

**ON YOUR ROOF —  
GET SET —  
GREEN!** GREEN ROOF STRATEGY  
FOR HAMBURG

## **HAMBURG'S GREEN ROOFS**

**ECONOMIC**

**EVALUATION**

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# AUF DIE DÄCHER — FERTIG — GRÜN! HAMBURGER GRÜNDACHSTRATEGIE

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## An Overview

With its current housing programme and the development of commercial sites, the Senate of the Free and Hanseatic City of Hamburg is setting new standards. The goal is to build at least 10,000 apartments and develop new commercial areas every year. As a result, the city will become more dense and there will be noticeable effects on the sealing of surfaces, the climate and the amount of open space. Hamburg's roofs have a great potential to mitigate these consequences. Hamburg's green roof strategy is pursuing the goal of developing new open space on rooftops and of taking advantage of green rooftops as a resource for rainwater storage and climatic comfort.

This publication deals with the economic dimensions of green roofs in Hamburg. By looking at the creation of nearly a dozen green roofs in the Hanseatic city, it considers the investment and maintenance costs involved as well as the economic benefits and effects. Everyone involved with the planning of buildings and the cost issues of green roofs is addressed here, and property owners and other decision-makers will find convincing arguments for investing in green roofs.

The results of this study show that an investment in green roofs is all the more worthwhile, the earlier and more consistently the topic is made a part of the planning process. The cost of building a green roof amounts to about 1.3% of a building's overall construction costs. In multi-storey residential buildings this share can sink to as little as 0.4 % of overall construction costs. When considering life-cycle costs, both black roofs (i.e. without greening) and green roofs have similar costs over a 40-year period.



## Objective and Approach

There are many reasons for creating green roofs in compactly built cities. Whether and to what extent a green roof is economical compared to a non-green roof depends on many different factors. This study has estimated the current production and maintenance costs of various Hamburg construction projects and used them as the basis for an economic feasibility study. In the process, different cost considerations were made: The investment in and maintenance costs of a green roof itself, the share of green roof costs as a part of total roof costs and total building costs, and green roof costs related to the usable area and life cycle costs over a period of 40 years.

The data results from an evaluation of the real construction costs of the buildings as well as a quotation price comparison of a current call for proposals. In addition, a survey of experts revealed what are often controversial aspects of cost calculation and accrual regarding green roofs, the results of which are presented here.

The study resulted in transferable findings for the construction of green roofs on buildings in Hamburg, and especially for residential buildings and commercial construction projects.

## Structure and Types of Green Roofs

### ■ STRUCTURE

According to the Green Roof Guidelines published by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e. V. (Landscape Research, Development and Construction Society, FLL), every professionally built green roof has the following standard structure (see Fig. 1), starting with root-resistant roof waterproofing:

- **Protective layer:** This protects the roof waterproofing and/or against root penetration.
- **Drainage layer:** Due to its cavity volume, this takes up excess water and guides it to the roof drains. At the same time it provides water storage, enlarges the root zone and has a protective function for the underlying structure.
- **Filter layer:** This prevents finer soil and substrate elements from being washed from the vegetation layer into the drainage layer, thus impairing the water permeability of this layer.
- **Vegetation stratum:** This forms the basis of plant growth and must allow for strong root growth. It consists of substances mixed together or of soil prepared according to defined requirements, and is thus also referred to as **substrate**.

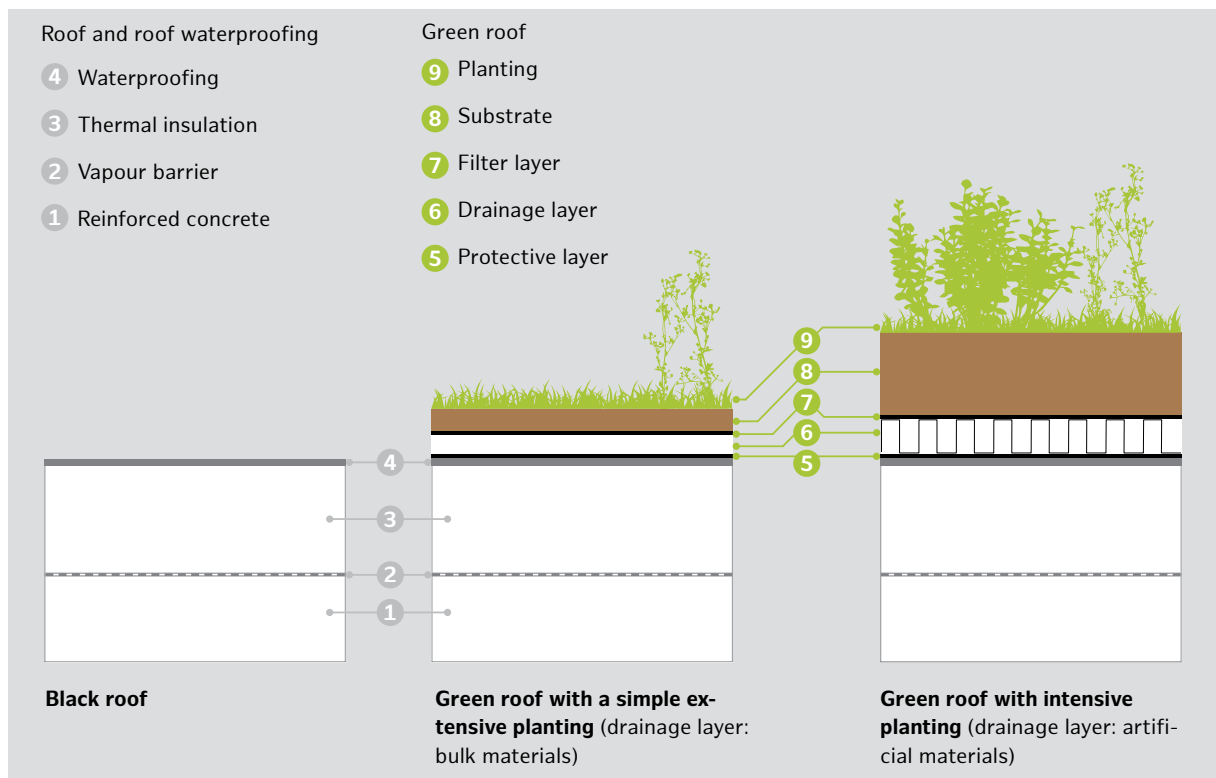
## ■ TYPES OF GREEN ROOF

Green roofs can be divided into three types, depending on the use, the technical parameters and the type of construction. In turn, the type determines the corresponding plant selection and appearance:

- **Intensive greening** can consist of perennials, grasses, bulbs, summer flowers and shrubs, and in individual cases, trees and lawns. They can be planar, height-differentiated or punctiform. With the appropriate features, they are comparable to ground-based open space in terms of the options for use and design. This type of greening can only be permanently maintained through intensive care, and especially a regular supply of water and nutrients.
- **Simple-intensive greening** usually consists of groundcover plants with grasses, perennials and shrubs. The use and design of such planting is limited in comparison to intensive plantings. The plants used are less demanding with regard to the layer structure, as well as on the supply of water and nutrients. They are less complicated to build than intensive greening and maintenance is also less demanding. Depending on the goal of the planting, self-propagating vegetati-

on, e.g. groundcovering herbs and mosses, can be tolerated.

- **Extensive greening** is similar to near-natural forms of vegetation that are largely self-maintaining and self-propagating. Plants with a high regenerative capacity and a special adaptability to extreme site conditions are used. The effort involved in creating and maintaining extensive plantings is generally lower than it is for intensive plantings.



■ Fig. 1 – Standard construction of a roof (warm roof) without and with roof greening



## Cost Distribution during Construction

When considering the costs of green roofs, it is interesting to find out how the costs are distributed among the individual components of a green roof, and what the price difference between different suppliers is.

This consideration is made possible by evaluating a price comparison of offers for an extensive green roof in a real call for proposals from 2016 for an approx. 300 m<sup>2</sup> green roof. The comparison of prices is shown in the adjacent table.

The following conclusions can be drawn from this:

(1) The prices vary depending on the position, and overall vary strongly; average values for the respective types of work are hard to derive. The totals of the offers vary greatly, ranging from about 10,500 € (approx. 35 €/m<sup>2</sup> roof area) to almost 17,000 € net (approx. 58 €/m<sup>2</sup> roof area), i.e. 1.5 times the first offer. This means that a qualified invitation to tender and the obtaining of various offers can strongly influence construction costs.

((2) The proportionate costs per position, on the other hand, are comparatively similar: The most expensive positions typically involve the drainage elements (on average 22.3 % of the bid total) and the substrate (on average 20.6 % of the bid total), followed by the extent of the gravel edging (on average 17.8 % of the bid total) and associated gravel

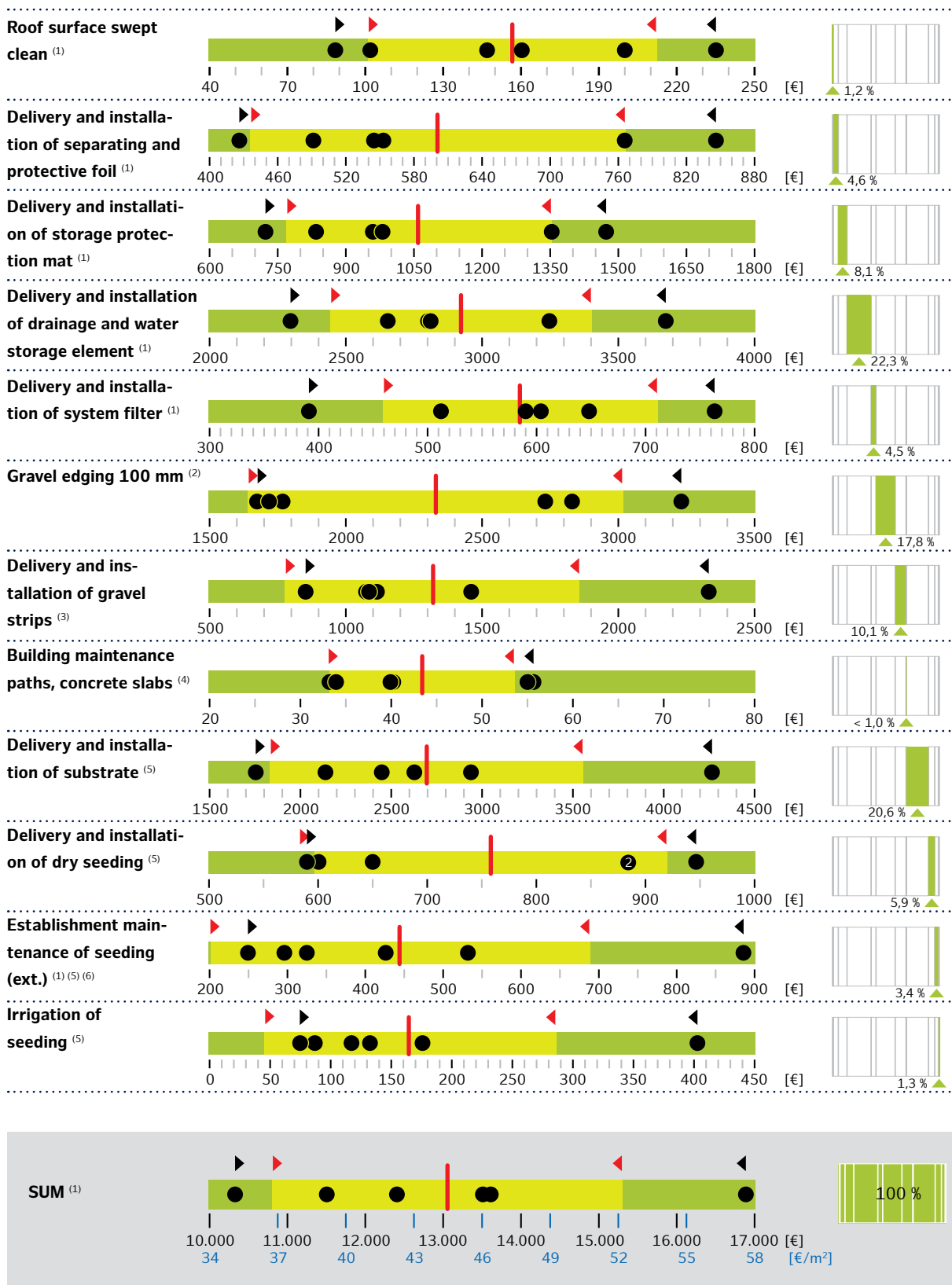
strips. Preparing for construction and the building of maintenance roads are negligible costs.

(3) Price optimisation for green roofs is possible for the positions that are proportionately more expensive, and achieved by searching for alternatives. Costs could possibly be reduced through modified structures (single-layer instead of multi-layer greening), drainage layers (bulk material instead of plastic), substrates, the edging of drains (gravel bedding instead of inspection shafts), dispensing with gravel edging and the reduction of gravel strips to the sizes required by fire prevention regulations. (B. W. Krupka, expert, 2017).

(4) Little price optimisation is to be expected in the area of completion care. Savings in this position should be avoided in order to achieve high-quality and the rapid development of green roof vegetation.



## PRICE COMPARISON - CONSTRUCTION COSTS



(1) Quantity = 295 m<sup>2</sup> / (2) Quantity = 130 m / (3) Quantity = 75 m<sup>2</sup> / (4) Quantity = 20 m<sup>2</sup> / (5) Quantity = 220 m<sup>2</sup> / (6) Establishment maintenance: Irrigation in dry months, filling-in of gaps between plants and removal of fast-growing, invasive foreign plants

● Value    ▶ min.    ▶ to    | mean value    ◀ to    ◀ max.

Fig. 2 – Price comparison after evaluation of offers for an extensive green roof (roof area 300 m<sup>2</sup>) in 2016



## A Cost Comparison

### ■ SELECTED BUILDINGS

This publication presents nine of Hamburg's buildings. Seven buildings have an extensive green roof, one an intensive green roof and one a conventional black roof, which is used in this study as a reference value for green roofs. The buildings have various functions: public emergency service, schools, sports halls, retail and residential.

This mix of uses is also reflected in the building sizes, which range from 232 m<sup>2</sup> to 5,360 m<sup>2</sup> of usable area (UFA). Multi-storey buildings are as common as single-storey buildings. The flat roof areas range from 196 m<sup>2</sup> for a small entry building to 1,944 m<sup>2</sup> for a 3-field sports hall. This means that the size of the roof areas is typical for urban areas, but by no means on a par with industrial production halls. The costs can also be transferred to residential construction due to the comparable size of the areas.

Each roof examined is unique and has certain peculiarities that also affect the price, and which are shown in the table on the following page. All the roofs were built after the turn of the millennium: The oldest roof dates from 2006; the newer ones from 2012, 2014 and 2015, or they were completed in 2016 at the beginning of, or during, the study. All cost parameters were calculated using a construction price index (May 2017) in order to make them clearly comparable.

All of the buildings investigated are presented on the following pages in a short profile in order to make the mix of factors more perceptible.

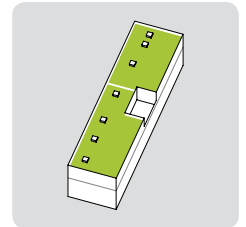
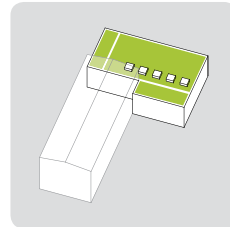
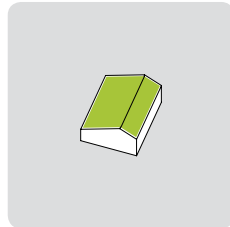
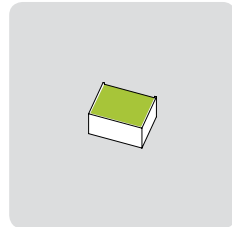
Just as the number of storeys and type of use in the group of examined roofs fluctuate, so too do the building costs. This changes the proportion of green roof costs regarding the overall building costs and the ratio of green roof costs to total roof costs (see Fig. 3, pp. 12/13).



#### **Indices** (some definitions)

In order to be able to economically evaluate Hamburg's green roofs, the following indices were applied:

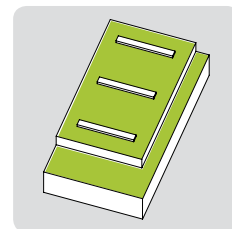
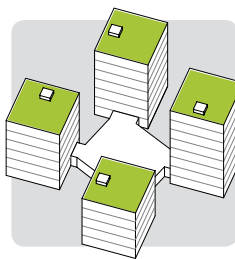
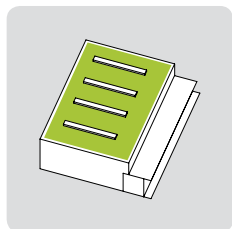
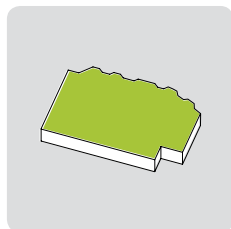
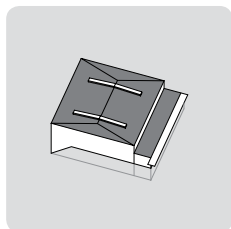
- **Useable area (UFA):** Partial area of the net internal area (NIA), which serves the essential purpose of the building, according to DIN 277 (2016) - *Floor areas and spatial contents in the building industry (building construction)*. Expressed in m<sup>2</sup>.
- **Building costs:** This is the sum of the costs of all the positions for the construction of the entire building. Costs that result as the sum of cost group 300 (building – construction work) and 400 (building - technical systems) according to DIN 276-1 – *Building Costs (Building Construction)*. Expressed in €. i
- **Roof costs:** This refers to the sum of the costs of all the positions for the 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 establishment maintenance - excluding root-resistant waterproofing). These costs can be part of cost group 360 (roofs) or cost group 500 (outdoor facilities) according to DIN 276-1 (2008) - *Building Costs (Building Construction)*. Expressed in €
- All costs are gross, including VAT.



Building number	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Main use	<b>Ochsenzoll Rescue Station</b>	<b>Fire brigade Moorwerder</b>	<b>School / Sport Barmbek-Süd (A)</b>	<b>Othmarschen Rescue Station</b>
Location				
Client	HGV <sup>(4)</sup> (B,C)	HGV <sup>(4)</sup> (B,C)	School building <sup>(D)</sup>	HGV <sup>(4)</sup> (B,C)
Year built	2009	2016	2014	2016
Usable area <sup>(1)</sup>	232 m <sup>2</sup>	349 m <sup>2</sup>	<sup>(5)</sup> 774 m <sup>2</sup>	1.875 m <sup>2</sup>
Cost of construction <sup>(2)</sup>	569.902 €	1.015.979 €	5.849.707 €	5.763.807 €
Cost parameters per m <sup>2</sup> useable area	2.456 €/m <sup>2</sup>	2.909 €/m <sup>2</sup>	1.987 €/m <sup>2</sup>	3.074 €/m <sup>2</sup>
Type of roof	GR Extensiv	GR Extensiv	GR intensive	GR extensive
Roof area	196 m <sup>2</sup>	414 m <sup>2</sup>	591 m <sup>2</sup>	1.000 m <sup>2</sup>
Green roof costs	14.242 €	18.077 €	34.562 €	43.361,22 €
Green roof costs per m <sup>2</sup>	73 €/m <sup>2</sup>	44 €/m <sup>2</sup>	58 €/m <sup>2</sup>	43 €/m <sup>2</sup>
Roof costs <sup>(3)</sup>	48.319 €	57.685 €	-	210.876 €
Share of green roof costs in building costs	2,5 %	1,8 %	0,6 %	0,75 %
Roof waterproofing costs	-	-	-	-
Costs of roof waterproofing per roof area in m <sup>2</sup>	-	-	-	-

(A) Gebäudemanagement Hamburg GmbH [GMH] / (B) Hamburger Gesellschaft für Vermögens- und Beteiligungsmanagement mbH [HGV] / (C) Sprinkenhof GmbH / (D) SBH Schulbau Hamburg / (E) SAGA Unternehmensgruppe Hamburg.

■ Fig. 3 – Compilation of the buildings in Hamburg, with and without green roofs



5 School / Sport Wilhelmsburg	6 Poppenbüttel retail business	7 School / Sport Barmbek-Süd (B)	8 Harburg retirement complex	9 Sport Eppendorf
GMH <sup>(A)</sup> 2015	SAGA <sup>(E)</sup> 2006	School building <sup>(D)</sup> 2014	SAGA <sup>(E)</sup> 2015	School building <sup>(D)</sup> 2012
1.264 m <sup>2</sup> 2.188.961 € 1.732 €/m <sup>2</sup>	1.200 m <sup>2</sup> 1.327.513 € 1.106 €/m <sup>2</sup>	1.946 m <sup>2</sup> 4.986.069 € 2.562 €/m <sup>2</sup>	5.360 m <sup>2</sup> 15.303.054 € 2.855 €/m <sup>2</sup>	2.424 m <sup>2</sup> 4.699.416 € 1.939 €/m <sup>2</sup>
Bitumen roof 1.050 m <sup>2</sup> - -	GR extensive 1.130 m <sup>2</sup> 33.096 € 29 €/m <sup>2</sup>	GR extensive 1.214 m <sup>2</sup> 57.204 € 47 €/m <sup>2</sup>	GR extensive 1.382 m <sup>2</sup> 59.305 € 43 €/m <sup>2</sup>	GR extensive 1.944 m <sup>2</sup> 103.533 € 53 €/m <sup>2</sup>
138.362 €	-	-	-	390.515 €
<sup>(6)</sup> 1,4 %	2,5 %	1,2 %	0,39 %	2,2 %
30.690 € 29 €/m <sup>2</sup>	21.098 € 19 €/m <sup>2</sup>	- -	- -	- -

(1) Usable area (UFA) according to DIN 277 Floor Area and Volume in the Building Industry (Building Construction) / (2) Building costs KG 300-400 according to DIN 276-1 (Costs in Building Construction) / (3) Roof costs: the sum of the costs of all items for the construction of the entire roof - corresponds to cost group 360 (roofs) according to DIN 276-1 / (4) Represented by Sprinkenhof GmbH / (5) The usable area of the entire building is 2,944 m<sup>2</sup> / (6) In this case, the building has a black roof, and only the cost of waterproofing was determined. All prices are in euros and calculated according to a construction price index from May, 2017



The **Ochsenzoll Rescue Station** (1) and the **Moorwerder Fire Brigade** (2) are comparatively small buildings. They only have one storey and thus have an economically less favourable ratio of roof area to building size; and building components, such as the roof or green roof, become significantly more expensive.

The **school in Barmbek-Süd** (3) has a complex sports hall building spatially connected to the school building. The building costs could not be calculated separately for the school building and the hall with green roof. The sports hall has a large number of skylights and is the only building with an intensive green roof. It is thus unique in this investigation.

The **Othmarschen Rescue Station** (4) is a two-storey building with a medium-sized green roof area and has a favourable ratio of circumference to area. The building shows slightly below-average green roof costs per square metre of roof area.

The **school in Wilhelmsburg** (5) is the reference roof and has double-layer bitumen sheeting.

The single-storey **retail building in Poppenbüttel** (6), connected to SAGA residential building, dates from 2006 and is characterised by an extraordinarily cost-effective extensive roof with a simple form.

The **sports hall in Barmbek-Süd** (7) has several large skylights that lengthen the surrounding edges of the green roof, thus making the price/m<sup>2</sup> of roof area slightly more expensive than expected.

The **senior housing complex in Harburg** (8) is also somewhat more expensive in its price/m<sup>2</sup> for the green roofs, because it concerns the four separate, and thus in each case smaller, roofs of the individual residential towers.

The **sports hall in Eppendorf** (9) has the largest roof area, which can compensate for a certain amount of elements that increase the circumference of the building. Although the total area consists of four individual roofs that have large skylights, it is not too far off the usual price/m<sup>2</sup>.

■ RESULTS

The adjacent diagram shows that the larger the green roof is, the lower the green roof costs per m<sup>2</sup> of roof area are.

**Construction costs and vegetation area**

If green roof costs are set in relation to the respective roof area, it becomes obvious that the **costs for most extensive green roofs** are in the range of **40-45 €/m<sup>2</sup> roof area** (the reference value is the total roof area in row 11 of Fig. 3). Of these average costs, about 30 % are attributable to the gravel strip and gravel edging service positions for green roofs (see p. 8, point (2) and (3), as well as Fig. 2), which, under cost-optimisation aspects can be somewhat reduced.

As expected, the intensive green roof is by far more expensive per square metre of roof area (58 €/m<sup>2</sup>) due to the more demanding nature of its planting.

Due to the direct visual reference to the roof at the school in Barmbek (3), however, there is also an additional aesthetic benefit.

### Green roof costs and useable area (UFA)

Green roof costs in relation to the useable area (UFA) range from 11 to 61 €/m<sup>2</sup> UFA, with an mean value of 33 €/m<sup>2</sup> UFA (see Fig. 4).

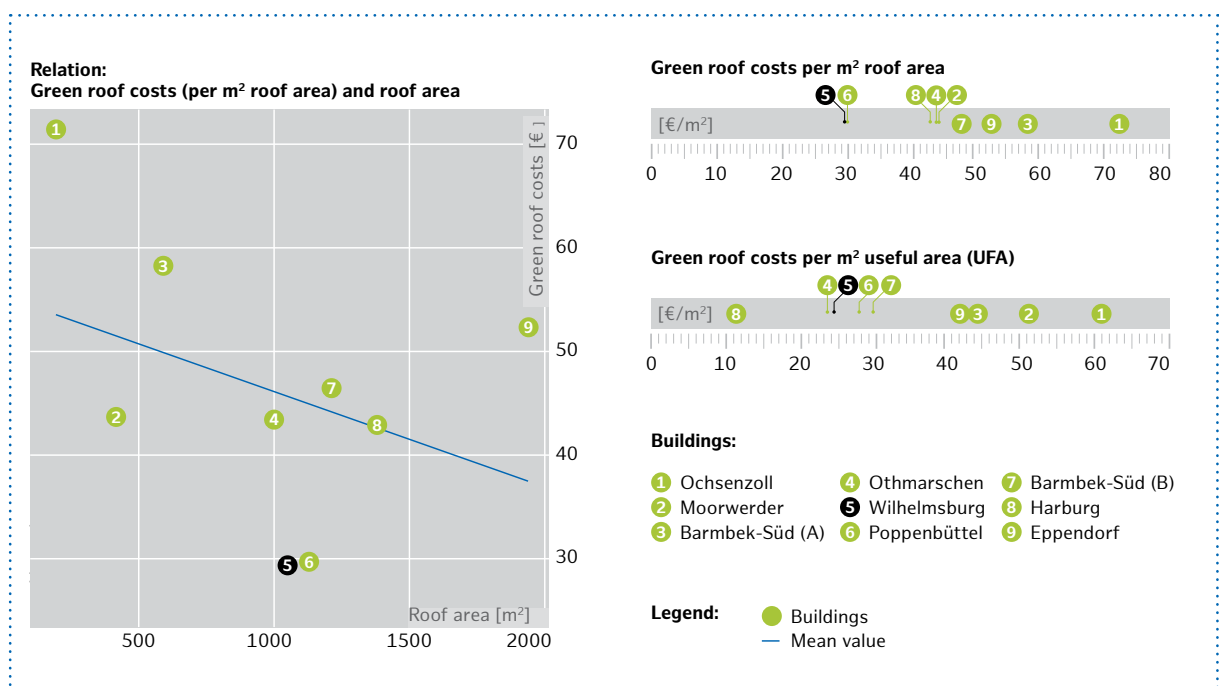
It is noteworthy that the extensive green roof of the senior housing complex in Harburg (8) (UFA: 5,360 m<sup>2</sup>) is 18 € below the square metre ratio of the reference roof (7) in Barmbek-Süd (UFA: 1,946 m<sup>2</sup>). This is a comparison between a six-storey residential building and a one-storey sports hall.

**This shows the positive influence multi-storey buildings have on average green roof costs per usable area, which is a particularly relevant parameter for residential construction.**

### Green roof costs and building costs

On average, the costs of the (green) roof account for about **1.5 %** of the building costs for one- to two-storey buildings. In the six-storey residential complex in Harburg (8), the share of the green roof costs is only about **0.4 %**.

The intensive greening of the two-part school sports building in Barmbek (3) is also well below the average, with green roof costs accounting for approx. 0.6% of the building costs for the entire building. However, only about half of the total roof area was designed as a green roof, and had the higher construction costs associated with intensive greening.



■ Fig. 4 – Green roof costs in relation to the roof area and the useful area

# Economic Life Cycle Assessment

**In addition to the analysis of construction costs, an economic life cycle analysis also includes the consideration of care, maintenance and repair costs as well as considerations of demolition and refurbishment at the end of service life. Furthermore, reduced costs such as rainwater drainage fees are included.**

## ■ SERVICE LIFE

Care begins with the **completion care**, which includes all measures necessary for the growth of the vegetation in the first year. It is therefore considered to be part of construction costs. Successful growth means that about 60% of the substrate's surface is covered by vegetation.

After the final inspection of the building, **general maintenance services** according to DIN 18919 becomes relevant for the long-term preservation of a green roof's advantages. Approximately two to four maintenance visits per year are to be expected; the amount of maintenance required depends on the type of vegetation. An extensive green roof with grasses may require the following work: weeding, in particular the fire protection strips, pruning, fertilising, irrigation of inclined and particularly exposed areas, replanting of bare and eroded areas, and plant protection measures. Extensive sedum roofs are considered to be largely self-sustaining and easy to maintain in the long term.

## ■ FACTORS AND ASSUMPTIONS

Since no data on maintenance care are yet available for the green roofs examined, empirical values of **0.50 €/m<sup>2</sup> to 2.00 €/m<sup>2</sup>** of vegetation area and year must suffice (Sproul et al., 2013; SBH Schulbau Hamburg). The costs depend on roof size, accessibility and green roof construction.

Other cost factors that are difficult to predict were not included in the compilation of Figures 5 and 6. These include **maintenance costs** for minor repairs and, in particular, **savings in energy costs**, which can have a positive effect on the cost balance in the long term. This analysis compares a bitumen roof to the average costs of four extensive green roofs

(Buildings 4, 6, 7, 8, Fig. 3). All have approximately the same roof size of 1,000 to 1,300 m<sup>2</sup>. The different roof waterproofing costs in the real data were adjusted to avoid distorting the comparison (see footnotes in Fig. 5). The exemplary balance sheet included:

- the **construction costs** of the buildings under investigation: see chapter Hamburg's Green-Roofs
- expected **maintenance costs**: 0.25 € (m<sup>2</sup>/a) for the black roof, 0.60 € (m<sup>2</sup>/a) for the green roof
- **Rainwater drainage fees**: 0.73 €/m<sup>2</sup> per year for the black roof, 50 % of that for the extensive green roof.

Thanks to the fact that sealing the roof protects against UV and infrared radiation, extreme weather events (e.g. hail) and drastic temperature fluctuations, the life expectancy of a green roof increases to **30-50 years**. In contrast, a black roof is subject to regular renovation cycles every **15-25 years** (BBSR, 2017). Additional demolition costs for the old roof are not included in this comparison, as no data is available. Periods of 40 and 20 years were chosen for this comparison.

A constant interest rate of 3% per year is assumed in order to take long-term price trends into account.

## ■ RESULTS

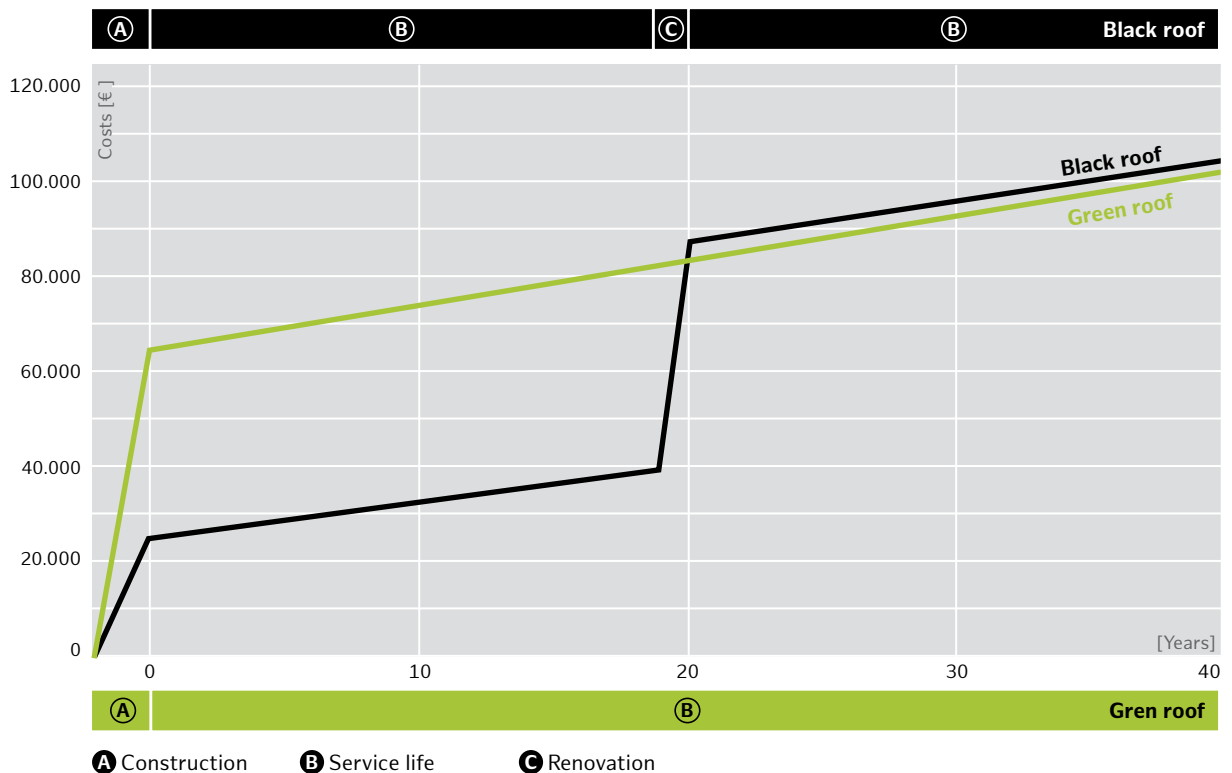
The adjacent graph and table overview show that even if other positive cost factors are neglected, **green roofs can, in the long term, have similar or even slightly lower costs than bitumen roofs.**

This result is in line with the results of cost-benefit analyses previously carried out by various authors (see, e.g. Mann, 2005), who established the long-term financial advantages of green roofs over non-green roofs as early as the late 1990s.

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

(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

■ Fig. 5 – Economic life cycle assessment



■ Fig. 6 – Graphic illustration of life cycle assessment for 40 years



## Economic benefits

**A representative greening of a building leads to an increase in the value of the property and to an image gain. If green roofs are planned as useable roofs and architecturally integrated, buildings, residents and employees all benefit. According to an estimate by TÜV Süddeutschland, the financial “green added value” of usable intensive green roofs was 6-8% more rental income.**

### ■ USED GREEN ROOF = HABITAT

Green roofs can be designed as usable open space with little additional effort. This space can then be made available to owners, tenants and/or employees, and - especially in densely populated inner city areas - supplement the limited amount of public space for recreation, health and leisure. Green roofs create additional green space on the same site without additional land acquisition costs.

### ■ PROFITABLE USE OF ROOFS

With a green roof, companies actively demonstrate that they are acting sustainably and making a contribution to the diversity of nature in the city, thus creating competitive advantages for themselves. Within the framework of DGNB certification for sustainable construction, green roofs are rated as positive, so that green roofs can be quantified directly.

Under nature-conservation-related intervention and compensation regulations, green roofs are included in the balance as a reduction measure. In this way, an intervention in a site’s ecological values can be partially compensated for directly on site, and the need for expensive compensatory measures can be reduced elsewhere.

However, according to the current state of research and developments in construction practice, these and subsequent aspects are not yet clearly quantifiable in monetary terms, but according to empirical values and calculations they do indeed provide a financial advantage (all the following data see Pfoser et al., 2013, and GERICS, 2017).

### ■ THE SYNERGY EFFECTS OF INSULATION

If the green roof is made with elements certified for their insulating performance, direct savings can be made regarding the construction costs: The green roof will be included in calculations as a functional, integrative component of the roof, instead of being considered as an added cost, as savings can be made on the insulation layer. In the winter heating costs will be less, and in the summer the evaporative cooling and thermal inertia of the living roof will provide cooler temperatures, especially in often overheated top floors. This cooling performance



has financial advantages: Running energy costs (and CO2 emissions) are reduced, and smaller-sized cooling systems can be purchased. In the case of large halls, the construction of cooling systems can possibly be omitted, permanently reducing energy costs.

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■ **IN COMBINATION WITH PHOTOVOLTAICS**

Green roofs, which are often up to 40° (C) cooler in summer than bitumen roofs, serve as a base for the mounting elements of photovoltaic modules, increasing the efficiency of the systems by up to 3 % per year and thus shortening the payback period of such an investment.

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■ **LOCAL CLIMATE AND AIR IMPROVEMENT**

The microclimate on the roof, and, to a lesser extent, around a building becomes cooler in summer due to the evaporative cooling effects of a breathing roof. Air humidity is increased when on hot days up to 0.5 l/m<sup>2</sup> of water is evaporated through the surface of leaves. In addition, up to 20% of various air pollutants are reduced, for example a green roof can bind dust particles.

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■ **SUSTAINABLE WATER MANAGEMENT**

Since extensive green roofs also retain up to 50-70 % of annual precipitation and up to 30-40 % of a heavy rainfall, and either evaporate or discharge it

with a delay and reduced flow, drainage systems are relieved. This effect can be further increased with special retention roofs. This in turn results in smaller on-site infiltration or retention systems, which can also save costs.

The combination of green roofs with rainwater harvesting systems is possible if the quantity of water is sufficient. The filter function of green roofs only changes the colour of the water, which can be used for toilet systems or irrigation. The savings are two-fold: Through the use of an additional storage tank the building can be completely freed from having to pay rainwater drainage fees, and drinking water costs can be reduced at the same time.

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■ **INNER-CITY CLIMATE EFFECTS**

Since climate change is likely to not only lead to an increase in heavy rainfall but also to longer and more frequent hot spells, the positive influence of being able to regulate the climate of surrounding areas should not be neglected. This can influence the attractiveness of entire districts. However, the desired effect can only be achieved if green roofs are built throughout a city.



**So-called “indirect additional costs of a green roof” are often included in debates about the cost of green roofs. This study therefore included numerous technical discussions with architects, structural engineers and construction supervisors concerning the following aspects, and the explanations briefly summarise the results of the discussions.**

■ **ATTIC HEIGHT**

If an attic is not high enough from the outset, the height of the green roof may make it necessary to raise the attic by about ten centimetres. If the attic is raised by 10 cm, approx. 15-20 € per running metre will be required, depending on the design (facing brick or plaster facade) (Prof. Dr. Hans-Hermann Sass, structural engineer, 2017). With regard to one square metre of green roof, costs of about 6.50 € to 8.50 € per square metre of roof surface for a plaster facade or facing attic should be calculated (see example, p. 9 with approx. 130 m roof edge border and a 300 m<sup>2</sup> roof surface). However, with many green roof projects (both new construction and renovation) alternative solutions are found in order to avoid these costs. In accordance with DIN requirements, for example, a set-back gravel edging strip is often used in green roof construction in order to prevent it from reaching the attic, thus avoiding the need for a higher structure. Depending on the wind load, the strip of roof cladding between the gravel edging strip and the attic is protected with gravel or concrete slabs.

■ **STATICS**

The consideration of an additional load regarding the statics depends on the chosen roof construction and the desired green roof type. For a gravel roof, a load of 100 kg/m<sup>2</sup> must be assumed, which corresponds to the usual average of a standard extensive green roof (80-200 kg/m<sup>2</sup>) and therefore does not

lead to any additional expenditures. If a green roof is planned (independently of a gravel roof) for a reinforced concrete roof using solid construction, with bitumen or plastic sheeting as a protective layer, about 2 kg of additional reinforcement per m<sup>2</sup> roof area must be provided for structural reasons. The foundations do not have to be reinforced as the loads are too low. The additional costs for the extensive greening of a building in terms of total statics are 3-4 € per m<sup>2</sup> roof area, according to experts. With a flat, wooden type of roof construction, reinforcement of the beams should be considered, which can lead to additional costs of 6-7 € per m<sup>2</sup> of roof surface if a green roof is planned (Prof. Dr. Hans-Hermann Sass, structural engineer, 2017).

■ **ROOF WATERPROOFING**

According to the FLL, the construction costs of root-resistant roof waterproofing vary depending on the product, and are cost-neutral compared to a non-root-resistant waterproofing system if selected correctly. For this reason, root-resistant roof waterproofing systems are now generally used in practice, even when a green roof is not used, as there is a desire to minimise the risk of root penetration caused by the growth of spontaneous vegetation.

■ **CONSTRUCTION PROCESS AND SCAFFOLDING**

The construction process is influenced by many factors. If the construction process is properly planned, the construction of a green roof will take no longer than it does with a conventional roof. As a rule, no special scaffolding is required for the construction of a green roof, as the material is brought to the roof by cranes and/or pumps.



# Planning Security with Regard to Costs

## What happens next?

**Planning security is an important criterion in the construction of green roofs. A comprehensive consideration of life cycle costs as well as a weighing of costs and benefits only makes sense if their marginal conditions do not change unexpectedly.**

### ■ WATER MANAGEMENT: FEE SPLITTING

In 2012 Hamburg's water management authorities introduced so-called "fee splitting", which was already common in many other cities and municipalities in Germany. This makes it possible to take the retention function of green roofs into account: Annual rain water charges in Hamburg are 50% less per m<sup>2</sup> of green roof. If necessary, the fee can even be waived completely if rain water is managed on the property itself. There is no indication that this fee-splitting will be done away with in the next few years.

### ■ GREEN ROOF STRATEGY

The Hamburg Senate's Green Roof Strategy has been implemented since 2014 in order to promote "Financial Incentive, Dialogue and Regulation"

Regarding the aspect of "Financial Incentive", the local Ministry of Environment and Energy has created funding guidelines, on the basis of which the Hamburg Investment and Development Bank (IFB) has a budget of € 3 million to use for funding applications for voluntary green roof projects on new buildings or for renovations. This provides property owners with support ranging from 14 €/m<sup>2</sup> to approx. 56 €/m<sup>2</sup> of green roof, plus 50% of the costs for com-

pletion care up to December 2019. The additional funding of open space areas, rain retention, the mounting of solar systems and inner-city locations is possible (see Hamburger Gründachförderung at the IFB Hamburg: [www.ifbhh.de](http://www.ifbhh.de)).

The goal of the "Dialogue" is to address the public, planners and owners of buildings in various ways in order to exchange facts and good examples, and to convince them of the strategy's virtues.

On the third level of action, "Regulation", the construction of green roofs has been made a requirement in development plans in order to commit both the city and private investors through a binding framework regarding new construction.

All in all, this means Hamburg has created a basis for the construction of green roofs and that the decision-making framework will essentially remain constant.



## Conclusion

After evaluating the data, it can be concluded that, especially in multi-storey residential construction, an increase in investment costs due to green roofs can be well below 1% of total construction costs. The life cycle costs over 40 years are comparable to those of black roofs. The range of prices for construction costs submitted by bidders is very wide. In order to reduce costs, it is advisable to obtain several offers from different companies who use systems made by a variety of manufacturers, and to optimise the use of building materials and technical construction methods during planning.

Individual conclusions:

- The subsequent evaluation of documents concerning the cost of green roofs is very complex. For many projects and building owners these are not available in a form that can be evaluated. Due to different designs, comparisons can only be made with great care.
- The construction costs of extensive green roofs - depending on the respective vegetation area - were in the range of 40 to 45 €/m<sup>2</sup> of roof area.
- For a square metre of planned usable area, the mostly single-storey examples in this study required around 32 €/m<sup>2</sup> for an extensive green roof. In the case of the six-storey building, however, the costs were, at 9 €/m<sup>2</sup>, much lower.
- According to experts, with sufficiently good planning no relevant additional costs were identified regarding statics, the height of parapets or the construction process. Additional statics-related costs for extensive vegetation are at most 3-4 €/m<sup>2</sup>, while an increase in the parapet height is not necessarily required, and if it was, the costs were approx. 6.50 - 8.50 €/m<sup>2</sup>. During the course of construction other costs were not usually incurred.
- The production costs of a (green) roof amounted to about 1.3% of the total construction costs of a building. With a six-storey residential building, the green roof accounted for about 0.4 % of the building costs.
- The ability to include green roofs in the intervention-compensation balance in accordance with nature conservation regulations reduces compensation costs needed elsewhere.
- The economic value of improving people's working and living environments, of upgrading the architecture, the microclimate and airborne sound insulation, the filtering of air pollutants, the increasing of biodiversity and improving of energy conservation is difficult to determine.
- Savings through green roofs are possible due to a reduction of drainage costs, the protection of roof waterproofing and an increase in the efficiency of photovoltaic systems.
- In the context of DGNB (German Sustainable Building Council) certification for sustainable building, green roofs are rated as positive.
- Using green roofs for leisure and recreation creates the potential to generate additional income from sales, rentals or leases.



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