GUIDE FOR FACADE VEGETATION TO PROMOTE BIODIVERSITY

Wild Climate Walls for Stuttgart

Foreword

Dear Readers,

we are increasingly seeing and feeling the effects of climate change - not only on a global level, but also here in Stuttgart. Extreme weather events with prolonged periods of heavy rain, heat or drought are on the increase and pose complex challenges for the city and society. For example, experts assume that Stuttgart will have to expect up to 50% rainier winters and around twice as many hot days in summer in 2050.

At the same time, we find ourselves in a world where species extinction and biodiversity loss are increasing rapidly and many animal and plant species are threatened with extinction due to habitat loss, environmental toxins and climate change. According to the UN, the average abundance of native species in most large terrestrial habitats has already declined by more than 20% since 1900. The fact that biodiversity is declining faster than ever before in human history also has drastic consequences for humans and the environment, because, as part of nature, our lives also depend directly or indirectly on a healthy and intact biosphere in many respects.

This makes it all the more urgent to come up with innovative ideas and approaches to counteract this dual climate and biodiversity crisis. In addition to effective climate protection measures, (international) agreements and guidelines, these are also concrete local solutions that help cities to adapt as well as possible to the consequences of climate change and create new natural habitats for native animals and plants - as well as an environment worth living in for future generations. One possibility for this is so-called "nature-based solutions", which ensure more species-rich and climate-regulating greenery in the city.

With the "wild climate wall", our interdisciplinary project team from research and practice has developed just such a solution that combines the topics of construction, microclimate and ecology in a biodiversity-promoting green façade. Over 70 plant species and diverse habitat systems for birds, bats and insects create a new natural space there and offer an opportunity for climate adaptation in high-density urban areas that are difficult to unseal.

In this guide, they pass on the knowledge they have gathered over the last two years and provide transparent information on planning and design options, potential and added value, as well as the costs and benefits of such systems. They also provide information on professional implementation and care, as well as sustainability aspects and the interaction between humans, animals and plants throughout the year. It therefore offers exciting insights for anyone who wants to campaign for a better climate and more nature in our city.

Enjoy reading and using it!

Sophie Mok

The Nature Conservancy
Climate Adaptation Project Coordinator
in the Stuttgart Climate Innovation Fund

1.

Introduction

1. Introduction

Urban greenery is more than just a decorative element in our built environment. Greenery contributes to the well-being and health of city dwellers, reduces urban heat islands, stores rainwater and creates quality and identity. At the same time, the potential of urban greenery extends far beyond its human benefits. With the right planning and care, valuable habitats can be created for urban flora and fauna.

Despite these positive functions, there is a lack of high-quality green spaces in many cities. Pressure and competition for space, especially in growing communities, often lead to a reduction in urban green spaces. In these densely populated and sealed areas in particular, the greening of façades can offer an opportunity to bring more greenery back into the city, even if it cannot necessarily replace natural green spaces.

This guide provides information on this special form of vertical greening. The potential, planning and maintenance requirements of innovative green façades will be presented based on the results of the research projects "The wild climate wall" and "Development of a green façade system to promote biodiversity as part of the urban green infrastructure" (BioDivFassade for short). The focus here is on promoting urban biodiversity - a topic that has not yet received sufficient attention in the field of vertical greening. The guide offers planning tips, advice and practical examples to make the implementation of biodiversity-promoting green façades accessible and easier.

At the same time, the guide is intended to inspire and encourage imitation. This is also intended to promote and support a future-oriented urban landscape - for people, flora and fauna alike .

1.1. Goal and target groups

The aim of the guide is to make green façades tangible and applicable as measures for climate adaptation and biodiversity promotion and thus support their spread. The aim is to give readers an understanding of the interrelationships and framework conditions relevant to planning, whether in new or existing buildings.

At the same time, the guide does not just focus on vertical greenery. With practical suggestions, recommendations on the use of plants and maintenance tips to support biodiversity-promoting greenery, this document is also suitable as a guide for the design and maintenance of various green spaces in the city. Above all, the guide should inspire and encourage the citizens of Stuttgart to bring more nature into their surroundings – whether in their own front yards, on their balconies or on the facades of their buildings.

The guide is formulated and prepared in a generally understandable way. At the same time, the planning and construction of green façades are subject to a large number of regulations and framework conditions. Transparent communication of these regulations and specifications can considerably facilitate and accelerate coordination processes between planners and public and private building owners. With this in mind, in addition to general information, specific content is also provided for specialist and expert groups, including:

- Planners from the disciplines of landscape architecture and architecture as well as environmental and engineering sciences,
- Employees of municipal institutions, offices and municipal administrations,
- Employees in gardening and landscaping.

If these (planning) groups pursue a strong vision together, even complex greening solutions can be successfully integrated into the urban infrastructure.

1.2. Backgrounds

Infobox: Disclaimer

This guide does not replace detailed planning. Each project must be planned individually; no liability is assumed for the design, planning or execution of greening solutions.

The guide brings together the results of two research projects. The "Wild Climate Wall" and "BioDivFaçade" projects involved the development, construction and monitoring of innovative green façade systems. The research work demonstrates the potential and requirements of green façades to promote biodiversity and increase climate resilience (i.e. resistance to climate influences) in urban areas.

The research project "The Wild Climate Wall" was funded by the Stuttgart Climate Innovation Fund together with The Nature Conservancy Europe in the Ivy Line over the period from November 2022 to October 2024 [35].

Infobox: Stuttgart Climate Innovation Fund

In the form of the Climate Innovation Fund, the state capital of Stuttgart provides a funding pot of 20 million euros for innovative projects from science, business and civil society in the field of climate protection and climate impact adaptation. The funded projects should demonstrate innovative approaches, try them out and make them tangible [34]. The Ivy Funding Lline to promote nature-based solutions (NBS) was established as part of a collaboration with The Nature Conservancy.

At the same time, 20 existing green façades in the Stuttgart region were analyzed over a period of two years in the "BioDivFassade" project. The analysis focuses on recording the surrounding urban landscape, the meso- and microclimate, green maintenance and biodiversity on the facades. The key factors for promoting biodiversity on green facades are identified from this data. The project runs from 2022 to 2025 and is funded by the Federal Ministry of Food and Agriculture.

2.

Ecosystems in the city

2. Ecosystems in the city

Cities create special climatic conditions and form their own complex ecosystems. Humans and their activities influence and change the environment and habitat. As a result, many ecosystems in the city differ significantly from natural or near-natural ecosystems. At the same time, the city provides important habitats for people and numerous animal and plant species. Both aspects and their interactions are examined in more detail in this chapter.

2.1. Urban climate

In Central Europe, and especially in southern Germany, average annual temperatures are rising faster than the international average [41]. This is accompanied by a particularly severe degree of climate impact. Possible and in some cases already recognizable consequences include heat, in particular urban heat island effects (> Infobox), dryness and drought as well as extreme weather and flooding events.

Infobox: Urban heat island effect (UHI)

The urban heat island effect describes the temperature increase in urban environments compared to rural or unspoilt surroundings. Depending on their geographical location and size, air temperatures in cities are often several Kelvin higher than in the surrounding countryside. One reason for this is the buildings themselves, as solid building materials such as concrete, for example, store a lot of heat. The high degree of sealing also favors the heating of urban areas and hinders their cooling - especially in conjunction with the often very dark surfaces such as road asphalt. In addition, combustion processes from traffic or energy generation as well as technical systems from building operation release heat and moisture into the urban atmosphere. [53]

Densely populated areas, such as cities, are particularly vulnerable to the consequences of climate change. The reasons for this are, for example, building density and high levels of sealing, but also the lack of ecosystem services provided by vegetation and thus the lack of shading, vaporization or oxygen production [37, 46]. At the same time, in densely populated areas, the negative

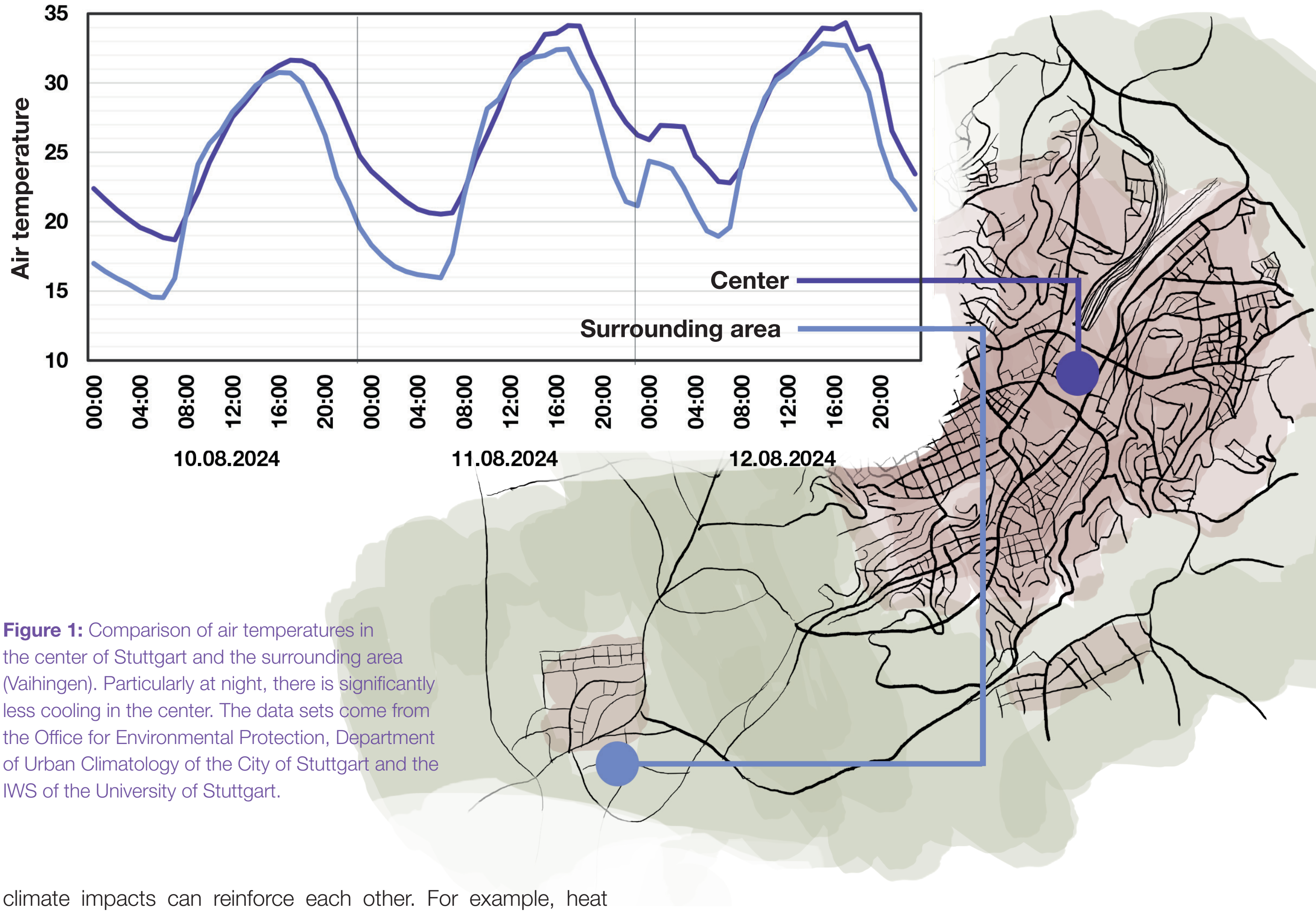


Figure 1: Comparison of air temperatures in the center of Stuttgart and the surrounding area (Vaihingen). Particularly at night, there is significantly less cooling in the center. The data sets come from the Office for Environmental Protection, Department of Urban Climatology of the City of Stuttgart and the IWS of the University of Stuttgart.

climate impacts can reinforce each other. For example, heat and dust pollution in the urban air also increases the local risk of storms [32] and thus the vulnerability of the city in the same way.

City dwellers are therefore already fundamentally exposed to an increased risk of the consequences of climate change. Some population groups are also at risk, for example because they have a pre-existing health condition. These people are in particular need of protection and must be given focused consideration in urban planning. [46]

CLIMATIC INFLUENCING FACTORS IN STUTTGART

The climate of a place is shaped by various influencing factors, including the geographical latitude, altitude and human influences such as building development or agricultural use. Stuttgart's climate is determined on the one hand by its extensive location in the Neckar Valley and on the other by its location in the "Stuttgart Basin". The basin location in particular has a major influence on all measurable and perceptible climate elements, including solar radiation, air temperature and humidity, precipitation and wind.

Other meteorological processes relevant to the city's climate are also influenced by Stuttgart's basin location. For example, the supply of fresh air is noticeably limited compared to "the open countryside". At the same time, air exchange is important for transporting pollutants and warm air masses out of the city. [28, 41]

THE STUTTGART HEAT BOILER

The geographical location and meteorological conditions contribute to Stuttgart being one of the warmest places in Germany. This manifests itself, for example, in a high average annual temperature with few frosts and
many hot days in the summer. The number of days on which the air temperature in Stuttgart rises above 30 degrees Celsius and so-called heat days are reached has been steadily increasing for years. In combination with the high solar radiation, this regularly leads to extreme heat stress in summer. [28, 41]

The Stuttgart Climate Change Adaptation Concept (KLIMAKS for short) identified climate risks in the city of Stuttgart back in 2013. Among the more than 50 countermeasures, however, there is only one measure that is also specifically beneficial to the promotion of ecological diversity [42]. At this point, this guideline supplements and expands the packages of measures already defined with a further measure that specifically addresses the promotion of biodiversity in the city, among other things.

Digression

Climate change and adaptation to climate change

Climate change is a global phenomenon, the causes and effects of which are now thoroughly researched. The primary cause can be identified as the drastic increase in greenhouse gas emissions compared to pre-industrial times. As a result, the composition of the Earth's atmosphere changes, which increases the so-called greenhouse effect. The additional gases in the atmosphere block the exchange of radiation with the space surrounding the earth, which results in an increase in the global average temperature. The effect is comparable to that of a greenhouse, through whose glass roof the sun's rays penetrate and heat the room inside, while the heat radiating outwards is reduced. Other human factors, such as deforestation and increasing soil sealing, as well as various secondary effects, such as the melting of glaciers and polar ice caps, are further exacerbating global warming. [13, 24]

Global warming is a particularly prominent consequence of climate change, but other consequences are also recognizable. The average temperature in Germany has risen by around 1.6 degrees Celsius since pre-industrial times. This also increases the number of hot days. These days with temperatures above 30°C in turn lead to heat stress for humans, animals and plants. Precipitation is also changing, resulting in more frequent heavy and extreme rainfall events. These events favor the occurrence of secondary phenomena such as floods or tidal waves, which can lead to enormous damage to public infrastructure and numerous victims among the population, such as the Ahr Valley disaster in 2021. In other regions, however, it is very dry and there is no rainfall, which can lead to consequences such as drought, crop failures and forest damage. [13, 26]

In order to mitigate climate change and its consequences, it is primarily necessary to protect and rebuild the existing environment. It is becoming increasingly important to implement effective structural and organizational adaptation measures. For urban spaces, this includes the use of green structures.

2.2. Urban ecology

Due to the challenges of climate change, biodiversity (> Infobox), i.e. the diversity of habitats, species and genetic diversity, is constantly being reduced. Low biodiversity in turn impairs the resilience of ecosystems.

Infobox: Biodiversity

The biological and genetic diversity of all species and the diversity of their communities are summarized under the term biodiversity. A high level of biodiversity is the basic prerequisite for the biosphere's resistance to harmful external influences. [15, 65]

FLORA AND FAUNA IN A CHANGING CLIMATE

Not only humans, but also many animal and plant species are suffering from the consequences of climate change that can already be felt today. Among other things, this affects species that live in cities, as the effects of climate change are particularly pronounced here [32, 46]. In the city, for example, plants have to compete with human infrastructure for sun, water and root space. Specialized animal species often lack food, shelter and nesting opportunities. The displacement of certain species can result in further ecological consequences, such as a change in predator-prey relationships.

CITIES AND THEIR ECOSYSTEMS

Some native wild animals have been increasingly drawn to residential areas for several decades. One reason for this is that pesticides are rarely used in the cities and the cultivated landscapes outside the cities are being farmed more and more intensively.

Urban areas therefore contain important ecosystems, just like areas outside cities, and must therefore also be taken into account in environmental and nature conservation measures. Planners, city authorities and residents must find joint solutions to protect species in the city and to improve urban living conditions for people, flora and fauna. One measure to make cities more liveable is the creation and improvement of green infrastructure, for example through green facades. [4, 40].

WILD BEE COLLECTS POLLEN FROM THE FLOWER OF THE PURPLE TOADFLAX (*LINARIA PURPUREA*)
ON THE WILD CLIMATE WALL

3.

Biodiversity promotion on green facades

Positive impact potential of green façades

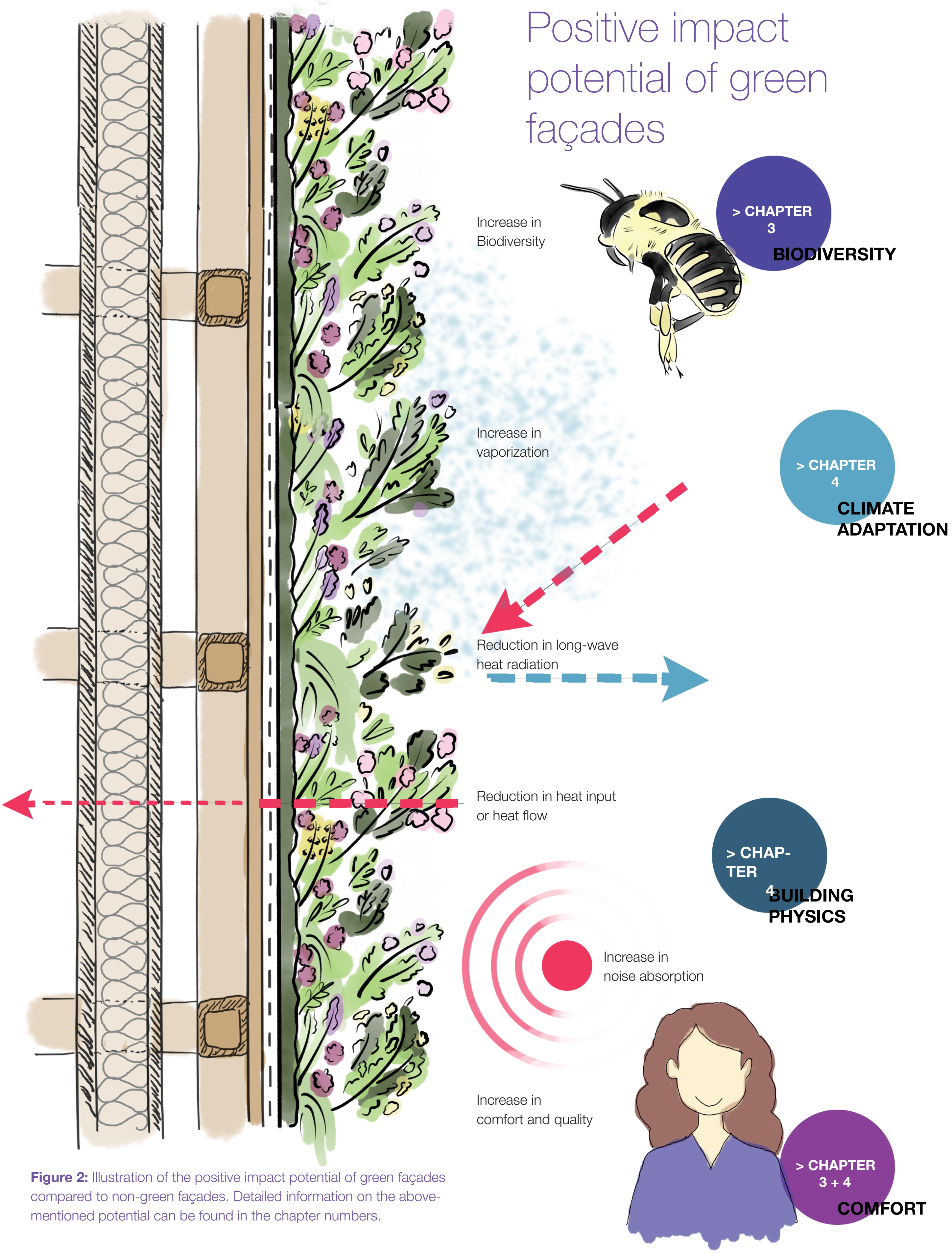


Figure 2: Illustration of the positive impact potential of green façades compared to non-green façades. Detailed information on the above-mentioned potential can be found in the chapter numbers.

3. Promoting biodiversity on green facades

Vertical or wall greening are technical terms for greening systems that allow plants to climb or grow up walls or other existing structures. Systems in which planters are stacked or fixed directly to the wall are also among the options for vertical greening. If the greening takes place on the façade of a building or if the greening forms the room closure, this is referred to as a green façade [10]. A distinction is made between three systems: ground, planter and wall-mounted green façades (> Chapter 5).

Ground-based green façade systems are the simplest and most widespread form of façade greening. These systems can be further subdivided depending on the type of climbing plants used (> Digression: Climbing plants). Wall-mounted systems, on the other hand, are more complex in terms of their technical design and requirements. This chapter concentrates in particular on the presentation of biodiversity promotion in wall-based systems, although the recommended measures and care instructions can also be applied to other greening systems.

VERTICAL GREENING IN URBAN SPACES

As little or no natural soil is required for the cultivation of vertical plants, façade greening can be used for the subsequent greening of heavily compacted urban spaces [10]. This is where the greening of facades offers particular potential, because: The higher a building is, the greater the ratio of façade area to building floor area. Even with windowless façades (e.g. logistics and industrial halls), a multiple of the floor area is available as a vertical surface that can be used for growing plants, even from low building heights. The larger the contiguous façade areas, the easier and more cost-effective it usually is to implement wall greening [9].

As a retrofit greening solution, vertical greenery offers many other opportunities. As with other types of greenery, façade greening is multifunctional and has an effect across several performance categories listed in Figure 2 - both inwards towards the building and towards the surroundings [10]. The effects and functions of green façades are determined in particular by the quantity and nature of the plants used. By individually planning the plant composition, climatic and ecological added value can be specifically promoted.

Digression

Climbing plants

There are different types of climbing plants, which differ in their growth habit and therefore their climbing strategy, and accordingly place different demands on an auxiliary structure. A distinction is essentially made between

SELF-CLINGING CLIMBERS

Self-clinging plants can climb upwards on their own, i.e. without a climbing aid, using aerial roots or suction pads. Examples of this are ivy (*Hedera helix*), which develops aerial roots, or the Boston ivy (*Parthenocissus tric.* 'Veitchii'), which uses suction pads to grow upwards. Old green facades are therefore usually overgrown with self-clinging climbers. However, these plants can also spread more uncontrollably and climb areas where no growth is desired, such as on the eaves, around the windows or in cracks and joints in the façade.

TWINERS AND WINDERS

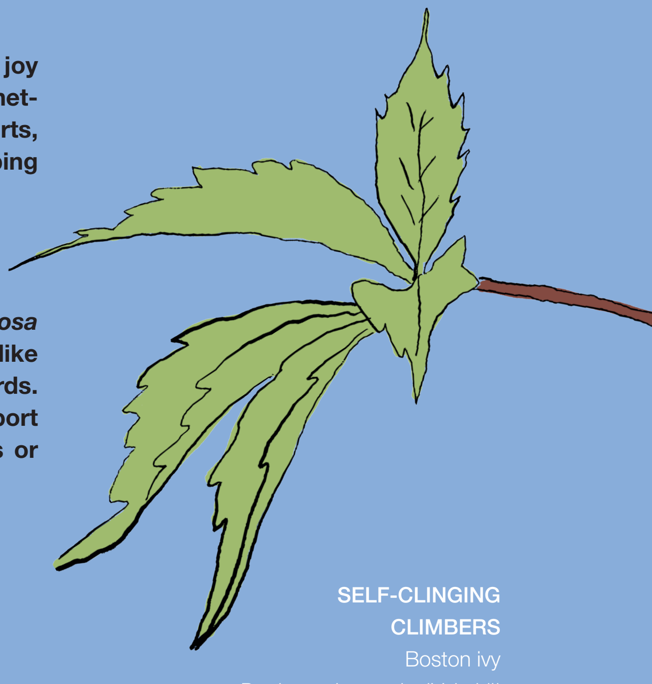
Twiners and winders require a rope or pole-shaped support structure on which they can grow upwards. An example of this is the honeysuckle (*Lonicera periclymenum*).

CLIMBERS

Climbing plants such as traveler’s joy (*Clematis vitalba*) ideally grow on net-like or trellis-like climbing supports, to which they cling with their climbing shoots and climb up in steps.

RAMBLERS

Ramblers such as wild roses (*Rosa* spec.) also need a mesh or lattice-like support structure to grow upwards. The plants hook onto the support structure with their spines, thorns or branches.



SELF-CLINGING CLIMBERS
Boston ivy
Parthenocissus tric. 'Veitchii'

TWINERS AND WINDERS
Honeysuckle
Lonicera periclymenum

CLIMBERS
Traveler's joy
Clematis vitalba

RAMBLERS
Wild roses
Rosa spec.

3.1. Planting to promote biodiversity

When planning a green façade, the quality of the greenery is just as important as the quantity. However, the extent to which green façades can provide valuable habitats for native fauna through targeted planting tailored to their needs is still largely unexplored and has not yet been part of common practice.

But it is obvious: cities are not only home to people, but also the habitat of many animal and plant species (> Chapter 2). If the needs of local, indigenous wildlife, especially endangered species groups, are taken into account in planning and suitable food and habitat structures are provided, cities in the biodiversity crisis can also be seen as an opportunity for some aspects of species and nature conservation. This is because an inclusive urban design that sees people, flora and fauna as a community is better adapted to changes in the environment today and in the future.

DIFFERENTIATION FROM CONVENTIONAL VERTICAL PLANTING

The selection of plants for common green façades is usually based on aesthetic aspects, the suitability of the plants for the vertical location and the availability of plant species in the trade. For this reason, only a few different plant species are usually used, which have already been tested for their suitability for the extreme location of façades in inner cities (high irradiation, sometimes high temperatures, high wind loads) [56]. Well-known species are traveler's joy, clematis species or ivy. Suitable wild perennials are rarely found in horticultural ranges, which are dominated by cultivated plants. However, the choice of resistant, mostly evergreen and homogeneous plant species provides little added value for the native fauna - a topic that has become more of a focus in recent years [45].

Green façades that promote biodiversity should therefore be adapted to local conditions, for example in terms of height, orientation and plant selection. These aspects must in turn be adapted to the needs of the animal species living in the surrounding area. This includes the recording of habitats, e.g. via biotope mapping, species occurrence and frequency as well as the determination of the quality of environmental factors such as air, water and soil. These preliminary investigations and this knowledge should enable concrete conclusions to be drawn about target species (> Infobox).

TARGET SPECIES

In contrast to many conventional green façades, when selecting plants to promote biodiversity, the focus is not (only) on the aesthetics of a vegetation pattern, but also on the needs of the target species. As a result, planting adapted to the target species characterizes the aesthetic image of the green wall.

The target species or target species groups of the wild climate wall are in particular pollinators, especially wild bees, birds and bats. The vegetation is selected in such a way that, in addition to generalists among the animal species, specialists, e.g. different species of wild bees, are specifically promoted. Specialists are species that depend on a specific food source or are dependent on certain other habitat parameters.

The target species of the wild climate wall are presented in digressions. (> Digression wild bees, Digression birds, Digression bats)

Infobox: Target species

Target species are primarily protected species or umbrella species relevant to nature conservation, whose habitat requirements are included in planning strategies. The aim is to specifically promote this species and potentially its associated species.

COMMA
ON THE WILD CLIMATE WALL

3.1.1. Plant selection for wild bees

Native plants are needed to promote native wildlife. Native animals and plants interact perfectly with each other, as they have evolved to work together. Among the specialized wild bee species, some species only collect pollen from a specific plant genus. The viper's bugloss mason bee (*Osmia adunca*), for example, is exclusively specialized to pollen from the native viper's bugloss (*Echium vulgare*) is specialized. Accordingly, the plant selection should be heterogeneous in order to appeal to as many wild bee species as possible. Common comfrey (*Symphytum officinale*), bird's foot trefoil (*Lotus corniculatus*) and spotted dead-nettle (*Lamium maculatum*) are examples of valuable native plants that support both a broad spectrum of insects and specialized wild bee species.

DIVERSE FLOWER SHAPES

A variety of different flower shapes supports a large number of different wild bees and other pollinating insects. Suitable plants that can also cope with vertical growth include

- Umbellifers (*Apiaceae*),
- The daisy family (*Asteraceae*),
- Cruciferous plants (*Brassicaceae*),
- The mint family (*Lamiaceae*),
- The borage family (*Boraginaceae*),
- The bellflower family (*Campanulaceae*).

Their flower shape not only supplies pollen and nectar, it also provides, for example, a place to sleep and nesting material for the bees.

COLOR SPECTRUM FLOWERS

Insects have highly developed abilities to see colors and thus, for example, to distinguish between flowers. Insects see differently from humans. Wild bees and many other pollinators can perceive UV light, and therefore cannot see red. The plants that have particularly conspicuous flowers for wild bees are the most popular for pollination. Highly UV-absorbing flowers in front of a green leaf, which in turn reflects UV light, are particularly popular with wild bees. For example, white and yellow flowers are particularly visible. Corn poppies or red roses are perceived as gray-black and are therefore not as attractive.

DOUBLE AND SINGLE FLOWERS

Ideally, only plant species or varieties with so-called single flowers should be used for planting to promote biodiversity. In contrast, flowers whose stamens have been reduced by cultivation or covered by petals are called double flowers. Double flowers often do not produce pollen (> Infobox Nectar, Pollen) or they are not accessible to pollinators. Semi-double flowers can still provide food in parts. [25]

FLOWERING PERIOD

The flowering period of the planting should also be coordinated with the flight period of the wild bees. The different species of wild bees in Germany fly from the beginning of March until late fall. The pollen and nectar supply should continue over this period.

'WILD BEE SCORE' ASSISTANCE

The 'Wild Bee Score' can be a useful aid in the search for suitable native plants for wild bees (www.wildbienenwelt.de). The score indicates how many different wild bee species use a plant species as a pollen source and is based on data from the book 'Die Wildbienen Deutschlands' [The Wild Bees of Germany] by Westrich [66].

SLEEPING WILD BEE IN A BELLFLOWER
ON THE WILD CLIMATE WALL

Infobox: Nectar, pollen

Wild bees and other insects that visit flowers, such as butterflies, are dependent on nectar and pollen as food. The nectar is produced by the plants as an attractant and serves as a source of energy for adult animals. The pollen is produced in the so-called stamens of a plant, is particularly rich in protein and is therefore reserved for breeding. Not all insects that visit flowers can reach the nectar and pollen of all flowers equally well. The flowers of native plants are usually reserved for specialized and adapted pollinators. Non-native flowering plants can therefore be a useful addition to the food supply for less specialized insects in cities. [25]

HERBARIUM

Plant selection for wild bees and other pollinators

Yarrow
Achillea millefolium

Family
Asteraceae

Flowering period (approx.)
June-July, September

Nectar + +
Pollen + +

Native wild form

wintergreen

Bugleherb
Ajuga reptans

Family
Lamiaceae

Flowering period (approx.)
May-June

Nectar + + +
Pollen +

Native wild form

wintergreen

Common columbine
Aquilegia vulgaris

Family
Ranunculaceae

Flowering period (approx.)
May-June

Nectar + + +
Pollen + +

Native wild form

deciduous

Balsam aster
Aster ageratoides

Family
Asteraceae

Flowering period (approx.)
September-November

Nectar no information
Pollen no information

Non-native wild form

deciduous

White heath aster
Aster ericoides

Family
Asteraceae

Flowering period (approx.)
September-October

Nectar no information
Pollen no information

Non-native wild form

deciduous

Creeping bellflower
Campanula rapunculoides

Family
Campanulaceae

Flowering period (approx.)
June-September

Nectar + +
Pollen + +

Native wild form

deciduous

Cyperus sedge
Carex pseudocyperus

Family
Cyperaceae

Flowering period (approx.)
June-July

Nectar no information
Pollen no information

Native wild form

deciduous

Purple coneflower
Echinacea purpurea

Family
Asteraceae

Flowering period (approx.)
July-September

Nectar + +
Pollen + +

Non-native wild form

deciduous

HERBARIUM

Plant selection for wild bees and other pollinators

Dropwort
Filipendula vulgaris

Family
Rosaceae

Flowering period (approx.)
June-July

Nectar no information
Pollen + + +

Native wild form

wintergreen

Bloody cranesbill
Geranium sanguineum

Family
Geraniaceae

Flowering period (approx.)
June-August

Nectar + +
Pollen + +

Native wild form

deciduous

St. John's wort
Hypericum perforatum

Family
Clusiaceae

Flowering period (approx.)
June-July

Nectar +
Pollen + + +

Native wild form

deciduous

Spotted dead-nettle
Lamium maculatum

Family
Lamiaceae

Flowering period (approx.)
May-June

Nectar + + +
Pollen + + +

Native wild form

wintergreen

Purple toadflax
Linaria purpurea

Family
Scrophulariaceae

Flowering period (approx.)
July-October

Nectar + +
Pollen +

Non-native wild form

deciduous

Bird’s-foot trefoil
Lotus corniculatus

Family
Fabaceae

Flowering period (approx.)
June-September

Nectar + + +
Pollen +

Native wild form

wintergreen

Alfalfa
Medicago sativa

Family
Fabaceae

Flowering period (approx.)
June-September

Nectar + + +
Pollen +

Non-native wild form

wintergreen

Pasqueflower
Pulsatilla vulgaris

Family
Ranunculaceae

Flowering period (approx.)
March-April

Nectar + +
Pollen + + +

Native wild form

deciduous

HERBARIUM

Plant selection for wild bees and other pollinators

Meadow sage
Salvia pratensis

Family
Lamiaceae

Flowering period (approx.)
May-July, September

Nectar + + +
Pollen + +

Native wild form

deciduous

Common comfrey
Symphytum officinale

Family
Boraginaceae

Flowering period (approx.)
June-August

Nectar + + +
Pollen +

Native wild form

deciduous

Wall germander
Teucrium chamaedrys

Family
Lamiaceae

Flowering period (approx.)
June-August

Nectar + + +
Pollen +

Native wild form

wintergreen

Saw-leaved speedwell
Veronica teucrium

Family
Scrophulariaceae

Flowering period (approx.)
May-July

Nectar + +
Pollen + +

Native wild form

deciduous

WILD BEE ON COMMON COMFREY (*SYMPHYTUM OFFICINALE*)
ON WALL-BOUND FACADE GREENING

Digression

Insects . Pollinators . Wild bees

INSECTS AND POLLINATORS

Insects can be found in almost every habitat and at 70%, represent the most species-rich group of all animal species. This makes them an essential part of our planet's biodiversity.

Both in Germany and worldwide, a continuous decline in insects has been observed for decades. This decline relates to both species diversity and the abundance of insect individuals. The Red Lists of endangered animal, plant and fungal species published by the Federal Agency for Nature Conservation (BfN) confirm the negative trend, as does the "Biodiversity Fact Check" as part of the BMBF Research Initiative for the Conservation of Biodiversity (FEdA) of 2024 [69]. According to the Red Lists, for example, around 50 percent of the approximately 600 species of wild bees living in Germany are already endangered.

The type and intensity of agriculture and land use are significant factors in the decline of many insects. This is one of the findings of the BfN Agricultural Report (2017). The causes of the hazard are complex and multi-layered. These include the quantitative loss of habitats due to changes in land use, excessive nutrient and pollutant inputs and the use of pesticides [6].

Specialists or species with low ecological tolerance are often the most affected by changes in ecosystems, as their dependence on individual environmental parameters is greater than that of generalists or species with broad ecological tolerance. However, their relevance for the functioning of ecosystems is equally important. For example, crops pollinated by wild insects produce significantly more fruit sets than plants pollinated exclusively by honey bees [19]. Pollinating insects include wild bees, honey bees, hoverflies, butterflies and beetles.

Pollinators play a key role in terrestrial ecosystems. Plants attract insects through their colors, flower shapes or fragrances and enter into a symbiosis with them. By flying from flower to flower, the pollinators ensure the reproduction of the plants and the plants provide the pollinators with vital pollen, nectar or oils in return. In this way, pollinators make a significant contribution to preserving native plant diversity and at the same time secure a substantial proportion of the world's food supply.

To ensure a stable food supply, German food production is also dependent on pollination by insects. This applies to the cultivation and harvesting of many crops and useful plants, such as fruit, vegetables and arable crops, as well as to the preservation of wild plant diversity. If the entire pollination service provided by insects were to fail in Germany, this would result in a dramatic decline in crop yields. It is difficult to quantify the far-reaching consequences this would have for ecosystems and the economy. In 2015, the value of pollination-dependent production in Germany was estimated at 1.13 billion euros [39].

In addition to their key function as pollinators, insects play an essential role in the decomposition of plant and animal material in our food and material cycles and form the food basis for many animal species, such as various bird and bat species.

The European wool carder bee approaching the lamb's ear (*Stachys byzantina*). The European wool carder bee is polylectic to a limited extent. The wool of furry plants such as sage, mullein and lamb's ear are used to build brood cells.

The viper's bugloss mason bee on the flower of the common viper's bugloss (*Echium vulgare*). This bee species is strictly specialized or olyglectic. The common viper's bugloss is its exclusive food source.

Digression

Insects . Pollinators . Wild bees

WILD BEES

Like honey bees, wild bees belong to the Hymenoptera group of insects and within this to the bee family. In contrast to the honey bee, which lives in a colony, most wild bees live solitary lives. Only the bumblebees and some species of forager bees also form social groups.

Around a third of the wild bees living in Germany are specialists. This means that they only use pollen from very specific plant families, genera or even species. The greater the degree of specialization, the greater the interdependence between the plant and the wild bee. This is also known as oligolectic.

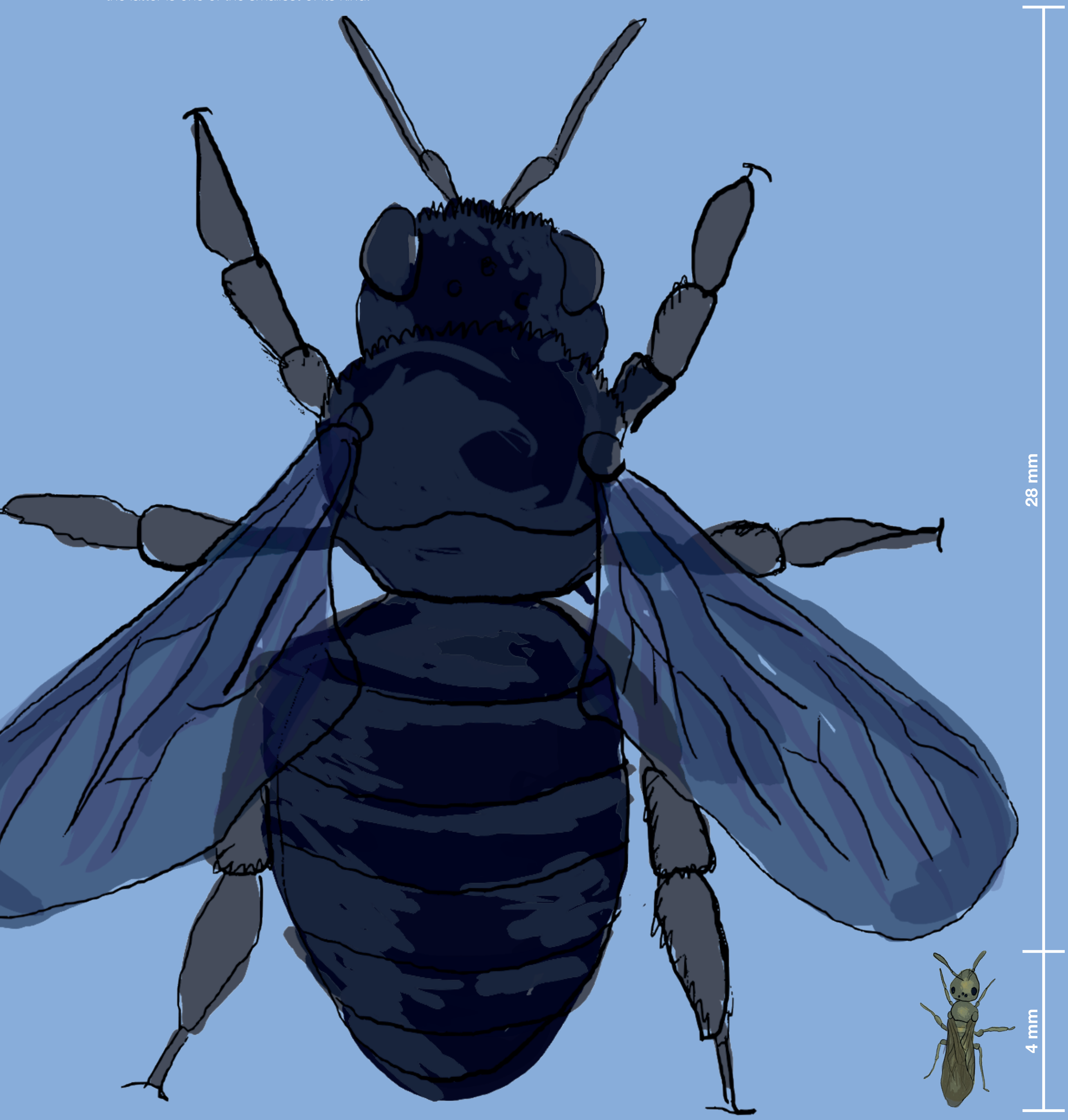
As diverse as the pollen sources of the different wild bee species are, so too is the diversity of the wild bees. Wild bees range in size from approx. 3 mm to 3 cm and have a variety of appearances - sometimes they are rather plump, sometimes slender, sometimes very hairy, sometimes almost smooth and their color spectrum is also remarkable.

The life of a female wild bee is designed to lay eggs and provide her brood with food in the form of pollen and nectar. Female wild bees build their nests without the help of males, which are only used for reproduction. The life cycle of a wild bee is about one year, during which it only flies actively for about four to eight weeks. In solitary bees, the males hatch first. After mating, the females immediately begin to build brood cells. Depending on the wild bee species, the brood cells are located in the soil, in vertical structures, in hollow plant stems or even in empty snail shells. Each brood cell is equipped with an egg and supplied with sufficient pollen and nectar for the complete development from larva to fully-grown bee. The brood cells are then firmly sealed with chewed plant parts, clay, sand, small stones or tree resin. It takes about a year for the next generation of wild bees to fly out of their nurseries. Then the reproductive cycle begins anew.

In order to raise the next generation of wild bees, a female wild bee needs an environment that provides sufficient food, building materials, retreats and a suitable nesting site. All parameters must be present in a relatively small space, because many wild bees, especially smaller species, have a small flight radius, sometimes only 150 meters [22].

Wild bees fly earlier and longer in the year than honey bees. They pollinate flowers that are already in bloom or are still in bloom when the honey bee is hibernating. Bumblebees, which are also wild bees, fly at temperatures as low as three degrees Celsius and even in light rain. Without this diversity of wild bees, the preservation of many wild plants and the pollination of important crops and useful plants that flower particularly early or late in the year would not be possible.

A comparison of the size of the violet carpenter bee and the Lasioglossum glabriusculum sweat bee. At approx. 28 mm, the violet carpenter bee is about 7 times larger than the Lasioglossum glabriusculum. At approx. 4 mm, the latter is one of the smallest of its kind.



3.1.2. Plant selection for birds

STRUCTURAL RICHNESS AND FOOD IN THE FORM OF BERRIES, SEEDS AND INSECTS

A mixture of different leaf sizes, structures and surfaces of the plants create a lively heterogeneity that provides habitat, building material and food for the fauna. Bird species such as blackbirds, greenfinches and house sparrows in particular use these structures to nest directly in the green walls, for example. Shrubs and bushes integrated in the verticals provide food in the form of berries, seeds and insects and complete the attractive habitat structures. For example, the berries of adult of ivy (*Hedera helix* 'Arborescens') and seeds from thistles such as the spiny sow thistle (*Sonchus asper*) are valuable food sources for blackbirds, goldfinches and similar bird species.

NESTING GREENFINCH ON THE WILD CLIMATE WALL

HERBARIUM

Plant selection for birds

Tree ivy
Hedera helix 'Arborescens'

Family
Araliaceae

Flowering period (approx.)
September-October

Nectar + + +
Pollen + + +

Native wild form

evergreen

Mountain currant
Ribes alpinum

Family
Grossulariaceae

Flowering period (approx.)
April-May

Nectar no information
Pollen no information

Native wild form

deciduous

Gooseberry
Ribes uva-crispa

Family
Grossulariaceae

Flowering period (approx.)
April-May

Nectar + + +
Pollen +

Native wild form

deciduous

Purple willow
Salix purpurea

Family
Salicaceae

Flowering period (approx.)
March-May

Nectar + + + +
Pollen + + + +

Native wild form

deciduous

HOUSE SPARROW NEST IN *CAREX MORROWII*
ON WALL-BOUND FACADE GREENING

Digression

Birds

The population of breeding bird species in Germany is one of the most species-rich in Central Europe, with more than 300 species recorded [64]. Most of them, such as swifts, nightingales and chiffchaffs, leave Germany in the fall to spend the winter in the warmer south. Other species, such as robins, blackbirds and great spotted woodpeckers, also remain in Germany over the winter months. They are therefore also dependent on sufficient food during the cold season. Many bird species that otherwise primarily eat insects also eat seeds, grains, nuts and berries in winter.

More than any other wild animals, we encounter birds as a matter of course in our everyday lives and they are part of urban life. Children chasing pigeons and intrusive sparrows in search of food are no strangers to anyone. However, the lives of birds are also vulnerable and the population numbers of many bird species, including in urban areas, have been declining for years. Between 1992 and 2016, Germany lost around 14 million breeding birds. This data is based on the 24-year trend of the BfN's bird monitoring. So-called "common species" such as goldfinches, starlings and swifts are also affected by the decline in bird species [64].

The population declines are primarily due to the fact that not enough offspring are being born. This happens when birds can no longer find a suitable habitat and sufficient food (e.g. in the form of insects, seeds, berries and worms). Birds are particularly exposed to these challenges in intensively farmed areas and residential areas, especially in inner cities.

If there are sufficient species and structural diversity, the populations do well and more offspring are born. Where diverse landscape structures coexist, the intensity of land use is low and settlement density is also low, species diversity is greater and rare bird species also settle there. For example, the north-east of Germany, where 'biodiversity hotspots' are located, is richer in species than the west and south of the country [64].

In addition to the loss of habitat and food, some bird species also have to contend with the extreme heatwaves that are becoming increasingly frequent in our latitudes as a result of climate change. For young swifts, for example, which often breed under roofs or in exposed nesting boxes, high temperatures in the nest can become a deadly danger if young birds fall out of the nest to escape the heat inside [50].

Thanks to extensive bird monitoring in Germany, set up to protect bird life and based on voluntary surveys, state programs and seabird counts by the BfN, reliable figures are available on the population trends of individual bird species. These figures make it possible to assess the current status of the native bird life and, if necessary, to initiate measures to protect a species. So-called species aid programs have led to a recovery of the black stork population from a historic low, among other species. Monitoring is therefore a crucial and effective tool for protecting the native bird population.

Goldfinch
on a thistle

Digression

Hedera helix

Ivy (***Hedera helix***) is a native, evergreen wild plant from the Araliaceae family and can be found in forests as well as on rocks, walls and house walls. Thanks to its versatile use, ivy is also represented in horticultural practice by a wide range of cultivated varieties.

However, ivy only has the ability to climb when it is "young". At around eight to ten years of age, the ivy's abilities and characteristics change and it transforms its outward appearance.
The leaves, which are pointed and three to five-lobed when young, now become rounded and unlobed. The ivy begins to grow like a shrub, become woody and bear flowers and fruit. This valuable plant can live for several hundred years.

Hedera helix is the only native shrub whose flowers don't form until the fall and open between September and October. They carry valuable pollen and nectar and are of great value to many native pollinators, not least because of their late flowering. One species of wild bee has even specialized in the ivy blossom: The ivy bee collects pollen exclusively from the flowers of ***Hedera helix***. Their occurrence is therefore dependent on the existence of the ivy flower.

The berries of the ivy are an important source of food for many native bird species in the winter months. Its structure itself provides safe roosting and breeding sites for numerous birds.

Due to the exceptional characteristics of the adult form of Hedera helix, cuttings from this very form (***Hedera helix*** 'Arborescens') are integrated into the wild climate wall

Ivy (*Hedera helix*)
at a "young age"

Adult form of *Hedera helix*
‘Arborescens‘ in flower

3.1.3. Plant selection for bats

NECTAR-RICH, INTENSELY FRAGRANT WILD PLANTS FOR THE EVENING HOURS

Bats are not attracted by the plants themselves, but by their visitors. Bats prefer to eat insects, especially moths. When the bats become active in the evening hours and swarm out, the moths are also on the move. These in turn are attracted by native, nectar-rich and intensely fragrant flowers. Examples of this are:

» oregano (*Origanum vulgare*) or
» the fragrant evening primrose (*Oenothera odorata*),

which also have open flowers in the evening and at night. Plants that attract moths can therefore be specifically integrated into green façades, thereby increasing the potential food supply for bats.

THE WILD CLIMATE WALL AT DUSK

HERBARIUM

Plant selection for bats

Oregano
Origanum vulgare

Family
Lamiaceae

Flowering period (approx.)
July-September

Nectar + + +
Pollen + +

Native wild form

wintergreen

Sage
Salvia officinalis

Family
Lamiaceae

Flowering period (approx.)
June-July

Nectar + + +
Pollen +

Non-native wild form

wintergreen

Common soapwort
Saponaria officinalis

Family
Caryophyllaceae

Flowering period (approx.)
July-September

Nectar +
Pollen +

Native wild form

deciduous

Red campion
Silene dioica

Family
Caryophyllaceae

Flowering period (approx.)
April-August

Nectar +
Pollen +

Native wild form

wintergreen

Peppermint
Mentha x piperita

Family
Lamiaceae

Flowering period (approx.)
June-August

Digression

Bats

Bats hunt in the dark, eat several thousand insects a night, orient themselves using a sophisticated echolocation system, sleep with their heads down, fly (and are the only mammals to do so) "with their hands" and have fascinated mankind for thousands of years, precisely because of their extraordinary characteristics.

Bats have been around for over 50 million years and are the most species-rich group of all mammals. Worldwide, 1420 bat species have been recorded [57]. Most of them are found in tropical climates, because bats love warmth.

The bat species found in Germany are among the smaller representatives of their species. Their body is usually no larger than 5 cm and their wingspan is a maximum of 25 cm. They sleep during the day and only become active at dusk. They use echolocation to find their way in the dark and go hunting. The animals emit sounds in the form of ultrasonic waves in the high frequency range. When these sound waves, which are inaudible to humans, hit an object (e.g. prey), they are reflected and sent back to the bat's ear as an echo. Depending on the reflection, this can then calculate how large an object is, where it is located and, if it is moving, at what speed. All this happens thousands of times in fractions of a second.

In the fall, the animals go to their winter quarters and prepare for hibernation. Before hibernating, they eat to create a sufficient store of fat so that they can survive the long resting phase. Mating also takes place before hibernation. However, fertilization of the egg does not take place until the following spring, when temperatures are mild and suitable for this part of the life cycle. In addition to sufficient food and suitable hunting grounds, bats need a winter roost, a summer roost and females need so-called nursery roosts to raise their young. Depending on the bat species and their habitat requirements, bat roosts can be attics, caves, crevices, tree hollows or even niches in walls or on buildings.

In the last 50 years, the German bat population has been severely decimated [49]. The BfN Red List (2020) classifies only nine species of the 25 known bat species in Germany as not endangered [47]. The reasons for the dramatic decline in the bat population in Germany are a lack of food (insect shortage) and the loss of potential habitats, which are increasingly being lost in residential areas and cities [58, 63]. The renovation and modernization of buildings using modern construction techniques and the felling of old trees make a decisive contribution to this [20, 48, 55].

The common pipistrelle uses narrow crevices for its nursery roosts, including in urban areas and on buildings.

3.1.4. Spontaneous vegetation

Native, spontaneously colonizing plants ("weeds") represent an added value for the diversity of our habitats and also expand the variety, structure and plant selection of green facades. They should therefore not be rigorously removed, but integrated into the planting to an appropriate extent. Spontaneously growing potentially invasive, non-native species must be monitored and removed if necessary. Current information on invasive species can be found on the BfN's list "Invasiveness assessment of alien vascular plants" at:

https://neobiota.bfn.de/invasivitaetsbewertung/gefaesspflanzen.html

MOSSES
ON THE WILD CLIMATE WALL

HERBARIUM

Spontaneous vegetation

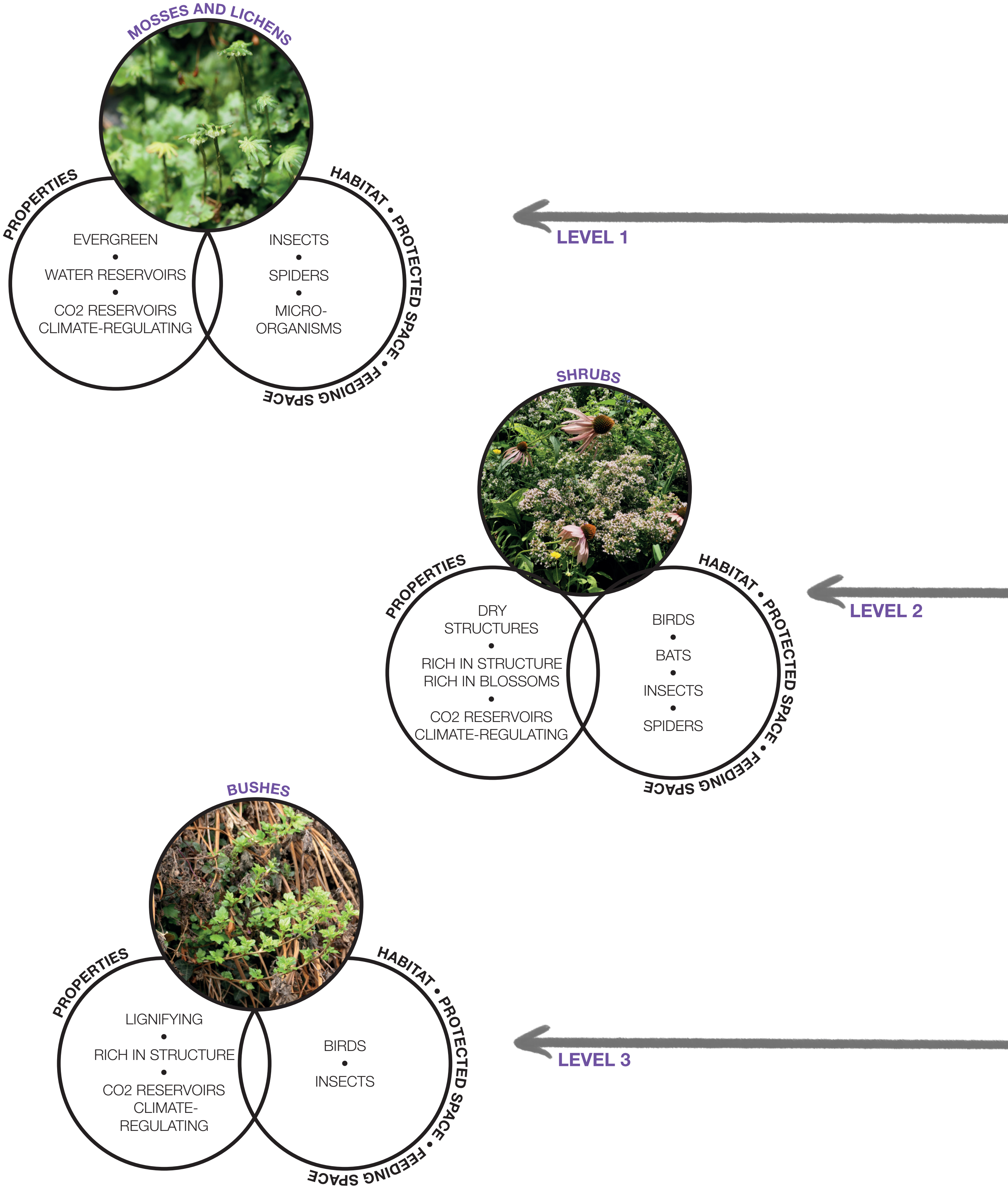
Common dandelion *Taraxacum officinale*	**Pussy willow** *Salix caprea*	**Spiny sow thistle** *Sonchus asper*	**Stinging nettle** *Urtica dioica*
Family *Asteraceae*	Family *Salicaceae*	Family *Asteraceae*	Family *Urticaceae*
Flowering period (approx.) April-June	Flowering period (approx.) March-April	Flowering period (approx.) July-October	Flowering period (approx.) June-November
Nectar + + + Pollen + + + +	Nectar + + + + Pollen + + + +	Nectar + + + Pollen + + +	Nectar + + Pollen + +
Native wild form	Native wild form	Native wild form	Native wild form
wintergreen	deciduous	deciduous	deciduous

Fireweed (rose bay willowherb)
Epilobium angustifolium

Family
Onagraceae

Flowering period (approx.)
July-September

Depth structure in the vertical



3.1.5. Location and orientation

Every location and every orientation (north, east, south, west) brings with it different conditions for a functioning planting. Shade-loving plants, such as spotted dead-nettle (*Lamuim maculatum*) or the great wood rush (*Luzula sylvatica*) should not be planted on the sun-exposed south side and, conversely, plants that need a lot of sun, such as meadow sage (*Salvia pratensis*) or the purple coneflower (*Echinacea purpurea*) should not be planted on the shady north side. The planting plan for wall A cannot therefore be transferred to wall B as a matter of course. The same applies to regionally occurring species: The faunistic diversity in northern Germany is different from that in southern Germany. The target species (> Chapter 3.1) are therefore possibly different and this is accompanied by a different plant selection.

RELEVANT FACTORS FOR A BIODIVERSITY-PROMOTING PLANT SELECTION

» Diversity
» Native species or varieties of a native species
» Flowering period, coordinated as well as possible with the life cycle of the fauna
» Color spectrum flowers
» Unfilled flowers
» Rich in structure
» Spontaneous vegetation allowed
» Adapted to location and orientation

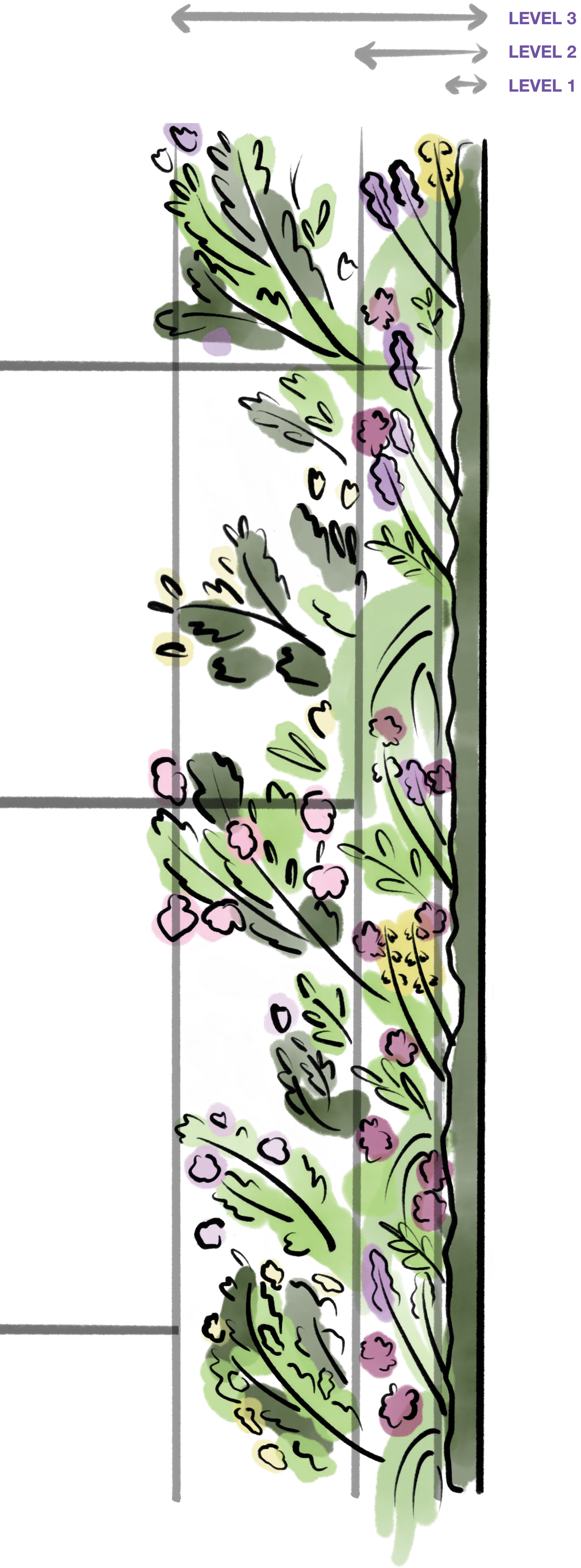
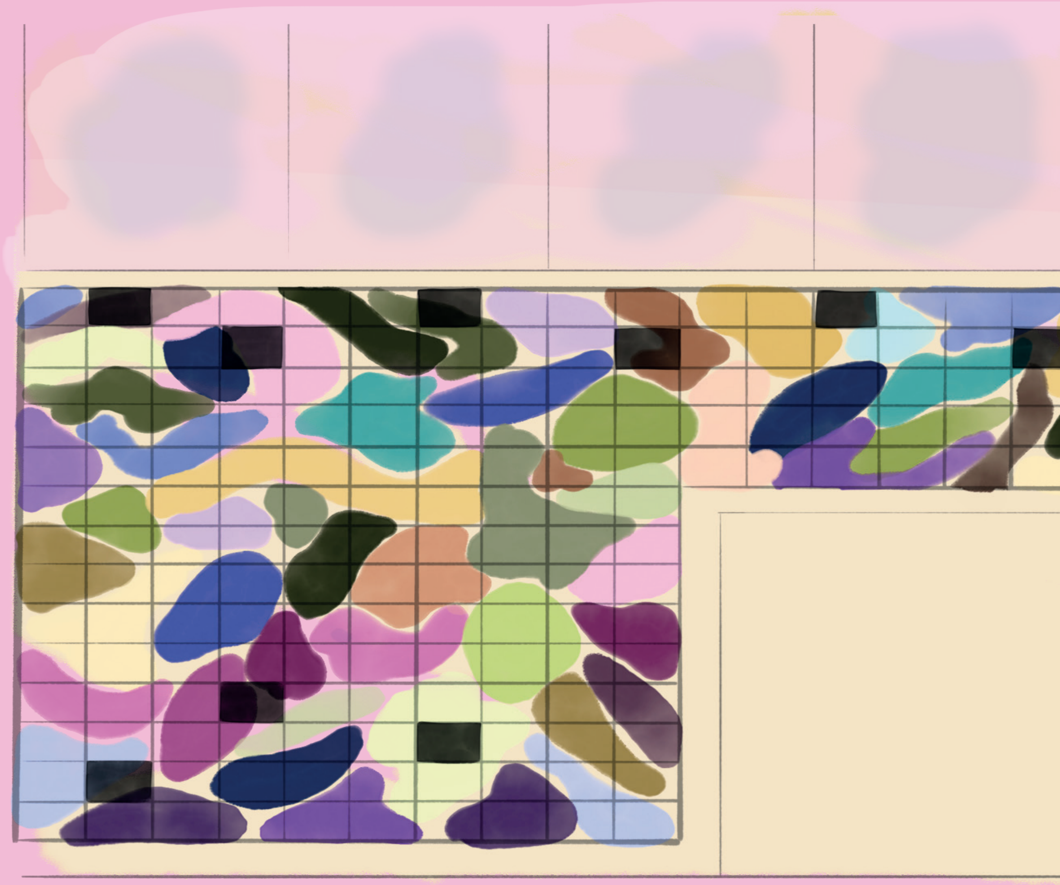


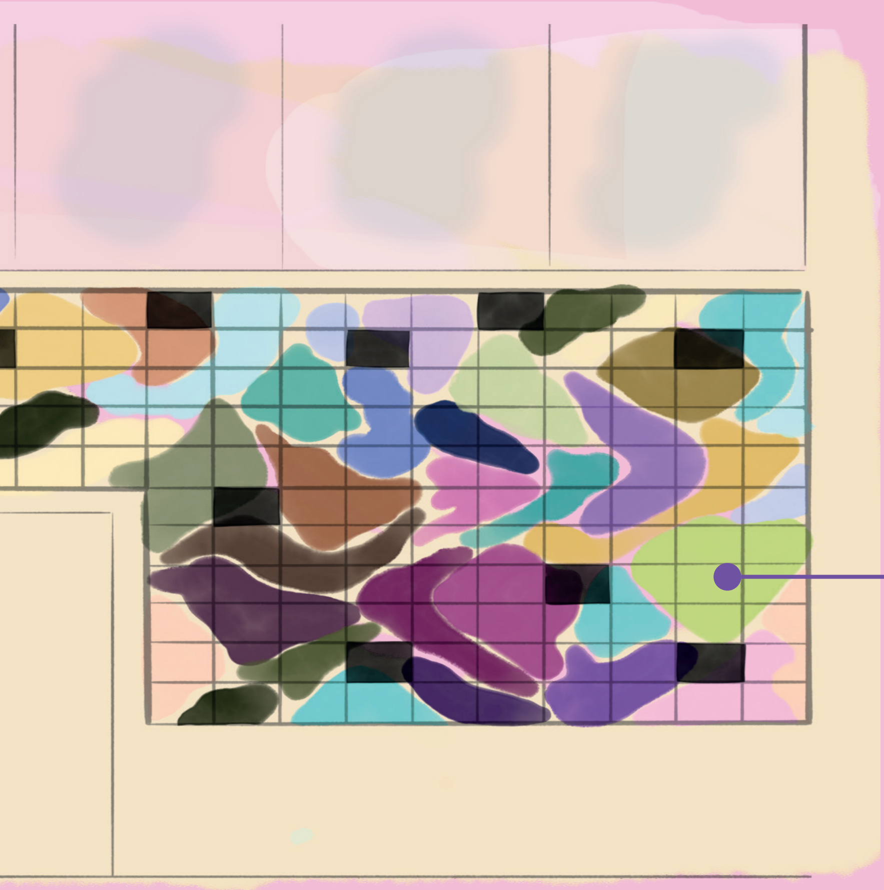
Figure 3: Vertical structures of a biodiversity-promoting, wall-mounted green façade. Depending on the choice and composition of the plants, three levels can develop, each of which is accepted as a habitat by different animals.

The wild climate wall

Planting plan



LATIN NAME	ENGLISH NAME	FAMILY
Achillea millefolium	Yarrow	*Asteraceae*
Ajuga reptans	Bugleherb	*Lamiaceae*
Aquilegia vulgaris	Common columbine	*Ranunculaceae*
Aster ageratoides	Balsam aster	*Asteraceae*
Aster ericoides	White heath aster	*Asteraceae*
Bergenia hybride	Bergenia	*Saxifragaceae*
Campanula glomerata	Clustered bellflower	*Campanulaceae*
Campanula rapunculoides	Creeping bellflower	*Campanulaceae*
Carex pseudocyperus	Cyperus sedge	*Cyperaceae*
Ceratostigma plumbaginoides	Blue leadwood	*Plumbaginaceae*
Dianthus plumarius	Common pink	*Caryophyllaceae*
Echinacea purpurea	Purple coneflower	*Asteraceae*
Melissa officinalis	Lemon balm	*Lamiaceae*
Mentha x piperita	Peppermint	*Lamiaceae*
Oenothera tetragona	Evening primrose	*Onagraceae*
Omphalodes verna	Creeping navelwort	*Boraginaceae*
Onobrychis viciifolia	Common sainfoin	*Fabaceae*
Origanum vulgare	Oregano	*Lamiaceae*
Phlomis russeliana	Turkish sage	*Lamiaceae*
Phlox Subulata	Moss phlox	*Polemoniaceae*
Plantago lanceolata	Ribwort plantain	*Plantaginaceae*



PLANTING PLAN OF THE WILD CLIMATE WALL
Each color stands for at least 2 plant species combinations

For example:
Common comfrey
(*Symphytum officinalis)*
Lemon balm
(*Melissa officinalis*)

Bushes, such as gooseberries (*Ribes uva-crispa)* or purple willow (*Salix purpurea)* have also been planted intermittently. Below is a selection of plant species from the wild climate wall planting plan.

LATIN NAME	**ENGLISH NAME**	**FAMILY**
Potentilla crantzii	Cinquefoil	*Rosaceae*
Potentilla neumanniana	Spring cinquefoil	*Rosaceae*
Ribes uva-crispa	Gooseberry	*Grossulariaceae*
Rosmarinus officinalis	Rosemary	*Lamiaceae*
Salix hastata	Halberd willow	*Salicaceae*
Salix purpurea	Purple willow	*Salicaceae*
Salvia officinalis	Sage	*Lamiaceae*
Salvia pratensis	Meadow sage	*Lamiaceae*
Sanguisorba officinalis	Great burnet	*Rosaceae*
Saponaria officinalis	Common soapwort	*Caryophyllaceae*
Silene dioica	Red campion	*Caryophyllaceae*
Stachys byzantina	Lamb’s ear	*Lamiaceae*
Symphytum officinalis	Common comfrey	*Boraginaceae*
Teucrium chamaedrys	Wall germander	*Lamiaceae*
Thymus serpyllum	Wild thyme	*Lamiaceae*
Thymus vulgaris	Garden thyme	*Lamiaceae*
Trifolium pratense	Red clover	*Faboideae*
Trifolium repens	White clover	*Fabaceae*
Veronica spicata	Spiked speedwell	*Scrophulariaceae*
Veronica teucrium	Saw-leaved speedwell	*Scrophulariaceae*

3.2. Habitats in the vertical

The term habitat is derived from the Latin word *habitare* meaning "to inhabit", and is used in ecology to describe the location or living space of a species within a biotope. The artificial habitats or nesting aids integrated into green façades are installed vertically, usually to support a target species.

PROMOTING LOCAL BIODIVERSITY, PIONEERING FUNCTION, EDUCATIONAL ASPECT

Green façade systems that promote local biodiversity in vegetation while providing integrated habitats can support important synergies between nesting support and other vital parameters, such as food and building materials. If microclimatic functions are taken into account at the same time, they offer great potential for promoting biodiversity in the city [31, 62]. In combination with educational and awareness-raising work, they also help to counteract the increasing alienation between humans and nature (> Digression: Human-nature relationship).

USING HABITATS SENSIBLY

To ensure that the integration of habitats on green façades, but also in urban areas in general, makes sense and does not become an "ecological trap", the following points, among others, must be taken into account:

Embedding in local species pool

A precise analysis of the site is crucial in order to find out for which species there is a need and potential for support. Ideally, not only generalists should be promoted - i.e. species that are less specialized - but also specialists. This is the only way to adequately support the species that are relevant for species conservation. [17]

Radius habitat

All parameters that are vital for the target species should be present in the habitat radius of the corresponding target species. This means that, in addition to the nesting structure, an appropriate food supply in the form of suitable flowering vegetation for insects or seeds and berries for birds should be considered. Many insect species are unable to cover large (flight) distances in search of food or nesting sites [1, 22, 67]. Sleeping and resting places as well as building material for birds and wild bees should also be available nearby.

Habitat quality

Particularly in the case of nesting aids for birds, bats and pollinators (the latter also known as "insect hotels"), the discrepancy between the high-quality nesting aids produced with specialist knowledge and many of the products available on the market is striking [66]. Many habitats, especially wild bee habitats, often show gross deficiencies in terms of materiality (heating, moisture, internal diameter, roughness), workmanship and suspension. These misconstructions are either not accepted or, in the worst case, can lure species into a trap. This is the case, for example, if they or their offspring are exposed to excessively high temperatures or if young wild bees damage their wings on fringed reed stems during hatching [12, 43]. It is therefore crucial to ensure that the work is carried out professionally.

The example of wild bees

Many wild bees, especially smaller species, only have a flight radius of about 150 meters [22]. Within this radius, they are dependent on food and building materials as well as a nesting site. If one of these habitat parameters is lost, it is not possible to raise the next generation. A wild bee habitat in a "concrete desert" without a corresponding range of flowers will therefore not work. However, if all parameters are met, for example on a biodiversity-promoting green façade, integrated habitats are a valuable addition for the interaction of flora and fauna.

Interaction between habitat and surroundings

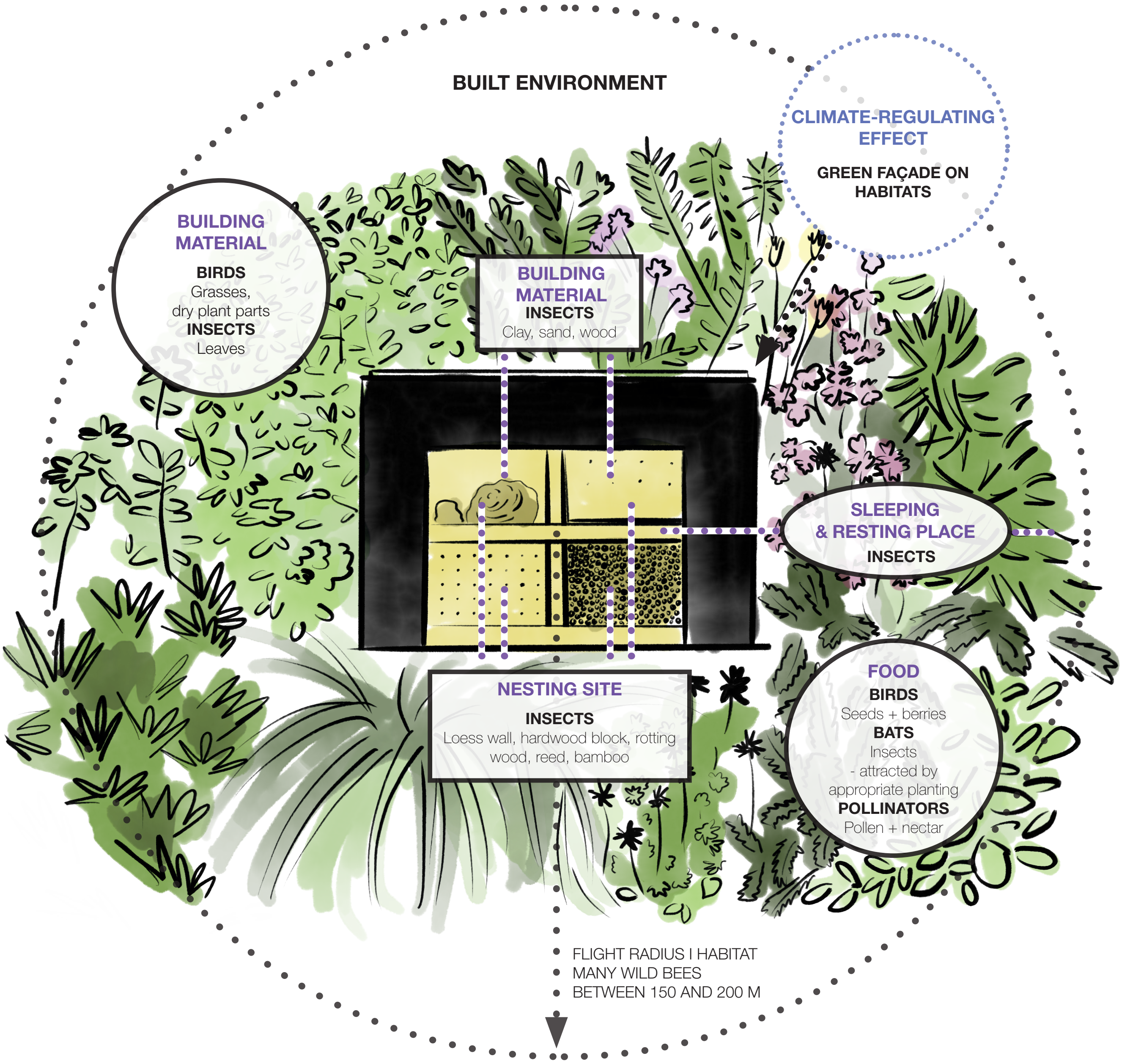


Figure 4: Illustration of the potential interaction of habitat system, environment and plants. When planning habitat systems, attention should always be paid to synergies with the surrounding area, e.g. embedding in the local species pool, potential radius of the target species' habitat or habitat qualities.

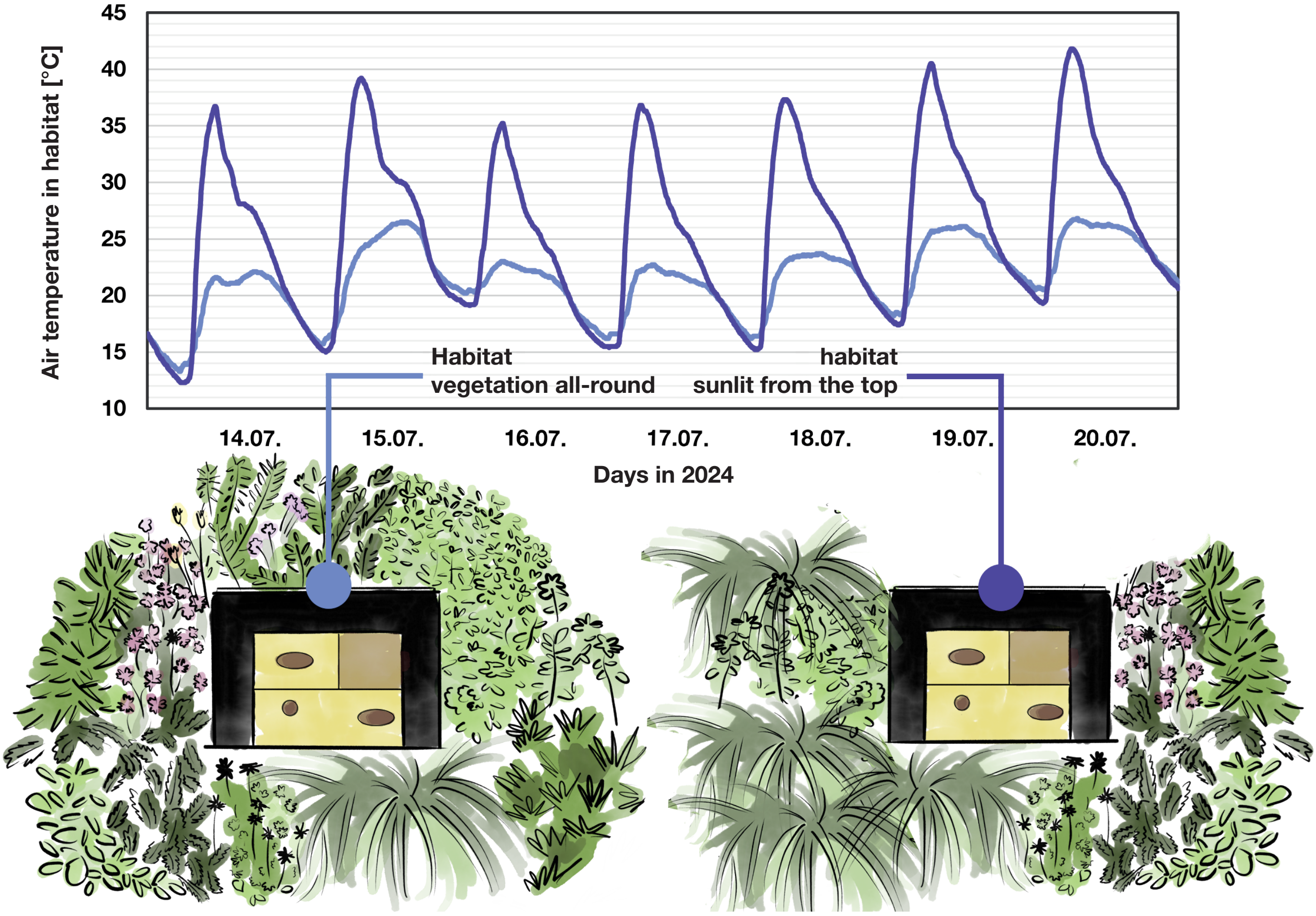


Figure 5: Comparison of air temperatures inside two nest boxes. The left nesting box is covered in green all around. The top of the nest box on the right is not covered with greenery and is fully exposed to the sun. This results in significantly higher temperatures in the nest box.

Microclimate in the habitats

Depending on the location, orientation, exposure and material used, the habitats develop their own microclimate. When determining the target species and planning the habitats, care must be taken to ensure that the microclimate that can potentially be expected supports the healthy development of the target species. Bats, for example, are very fond of warmth. Nevertheless, an exposed box on a south-facing façade can quickly overheat. Ideally, therefore, several boxes should be planned, for example on the south and east façades. If it gets too warm for the bats on the south façade during hot spells, they can simply change boxes.

The situation is different for birds. Once a box is occupied for rearing the brood, they do not change location. Here too, overheating poses a risk to the health of the animals, especially the chicks. The young swifts, for example, cool down by panting and therefore need a lot of energy.

Measurements of the nesting boxes of the wild climate wall have shown that bird nesting boxes surrounded by a dense layer of plants heat up significantly less than boxes where the top is fully exposed to the sun. As Figure 5 shows, temperature differences of over 15°C were recorded in the corresponding boxes during a hot summer week.

Most wild bees are very thermophilic. These habitats should therefore be exposed to the sun for as long as possible during the day, e.g. by orienting them to the south. At the same time, care must be taken to ensure that the nest entrances are protected from driving rain and moisture ingress.

Mold growth must be avoided in all habitats, regardless of the target species. This can occur, for example, if the habitat is soaked by driving rain over a longer period of time and at the same time cannot dry out completely. Good ventilation of all materials must therefore also be taken into account during planning and fitting.

What has to be borne in mind when building habitat systems and nesting aids?

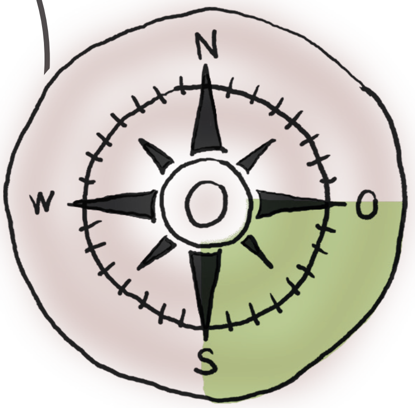
CONSTRUCTIVE

Weatherproof design with protection against driving rain and splash water

Consider fire protection and structural requirements

Orientation/alignment tailored to target species

Ensure ventilation



CARE

Ensure free approach path

Do not use any vigorous plants around the habitat systems

Regular visual inspections

Ensure accessibility for cleaning and exchange if necessary

ECOLOGICAL

Embedding in local species pool

Selection of suitable target species

Accessibility of all parameters (food, building material, sleeping and resting places) of the target species are available within a corresponding radius

MATERIALITY

Use untreated and weather-resistant materials

D not use any chemical, vaporizing composite materials

Do not use softwood or materials that splinter

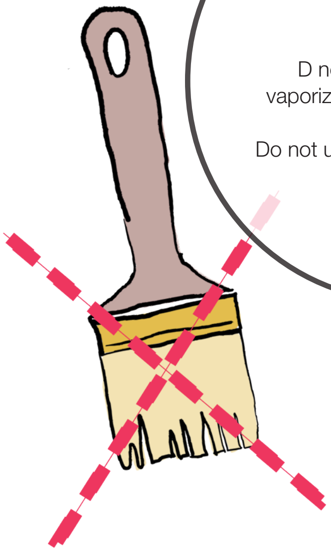


Figure 6: Illustration of the most important components in the planning and construction of habitat systems for wild bees, birds and bats.










SELECTIVE SIGHTINGS
OF DIFFERENT
ANIMAL SPECIES ON THE
WILD CLIMATE WALL

Without flowers no pollinators...

WILD BEE SEARCHING FOR POLLEN ON THE BLOSSOM OF THE VIPER'S BUGLOSS (*ECHIUM VULGARE*).

Digression

The relationship between humans and nature

In vertical greening, many plant species are selected to support and improve the aesthetic quality of the walls; in the past, this has often led to homogeneous planting with little species diversity. In contrast, the innovative approach to the design and implementation of the biodiversity-promoting vertical greening shown here focuses on the use of many different plant species. In this context, little is known about whether such greenery is attractive and aesthetically pleasing to people. However, if such vertical greening is to be developed as part of the green infrastructure in the future, the needs of people must also be incorporated into the design. For this reason, a study on the acceptance and aesthetics of vertical greening systems was carried out as part of the project.

A survey of over 200 participants was used to find out how people in the city perceive and value vertical greening*. The most important points of the survey included questions on aesthetic preferences of the sample façades in different seasons and questions on the evaluation of biodiversity, such as the evaluation of the attractiveness of flowers and the evaluation of different animal and plant species. Questions were also asked about possible restrictions and concerns regarding vertical greening, such as high costs or possible damage to the building.

In terms of aesthetic evaluation, respondents preferred spring and summer planting to the appearance of vegetation in fall and winter. Of the vegetation features, the respondents particularly liked the flowers and a mix of different plant species. The idea that uniform, homogeneous plantings are more attractive to people could therefore be a misconception or a now outdated opinion. Respondents indicated that the cost of implementation and maintenance was their biggest concern. This could explain why people rarely install these systems at the moment, although there is already a high level of awareness of the benefits.

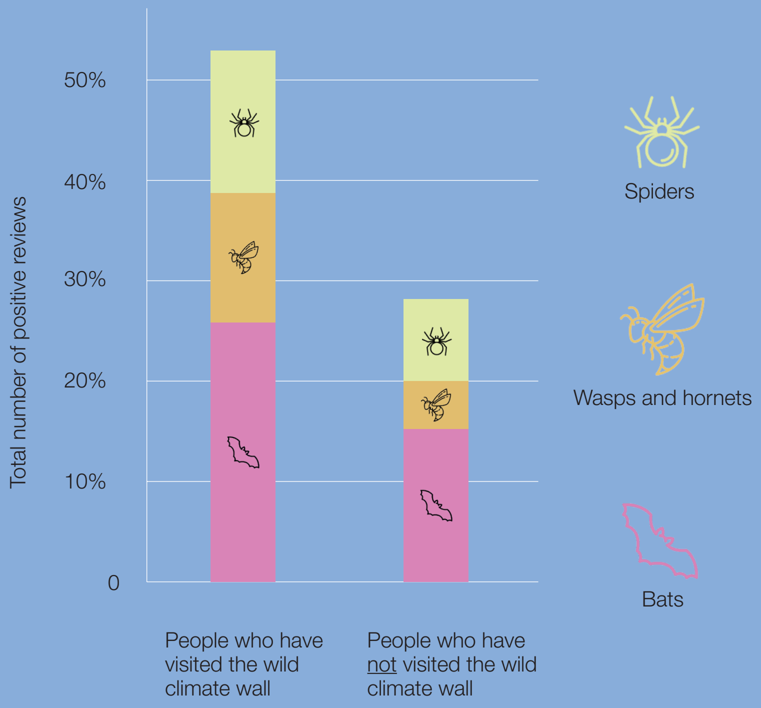
Respondents were also asked to rank different animal species on a scale from 1 being the lowest to 5 being the highest. Animals such as wasps, bats and mice received lower average scores than bees, butterflies and birds, for example. It can be assumed that the social discussion about insect decline and the associated awareness-raising in recent years has contributed to wild bees being more accepted in the survey than other insects. Nevertheless, some people stated in the survey that some animals would have a rather negative effect due to the proximity to plants as in the "wild" walls studied. In the long term, practical examples that work with many different plant species, like wild climate wall, can bring people back into contact with diverse natural elements in the future.

Previous studies have found that knowledge of the benefits of urban greenery leads to pro-ecological behavior and a better appreciation of biodiversity. To find this out, the participants in the study were divided into two groups. The first group had visited the wild climate wall and listened to a presentation on the benefits of vertical greening for local biodiversity, including the importance of different plant and animal species. The second group had neither visited the wall nor heard the lecture. The answers on the attractiveness of animal species were compared between the two groups. The group that had visited the wild climate wall rated the less preferred animal species (wasps, hornets, bats and mice) more positively than the group that had not visited the wall (see diagram). From this result it can be deduced that knowledge can also play a role in assessing the biodiversity of vertical greening. Environmental education and awareness-raising in the areas of biodiversity and climate and nature conservation can therefore also be of crucial importance in the context of vertical greening. Their contribution can lie not only in communicating the positive and negative aspects of vertical greening, but also in influencing perception and acceptance through their own direct experience.

By integrating design, education and scientific research that includes the voices of the public, we can bring more nature into cities, which also have a role to play in biodiversity conservation. Even though more experimentation is certainly needed in this area, involving the public is a further step towards holistic planning and implementation that brings people closer to a piece of urban nature.

WHICH ANIMALS DO YOU LIKE ON SUCH GREEN WALLS?

The graph below shows the total number of positive ratings for three groups of animals (spiders, wasps and hornets, bats) and in comparison of two groups of respondents, people who visited the wild climate wall and people who did not. In general, the respondents who visited the wild climate wall rated it more highly. This points to the influence that nature experience and knowledge can have on the assessment of biodiversity and the acceptance of different animal species in urban green spaces.



* Results from the master thesis *People-Nature Relationships of Vertical Greening Systems* by Miljana Drincic, ILPÖ in the study program Integrated Urbanism and Sustainable Design, 2024

3.3. Biodiversity-sensitive maintenance

Biodiversity-sensitive maintenance aims to create and maintain habitats that support a variety of plant and animal species. In addition to aesthetic and functional aspects, ecological considerations are particularly important. This approach ensures that green façades are not just decorative elements, but also help to promote biodiversity.

A diverse and vital plant community forms the basis for valuable habitats for numerous animal species. Continuous care is essential to maintain and increase plant diversity and vitality in the long term. This primarily includes regular pruning of the plants, supplying them with water and nutrients, checking for pest infestation and, if necessary, counteracting this by using beneficial insects. On the one hand, these measures are necessary in order to maintain or promote a certain appearance, but on the other hand they are also necessary from a horticultural point of view in order to maintain the long-term vitality of the plants and, for example, to prevent individual plants from becoming woody and thinning out. In addition, very dominant species can be cut back to give other species more space and light.

These holistic approaches turn the maintenance of green façades into a comprehensive process that combines horticultural, ecological and aesthetic aspects.

Infobox: Maintenance phases in practice

In practice, a distinction is made between completion, development and upkeep maintenance.

» Completion maintenance is included in the construction of the green façade and provides a pre-defined condition or degree of coverage (in the tender). It serves as the basis for the acceptance and subsequent successful development of the vegetation.
» The development maintenance follows the completion maintenance or acceptance and serves to achieve a "functional condition" in accordance with DIN 18919. Depending on the system and location, this can take several weeks or years.
» According to DIN 18919, upkeep maintenance then comprises the "preservation of the functional condition" and therefore corresponds to the long-term maintenance of the green façade.

Development and upkeep maintenance must be agreed through care and maintenance contracts.

PRUNING THE WILD CLIMATE WALL

3.3.1. Goals in maintenance

Overall, the concept of biodiversity-sensitive maintenance aims to increase the ecological value of green facades and turn them into high-quality components of urban green structures (> Figure 6).

The main difference from the maintenance of conventional façade greening lies in the way the plants are pruned and spontaneous vegetation is allowed to grow, and is based on the extensive maintenance of other landscape elements.

If possible, each section of the façade is only cut once or twice a year at most. Care is taken to ensure that the entire area is not taken back at the same time. This allows the animals in the wall to retreat to uncut areas. Sufficient dead plant material is left on the wall over the winter, as many insect species overwinter in it and it also provides food for birds, for example through the seed heads that form after flowering (> Chapter 3.4). In addition, the breeding times of the birds must be taken into account during maintenance work so that they are not disturbed when building their nests or rearing their broods. If possible, the plants should only be cut back once they have finished flowering and forming seed heads in order to fully exploit the food supply for wildlife.

Another significant difference to the maintenance of conventional green façades is the handling of spontaneous vegetation (> Chapter 3.1.4). The targeted integration of spontaneous vegetation into maintenance management can even increase plant diversity in the long term.

Infobox: Growth habit and fruiting period of different plant species

Plants for greening buildings can be classified according to their growth form, i.e. herbaceous or woody, and the fruiting period, among other things. Woody structures are defined by the storage of lignin, which hardens stems and trunks and makes them more robust against environmental influences.

Annual and biennial plants flower and fruit in the first or second year after germination and then die. These species do not form woody structures. Some perennial species often become woody in order to overwinter, but flower and fruit only once in their lifetime. This distinguishes them from other perennial plants that flower and bear fruit for several years in succession. Perennial plants include woody, herbaceous plants and mixed forms such as semi-bushes.

Shrubs are herbaceous perennial plants that overwinter either below, on or above the soil surface. [25, 33]

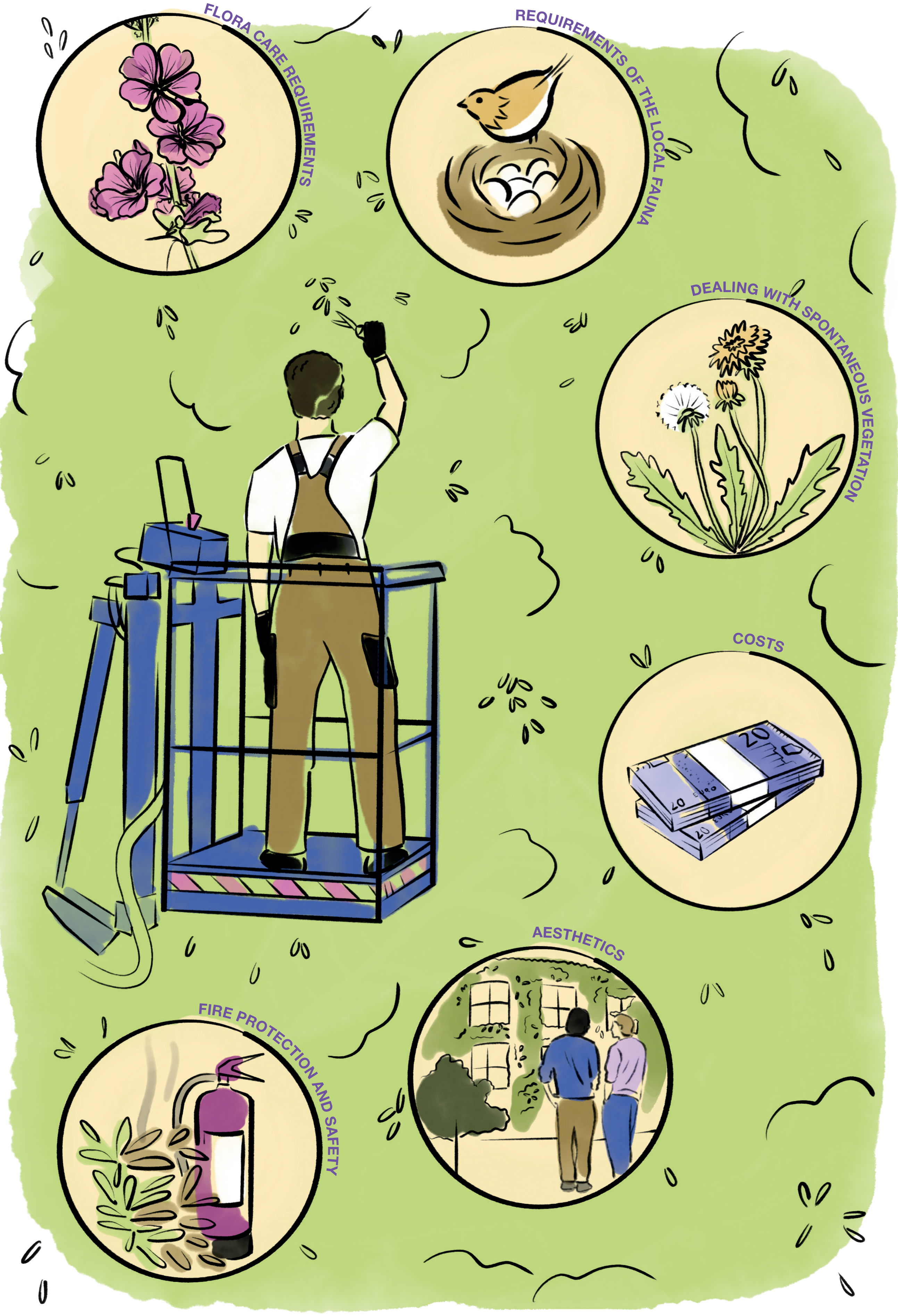


Figure 6: Goals and requirements in the maintenance of biodiversity-promoting green facades.

3.3.2. Conflicting objectives

The implementation of biodiversity-sensitive cultivation practices in vertical growing poses a number of challenges and requires a basic understanding of ecological relationships. For example, the annually changing weather conditions have an influence on the breeding behavior of the fauna. Both the hatching times of wild bees and the start of nest building in birds in spring are strongly dependent on the weather and do not occur at the same time every year. This complicates the planning and implementation of pruning.

PROTECTION AND CONSERVATION OF BREEDING SITES

Pruning in spring should only be carried out after the insect larvae have hatched [23]. The challenge here is that the first birds have already started breeding at this time. Observations have shown that birds start breeding very early due to the mild urban climate, proximity to buildings and increasingly mild winters [44]. The breeding season for the various bird species then extends over several months until late summer. This has also been observed on the wild climate wall: The first pruning in 2024 was to take place in March, after it had been ensured that the first wild bees had hatched. However, the first nesting blackbirds were already in the wall at this point. Before any maintenance work is carried out, it must therefore be ensured through sufficient and professional observation that no birds are currently breeding or building their nests in the wall. If this is already the case, maintenance must be adapted accordingly so as not to disturb the brood. Of course, nests must not be damaged or destroyed under any circumstances; this is also stipulated in the Federal Nature Conservation Act.

FIRE PROTECTION

Another challenge when leaving dead and dry plant material over the winter is fire protection. It must be ensured that the dry plant material does not pose a fire hazard to the building. How to deal with this and what needs to be taken into account can be found, for example, in the technical information "Requirements for fire protection in green roofs and façades" published by the Bundesverband für Gebäudegrün [9].

SPONTANEOUS VEGETATION

The handling of spontaneous vegetation must also be taken into account in maintenance management: These plants are often of high ecological value and are excellently adapted to the site due to their independent seeding [5]. However, it must be ensured that plant diversity is not impaired by the establishment and spread of spontaneous vegetation. Spontaneous vegetation should therefore be included in maintenance from the outset and its growth controlled at an early stage. In the first year after planting, the following species, among others, have colonized the wild climate wall:

- Spiny sow thistle (*Sonchus asper*)
- Common sow thistle (*Sonchus oleraceus*)
- Prickly lettuce (*Lactuca serriola*)
- Canadian horseweed (*Erigeron canadensis*)
- Dandelion (*Taraxacum sect. Ruderalia*)
- Fireweed (rose bay willowherb) (*Epilobium angustifolium*)
- Narrow-leaved ragwort (*Senecio inaequidens*)
- Common nettle (*Urtica dioica*)

CONFLICTING OBJECTIVES IN BIODIVERSITY-SENSITIVE MAINTENANCE

- Consider breeding seasons of the fauna
- Consider fire protection
- Allow spontaneous vegetation within the right framework

DRY WINTER STRUCTURES
ON THE WILD CLIMATE WALL

3.4. Biodiversity-promoting green façades throughout the year

The more plants and vegetation structures there are in the green façade, the wilder and more varied it is. The façade also changes with the seasons: Flowers turn into fruits and seeds, leaves and stems change color and dry out, shrubs shrivel up and die above ground. Not only the appearance of the wall, but also its ecological benefits are constantly changing. The flowers disappear when the wild bees stop flying in late fall. The remaining seed heads are valuable sources of food for native birds. Dry plant stems can provide a habitat for insect larvae and pupae, which hatch from them the following spring, or can be used for overwintering. The native fauna is adapted to the native flora and is alive in every condition. These interactions over the course of the year are shown in Figure 7.

Each season is part of a recurring ecological cycle. This makes it all the more important to explain the ecological benefits and the function of dead plant material, for example, through targeted educational work and awareness-raising, thus creating awareness in society. The same awareness-raising and educational work is currently being carried out at , e.g. for insect meadows and ruderal areas in the cityscape. Understanding the ecological value of wild vegetation in urban areas can raise awareness, acceptance and support for biodiversity among the population.

CHANGEABLE AESTHETICS

The aesthetic design of green façades plays a key role in their implementation and perception in society. Biodiversity-promoting green façades create dynamic façade images that are subject to the changing seasons thanks to their diverse selection of plants and variety of structures. Each season brings its own ecological benefits and aesthetics. The changing seasons are clearly visible in the open countryside, city parks and gardens. In many cities, these differences are less pronounced. Here, too, the foliage changes color, plants lose their leaves and sprout new shoots, but the building facades always look the same. Dry winter structures on a house façade can appear strange and initially do not fit into the image of an urban landscape. However, if biodiversity-promoting structures are anchored in the cities, the seasonal change in vegetation can also be experienced in the cities and a new, appealing aesthetic can be created.

RECOMMENDED READING

CHAPTER 3

FLL (2020) Technical report on bee pasture. Instructions on how to improve the range of honey and habitats for bees and other flower-visiting insects. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.

Schwingesbauer, S. (2023) Naturally beautiful and surrounded by wildlife. Planning, implementing and maintaining insect-friendly flower beds. Haupt Verlag.

Davroux, A. (2022) Grows almost without water. Publisher Eugen Ulmer.

Voskuhl, J. & Zucchi, H. (2020) Wild bees in the city. Discover, observe, protect. Haupt Verlag.

Wittig R. (2008) Vegetation in settlements, ecosystems of Central Europe from a geobotanical perspective. Publisher Eugen Ulmer.

AUTUMN IMPRESSIONS
ON THE WILD CLIMATE WALL

PHOTO MAX KROLL

The wild climate wall in the course of the year

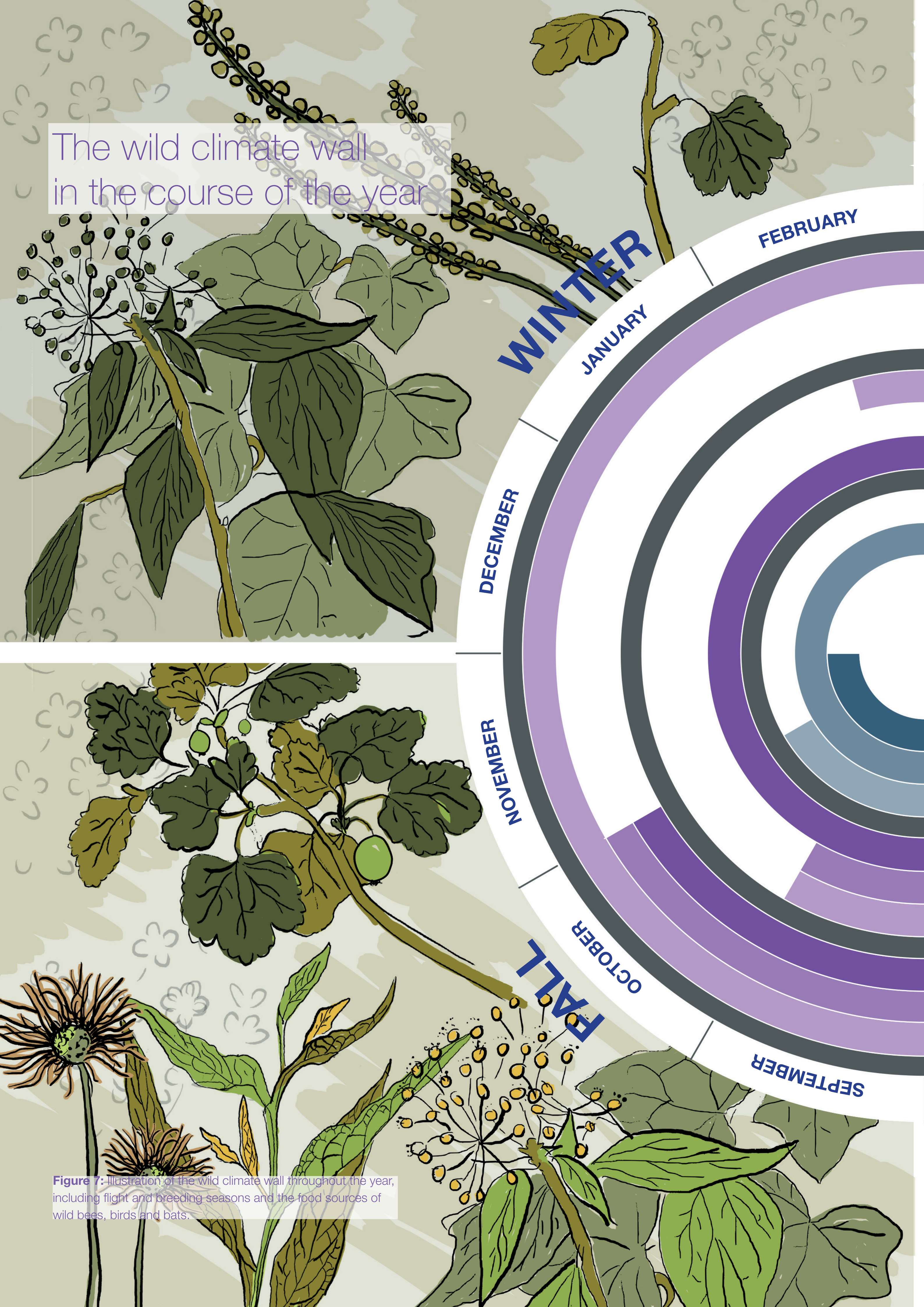
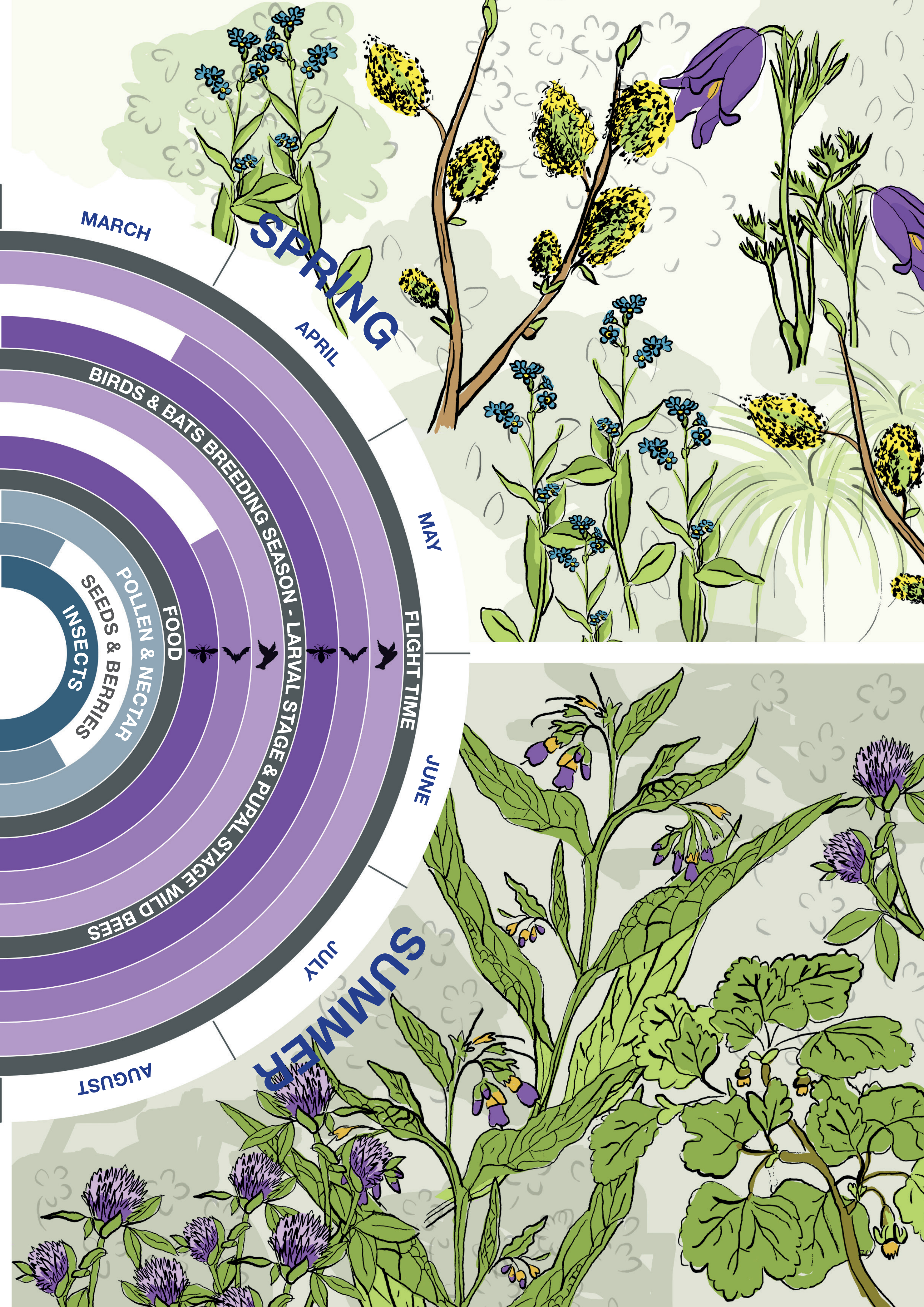


Figure 7: Illustration of the wild climate wall throughout the year, including flight and breeding seasons and the food sources of wild bees, birds and bats.



SPRING

MARCH

APRIL

MAY

JUNE

JULY

AUGUST

SUMMER

FLIGHT TIME

BIRDS & BATS BREEDING SEASON - LARVAL STAGE & PUPAL STAGE WILD BEES

FOOD

POLLEN & NECTAR

SEEDS & BERRIES

INSECTS

DRY WINTER STRUCTURES
ON THE WILD CLIMATE WALL

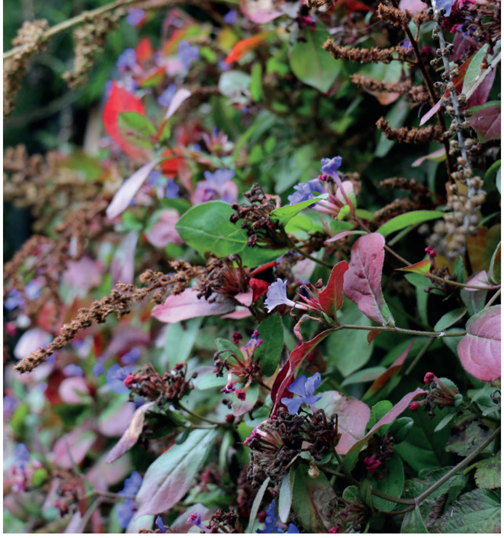


PHOTO MAX KROLL

PHOTO MAX KROLL

4.

Plants for climate resilience in cities

4. Plant selection for birds Climate resilience in cities

In addition to ecological aspects, cities are increasingly urgently seeking measures to adapt to climate change and the resulting consequences (> Chapter 2.1). Plants in cities contribute in many ways to promoting climate-resilient urban development. This primarily includes the potential to adapt to heat through shading and the modification of the urban energy and radiation balance as well as vaporization.

Infobox: Solar radiation

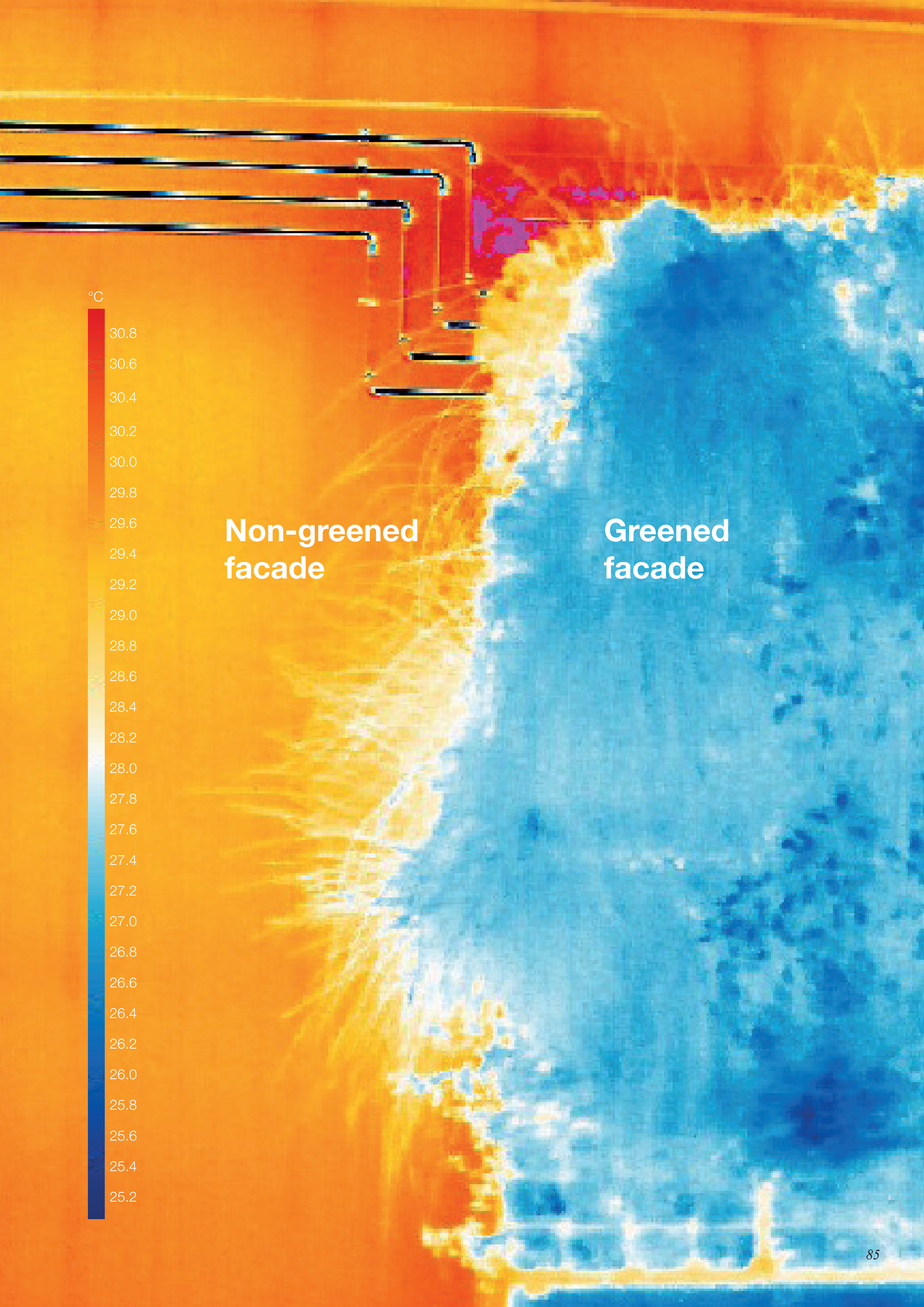
High-energy short-wave solar radiation reaches the earth, which is refracted, reflected or absorbed by various atmospheric processes. The sum of direct, diffuse and reflected radiation that can be measured on the earth's surface is referred to as global radiation.
The non-reflected portion of the high-energy solar radiation is absorbed by objects or materials on the earth's surface, which heat up and in turn emit or emit (thermal) radiation themselves. The heat-transporting radiation is referred to as long-wave radiation. [46]

4.1. Energy and radiation balance

Green infrastructures, whether urban trees, green facades or green roofs, have a lower heat storage capacity than solid buildings or sealed infrastructure surfaces. This means that overgrown surfaces do not heat up as much as a solid concrete wall, for example [31]. Each surface releases the absorbed heat, in the form of long-wave heat radiation, back into the environment with a time delay. This process is particularly noticeable on summer nights in urban areas - including Stuttgart: The city center in particular only cools down slightly during a summer night, as the energy stored in the urban surfaces during the day is released back into the environment at night through the process of heat radiation. The level of long-wave heat radiation is directly dependent on its surface temperature. To put it simply: the higher the temperature of a surface, the higher the long-wave heat radiation.

Green façades are often positioned in front of a solid façade. As the sun no longer shines directly on the solid component, it no longer heats up as much. On the other hand, the lower heat storage capacity of the plant leaves has a positive effect on the surface temperature of the green façade itself and thus also on the level of long-wave heat radiation into the urban space.

Figure 8: Thermal image of the wild climate wall
compared to a non-greened wall. The photos were taken in the summer in the late evening hours (August 18, 2024 at 7 p.m.).


°C
30.8
30.6
30.4
30.2
30.0
29.8
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27.4
27.2
27.0
26.8
26.6
26.4
26.2
26.0
25.8
25.6
25.4
25.2
Non-greened facade
Greened facade

4.2. vaporization

In addition to the lower heat storage capacity or surface temperature, the lower heat radiation in plants is also due to the effect of vaporization via the leaf surface.

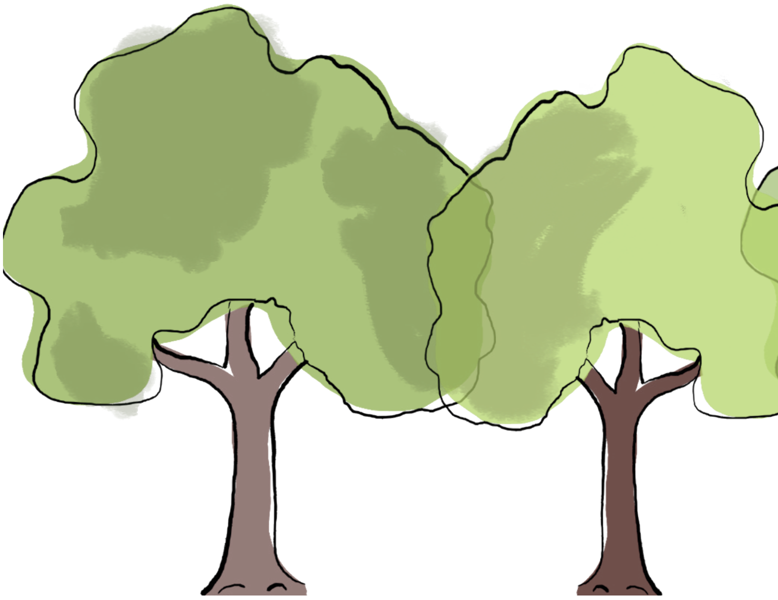
Plant leaves (transpiration) and plant substrates (evaporation) "sweat", i.e. they vaporize water via their surfaces. During this process, the water is converted from a liquid to a gaseous state. This process requires energy and is defined as vaporization or evapotranspiration cooling. At the same time, this process removes heat from the surrounding air and cools it down. The plant protects itself from overheating through the vaporization process. On hot days with high solar radiation, the plants specifically increase vaporization and thus also the cooling capacity to generate more cooling.

In order for plants to release a high level of vapor and thus also a high cooling potential in the summer months, sufficient water must be available. Satisfactory watering is therefore particularly important in the summer months.

The example of the wild climate wall:
A thermal image (> Figure 8) of the wild climate wall in the evening hours after a hot summer day shows that the leaves are significantly cooler than the surface temperatures of the surrounding buildings. This has a positive effect on the urban climate and people's sense of comfort (> Chapter 4.3).

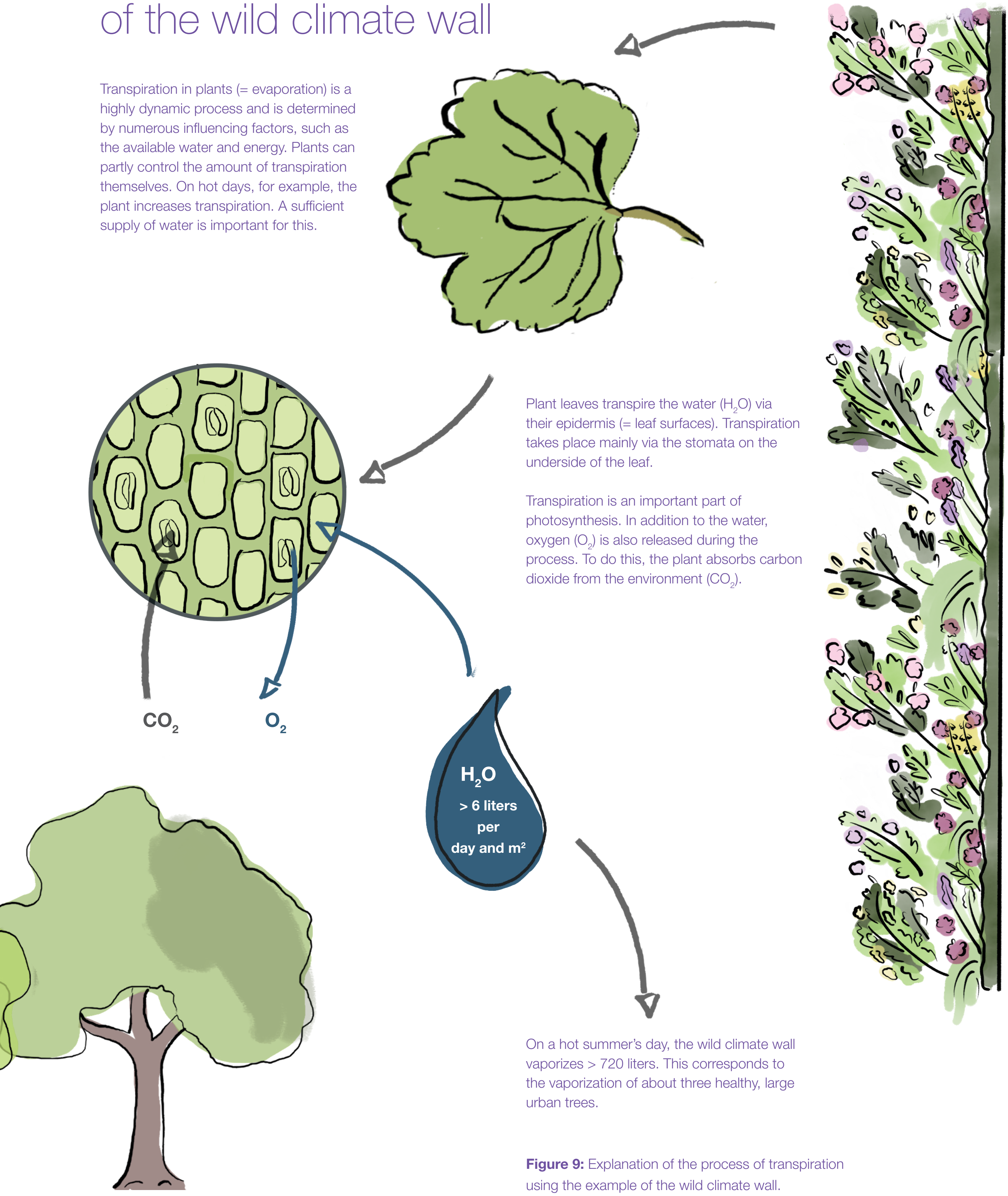
Figure 9 illustrates how much water the wild climate wall vaporizes on a hot summer's day. On peak days, the dense plant layer causes evaporation of over 6 liters per m². With a wild climate wall area of 120 m², that's over 720 liters per day. This corresponds to the vaporization of about three healthy, large urban trees.

A large part of the incident solar radiation or energy is used by the plants of the wild climate wall for the vaporization process. At an ambient temperature of 20°C, 2453 kJ of energy is required per kilogram of vaporizing water . With the wild climate wall this results in a cooling capacity of approx. 20.4 kW per day. An average air conditioning system for living spaces has a capacity of around 2 to 3 kW. The cooling capacity of 20.4 kW therefore corresponds to the cooling capacity of around 7 to 10 air conditioning systems that could be operated simultaneously.



Transpiration process of the wild climate wall

Transpiration in plants (= evaporation) is a highly dynamic process and is determined by numerous influencing factors, such as the available water and energy. Plants can partly control the amount of transpiration themselves. On hot days, for example, the plant increases transpiration. A sufficient supply of water is important for this.



Plant leaves transpire the water (H_2O) via their epidermis (= leaf surfaces). Transpiration takes place mainly via the stomata on the underside of the leaf.

Transpiration is an important part of photosynthesis. In addition to the water, oxygen (O_2) is also released during the process. To do this, the plant absorbs carbon dioxide from the environment (CO_2).

On a hot summer's day, the wild climate wall vaporizes > 720 liters. This corresponds to the vaporization of about three healthy, large urban trees.

Figure 9: Explanation of the process of transpiration using the example of the wild climate wall.

4.3. Perceived comfort in the urban space

The radiation balances and surface temperatures in urban spaces also play an important role in people's sense of comfort. With their surfaces, i.e. their skin, humans are in a constant exchange of radiation with the surfaces that surround them. As a result of the lower surface temperatures of green structures in the summer months, the radiation exchange between the skin and the surrounding surfaces is also reduced. This also reduces the "perceived temperature" in the urban space. Especially on hot days with high air temperatures, reducing the surface temperature of the surrounding surfaces can make a significant contribution to increasing people's sense of comfort. Figure 10 shows this dependency.

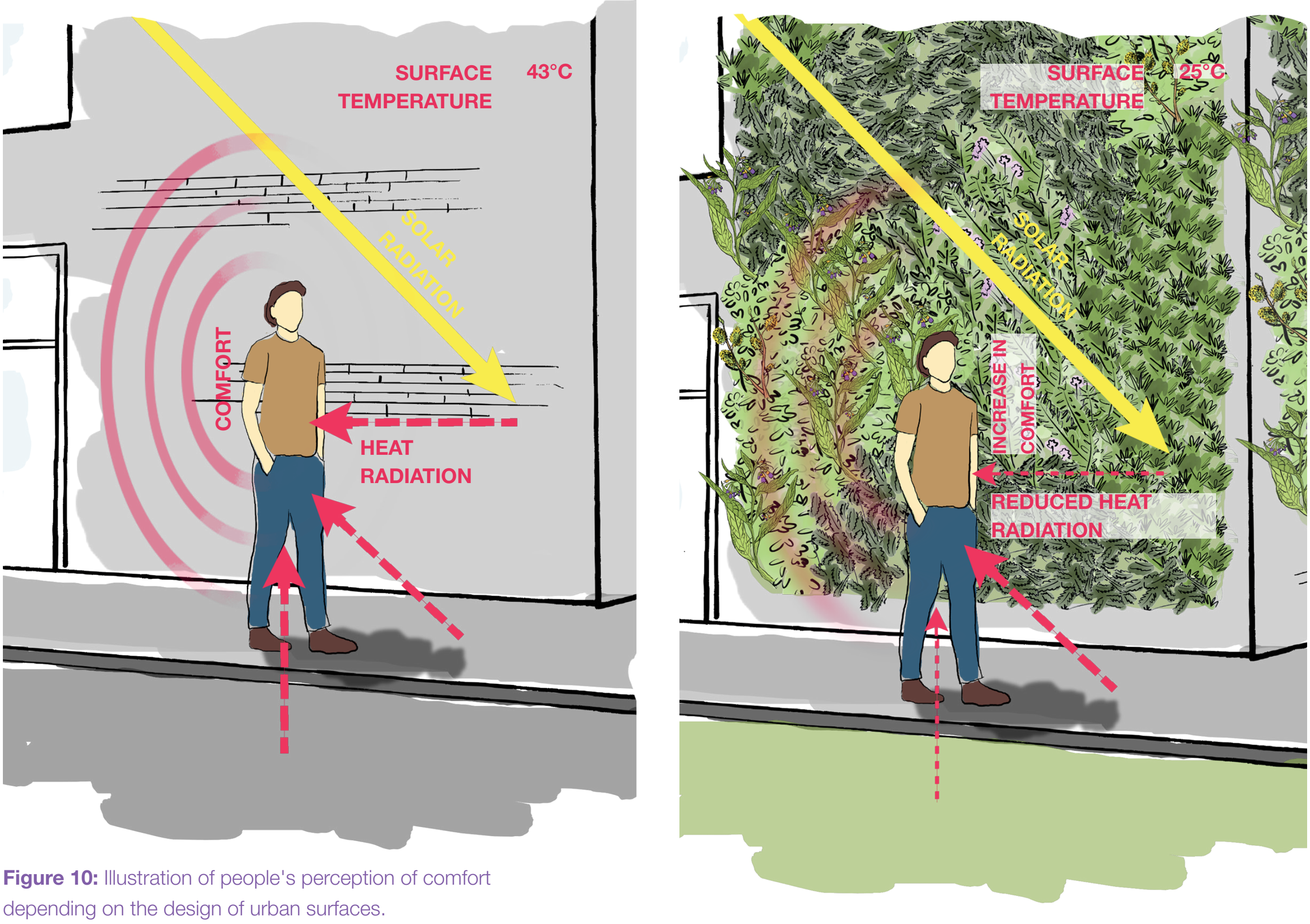


Figure 10: Illustration of people's perception of comfort depending on the design of urban surfaces.

4.4. Resilience of plants

Alongside people, urban vegetation is also affected by the consequences of climate change. The extreme climate in the city can have a negative impact on healthy plant growth. In addition to heat and drought, there are other influences such as pollutants, insufficient root space and/or saline soils. When planning and planting green structures, attention should therefore also be paid to the plant's resistance to heat and other anthropogenic influences.

Infobox: Strategies against heat

Plants have different strategies for dealing with heat. For example, the lamb's ear or the pasqueflower protect themselves from high levels of radiation with white hairs on their leaves and stems. The hairs reflect the short-wave solar radiation and thus protect the plant leaf from burns. Rosemary, on the other hand, pursues a different strategy: it has very small leaves. On the one hand, the small leaves or plant surface reduce the solar radiation reaching the plant leaf. On the other hand, the area over which the plant can release water through the vaporization process is significantly reduced compared to large-leaved plants.

HEAT RESILIENT PLANTS
ON THE WILD CLIMATE WALL
INCLUDE:

Pasqueflower
(*Pulsatilla vulgaris*)

Yarrow
(*Achillea millefolium*)

Lamb's ear (> Figure 11)
(*Stachys byzantina*)

Common soapwort
(*Saponaria officinalis*)

Meadow sage
(*Salvia pratensis*)

Wild thyme
(*Thymus serpyllum*)

Purple coneflower
(*Echinacea purpurea*)

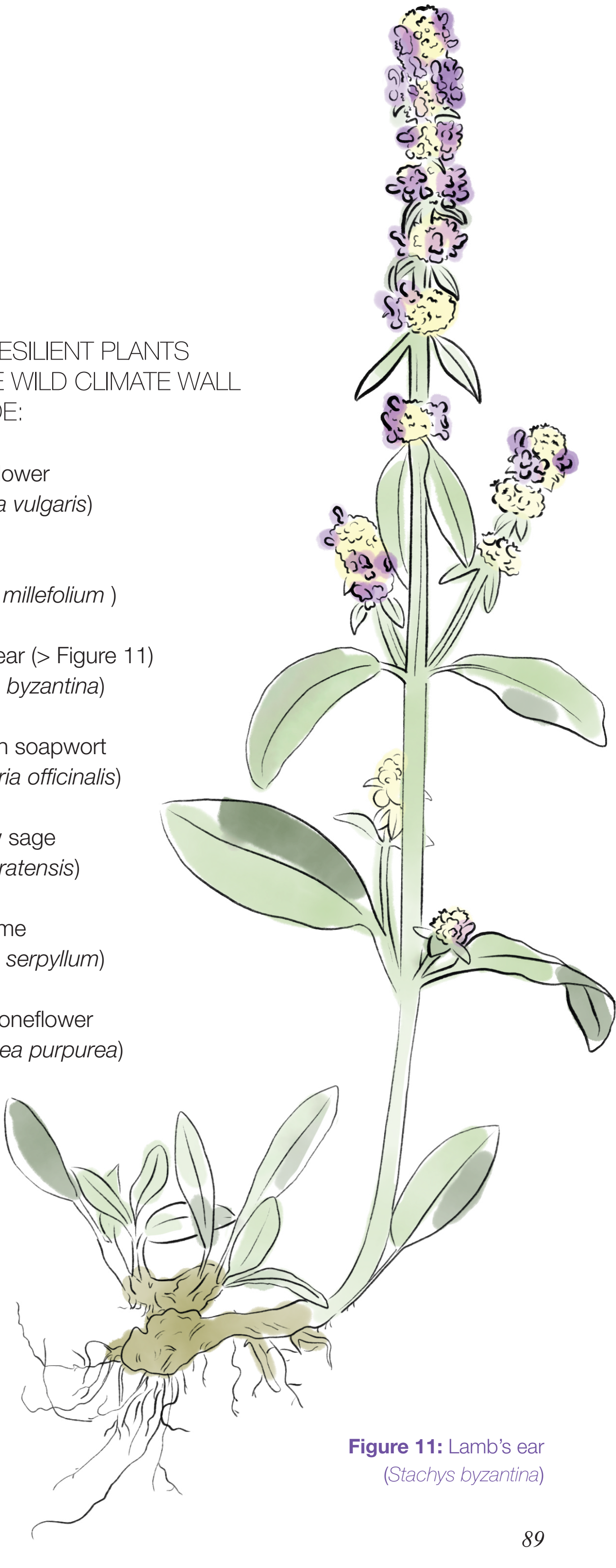


Figure 11: Lamb's ear
(*Stachys byzantina*)

Digression

Green facades and building physics

The low surface temperatures of the façade during the summer months thanks to greenery also have a positive effect on the indoor climate of the building. In the summer months, when the air and surface temperatures outside are warmer than inside, heat flows through the building component from the outside to the inside. At the same time, heat is introduced into the building. The level of heat flux density depends on the external and internal surface temperature difference of the façade. The greater the temperature difference, the greater the heat flux density. In [3, 31], significantly lower surface temperatures of a green façade were found in direct comparison with a concrete wall. The heat input in the area of the green façade is also reduced accordingly. If the green façade is planned and implemented correctly, this can lead to an increase in indoor comfort and/or a reduction in cooling energy in the building.

Façade greening also provides effective protection for the building components behind it against the effects of the weather and major temperature fluctuations. High temperature changes within a short period of time can lead to material fatigue and cracking on the surface. [31] illustrates that the surface temperatures are significantly buffered by the greenery, which prevents extreme temperature differences on the façade behind. This helps to maintain the material quality of the components in the long term.

In a further study, noise-reducing effects were identified with the wild climate wall. When measuring the sound absorption of the wild climate wall in accordance with DIN EN ISO 11654, a weighted sound absorption coefficient of a_w = 1.00 and the associated sound absorption class A [30]. This means that almost all of the incident sound energy is absorbed by the green modules. This effect can in turn have a positive impact on cities and their noise pollution. Sound-absorbing surfaces and materials help to effectively reduce multiple sound reflections, especially in dense street canyons.

MEASUREMENT OF SOUND
ABSORPTION IN THE FRAUNHOFER IBP
ECHO CHAMBER

The wild climate wall

12 facts worth knowing

1 The wild climate wall is home to over 70 different plant species on approx. 120 m².

2 The construction time was 3 days.

3 The first wild bee visit took place during the construction phase.

4 The first pair of blackbirds nested in the façade two weeks after completion.

5 The planting plan and composition ensured a flowering spectrum from March to late autumn.

6 The first pruning on August 8, 2023 produced 47 kg of biomass - in total, 141 kg were produced in 1.5 years.

7 The cooling capacity of the wild climate wall on a hot summer day is equivalent to about three healthy city trees or 7 to 10 air conditioners.

8 The wild climate wall has noise absorption class A

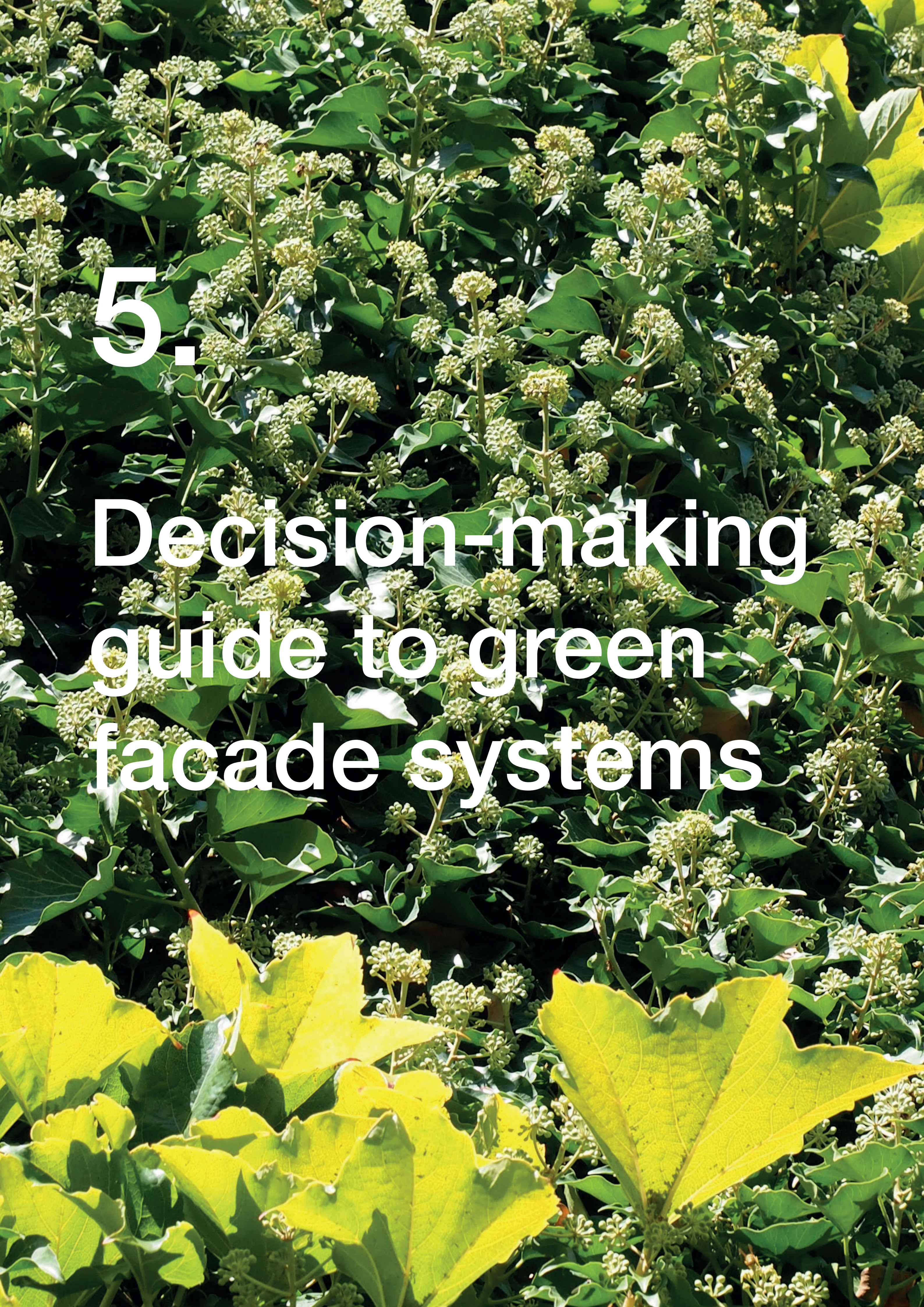
9 The wild climate wall won the special biodiversity prize and the audience award at the DGNB Sustainability Challenge 2024.

10 Large and small visitors: The wall was visited by both the largest species of wild bee, the carpenter bee, and one of the smallest species of wild bee in Germany, the sweat bee.

11 Lots of new blood: Four different bird species have already nested in the wall: blackbirds, blue tits, great tits and greenfinches.

12 The film team of the children's TV program *Sendung mit der Maus* visited the wild climate wall twice.

Visit *by the mouse* to the wild climate wall as part of the event *Doors open with the mouse.*



5.

Decision-making guide to green facade systems

Green structures in urban areas

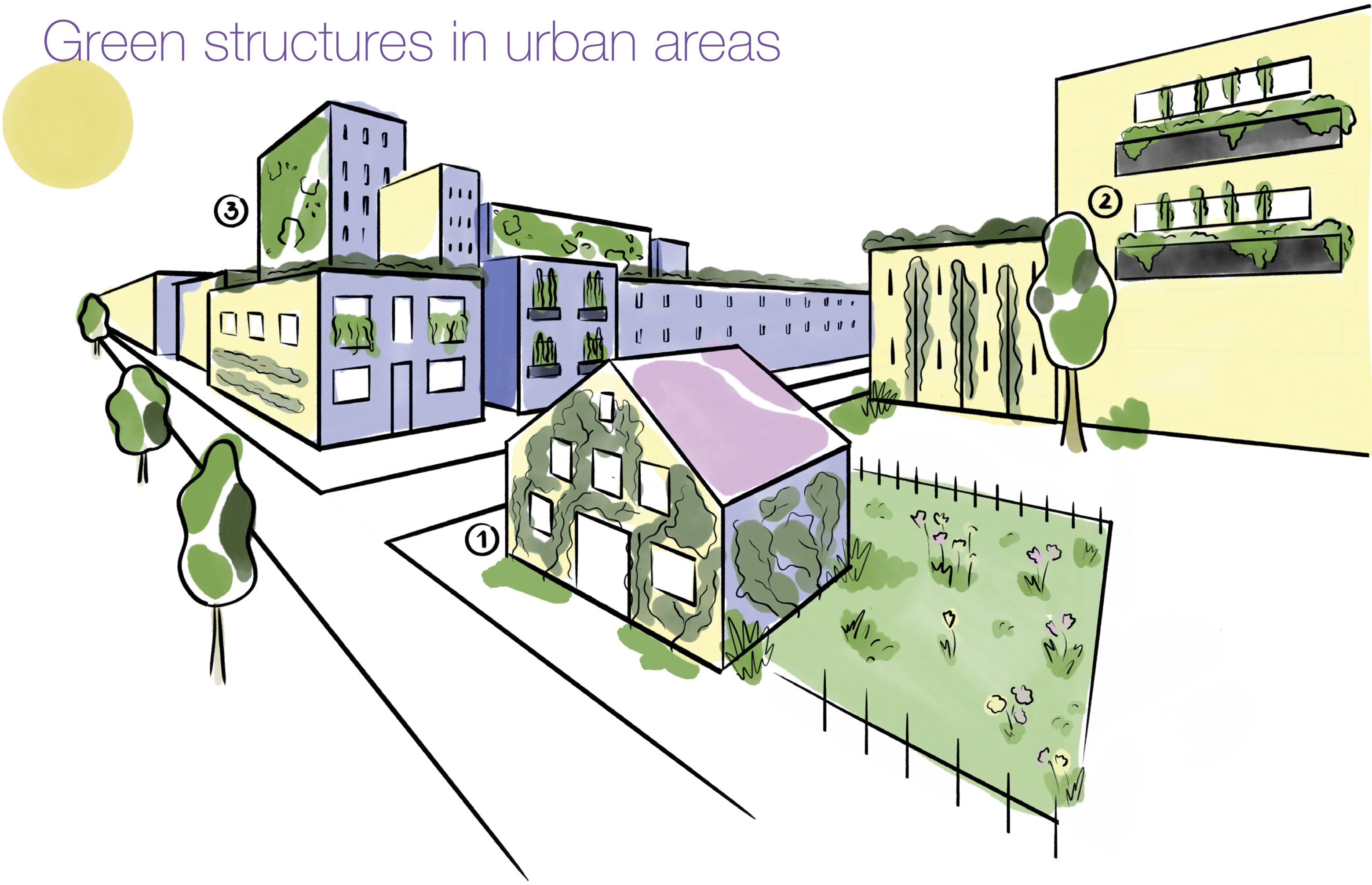


Figure 12: Illustration of different green structures and solutions in urban spaces.

5. Decision-making guide to green facade systems

Different green façade systems have different requirements in terms of space requirements, façade characteristics, maintenance requirements and investment costs. At the same time, they also offer different potentials in terms of design scope, contribution to climate adaptation and ecological quality.

The information in this chapter is intended to help you choose a suitable façade greening solution for various framework situations. For existing buildings in particular, the possibilities for greening depend on factors such as root space, load-bearing capacity and the condition of the façade. These guidelines and the decision-making guide in this chapter focus in particular on biodiversity and the climate adaptation potential of green façades. In addition, reference should be made to other existing recommendations for action on façade greening, which also contain valuable implementation recommendations and planning advice on various key topics (> Recommended reading, p. 104).

Figure 12 illustrates a selection of green façade systems and other components of inner-city green infrastructure. Green façade systems can be flexibly combined with each other or with other forms of greenery such as green roofs, flower strips or urban trees. In addition to Figure 12, Table 1 lists a classification of greening solutions in terms of their potential and requirements. The categorization takes place within the construction types ground, planter or wall-based. The classification is intended to provide an initial assessment of which solution might be suitable in individual cases.

Table 1: Classification of the greening solutions shown in Figure 12 in terms of potential and requirements, separated into new planting and existing planting.

Type of greening	Ground-based façade greening (trellis climbing plants or self-climbers) ①	Planter-based facade greening (trellis climbing plants + underplanting if necessary) ②	Wall-based facade greening (Living Wall Systems) ③
Biodiversity potential			
New planting	●○○	●○○	●○○
Existing	●●○	●○○	●○○
Integration of commercially available nesting aids	✓	✓	(✓)
microclimatic potential			
New planting	●○○	●○○	●○○
Existing	●○○	●○○	●○○
Requirements			
Connection to the ground	✓	-	-
Additional construction	(✓) trellis if necessary	✓ Planter + technology + Trellis	✓ Substructure + technology + modules/fleece/…
Irrigation	(✓) for new planting and drought stress	✓	✓
Maintenance (pruning/visual control)	✓	✓	✓
Digital technology/monitoring	-	✓	✓

○○○ No effect ●○○ Low effect potential ●●○ Medium effect potential ●●● High effect potential

5.1. Potentials

PROMOTING BIODIVERSITY AND SPECIES DIVERSITY

Both species and habitat diversity can be influenced by the choice of plants and the structural design of the area. Even on relatively small areas, a variety of habitat qualities can be created through different structures and microclimatic heterogeneity, which in turn promote insect diversity [3, 16].

Careful plant selection can create a long-term food supply for diverse pollinator insects. As already explained in > Chapter 3.1, native species are essential when selecting plants in order to appeal to the specialists of the local fauna.

Infobox: Native climbing plants

In Germany, there are only a few native species of climbing plants that are suitable for dense and extensive façade vegetation for ground-based or planter-based green façades [27]. Plant species diversity is therefore only possible to a limited extent with these systems, but can be increased, for example, by appropriate underplanting of the planters.

The greater the diversity of structures and climatic conditions within a planting system, the higher the potential species diversity [3, 16, 65]. The structural richness can also be specifically increased in façade greening, especially in planter and wall-based systems, for example through different growth characteristics or the integration of habitat systems (> Chapter 3.2).

Age also plays an important role in the ecological benefits of greening. Over the years, different structures and thus habitats can develop. Dead material and dead wood attract other living organisms and some plant species only flower after a few years, such as ivy (> Digression: *Hedera helix*). Therefore, the ecological potential of new plantings is usually not yet fully exploited [21].

MICROCLIMATIC POTENTIAL AND CLIMATE ADAPTATION

Areas that are shaded by greenery, whether by a tree or a green façade, heat up less than areas that receive direct sunlight (> Chapter 4.1). The ability of plants to vaporize water via the leaf surfaces also contributes to the cooling potential of greenery [38, 52] (> Chapter 4.2). If the green infrastructure is to make a significant contribution to reducing summer overheating, it must be sufficiently large.

Façade greening with climbing plants usually takes some time to achieve a dense and lush appearance and full surface effect. Accordingly, their microclimatic potential is not yet exhausted during this period. With soil-based systems, this development period can be 3 to 10 years, with planter-based and wall-based systems it is faster with the help of pre-cultivated plants. With soil-based systems in which the plants are not watered automatically, there is a risk that they will not receive a sufficient supply of water via the soil during dry periods. This can lead to heat stress and a lack of vitality. As a result, façade greening has little or no positive effect on the microclimate [54]. Accordingly, care must be taken to ensure that plants can only provide ecosystem services, such as climate regulation, if they are vital and have an adequate water supply even during periods of heat [29, 54].

5.2. Requirements and framework conditions

CONNECTION TO THE GROUND

Plants supply themselves with water and nutrients in permeable soil [27]. If there is sufficient space for roots to grow through, soil-based greenery can be installed.

There is a connection to the ground

Soil-based greenery requires sufficient space in the soil for roots to grow through. The individual planting pit should be at least 50 cm deep and have a volume of at least 1 m³ [18]. Care should be taken to use a suitable planting substrate. This can be particularly relevant in urban areas and the filling soil may have to be replaced [52]. The plants should be connected to the groundwater so that no additional irrigation is required. For new plantings in urban areas and in the event of drought stress, water management is also necessary for soil-based new plantings, as otherwise a sufficient water supply cannot be guaranteed.

There is no connection to the ground

For planter-based systems, the same recommendations regarding root space apply to the requirements for the planter as for soil-based systems. In wall-based systems, the substrate is in the system itself and the plants have no direct connection to the ground. This means that these systems are also suitable for densely built-up or sealed areas, but must be supplied with nutrients via an automatic irrigation system.

TECHNICAL MEASURES

Different greening solutions differ in particular in terms of the technical or structural measures required for installation and operation. In the case of façade greening, this primarily relates to the aspects of irrigation and possible structures for load-bearing capacity and climbing support.

Low technical effort

The technical requirements for soil-based self-climbers are minimal and consist primarily of an intact, crack- and joint-free façade with sufficiently load-bearing plaster. Thermal insulation composite systems are not suitable as a substrate for self-climbers [27, 52].

Soil-based or planter-based climbing plants with climbing support (nets, trellises, ropes, etc.) are recommended for various wall constructions. A distance of at least 15 cm between the auxiliary construction and the façade ensures that the function of the façade is not impaired. Hoses embedded in the soil or substrate for drip irrigation ensure a reliable and economical water supply [52].

Technical effort required

In the case of wall-mounted greenery, the façade must have sufficient load-bearing capacity to hold the support system including plants and water-saturated substrate. This must always be checked on a case-by-case basis and an additional substructure may be required to transfer the load to the building structure. In addition, wall-mounted greening usually requires a small technical room for the installation of the pump station, control unit, fertilizer tank and compressor. Planter-based green façades have the same requirements if they are to be hung in front of the façade and extend over several storeys.

The wild climate wall

FAQs (Frequently Asked Questions)

WHAT DOES IT COST TO PURCHASE AND MAINTAIN THE WILD CLIMATE WALL?

The costs vary greatly depending on the individual framework conditions and the underlying greening system. The investment costs for technical and horticultural planning and implementation range from 700 to 1,500 €/m² (net) for wall-based systems. In addition, there are annual maintenance costs for upkeep and operation of approx. 10-40 €/m² and horticultural care of 15-100 €/m². Further information in > Chapter 7.

IS THE MAINTENANCE OF A BIODIVERSITY-PROMOTING GREEN FAÇADE MORE COMPLEX THAN WITH A CONVENTIONAL GREEN FAÇADE?

No, not necessarily. The cost of ongoing maintenance is made up of (remote) monitoring, the necessary travel and the actual working time on site. The idea of biodiversity-sensitive maintenance is to prune sections of the façade only once or twice a year, which is usually less often than with a conventional façade. However, the on-site maintenance process may take longer, as it involves manual and selective pruning. Further information in > Chapter 3.3.

WHEN IS THE RIGHT TIME TO CUT BACK THE GREEN FAÇADE?

Biodiversity-sensitive maintenance requires a deep understanding of ecological relationships and is dependent on annually changing weather conditions and the resulting breeding behavior of the fauna. Both the hatching times of wild bees and the start of nest building in birds in spring are strongly dependent on the weather and do not occur at the same time every year, but it is essential to consider them in any possible maintenance work in the spring. Further information in > Chapter 3.3.

ARE THE PLANTS ON THE WILD CLIMATE WALL HARDY?

Yes, the plants used are hardy (perennial) and overwinter in the green façade. It should be noted that the plants must also be supplied with water in winter.

WHY ARE DEAD PLANT PARTS NOT CUT OFF?

Dry plant stems can provide a habitat for insect larvae and pupae, which hatch from them the following spring, or can be used for overwintering. Dry structures are also used by birds to build their nests. The native fauna harmonizes optimally with the native flora, even if (parts of) plants die off. Further information in > Chapter 3.3.

WHY ARE THE WEEDS ON THE WILD CLIMATE WALL NOT REMOVED?

Colloquially known as "weeds", spontaneous vegetation is part of biodiversity and often fulfills important ecological functions. Due to independent sowing or propagation, these plants are usually very well adapted to the location in which they settle. However, these characteristics can also become a problem in connection with the deliberately planted species: If spontaneous vegetation restricts the growth of other species, it is therefore removed. Further information in > Chapter 3.1.4

WHAT RISKS ARISE WHEN INSECT HABITATS ARE INSTALLED CLOSE TO WINDOWS AND DOORS?

The habitats are aimed at promoting wild bees and other, mostly solitary insects, which are generally not aggressive and also show no interest in human food, as is the case with the common wasp, for example. However, insects or other animals may occasionally stray into human spaces. This can be easily prevented with insect screens. Further information in > Chapter 3.2.

HOW ARE INSECT NESTING BOXES PROTECTED FROM BIRDS?

There are no protective measures of this kind on the wild climate wall. During the project period, no birds were observed to rob the insects' nesting sites. A coarse-meshed wire mesh in front of the nesting aids can prevent birds from gaining access if necessary.

MAINTENANCE AND CARE COSTS

The aspect of maintenance and care must be taken into account from the outset during planning and is crucial for the long-term development of the green façade. Good green space maintenance not only involves complex façade greening, but also many other natural elements in the city - for example the regular mowing of flowering meadows or the maintenance of urban trees. In high-density urban areas in particular, where many uses come together, green spaces must be regularly maintained in order to sustain their positive effects and prevent safety-related hazards such as falling branches or obstructed visibility in road traffic. Maintenance and care include aspects such as watering, visual inspections, pruning and replanting. (> Chapter 6.3)

Infobox: "Do-it-yourself” solutions

In principle, it is possible to carry out the planning, construction and maintenance of simpler forms of greening, such as trough planting or the system from Fact Sheet 3 (> Chapter 5.3), yourself if you have the basic horticultural knowledge and the time and capacity to do so. Otherwise, it is always advisable to have them professionally executed and maintained.

Low maintenance and care costs

The maintenance of technical systems such as automated irrigation and fertilizer addition can be omitted for simpler façade greening systems such as soil-based greening with sufficient root space. However, all green façades require annual pruning, for example.

High maintenance and care costs

Due to their technical installations, wall-mounted green façade systems require more maintenance and servicing, and care is generally more complex than with soil-based systems. However, soil-based or planter-based systems can also be more maintenance-intensive if accessibility for carrying out maintenance measures is limited or the plant selection requires shorter maintenance intervals. An important criterion for the maintenance effort is the height of the façade and its accessibility. Corresponding space requirements and occupational safety aspects must be taken into account at the planning stage. For this reason, the height for green facades is usually up to 20 meters.

5.3. Fact Sheets
green facade systems

Of the urban greening options shown in Figure 12, four façade greening systems are presented in more detail below in brief fact sheets. The systems presented are offered by different companies and system manufacturers and can therefore be found on the market under individual product and brand names.

The green façade systems represent exemplary solutions, each of which has characteristic properties and is therefore suitable for different applications and budgets. Additional explanations of the stated costs (net) and what is included can be found in > Chapter 7.

The "classic" soil-based façade greening using self-climbers such as ivy or wild vines is not listed in the following fact sheets. In order to minimize possible risks in connection with green façades, a climbing aid is always recommended as a second level in front of the façade for ground-based green façades (information sheet 1).

Fact Sheet 1

Soil-based vegetation - little effort, great effect

SUITABLE PLANT SPECIES	**Climbing plants**
NUMBER OF POSSIBLE PLANT GENERA AND SPECIES	**> 30 (climbing)**
MAX. HEIGHT	**12 m**
DURATION UNTIL FULL-SURFACE COVERAGE IS ACHIEVED	**3-10 years, depending on height**
COSTS (PER M^2)	**€ 200-300** (without irrigation, > Chapter 7.4)
INTEGRATION OF CONVENTIONAL HABITATS POSSIBLE	**yes**
PLANNING BY	**Landscape architects, GaLaBau**
CONSTRUCTION BY	**GaLaBau or private**
MAINTENANCE BY	**GaLaBau or private**

CHARACTERISTIC PROPERTIES

Soil-based vegetation with climbing plants on a climbing aid is a very simple form of façade greening, as it is basically possible on almost any façade and requires few technical measures and maintenance. This means that it is also possible to create and maintain this form of façade greening yourself at low cost if you have the basic knowledge and the time and physical capacity to do so.

For climbing plants, whether soil-based or planter-based, the plant and climbing support must be matched to each other, as there are different types of growth (> Digression Climbing plants). This in turn offers design options for the appearance of the façade: In this way, plants can either grow upwards at certain points (e.g. on steel cables) or a net/grid can be stretched over an area of the façade that will later be densely overgrown. Although this green façade solution is often implemented without an irrigation system, the need for irrigation should be checked in extreme locations, such as the city center.

Some bird species that normally breed mainly in hedges, such as blackbirds, are very happy to use green façades as nesting sites. A dense ivy façade or the additional climbing structure provide sufficient support for the birds to build their nests in. The range of species of native climbing plants is not as extensive as that of wild shrubs, for example. In the interests of promoting biodiversity, therefore, all the more care should be taken to use plants that offer a high quality of food and habitat for the typical local fauna, for example through pollen and nectar or fruits and seed heads. To increase this potential, the soil-based vegetation in the ground soil area (bed) can be supplemented with small bushes or a diverse flowering shrub underplanting.

TRADITIONAL FAÇADE GREENING WITHOUT CLIMBING SUPPORT

Fact Sheet 2

Planter-based greening - Flexible application site, versatile plant selection

SUITABLE PLANT SPECIES	**Climbing plants, bushes, shrubs, Urban Gardening**
NUMBER OF POSSIBLE PLANT GENERA AND SPECIES	**> 30 (climbing)**
MAX. HEIGHT	**7 m per planter row**
DURATION UNTIL FULL-SURFACE COVERAGE IS ACHIEVED	**2-4 years, depending on height**
COSTS (PER M²)	**€ 600-900** (> Chapter 7.4)
INTEGRATION OF CONVENTIONAL HABITATS POSSIBLE	**yes**
PLANNING BY	**Specialist planner facade greening**
CONSTRUCTION BY	**Special firms within GaLaBau or specialist facade greening planning company**
MAINTENANCE BY	**Special firms within GaLaBau or specialist facade greening planning company**

CHARACTERISTIC PROPERTIES

Planter-based vegetation is well suited to glazed façade surfaces with a maintenance corridor. With these systems, it is possible to see through the vegetation and at the same time make use of shading effects. If plants are chosen that shed their leaves in winter, the planting contributes to a positive energy balance of the interior depending on the season: In summer, the room is protected from strong solar radiation; in winter, light and solar heat gains can be used. [14]

But planter-based façade greening is also popular in parking garages or on balconies, for example. Even tall buildings can be greened using planters or tubs set up storey by storey. This usually requires a secondary structure to which the planterscan be attached.

The design options for container planting are vast. Climbing plants on scaffolding can be used to create a lush surface effect, but edible plants, as in urban gardening projects, are also possible. In order to create a high ecological value, the integration of (bird) bushes or a species-rich underplanting with native wild shrubs is recommended. With a planter-based system, conventional nesting boxes for birds or wild bees can be added very easily, for example by attaching them to the existing climbing support.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NEW YORK

Fact Sheet 3

Wall-based greenery - stackable - simple solution for smaller areas

SUITABLE PLANT SPECIES	**Perennials, herbs, urban gardening**
NUMBER OF POSSIBLE PLANT GENERA AND SPECIES	**> 100**
MAX. HEIGHT	**3 m**
DURATION UNTIL FULL-SURFACE COVERAGE IS ACHIEVED	**4-8 weeks**
COSTS (PER M²)	**€ 300-400** (> Chapter 7.4)
INTEGRATION OF CONVENTIONAL HABITATS POSSIBLE	**yes**
PLANNING BY	**Landscape architects, GaLaBau or private**
CONSTRUCTION BY	**GaLaBau or private**
MAINTENANCE BY	**GaLaBau or private**

CHARACTERISTIC PROPERTIES

Wall-mounted greenery made up of stackable modules is a suitable solution for private properties to vertically green even smaller areas. Such vertical wall gardens are available as channel or planter systems that can be individually assembled and planted. An integrated irrigation system ensures the water supply, so that the maintenance effort is limited to pruning and possible replanting. The advantage of these systems is that the load can be transferred via the soil; only an additional anti-tilt device is required. This eliminates the need for complex and cost-intensive substructures.

Some of these systems have a very simple design that makes it possible to implement the greening project yourself. The costs can be reduced to material and consumption costs (water, electricity) if gardening skills and the appropriate time and reliability are available for maintenance.

The system can be filled directly with pre-grown plants during the vegetation period so that dense growth is established after just a few weeks. The possibilities in terms of plant selection are almost unlimited: from evergreen plants to shrubs, grasses and ferns to smaller fruit or vegetable plants and herbs. Accordingly, the right choice of plants can create a rich food supply for local wildlife and contribute to biodiversity. Here too, the range of breeding sites and nesting opportunities can be increased by installing commercially available habitat systems, for example for birds or wild bees.

Fact Sheet 4

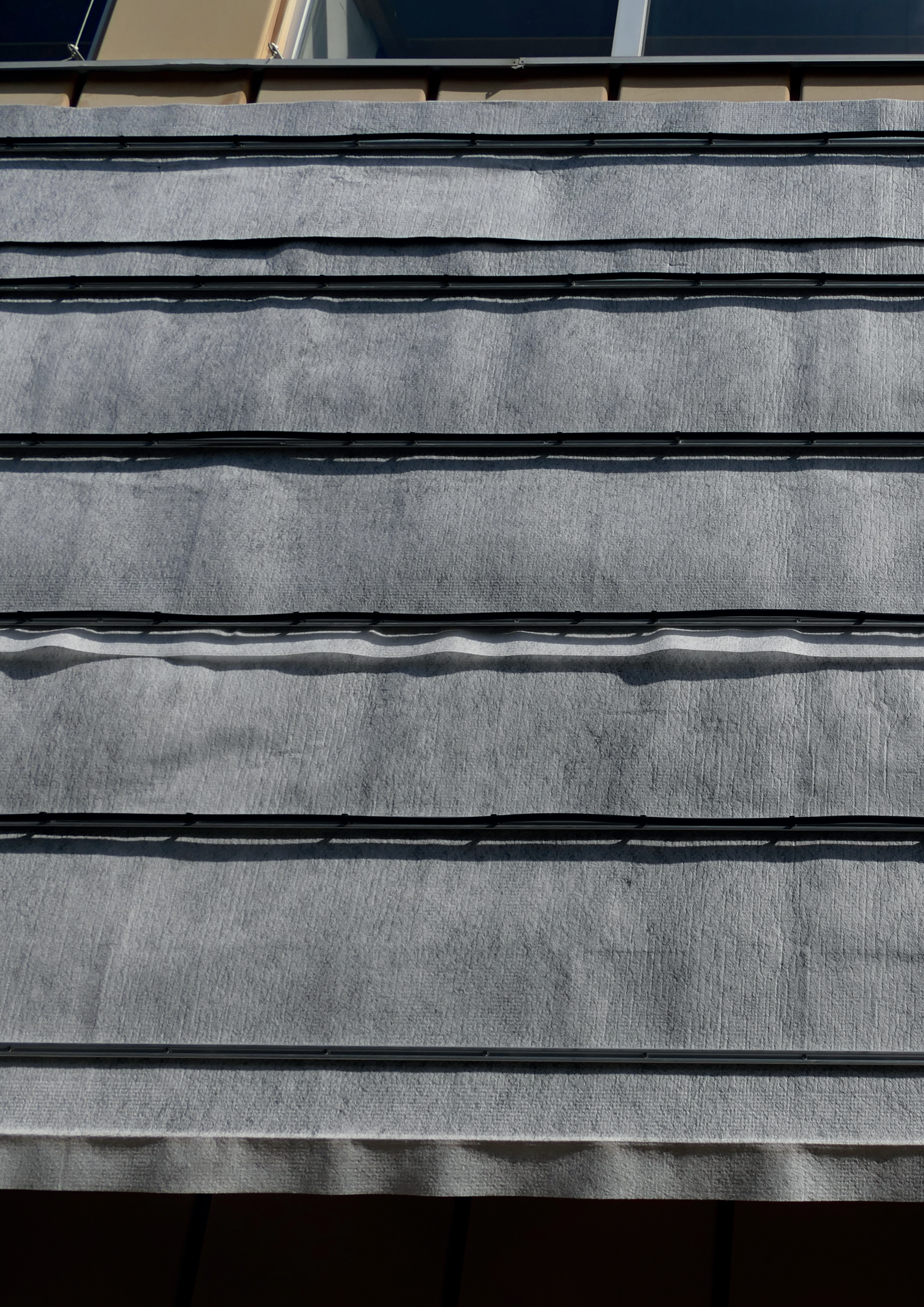
Wall-mounted vegetation - Living Wall • technically sophisticated, guaranteed eye-catcher

SUITABLE PLANT SPECIES	**Perennials, herbs, small shrubs, Urban Gardening**
NUMBER OF POSSIBLE PLANT GENERA AND SPECIES	**> 100**
MAX. HEIGHT	**approx. 20 m**
DURATION UNTIL FULL-SURFACE COVERAGE IS ACHIEVED	**immediate**
COSTS (PER M²)	**€ 700-1,500** (Chapter 7.4)
INTEGRATION OF CONVENTIONAL HABITATS POSSIBLE	**(yes)**
PLANNING BY	**Specialist planner facade greening**
CONSTRUCTION BY	**Specialist facade greening planning company**
MAINTENANCE BY	**Specialist facade greening planning company**

CHARACTERISTIC PROPERTIES

Wall-mounted vegetation using a modular system or a fleece/geotextile system offers the greatest design options in terms of plant selection, arrangement and the overall appearance of the façade. The plants are arranged here in the planning process using a design concept or a planting plan, meaning that color spectra, patterns and structures can be selected individually (> Chapter 3.1). As the systems are variable in their design, shape and dimensions, they can be adapted to suit local conditions. Design accents can be set, but façade areas such as windows and doors can also be left out. This also makes them a suitable solution for high-density urban areas, where often only the facades are available as surfaces for integrating greenery. Neither root space nor an installation area is required, only the "widening" of the building by the green façade must be taken into account.

Wall-mounted Living Wall systems are installed pre-cultivated and therefore have a full-surface effect right from the start. This is not only visually advantageous, but also in terms of the microclimatic effect and for the local fauna, for which the green façade can serve as a source of food and habitat from day one.



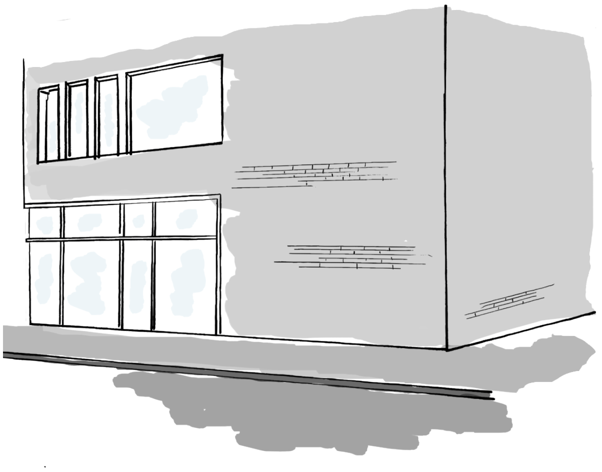
6.

Recommendations for planning, construction and awarding contracts

6. Recommendations for planning, construction and awarding contracts

The path from the idea to the finished biodiversity-promoti green façade can vary greatly depending on the syste framework conditions and requirements. For the planning a implementation of façade greening, it is generally advisable seek the support of experts.

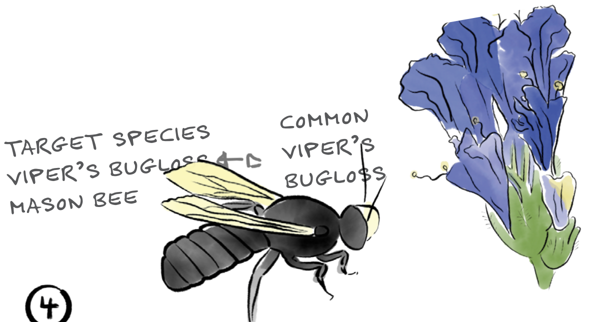
The following chapter describes the process from planning implementation and provides recommendations for action. addition, Figure 13 below (points 1-6) summarizes the planni process for the creation of biodiversity-promoting green façad as an example.



①

PRELIMINARY INVESTIGATION BUILDING

Analysis of the (building law) framework conditions, requirements and wishes of the existing building and/or new building.



④

DETERMINATION OF FAUNISTIC TARGET SPECIES

Step 3 results in the determination of the faunistic target species. For example, the "Baden-Württemberg target species concept" can be used to support this. These target species result in floristic target species and the corresponding habitat structures.

③

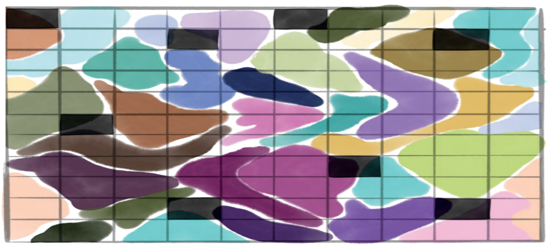
ECOLOGICAL AND CLIMATIC SITE INVESTIGATION

Identification of the ecological potential and habitat quality of the location and surroundings. Climatic analysis of exposure, orientation and weather conditions at the site.

②

PRELIMINARY INVESTIGATION SYSTEM

Analysis and definition of a suitable green façade system, taking into account the results from Step 1. Table 1 lists the corresponding requirements for the green façade system.



⑤

PLANTING PLAN

Development of a planting plan based on the defined faunistic and floristic target species, taking into account the climatic conditions.

⑥

IMPLEMENTATION PLANNING

Preparation of the detailed and implementation planning including planning of the technical center and the irrigation concept.

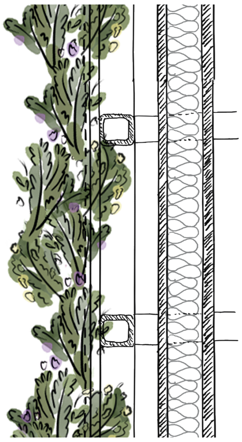


Figure 13: Illustration of an exemplary planning process for a biodiversity-promoting green façade (points 1-6).

6.1. Planning

COMMISSIONING OF THE PLANNING

Experts from the fields of architecture, urban planning and (urban) horticulture can be consulted for the planning implementation. If necessary, experts from the fields of statics and fire protection should also be involved in the planning process. If the greening is part of an approval-relevant measure, a person authorized to submit building plans must be involved. In Germany, this status is usually held by active members of the chambers of civil engineering and architecture. Many specialist greening companies have their own planning departments or work together with planning offices.

PRELIMINARY EXAMINATIONS

Before the planning of a biodiversity-promoting greening measure can begin, preliminary economic, technical and ecological studies should be carried out. This allows opportunities and potential, but also potential risks, to be identified at an early stage and integrated into the planning process.

The preliminary economic and technical investigations include clarifying the ownership structure and evaluating local legislation. It must be ensured that all relevant (building) law requirements for the planned measures can be met. For example, development plans or bylaws must be checked, which can be viewed at the municipality, often even online. Potential funding opportunities must also be considered at an early stage.

The preliminary ecological investigations include measures that make the ecological potential of a site visible (> Chapter 3.1). In terms of the sustainable use of resources, it should also be checked in advance whether and how rainwater can be used to irrigate the greenery. It may also make sense to consider using renewable energies to operate the irrigation system.

PLANTING PLAN

A planting plan will be drawn up for the façade in order to achieve biodiversity-promoting, site-appropriate and long-lasting planting. The plants are later planted on site according to this plan. The more plants are integrated into the green façade, the more important it is to plan well in order to optimize the appearance and health of the plants. Green façade system manufacturers usually have the relevant expertise, but it should be clarified whether advice, design and final planting plans are included in the offer.

IRRIGATION PLANNING

In contrast to some green roofs, wall-mounted green façades in particular are not able to store water over a longer period of time and supply the vegetation due to their construction and static and structural requirements. In addition, automated irrigation should usually be used in urban, densely populated areas with ground-based systems.

Synergies with rainwater management must be created. Some regions in Germany are already experiencing water shortages in summer and the consumption of drinking water will lead to conflicts of use in the future [8]. In order to continue to have sufficient drinking water resources available, the use of rainwater for horticultural irrigation should be examined and considered.

When using rainwater to irrigate green facades and other greening solutions, ensure that the water quality is high. Roof areas connected to a cistern must therefore be free of herbicides and pesticides. Rainwater from traffic areas can be used if it is free of particles such as microplastics, hydrocarbon-containing compounds such as petrol and other contaminants. It is also important to ensure that no salt is used on the connected traffic areas in winter. In addition, no chemicals, such as those produced by washing cars, may enter the water cycle.

GREEN FACADE IMPLEMENTATION PLANNING

Once the preliminary investigations have been completed, the collected findings are to be bundled and gradually transferred into a concept through to implementation and detailed planning. The knowledge base creates a foundation for subsequent decisions and any necessary exchange with experts. A dialog with experts can always help to combine practical solutions and innovative approaches.

PRE-CONSTRUCTION MEASURES

If greening is to be retrofitted to existing buildings, the building must generally be prepared for greening. Structural and infrastructural measures, such as electricity and water pipes, must therefore also be taken into account in the planning process.

There are also logistical factors to consider, as materials have to be delivered for construction and the green façade should be as easily accessible as possible for care and maintenance. In some cases, it is also necessary to use machines, whose routes and installation areas must also be planned in good time.

THE TECHNICAL CENTER

The technical center is the technical control center of an automatically irrigated green facade and usually consists of a pumping station with various, sometimes optional components such as a control unit, a water filter, a compressor and a fertilizer tank with mixing device.

The location of the technical center must be easily accessible and is usually optimized with regard to short cable lengths. Ideally, the technical center is therefore located in a room close to the green façade, from which the green façade can be supplied with water, electricity or sensors. A power connection and a water connection with rainwater or fresh water are required for their operation.

INTERFACES

For the manufacturers of greening systems, it is important that the interfaces to other trades are clarified before installation. Important interfaces exist primarily between greening, façade construction and building technology. For example, anchor points, installation areas, cable routing and transfer points for supply and disposal need to be clarified.

APPEARANCE OF THE
WILD CLIMATE WALL
ON THE DAY OF INSTALLATION

Digression

Public tenders

As a rule, municipalities must put construction services out to public tender. A so-called bill of services (BOS) is usually drawn up for this purpose. All partial services are listed in detail in the specifications. The BOS serves to establish comparability between the companies offering services. Under certain conditions, a performance program can also be drawn up in which the desired result rather than the tasks are described (Article 7c VOB [Construction Tendering and Contract Ordinance]A).

According to Article 7 para. 1 of VOB/A, all external factors that have an influence on the tender must be stated in the tender documents. The tendering body must therefore carry out (or have carried out) a survey of the initial situation and disclose all influencing factors that have arisen.

As the creation of service specifications and programs involves a great deal of effort, the tender texts are often based on templates or preliminary work. Some templates are available free of charge on the internet, but are then often provided by system manufacturers and naturally favor their own systems. It is also popular with planning offices and client representatives to use passages from previous projects. However, this means that some of the necessary innovations and adjustments fall by the wayside. Climate adaptation and biodiversity promotion have rarely been prioritized in the design and maintenance of green façades. This guideline is intended to motivate people to place a higher value on the above-mentioned aspects.

Digression

Building law framework

Urban space is always a planning challenge, if only because of the multitude of competing uses. In order to regulate land use in a city and prevent conflicts of interest, the public sector uses the planning law instruments of urban land use planning (> Digression: Options for action by municipalities). Various stipulations relating to urban greenery can be made in the development plan, which specifies the urban development use of a property. Typical stipulations are, for example, mandatory areas for the greening of roofs and facades as well as the preservation or planting of trees or hedges. In individual cases, the necessary quality of implementation is also described, for example by requiring certain tree species for new planting or intensively greened roof areas.

In addition to the possible planning law framework conditions, building law framework conditions, e.g. with regard to fire protection, must also be observed when erecting buildings and greening them. Green facades are part of the building envelope. As of October 2024, there is still no standardization in Germany that regulates the handling of façade greening from a fire protection perspective. Consequently, general regulations, such as the relevant state building regulations, must be observed when greening buildings. The greening must be carried out in such a way that the development of fire and the spread of fire and smoke are prevented. In addition, the rescue of people and animals and fire-fighting work must not be hindered.

6.2. Care and maintenance

TENDERING OF MAINTENANCE SERVICES

Greening services should always be tendered with a view to long-term maintenance of the greening. When concluding a contract with a specialist company for façade greening, it should therefore be clarified whether a maintenance contract is also part of the service. In practice, a distinction is made between completion, development and upkeep maintenance (> Chapter 3.3). If the maintenance measure is to be biodiversity-sensitive, this must be stipulated and defined in the invitation to tender or, at the latest, in the maintenance contract.

CONTROL

The façade greening, including any existing technology, should be inspected at regular intervals by an expert. Possible technical malfunctions can be identified and rectified and the development of the planting can be checked. This is particularly relevant for technically more complex systems (e.g. Living Wall systems, Fact Sheet 4, > Chapter 5.3).

The irrigation system also needs to be checked and maintained regularly. In the fall, prepare automatic irrigation systems for winter operation. In the case of wall-mounted systems, a compressor is usually integrated into the irrigation technology, which blows the pipes free after each watering cycle in winter, thus preventing frost damage. [27, 52]

UNPLANNED MEASURES

In addition to regular care and maintenance work, unplanned work may also be required. Malfunctions or failures, for example of the irrigation management system, are possible, especially with technically complex façades. The responsibilities for rectification of such problems at short notice should be contractually defined in advance. In individual cases, it may also be necessary to repair or prevent damage caused by e.g. vandalism (removal or damage to plants), severe storms or damage to pipes and hoses.

RECOMMENDED READING

CHAPTER 5 + 6

Bundesverband Gebäudegrün e.V. (BuGG) Technical information (2023) "Fire protection requirements for green roofs and façades"

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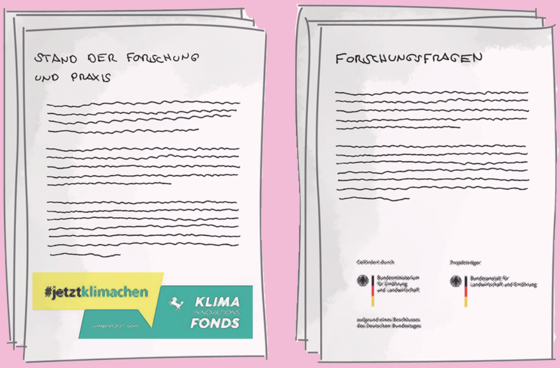
CONTROL AND SELECTIVE PRUNING
ON THE WILD CLIMATE WALL

The wild climate wall

Implementation example

① RESEARCH AND ANALYSIS



Research and analysis on
the state of knowledge and practice

BIODIVERSITY-PROMOTING
GREEN FACADES

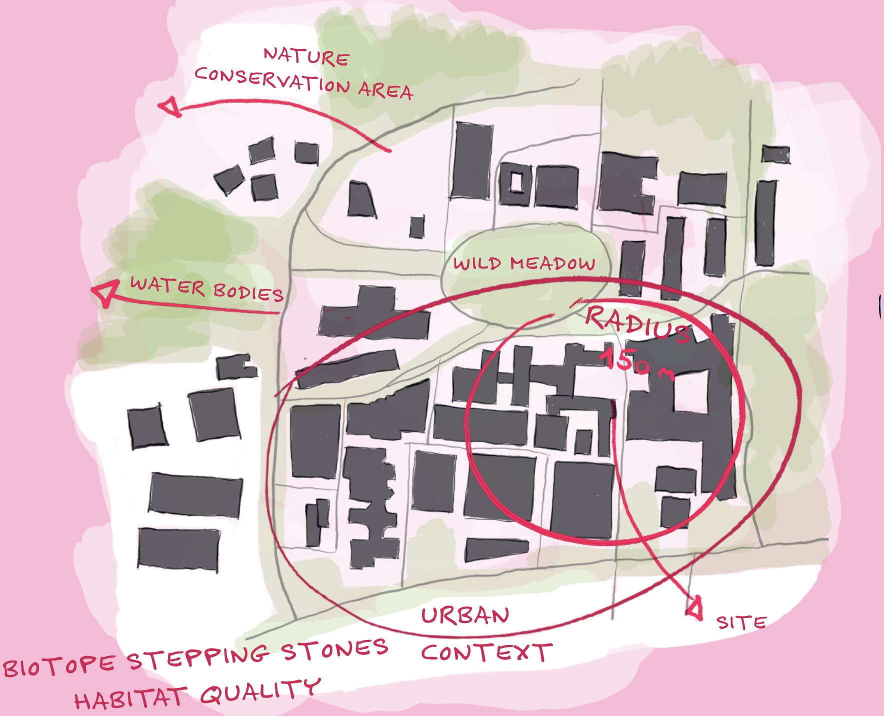
Identification of development needs with:

- Development of biodiversity-promoting green façade system
- Monitoring, testing and development of care management

② START DEVELOPMENT: PRELIMINARY INVESTIGATION

Ecological and climatic preliminary investigation of the site.
Identification of ecological potentials and habitat qualities.

Among other things, the target species concept Ba-Wü / species protection concept Stuttgart / weather data sets were taken into account here.



③ DEFINITION OF TARGET SPECIES

Definition of the faunistic target species incl. their habitat requirements,
> Figure 4:

OBSERVE
AND BE ASTONISHED!

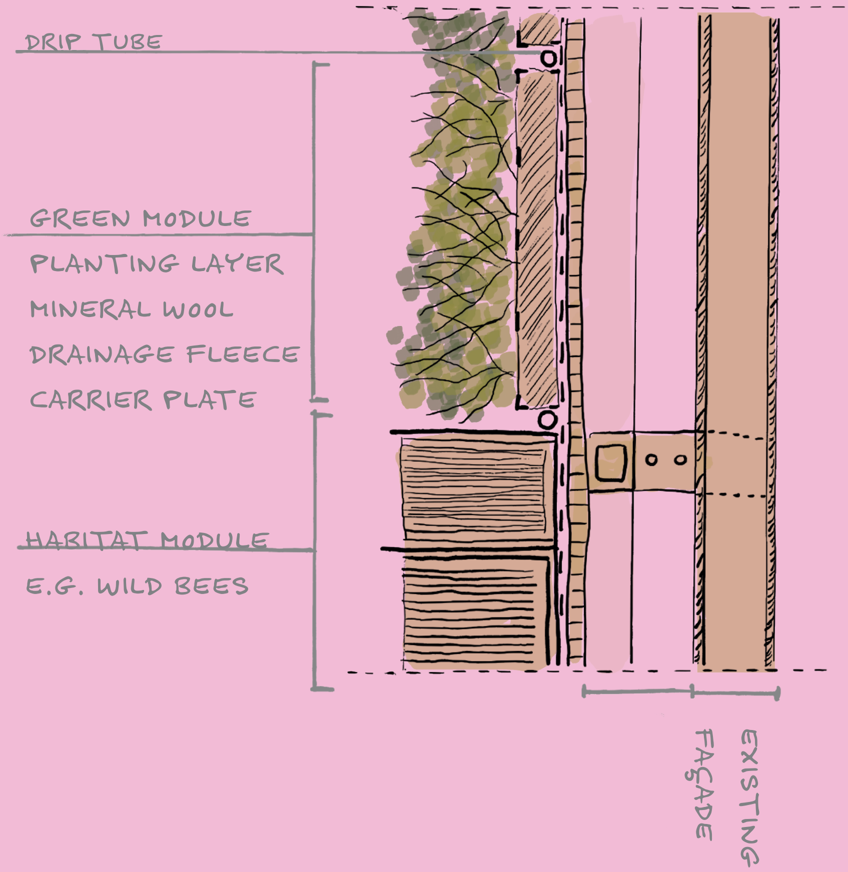
⑥ MONITORING AND CARE

Development of biodiversity-promoting maintenance concept for vertical greenery.

Scientific monitoring and analysis of the ecological and climate-regulating qualities and effective functions.

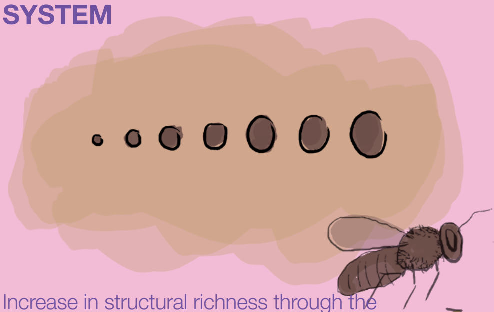
CLOSE COOPERATION BETWEEN
science and practice
IN ALL PLANNING AND

⑤ IMPLEMENTATION PLANNING AND CONSTRUCTION



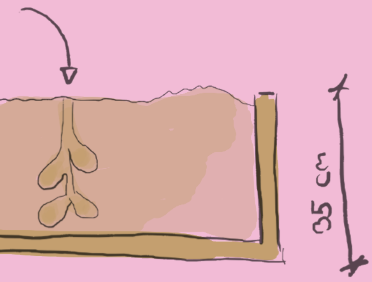
Derivation plants and development of a planting plan,
> Chapter 3.1. and p. 60

④ DEVELOPMENT OF PLANTING PLAN AND HABITAT SYSTEM



Development of habitat systems,
> Chapter 3.2.

Development of habitat systems for wild bees nesting in the soil



Increase in structural richness through the provision of nesting tubes from 2 to 10 mm.
Use of different materials:
Reeds/bamboo/hardwood (beech)/
dead wood/clay and sand mixtures.

Digression

Options for action by municipalities

There are various strategies for public authorities to promote the expansion of green façades as part of urban climate adaptation and biodiversity promotion.

URBAN GREEN IN BUILDING PLANNING LAW

One of the tasks of local government is to implement agreed political strategies and concepts. In many cases, implementation cannot be accomplished by the municipality itself, but must be tackled together with private households and commercial enterprises. To this end, local authorities have various tools with which they can promote specific actions or, in individual cases, prohibit them. Direct economic incentives for certain actions, such as the greening of roofs and facades, can be created through subsidy programs or concessions on taxes and levies. Municipalities can also intervene to regulate, for example by levying fees, issuing ordinances, guidelines and action plans. The regulatory tools in particular are usually based on state or federal law. Possible legal bases are the Federal Nature Conservation Act (BNatSchG), the Building Code (BauGB) and the Federal Immission Control Act (BImSchG). [41]

The Building Code clarifies the responsibility of municipal urban land-use planning for general environmental and climate protection: According to Article 1 para. 6 of the German Building Code (BauGB), the effects of construction projects on animals, plants, soil, water, air, climate and the interactions between them, as well as the landscape and biodiversity, must be given special consideration. With the help of urban land-use planning, municipalities can control the implementation of climate and environmental protection measures locally. Important tools for this are landscape and green structure plans as well as development plans. In the latter, the local authority defines the stipulations of the urban planning regulations that must be taken into account in new or revised plans. In this way, particularly climatically relevant parameters such as soil sealing, the proportion of green and open spaces, building height and the design and use of the building envelope, e.g. for energy generation, can be controlled. Development plans have locally defined areas of application and must be adopted in the form of a statute. [41]

FOR EXAMPLE: BUILDING GREENING IN URBAN LAND USE PLANNING

Below are some examples of provisions for urban and building greening in one of the development plans for the new Neckarpark district being built in Stuttgart (planning area Ca 283/5):

a) Areas are to be landscaped and planted as vegetation areas, planted with native, site-appropriate deciduous trees (minimum size 20/25) and deciduous shrubs and thus permanently maintained.

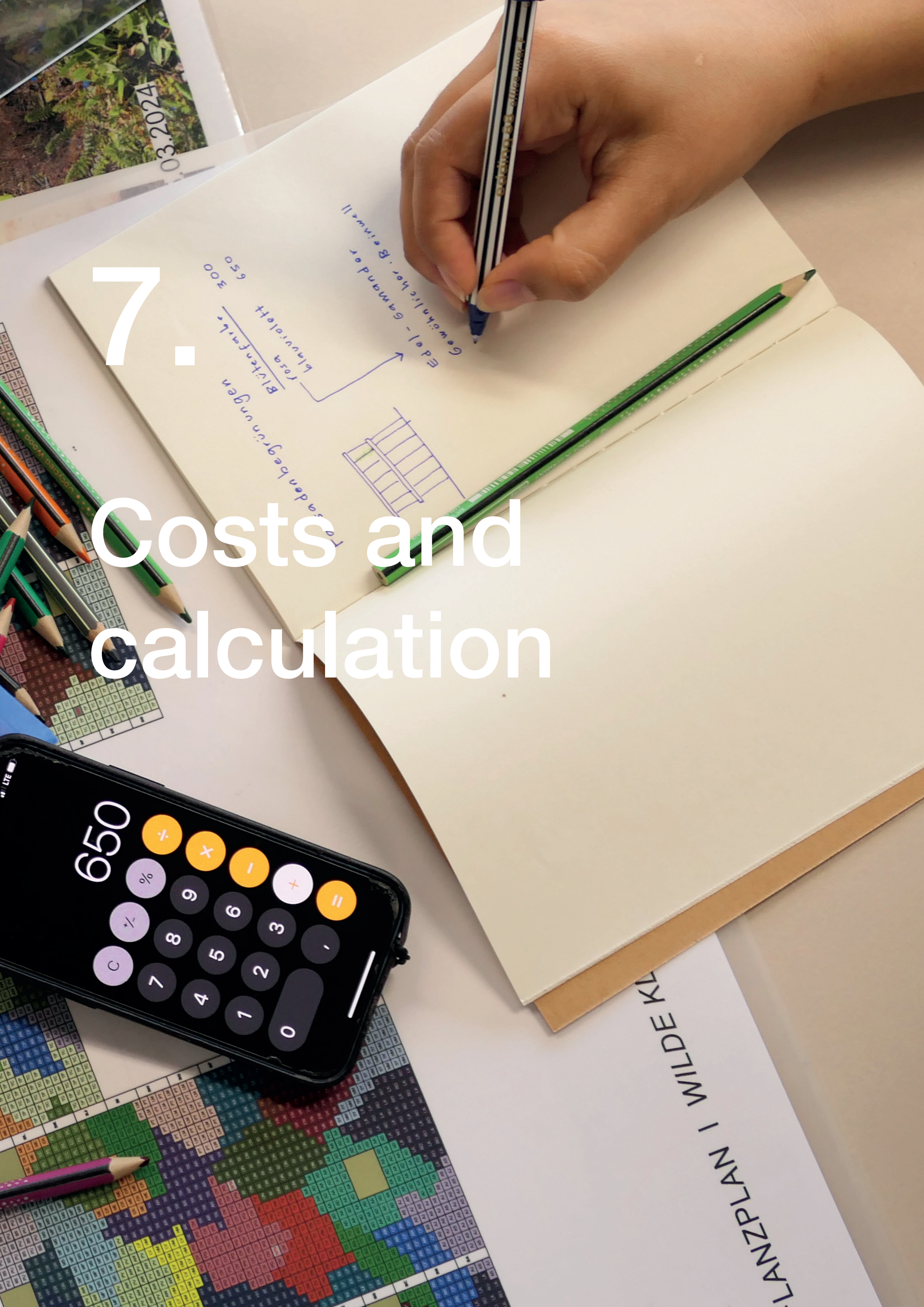
b) For reasons of the urban climate and in particular to reduce the run-off of rainwater, roof surfaces must be greened.

c) Surfaces of the basement that are not built over [...] must be covered with a layer of soil substrate at least 60 cm thick and must be permanently and professionally landscaped. [...] One native deciduous tree is to be planted for every 250 m^2 of surface area.

FOR EXAMPLE: CONCEPT FOR THE PROMOTION OF BIODIVERSITY

In the recent past, ecological urban design has also received attention in Stuttgart, e.g. as part of the species protection concept developed by the Stuttgart Office for Environmental Protection in 2017. A large number of protection and promotion measures for wild animal and plant species have been developed in this context [36]. The concept recognizes that the quality of protected areas and biotopes in and around Stuttgart is declining and that these areas are increasingly isolated from each other - which makes it much more difficult to preserve their ecological value [61]. Biodiversity in Stuttgart is to be preserved or restored wherever possible by protecting and maintaining existing biotopes, promoting individual species and improving the biotope network [61]. The species protection concept of the city of Stuttgart also includes measures for insect protection [61].


STAEDTLER
Noris colour
Upcycled Wood
MADE IN GERMANY
13:57



7.

Costs and calculation

7. Costs and calculation

The range of costs for green facades is wide and is influenced by various factors. As the actual costs always depend on the project, it is not possible to put a general figure on the costs of a green façade. Instead, this chapter is intended to enable you to:

» Be able to better estimate the costs incurred for a green façade.
» Be aware of possible "cost traps" and to take these into account in the course of planning or cost estimation
» Get an overview of possible subsidies.

In principle, the following applies: Complex building geometries and special technical solutions increase the costs of a green façade system. In contrast, greening solutions that are independently "planned", implemented and maintained over the years can already be realized quite cost-effectively.

The sometimes high costs of a green façade must be set against the potential savings and positive effects, although the monetary value of these is difficult to quantify. In science, there are approaches to quantifying the positive effects and comparing them with the expenditure in the form of ecosystem services (> Figure 2).

7.1. Regular investment costs

Investment costs include all (one-off) expenses incurred for planning, construction preparation and material and personnel costs in the procurement and construction of the green façade.

PLANNING

Planning law aspects, such as whether planning permission is required, compliance with boundary distances or fire protection requirements, should be clarified in advance to avoid delays or unplanned costs. The planning costs for the basic assessment and the actual planning of the green façade vary depending on the size and complexity of the existing situation and the façade system. For systems with technical irrigation, the availability and routing of electricity and water must be taken into account. In addition, there may be costs for specialist planners in the areas of statics or fire protection (see section "Additional investment costs").

PLANT PROCUREMENT

Pre-grown plants are generally used for planting green facades. This means that they have already reached a certain size in order to form dense growth on the façade more quickly. To do this, they must be grown in advance in a greenhouse. These expenses are usually included in quotations from green façade manufacturers. However, the market for native wild shrubs, which are particularly suitable for biodiversity-promoting greening, is still small. Additional costs may be incurred if plants have to be grown from seed or if the procurement process is particularly complex. The availability and procurement of plants should therefore be coordinated with the system manufacturers at an early stage.

CONSTRUCTION OF THE FACADE

Material and labor costs are incurred for the construction of a green façade. The labor costs also depend on the system and installation effort, but are less significant given the short construction times.

7.2. Additional investment costs

The construction of green facades can result in further investment requirements (planning or investment costs), which are not included in Table 2 due to the high degree of individuality. This refers, for example, to the statics, including their examination and the creation of possible substructures. When creating substructures, professional execution is always required, in particular to ensure the thermal and moisture protection of the façade below. This may also require the involvement of other specialist planners.

PLANTED MODULES
THE WILD CLIMATE WALL
IN A GREENHOUSE

7.3. Running costs

After completion of the green façade, further costs will be incurred for long-term care and maintenance:

MAINTENANCE COSTS INCL. INSPECTIONS AND PRUNING

To support healthy and long-term growth, it is advisable to hire a specialist company to maintain the green façade. If biodiversity-sensitive care is to be implemented, the expertise of experts trained for this purpose should also be utilized (> Chapter 3.3). The costs for this depend on the size of the green façade, accessibility (e.g. whether a cherry picker is required) and the customer's design requirements.

In addition to the maintenance costs, the system and irrigation technology should be regularly inspected and maintained by specialist personnel if automatic irrigation is available. When a care contract is concluded, these framework conditions are recorded in advance.

In the case of smaller and less complex green façade systems, such as those from Fact Sheets 1 and 3 (> Chapter 5.3), maintenance can also be carried out independently. Accordingly, no further costs are incurred.

COSTS FOR ELECTRICITY AND WATER

With soil-based green facades, which can cover their water requirements completely from the soil even in dry periods, there are no running costs for electricity and water. All other systems must be watered, at least temporarily. Experience has shown that the expenses for this amount to approx. 5-15% of the maintenance costs (see example of empirical values for running costs).

FOR EXAMPLE: EMPIRICAL VALUES FOR RUNNING COSTS:

(non-binding empirical values from Helix Pflanzensysteme GmbH, as of 2024)

» Water

The water consumption of the wall-mounted modular Living Wall System "Biomura" is around 0.5-1 m³/m² per year. With drinking water prices of €2.6/m³ (as of September 2024), the annual costs for water consumption are around €1.30-2.60/m² of façade area [60].

» Electricity

The annual electricity costs are usually similar to the water costs.

» Maintenance (various systems)

The maintenance costs for the Living Wall System "Biomura" amount to 50-100 €/m² per year, depending on the project. Costs of €15-45/m² per year can be expected for the maintenance of a planter/based green façade.

7.4. Summary

Table 2 provides a system-dependent comparison of the reference values for the investment costs per m² of the systems presented in Chapter 5.3 (non-binding information based on empirical values from Helix Pflanzensysteme GmbH - as of September 2024).

The table lists only the investment costs. In addition, there are notes on which material costs and services are included in the stated costs and which additional costs need to be taken into account. This enables an initial classification of the required budget depending on the desired green façade solution.

In > Digression: Funding options for green façades at the end of the chapter, various options for monetary compensation are listed.


Fact Sheet 1: Soil-based vegetation


Fact Sheet 2: Planter-based vegetation


Fact Sheet 3: Wall-based vegetation - stackable


Fact Sheet 4: Wall-based vegetation - Living Wall

Table 2: Cost breakdown of the four systems from Fact Sheets 1 to 4 above.

System/ costs	Fact Sheet 1: Soil-based vegetation (trellis plants)	Fact Sheet 2: Planter-based vegetation (scaffolding climbing plants, shrubs, underplanting)	Fact Sheet 3: Wall-based vegetation (modular stackable system)	Fact Sheet 4: Wall-mounted Living Wall vegetation (fleece, modules)
Costs/m^2 (net, without VAT)	€ 200-300 With irrigation € 250-350	€ 600-900	€ 300-400	€ 700-1,500
Included in the costs	» Vegetation planning » Material costs: > Plants > Trellis » Implementation	» Vegetation planning » Material costs: > Plants > Planter (made of Wood, plastic or Metal) > Substrate > Trellis > Irrigation system incl. fertilization » Implementation	» Vegetation planning » Material costs: > Plants > Modular system (plastic) > Substrate > Irrigation system » Implementation	» Vegetation planning » Material costs: > Plants > Modular system with integrated substrate > Irrigation system incl. fertilization (in the technical room > Carrier plates, fleece and rails for fixing plants planting modules » Implementation
Additional costs to be taken into account	» Professional planning » Running costs/ water costs » Maintenance Optional: > Cistern or similar for rainwater utilization > Habitats (commercial)	» Professional planning » Running costs/ water costs » Care » Load-bearing construction Optional: > Cistern or similar for rainwater utilization > Habitats (commercial)	» Professional planning » Running costs/ water costs » Maintenance Optional: > Cistern or similar for rainwater utilization > If applicable, substructure > Habitats (commercial)	» Professional planning » Running electricity/ water costs » Maintenance » Substructure » Irrigation pipes » from technical room to facade Irrigation pipes from technical room to facade Optional: > Cistern or similar for rainwater utilization > Habitats (special production)

Digression

Funding opportunities for green facades

The implementation of innovative projects is often associated with monetary hurdles and risks. With the help of funding, various actors in urban society are enabled to implement biodiversity-promoting greening measures.

Relevant research tools in this field are listed below. The respective references are marked according to the target groups they address. For this list, a distinction is made between private individuals (P), clubs and associations (V), companies (U) and municipalities (K).

Note: The funding conditions must always be checked before submitting an application.

SUBSIDIES FROM THE CITY OF STUTTGART

In larger cities, there are often funding programs offered by the city administration to promote climate adaptation, environmental protection and similar issues, as is the case in Stuttgart.

The "JETZKLIMACHEN" campaign page of the City of Stuttgart lists various funding programs for sustainability transformation, sorted by department. These include the Stuttgart Green Program, the Urban Gardens funding program and the Stuttgart Climate Innovation Fund.
https://jetztklimachen.stuttgart.de/foerderprogramme (P, V, U)

STATE FUNDING

To get a basic overview of various funding programs, it is a good idea to take a look at a funding database. Alternatively, funding advice can be obtained. Both are offered by the Center for Climate Adaptation for municipalities and social associations.
https://zentrum-klimaanpassung.de/beratung-fortbildung/foerderberatung (K, V)

The portal of the foundation "Die grüne Stadt" offers municipalities the opportunity to search for funding with a focus on green infrastructure, depending on the federal state.
https://die-gruene-stadt.de/foerdercheck/ (K)

FEDERAL FUNDING

Federal funding is often aimed at projects with national and international scope or transdisciplinary project consortia.

The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) primarily funds climate protection projects. The database can be filtered by region and target group.
https://www.bmuv.de/foerderung/foerdermoeglichkeiten (P, V, U, K)

The federal ministries often outsource the organization of their tenders to project management agencies. One of these organizations is Zukunft Umwelt Gesellschaft (ZUG). It is possible to search for climate adaptation and climate protection programs in the ZUG tool.
https://www.z-u-g.org/foerderung/ (V, U, K)

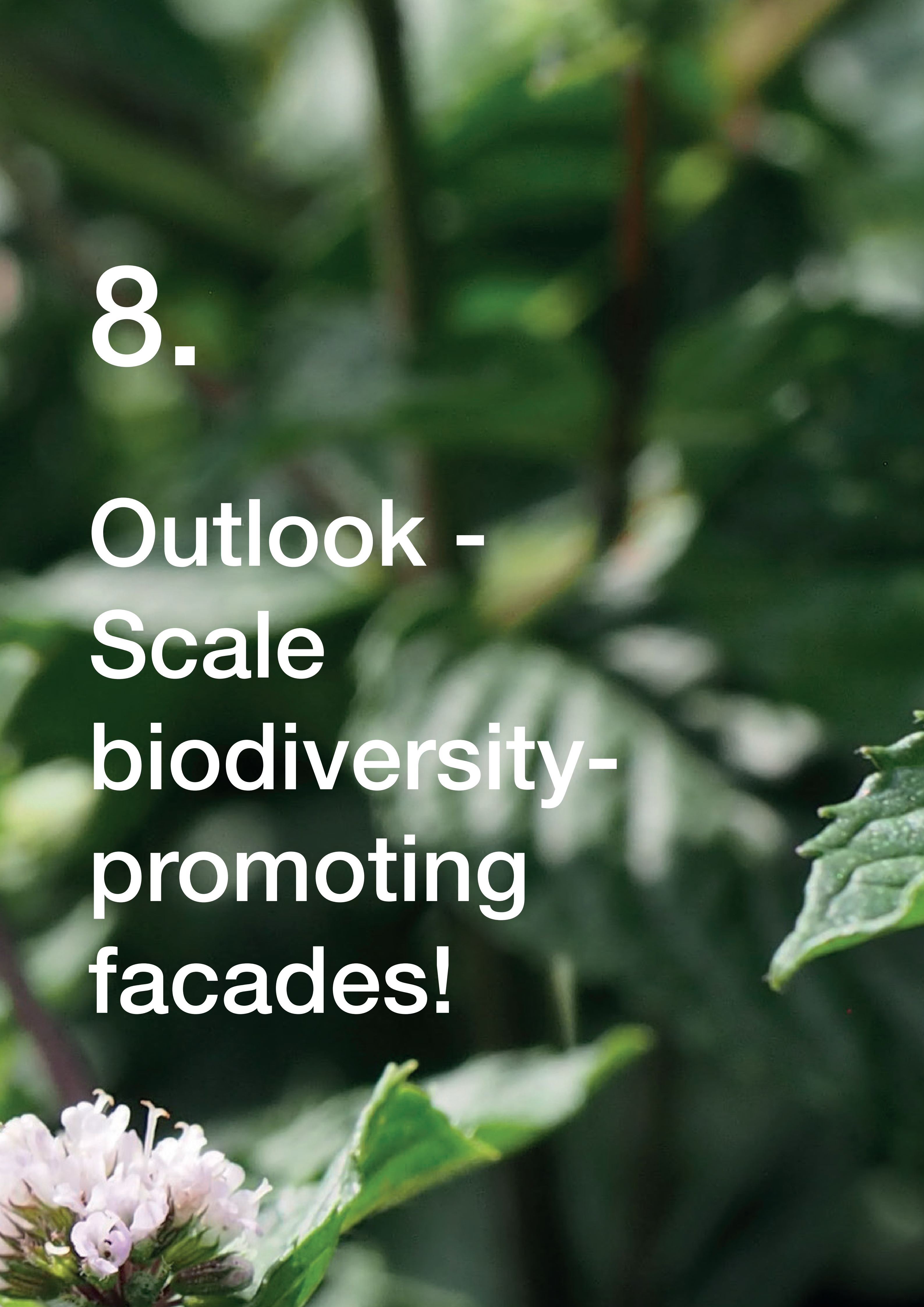
In addition to the databases, there are also funding bodies that specialize in sustainable projects, such as the German Federal Environmental Foundation (DBU), which continuously supports projects to protect the environment in various subject areas.
https://www.dbu.de/foerderung/projektfoerderung/ (P, V, U)

There are also topic-specific funding programs on the subject of biodiversity, such as the Federal Biodiversity Program of the Federal Agency for Nature Conservation. Project applications can be submitted annually for the "Urban Nature" funding priority.
https://www.bfn.de/thema/bundesprogramm-biologische-vielfalt
(P, V, U)

As a promotional bank, the Kreditanstalt für Wiederaufbau (KfW) awards grants for natural climate protection in municipalities (grant No. 444) as well as subsidized loans with repayment subsidies for natural climate protection measures on buildings or company premises (loan No. 240, 241).
https://www.kfw.de/kfw.de.html (U, K)

FURTHER INITIATIVES

The framework conditions for the implementation of ecologically motivated transformations are improving. There are more funding programs, more social initiatives and also more regulatory obligations to take environmental aspects into account in the planning and construction of cities. Biodiversity-promoting green façades can have a positive effect on the sustainability certification of (company) buildings or neighborhoods, for example. The German Sustainable Building Council (DGNB) has also had a certification system for biodiversity-promoting outdoor spaces since 2023.



8.

Outlook - Scale biodiversity-promoting facades!

8. Outlook – Scale biodiversity-promoting facades!

The results of the research projects "The wild climate wall" and "BioDivFassade" show that innovative vertical greening concepts can be a solution component for designing climate-resilient and biodiversity-promoting cities. The implementation of such systems in urban spaces is not only a response to the challenges of climate change, but also offers the potential to introduce new aesthetic and ecological qualities into the urban landscape.

Due to the low horizontal space requirement in cities, façade greening is well suited for retrofitting on existing façades or for special applications where conventional greening cannot be installed. The combination with "conventional" ground-based, near-natural urban greenery and other forms of building greening offers new potential for urban ecology and the urban climate that has rarely been exploited to date.

It can be assumed that ecologically optimized greening systems will gain in social and economic importance in the future. On the one hand, this is due to the need to implement functional, climate-resilient and biodiversity-promoting measures even in densely populated urban areas. On the other hand, the trend is based on a growing ecological awareness among the population and the increasing acceptance of and desire for more nature-based solutions. At the same time, reliable educational programs increase understanding of the needs of flora and fauna.

By communicating scientific findings, these guidelines aim to support the scaling of biodiversity-promoting green façades - also beyond Stuttgart. In the long term, close cooperation between experts from the city administration, planning and citizens will be crucial in order to create resilient, climate-adapted and biodiversity-promoting and, last but not least, urban landscapes worth living in.

Ultimately, the aim is also to raise awareness that green spaces that promote biodiversity, whether vertical or horizontal, have great potential for creating identity-defining urban landscapes.

VEGETAION DIVERSITY ON THE
WILD CLIMATE WALL

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BIODIV FACADE (LEFT)
THE WILD CLIMATE WALL (RIGHT).

PHOTO MAX KROLL

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AUTHORS, in alphabetical order

Institute for Acoustics and Building Physics (IABP), University of Stuttgart
Prof. Dr.-Ing. Philip Leistner (Project Manager)
Dr.-Ing. Holger Röseler
M.Sc. Moritz Weckmann
B.Eng. Melina Wochner
info@iabp.uni-stuttgart.de
https://www.iabp.uni-stuttgart.de/

Institute for Landscape Planning and Ecology (ILPÖ), University of Stuttgart
Dipl.-Ing. Eva Bender
Further thanks are due to Dr. rer. nat. Leonie Fischer
sekretariat@ilpoe.uni-stuttgart.de
https://www.ilpoe.uni-stuttgart.de/

Helix Pflanzensysteme GmbH
M.Sc. Julian Käß
Hans Müller
info@helix-pflanzensysteme.de
https://www.helix-pflanzensysteme.de/

Fraunhofer Institute for Building Physics IBP
Dr.-Ing. Pia Krause
info@ibp.fraunhofer.de
https://www.ibp.fraunhofer.de/

DESIGN

Dipl.-Ing. Eva Bender, Institute für Landscape Planning and Ecology at the University of Stuttgart (ILPÖ)
Maike Klemm, Fraunhofer Institute for Building Physics IBP
Dr.-Ing Pia Krause, Fraunhofer Institute for Building Physics IBP

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