of stipulations always illustrate the particular aspect discussed and must be considered in combination with any special requirements for the specific planning area. The same applies to the substantiations.

Base stipulation

- In the ..... areas, flat roofs and shallow-pitched roof surfaces of buildings and parts of buildings are to be greened.

Exemplary stipulations

- In the general residential area and on the land for public facilities, the roof areas of buildings and parts of buildings are to be greened.
- Roof areas of ancillary buildings and the roofs of underground car park access ramps are to be greened.
- In commercial / light industrial zones, the roof areas of buildings and parts of buildings are to be greened

Exemplary statements for substantiations

- Green roofs contribute to improvement of the climatic situation by filtering pollutants from the air and mitigating the radiated heat and also have a balancing effect on the water balance through retention, storage, evaporation and delayed discharge of rainwater. Greened roof areas form vegetation areas that are ecologically effective in urban areas and offer alternative habitats and complementary habitats for animals adapted to the location, such as insects and bird species. In combination with biotope structures in the surroundings, they contribute to the networking of habitats in the metropolitan area.

▶ **Legal reference:** It follows from this reasoning that the stipulation was made on the basis of nature conservation law. Climatic grounds are also represented in this stipulation, but only on the basis of § 1a (5) of the BauGB as an issue for consideration.

- Green roofs contribute to decentralised retention and delayed discharge of surface water. They have a stabilising effect on the microclimate, since the roof surfaces heat up less, bind dust particles and promote water evaporation. They should also be available to the insect world and to birds as a substitute habitat. Greened roof areas also contribute to an increase in the value of the urban space, as they can be used freely and/or can be seen from other buildings and experienced as a verdant enrichment to the surroundings.

▶ **Legal reference:** It follows from this reasoning that the stipulation was made on the basis of nature conservation law, urban development and climatic considerations.

- Green roofs have a stabilising effect on the microclimate, since greened roof areas do not heat up as much. In the summer, green roofs are an effective way to protect rooms underneath from the heat of the summer sun. In the winter, the vegetation and the roof substrate diminish the thermal transmission value and thus provide increased thermal insulation. In addition, green roofs bind dust particles and promote water evaporation. The reduced and delayed rainwater runoff relieves the discharge system. Depending on the type of planting, the precipitation water is held in the upper layers for different periods of time and then flows away, except for the water that is lost through evaporation and transpiration. Extensive green roofs also form a secondary habitat for insects, birds and plants and which is little disturbed by humans. Moreover, green roofs enliven the appearance of new buildings as seen from higher neighbouring buildings.

▶ **Legal reference:** It follows from this reasoning that the stipulation was made on the basis of nature conservation law, urban development and climatic considerations.

☐ 02 ROOF SLOPE

Brief explanation

Roof areas for which greening is envisaged are to be constructed and greened as flat roofs or as low-pitched roofs with a slope of 2–20°. Roofs with a slope of less than 2° require special measures for proper roof drainage: a multi-layered system with a drainage layer shall be constructed. The minimum slope of 2° guarantees reliable water drainage. The limitation to 20° is economically appropriate. Although a green roof on a roof pitch of up to 45° is technically feasible, that results in considerably higher costs for both construction and maintenance.

The design objectives apply equally to the insertion of new buildings within the urban context and to improved environmental quality in analogy to § 81(1)(2) of the HBauO. Flat roofs and shallow-pitched roofs limit the building heights. Walkable green roofs are usable outdoor spaces (for leisure, sports and play areas, experiencing nature, quiet zones, social interaction) and thus increase the quality of life. [Publication 20/11432, B. no. 1.a]

Exemplary stipulations

- In development zones, roof surfaces are to be constructed as flat roofs or as shallow-pitched roofs with a slope of up to 10°.
- In commercial / light industrial zones, only flat roofs and shallow-pitched roofs with a slope of up to 20° are permitted.
- Only flat roofs and shallow-pitched roofs with a maximum slope of 20° are permitted.

Exemplary statements for substantiations

- The stipulation of flat roofs is intended to ensure that the obligation to green roof areas can be realised and that the associated functions, in particular rainwater retention, stabilisation of the micro climate and species protection, can be fulfilled. The construction of flat roofs also makes it posible to increase the proportion of private outdoor areas by enabling the creation of roof terraces. Roof terraces offer a high amenity value and can thus contribute to a high quality of living and a better working environment in a dense urban quarter.

- The roof areas of the buildings are to be constructed as flat roofs. This stipulation is made to ensure a uniform roof landscape and is also intended to establish a consistent modern design and to enable green roofs.

Note

▶ This stipulation is only permissible if, for reasons of urban design, a uniform cityscape is prescribed for a large development zone.

- The design stipulations contribute to the high-quality design of the buildings. They create an overall image for the new residential quarter while permitting latitude for architectural design, and they contribute to harmonisation with adjoining neighbourhoods.

- Out of respect for the existing buildings and to ensure good sunlight exposure for new development, the roof slope of tall buildings should be kept to a minimum.

☐ **03 AREA VALUES AND DIMENSIONS** (partial)

Brief explanation

The objective is full-coverage rooftop greening. A full-coverage green roof may be dispensed with if the necessary means of access and paths, protective strips, fire safety equipment, daylight openings, openings for ventilation and exhaust, terraces or areas for technical systems are adversely affected. Then, however, it is necessary to stipulate a minimum amount of greening. In such cases, it should be made clear whether the greening is a compensatory measure for the purposes of nature conservation, in the interests of reducing the impact to nature and landscape, or whether the greening measure is stipulated for design reasons. The portions of a green roof that lie below elevated solar equipment are counted as compensatory measures in the service of nature conservation.

Exemplary stipulations

- In general residential areas, at least 80 per cent (%) of the roof areas are to be provided with at least a ..... cm thick root-penetrable substrate assembly and greened.
- In development zones and on land for public facilities, the roof areas of the buildings and parts of buildings shall be provided with at least a ..... cm thick root-penetrable substrate layer and extensively greened. Greening may only be dispensed with in areas that serve as terraces or are designated for daylighting, ventilation, fire safety equipment or the accommodation of technical systems. The proportion of roof area to be greened must amount to at least 80 per cent (%).

- The roofs of buildings and garages in the general residential area shall, over at least 50 per cent (%) of the roof area of the building, be provided with at least a ..... cm thick root-penetrable substrate assem-

bly, extensively greened and maintained. It is possible to combine raised equipment for the use of solar energy and surface greening that also extends beneath the modules.

Exemplary statements for substantiations

- With a mostly continuous greening of the roof areas amounting to at least 80 per cent (%), the appearance of the visible roof areas is enlivened and the design improved. In addition, ecologi cally effective alternative habitats for animal and plant species are created in development zones. The greening is climatically effective. It reduces the heating effect of roof surfaces, lessens the intensity of reflections onto neighbouring areas, improves the binding of dust particles, delays rainwater discharge from roofs and increases the reintroduction of precipitation into the natural cycle through evaporation and transpiration (evapotranspiration). For sustainable perpetuation of the ecological and visual impact of the extensive green roofs, substrate thicknesses of at least ..... cm are prescribed.

- Green roofs must be realised on at least 50 per cent (%) of the roof areas of buildings and garages. Excluded from the greening are any areas necessary for terraces, as well as areas that serve for daylighting, ventilation or the accommoda tion of technical systems. Solar energy harvesting systems can be combined with green roofs, the reby increasing their efficiency factor. By stipula ting the proportions of the roof areas of the buil-dings that need to be greened, a minimum amount of rooftop greening is ensured.

☐ 04 TYPE AND HEIGHT OF SUBSTRATE FILL

Brief explanation

Green roofs are to be executed with substrate material that is suitable for the intended position, planting and use and has a root-penetrable thickness of at least 12 cm, and they shall be permanently maintained.

The following advantages speak for a root-penetrable substrate thickness of at least 12 cm:

- More appealing visual appearance of the green roof with greater substrate height (due to variety of plant selection with varied growth heights)
- Larger choice of plants, possibility of using wild perennials and woody plants (woody plants and perennials possible with a thickness of at least 15 cm)
- With greater thickness, the species are less susceptible to the effects of wind, the intensity of solar radiation and drought.
- There is less sensitivity to hot and cold air emissi-ons and individual species, particularly evergreens, possess greater winter hardiness as well as greater strength to fend off competitors.
- Greater evaporation capacity is possible with intensive greening due to the types of plants available for selection.
- There is a higher nutrient capacity and greater water retention in the vegetation stratum due to the inclusion of organic components.
- As a result of the greater water retention, the vegetation can better endure dry phases.
- The rainwater runoff (peak runoff coefficient Cs as per DIN 1986-100) is lower for a root-penetra-ble thickness of 12 cm: the Cs value (for orienta-tion) is only 0.4/0.5. For comparison: a root-penetrable thickness of 6–10 cm corresponds to a Cs value of 0.5/0.6, while an unvegetated roof equates to a Cs value of 1.0.

In the case of roof areas above underground car parks (covering over subterranean areas with no building above), the total layer thickness should amount to at least 60 cm; in areas where trees are to be planted, the total layer thickness must amount to at least 100 cm. It is recommended that only deciduous trees with small crowns be planted there. In specially justified individual cases, a deviation from the regular 12 cm substrate thickness can be permitted and smaller substrate thicknesses, such as 6–8 cm, can be stipulated.

Exemplary statements for substantiations

- For the green roof to be effective, the substrate assembly must have a suitable minimum thickness

Exemplary stipulation

- In the general residential areas, at least ..... per cent (%) of the roof surfaces are to be provided with at least a 12 cm thick root-penetrable substrate assembly, to be greened and to be maintained.
- Roof areas from a size of 100 m² are to be designed as usable roof gardens, intensively greened with lawns, perennials and shrubs, and maintained. A root-penetrable total layer thickness (including drainage layer) of at least 30 cm must be created. (Recommendation: The stipulation should not be applied to fragmented roof landscapes with a majority of roof areas and parts that are less than 100 m², so that the total proportion will not be too low.)
- With the exception of paths, playgrounds and terraces, roof areas of underground car parks that have not been built over are to be executed with a root-penet rable substrate thickness of at least 60 cm and greened over their entire surface. If tree plantings are carried out atop underground car parks, the layer thickness of the root-penetrable substrate assembly must amount to at least 100 cm on an area of at least 10 m² per tree.

that enables greening with grasses and perennials and also ensures that the vegetation is sufficiently nourished to survive hot spells.

- For economic reasons, a green roof is only required for a roof size of 100 m² or more. Green roofs are able to bind pollutants from the air. The measure thus contributes to improvement of the air quality. Furthermore, the green roof increases the atmospheric humidity, delays the discharge of rainwater and retains it. Especially during heavy rainfall events, this has the advantage that the storm water sewer is temporarily relieved.

- The aim of the stipulation is to ensure the planting of vegetation with an effective design on the areas where an underground car park is built beneath, and thus to considerably increase the amenity value and the possibilities for use of these areas. A minimum substrate thickness of 60 cm is needed to provide suitable growing conditions for the sustainable development of lawns, perennials and shrubs. It allows the retention of sufficient accessible water to fores tall damage to the vegetation during dry periods. To enable the planting of both small- and large-crowned trees above underground car parks, and to permanently maintain them, thicker planting beds (min. 100 cm in the trees' root zone) are required over an area of at least 10 m² each. This measure reduces the effects of soil sealing and improves the water balance as well as the local climate.

☐ 05 VEGETATION SELECTION

Brief explanation

The plant selection and vegetation forms must be adapted to the site conditions. Thus the climatic and weather-related factors (e.g. prevailing wind direction, amount of precipitation, microclimate) are to be taken into account, as are the factors specific to the building (e.g. exposure and slope of roof surfaces, sunny and shady areas, effect of exhaust air emissions, exposure to reflective facades and building components, possibility of the increased occurrence of foreign growth of the surrounding flora (e.g. poplars, birch trees), the individual functional requirements (such as used or unused green spaces, crop planting, visual or wind protection) and plant-specific factors. The use of near-natural grasses, herbs, perennials and shrub species from the range of species native to the region is preferred to the greatest extent practicable for the green roof.
One example is the seed mixture "Hamburger Naturdach", which was compiled using regional species for extensive green roofs.
www.ifbhh.de/fileadmin/pdf/IFB_Download/IFB_Wohneigentum/Pflanzenliste_Extensivbegruenung.pdf

Wooded and shrub-free areas are to be created in combination with each other.

The planning authority can specify species lists for the greening and can exclude species in order to achieve a higher quality biotope in addition to the green space design.

Exemplary stipulations

- At least 30 per cent (%) of the roof areas in general residential areas and mixed-use areas are to be extensively greened with site-adapted shrubs and grasses using a root-penetrable substrate with a minimum thickness of 12 cm. In addition, at least 20 per cent (%) must be greened intensively with shrubs and bushes using a substrate with a minimum thickness of 50 cm.
- In general residential areas and the parts of mixed-use areas designated with "(D)", at least 50 per cent (%) of the roof areas are to be greened with native shrubs and grasses suitable for the location using a root-penetrable substrate with a minimum thickness of 15 cm. The green roof is to be maintained permanently.

Exemplary statements for substantiations

- On the one hand, the minimum substrate thickness of 50 cm for perennials and shrubs on areas of a property that are almost completely occupied by underground car parks satisfies the objectives set out in the HafenCity master plan for high-quality greening of the quarters through differentiated substrate thicknesses, and on the other hand, it minimises the construction costs and structural effort needed to address the loads above the underground car parks. In the areas with substrate thicknesses of at least 50 cm, planting with higher-growing shrubs and more demanding perennials is planned in order to achieve a screening effect. This way, the privately usable space is given visual privacy by a planted screen.

• The areas with a substrate thickness of 12 cm should be planted with undemanding, flat-growing grasses, herbs and perennials. These species also tolerate occasional summer droughts. Both roof plantings contribute to water retention, evaporation, an improved microclimate and improvement of the natural environment and the overall appearance of the landscape. The aim is to offer reference areas and species-rich habitats and to preserve them permanently in order to strengthen suppressed flora and fauna in the residential area. Green roofs contribute to decentralised retention, delayed drainage and the evaporation of surface water. They have a stabilising effect on the microclimate, since the ro surfaces heat up less, they bind dust particles and they promote water evaporation from the plants and substrate surfaces. They should also be available to the insect world and to birds as a substitute habitat. Greened roof areas also contribute to an increase in the value of the urban space, as they can be used freely and/or can be seen from other buildings and experienced as a verdant enrichment to the surroundings. A minimum root-penetrable substrate thickness of 15 cm for shrubs and grasses makes it possible to achieve a lasting greening of roof areas. Since all greening measures are at the same time also measures to mitigate interventions in nature and the landscape, these, with all their positive impacts in the natural environment, are to be permanently maintained.

☐ 06 TYPES OF USE

Brief explanation

Green roofs must fulfil ecological, design and functional requirements.

A clear use concept developed early on is a prerequisite for avoiding undesirable developments and deficits, because adapted substrate types and thicknesses, plant suitability and maintenance must harmonise unerringly. The effects of green roofs can be divided into active and passive benefits:

Active benefits lie in the increased supply of public and private space and its quality of use (recreation, health, exercise, play, sports, rest, natural diversity, improvement of the microclimate), visual quality (design diversity, residential attractiveness) and year-round improvement of the residential environment. Green roofs create additional planted areas on the same lot area without additional land acquisition costs.

The **passive benefit** of green roofs is rooted mainly in ecological objectives to support of urban flora and fauna, in oxygen production that contributes to an improved climate, in the filtration of air pollutants, in carbon storage and in evaporative cooling. Other passive benefits are the protection of

the roof waterproofing against weather influences (temperature extremes/ UV radiation), mechanical stresses (hail) and chemical loads and the reduction of airborne sounds. Furthermore, green roofs retain 50–90 per cent of the annual precipitation and up to 30–40 per cent of a heavy rainfall; this water then evaporates or it is released in a delayed fashion at lower flow rates and thus the drainage systems are relieved. Greened roof areas are subject to 50 per cent lower storm water fees.

Exemplary stipulations

- In the general residential areas, at least two thirds of the roof areas are to be provided with a root-penetrable substrate assembly at least 12 cm thick, and they shall be extensively greened and maintained. It is possible to combine equipment for the use of solar energy and green roofs.
- Equipment for the use of solar radiation energy are to be installed on raised supports above a green roof covering the entire rooftop.
- Roof areas of up to 100 m² must at least be planted extensively. If they are not actively used as functional open space, for instance as recreational, play or sports areas, a richly varied habitat must be created for greater species richness.

Exemplary statements for substantiations

- A day care centre for children is planned within the general residential area. Here, at least two thirds of the building's roof areas must be greened. This makes it possible to create the necessary essential superstructures on the remaining roof areas to accommodate technical equipment and to create transparent roof openings for the realisation of naturally lit spaces for the sake of improving the quality of the indoor environment for the children and carers. Roof superstructu res also include technical facilities for solar heat recovery and power generation. Simultaneous use of green roof areas is not ruled out; it actually increases the efficiency of raised systems at times of high summer temperatures due to the cooling effect of the roof vegetation.

- The use of green roof areas and equipment (raised) for the use of solar energy complement each other; positively, on the one hand by increasing the yield of solar energy and on the other hand by providing a shaded living space that is therefore better protected from drying out. Attention must be given to ensuring that the vegetation receives sufficient water and sunlight, even beneath the modules, and it must be noted that timely maintenance measures will be needed to remove plants that are growing too tall.

07 SUPPLEMENTAL COMMENTS AND EFFECTS

In the following, examples are given of stipulations and grounds that can also be specified in development plans independently of green roofs. However, they are also directly related to the stipulations for a green roof, for example when rainwater cannot be completely retained on the roof.

RAINWATER RETENTION AND WASTE-WATER LAW

Brief explanation

Due to the rapid growth of the city and the continued sealing of ground surfaces, heavy rainfall events can in some cases no longer be taken up by the public sewer system. The problem can be addressed by moving away from traditional rainwater disposal and toward rainwater management. With optimal rainwater management in residential areas, the conventional sewer system can be relieved and an approximation of the natural water cycle as it exists in undeveloped areas can be achieved.

The rapid run-off of rainwater from sealed surfaces accounts for increased discharge into bodies of water. Evaporation, retention and infiltration of rainwater as well as decentralised (i.e. on-site) measures lead on the one hand to the hydraulic relief of running waters and, on the other hand, to a reduction of flood damage due to heavy rainfall events.

Water from precipitation that is stored on the green roof can be conducted away via infiltration systems, open drainage systems or conventional sewage systems.

Fundamentally (§ 55(2) of the Federal Water Act, WHG), precipitation is to be collected where it accumulates and – to the greatest extent possible – returned on the premises to the natural water cycle by means of appropriate facilities. All measures for decentralised rainwater management pursue this goal, are cost-effective, technically well developed and easy to implement.

With the introduction of the "split wastewater fee" in May 2012, a financial incentive was created to reduce the fee-based discharge of rainwater into sewers and – for existing buildings – to encourage the implementation of decoupling measures.

The decentralised, near-natural approach to handling rainwater on properties is portrayed in the following brochures issued by the City of Hamburg:

- *„Dezentrale naturnahe Regenwasserbewirtschaftung"* [Decentralised near-natural rainwater management] (new edition in progress) www.hamburg.de/regenwasserbroschuere/
- *„Regenwasser Handbuch – Regenwassermanagement an Hamburger Schulen"* [Rainwater manual – Rainwater management in Hamburg schools] www.hamburg.de/contentblob/4106776/24ca1633b9644e7a9ef65803cf537eeb/data/regenwasserhandbuch.pdf

Note: § 55(2) of the Federal Water Act (Wasser haushaltsgesetz, WHG): "Precipitation water shall be percolated locally, used for irrigation or discharged either directly or via a sewer system into a water body without being mixed with waste water, in so far as neither water law nor other provisions of public law or water management are in contradiction."

Exemplary statements for substantiations

- In the special-use areas and the commercial / light industrial zones, the precipitation water that accumulates from the roof areas and footpaths shall be percolated in order to impair the local soil water conditions and groundwater levels as little as possible and to keep the precipitation water within the natural water cycle. The precipitation water that accumulates from the roof areas and footpaths does not reveal any significant pollutant loads, even in the case of commercial or light industrial use. Percolating the precipitation water through a surface horizon effectively ensures its pre-clarification.

Exemplary stipulations

- The water from precipitation that falls on private properties is to be conducted into the public drai nage system via open trenches and swales.

Legal basis: Nature conservation law, § 4(3) HmbBNatSchAG

- The water from precipitation that falls on areas of private property is to be retained on the respective properties via the vegetation-covered soil zone and swales or via swale-trench systems, then conducted into a swale and percolated into the ground.

Legal basis: Nature conservation law, § 4(3) HmbBNatSchAG

- In the special-use areas and in the commercial / light industrial zone, the precipitation water that accumulates from the roof areas and footpaths is to be percolated through the surface horizon.

Legal basis: Nature conservation law, § 4(3) HmbBNatSchAG

- In order to retain the surface water, infiltration ditches of approx. 1 m width shall be laid out at the backs of private properties in purely residential areas. The subsoil on the site, below an ave rage 0.7 m thick topsoil layer, consists chiefly of well-permeable fine, medium and coarse sands. The prerequisites needed for infiltration of the accumulated precipitation water are thus given in the greater part of the development areas.

- The surface water from the roof areas shall be percolated directly on the properties using infiltration ditches with perforated pipe. The trenches shall be located in the rear part of each private property and connected with one another to form a system. This allows discharged water in areas with lower soil permeability to spread into more permeable zones and percolate without causing damage.

COMBINATION WITH TECHNICAL SYSTEMS

Brief explanation

Roof locations used for the installation of photovoltaic systems for generating electricity and/or solar thermal systems for recovering thermal energy must be greened over their entire surface. To do so, the technical equipment must be raised up, and the distances between the rows of modules, their depth and their position above the roof must be coordinated with the vegetation.

Exemplary determination

- Equipment for the use of solar radiation energy are to be installed on raised supports above a green roof covering the entire rooftop.

Exemplary statements for substantiations

- Simultaneous use of green roof areas and equipment (raised) for the use of solar energy complement each other positively: For one thing, the green roof's low surface temperature (compared to roofs exposed to the weather or covered with gravel) results in less heat build-up that would adversely affect the photovoltaic modules, and thus it leads to a greater solar energy yield. For another thing, varied solar radiation conditions and moisture levels develop on different parts of the roof, resulting in varying site conditions that contribute to an increase in the biodiversity of flora and fauna.

Additional information

- As penetrations and ascending components, all roof superstructures for technical equipment (such as ventilation equipment pads, lift penthouses) must be designed in accordance with DIN 4102 Part 7 with the specified protective strips of gravel or concrete slabs. To ensure good performance, portions of the roof need to be kept free for inflow and outflow, and these are not suitable for greening.

AIR POLLUTANTS

Brief explanation

In order to reduce air pollutants, the potential of greenable roof areas must be fully exploited. Green roofs or facades can have a positive effect on air quality in the densely built inner city by binding particulates, metabolising air pollutants and producing oxygen. In street segments with high levels of fine particulate air pollution, the green roof and other biomass can improve the overall air quality situation by binding fine particulates and, to a lesser extent, nitrogen dioxide. Fine particulates agglomerate on leaves to form larger, non-respirable particles and, through the annual renewal of the foliage, enter the resource cycle in physically and chemically modified form [see 23; 26].

To optimise this effect (for NO2), mosses should be present in the vegetation composition. Moss growth on gravel edge strips and joints of pavers and slabs should be tolerated.

NOISE

Brief explanation

Substrate on the roof affords increased acoustic insulation. For the upper floor, however, the other surrounding components (walls and windows) are of course also important for the total sound attenuation of the building's exterior envelope. Crucial to the roof's insulating performance is the mass that is applied (substrate height and composition).

HYGIENE

Food hygiene and green roofs do not contradict each other. Regulations on food hygiene are concerned with the interiors of places of business. If the required hygiene standards are not achieved in the interior spaces, technical measures must be taken – such as additional filtering measures in the ventilation equipment, insect protection at ventilation openings and windows or positioning the ventilation openings higher.

Even with a conventional flat roof, insects or other pests are found in the immediate vicinity of a building; a green roof does not change this situation.

☐ 08 LEGAL BASIS

Urban development grounds

- § 1(5) of the BauGB [German Federal Building Code], general grounds pertaining to urban development
- § 9(1)(25) BauGB, planting requirement can be used as a legal basis for stipulating green roofs (also for parts of buildings: roofs + facades).
- § 81(1)(2) HBauO (“äußere Gestaltung” [exterior design]) (in conjunction with § 5(1) Bauleitplan feststellungsgesetz [Land-use planning approval act])

Nature conservation grounds

- § 9(1) HmbBNatSchAG, biotope network, biotope cross-linking
- § 4(3)(1) HmbBNatSchAG in conjunction with § 9(3)(1)(4) BNatSchG

Climatic grounds

- § 1a(5) BauGB, issue for consideration, no determination according to § 9(1)(23), general
- HmbKliSchG: eventually possible, but in Hamburg not part of the land-use plan (only statutory authorisation under § 4(1) HmbKliSchG “Anschluss- und Benutzungsgebot”)
- For grounds of urban development and climate alike (but not for purely climatic grounds) the greening of roofs can be stipulated on the basis of § 9(1)(25) of the BauGB. It must be demonstrated that the required and indeed feasible green roofs can actually make a tangible contribution to improving the urban situation (with regard to (open space) design, binding of particulates and dust, noise reduction, cooling, etc.).

Water management grounds

- § 9(4) HmbAbwG The draft amendment to the Hamburg Wastewater Act stipulates that infiltration areas are to be provided for rainwater, a discharge rate for rainwater can be specified and the discharge of rainwater is to be retarded by means of rainwater retention systems.



Your green roof: Guidance and information

Here you can apply for Hamburg's green roof subsidy
The IFB Hamburg advises on all matters of funding and assists in the application process. Information about all IFB Hamburg programmes and funding guidelines, along with the corresponding forms, can be found at www.ifbhh.de/gruendachfoerderung

Hamburgische Investitions- und Förderbank (IFB Hamburg), Besenbinderhof 31, 20097 Hamburg,
Telephone: 040 248 46-345, Fax: 040 248 46-432, e-mail: energie@ifbhh.de, www.ifbhh.de

Green roofs are designed by architects and landscape architects and constructed by gardening and landscaping specialists or by roofing contractors. Recommendations can be obtained from the relevant trade associations and the following organisations.

Federation of German Landscape Architect
Hamburg state association
Holstenring 18, 22763 Hamburg
email: hamburg@bdla.de
www.hh.bdla.de
www.landschaftsarchitektur-heute.de/bueros
(search via „Erweiterte Planungsbürosuche",
Schwerpunkt „Dach- und Fassadenbegrünung")

Hamburg Chambers of Architects
Grindelhof 40, 20146 Hamburg
www.akhh.de (search via "Architekten- und Stadtplanersuche")

Hamburg House of Landscaping
Association for Landscaping and Sport Grounds Construction Hamburg
Hellgrundweg 45, 22525 Hamburg
Telephone: 040 340983, www.galabau-nord.de

Roofers' Guild of Hamburg
Barmbeker Markt 19, 22081 Hamburg
Telephone: 040 29 9949-0
email: innung-hamburg@dachdecker.de
www.dachdecker-innung-hamburg.de

Hamburg Chamber of Crafts on ELBCAMPUS
The "ZEWUmobil" energy experts from the Centre for Energy, Water and Environmental Technology (ZEWU) and the consultants at the EnergieBauZentrum will advise you about green roofs. Here you can also find out about other funding programmes offered by IFB Hamburg and the KfW Banking Group.
Telephone: 040 35905-505, www.zewumobil.de
Telephone: 040 35905-822, www.energiebauzentrum.de

Hamburg Chamber of Commerce
The Hamburg Chamber of Commerce has created the advisory service "HK-Energie-Lotsen", which helps small and medium-sized companies to identify and make optimum use of energy-saving potentials – such as those of green roofs.
Telephone: 040 36138-979
email: energielotsen@hk24.de, www.hk24.de

Hamburg Consumer Centre
Consultation by phone / energy and climate hotline
Telephone: 040 248 32-250
Mon.–Thurs. 9:30 am–4:00 pm, Fr. 9:30 am–2:00 pm
email: klima@vzhh.de, www.vzhh.de

Here you can find information (in German only) about constructing green roofs: Bundesverband GebäudeGrün BuGG e.V.: www.gebaeudegruen.info

Mandatory requirements are listed in "Förderrichtlinie für die Herstellung von Dachbegrünung auf Gebäuden" [Funding guidelines for the construction of green roofs on buildings]: www.ifbhh.de/gruendachfoerderung

In-depth information about combining green roofs and rainwater harvesting is available on the website of the Fachvereinigung Betriebs- und Regenwassernutzung e. V.: www.fbr.de

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