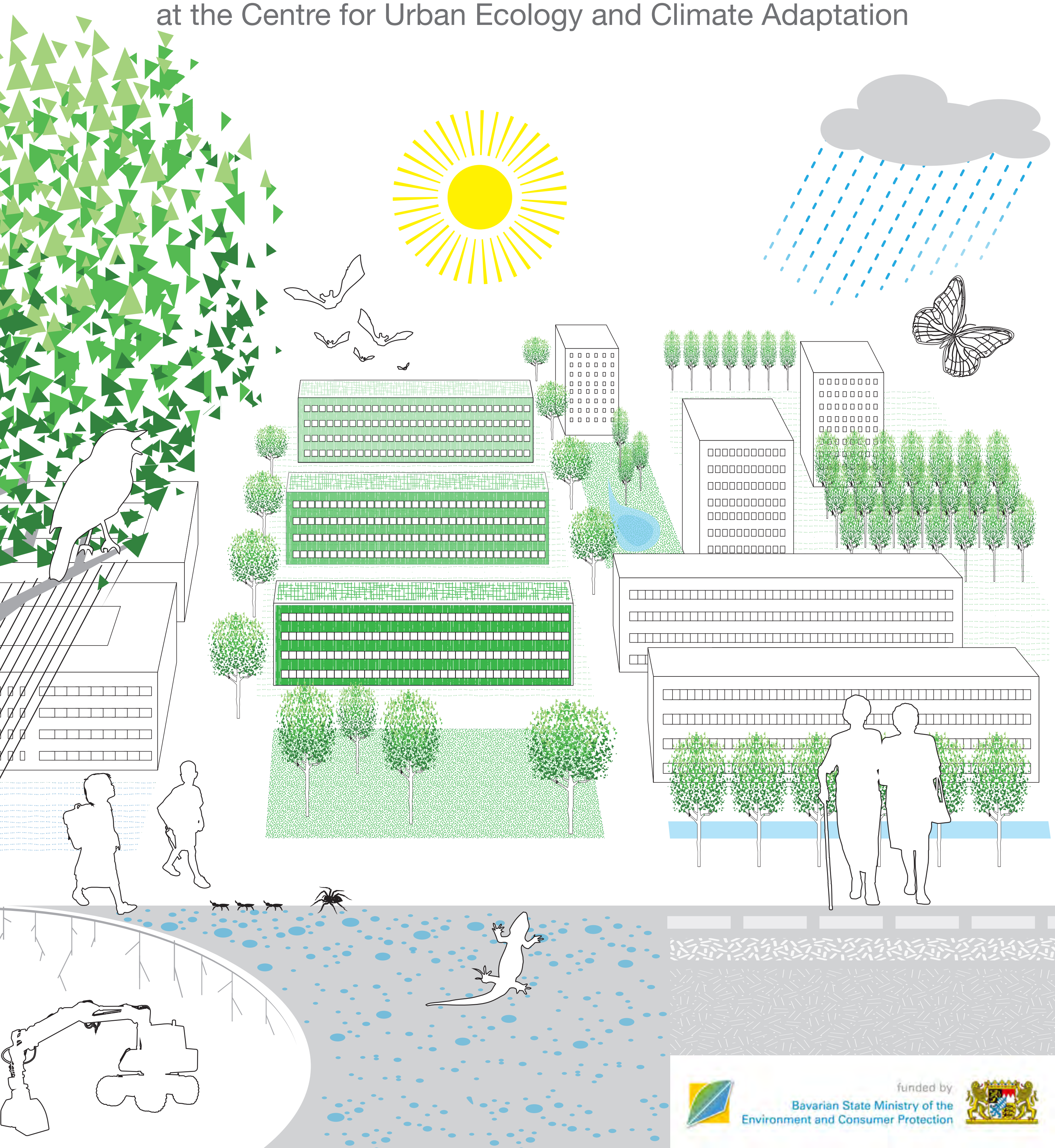
Guidelines for climate-oriented communities in Bavaria

Recommendations from the project

Climate protection and green infrastructure in cities

at the Centre for Urban Ecology and Climate Adaptation



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Content

Foreword

'Many of the arising risks of climate change accumulate in urban areas' the Intergovernmental Panel on Climate Change states in its 5th Assessment report about the consequences of climate change. And these risks will increase rapidly: Until the end of the century, Central Europe might be characterized by a subtropical climate similar to the climate of North Africa today, the Intergovernmental Panel on Climate Change warned only last year. For our cities, this implies long lasting heat waves and drought in summer together with all the negative impacts on the health of the citizens. In addition, there is an increasing risk of severe weather events with storms, hail and floods.

Therefore, it is even more important to prepare in smart ways and early on for the consequences of climate change. The guideline at hand will support you in this endeavour. Its main message is: 'The climate resilient city of the future breathes fresh air with green lungs!' The use of natural ecosystem services is key for urban living quality under climate change: City trees and green belts provide shade, cool and humidify the air. Green areas provide retention areas for heavy rainfall events and are a refuge for species diversity. Besides climate improvements and flood prevention, attractive urban recreation areas are created – flora, fauna and humans win! Innovative ideas are provided for you within this guidance by the 'Centre for Urban Ecology and Climate Adaptation' at the Technical University of Munich (www.zsk.tum.de). Experts and scientists of architecture, landscape planning, engineering, green technologies in landscape architecture and ecology work hand in hand with municipalities and authorities. For the first time, this guidance will also be published in English language this year because we want to initiate a cross-border discussion about the sustainable city of the future.

All efforts for adaptation to the consequences of climate change must go hand in hand with a dedicated reduction of green-house gas emissions. Until 2050 Bavaria should be climate neutral, as the draft for the Bavarian Climate Protection Law intends. Until 2030 we want to reduce the Bavarian emissions of greenhouse gases by 55 percent. Compensation of the remaining emissions will be managed by a Bavarian compensation platform at the Bavarian State Agency for Energy and Climate Protection. I appeal to you: commit yourself to this goal – it will not be achieved without our cities! You can rely on state support and funding, for instance for the energy and climate management of municipalities and use our new platform.

With this in mind I wish you an exciting read!

Sincerely, your

Thorsten Glauber, MdL
Bavarian State Minister for the Environment and Consumer Protection

Foreword

The development pressure currently being placed on Germany's growth regions has added a completely new dimension to the importance of the 'compact city' in urban developing policy. With the 'Urban Area' concept, the 2017 amendment to the construction planning laws has given cities and communities a tool for developing new residential districts with high usage density and a small-scale usage mix in future. The shortage of space and the associated explosion in land prices have triggered a debate how empty blocks and fallow land can be used most efficiently. Spacing depth and building heights are being discussed at a completely different level compared to just ten years ago. Even green and open spaces are unable to halt the pressure of land use. Multipurpose spaces are being increasingly proposed as possible solutions.

The latest forecasts from the Bavarian State Office for Statistics and Data threaten to fuel the debate further. The population of the already very densely built-up Munich region is expected to increase by around 14 percent on its 2015 figure by 2035. Significant increases are also anticipated in the greater area between Augsburg, Regensburg, Landshut and Rosenheim and in the Nuremberg metropolitan area.

But the debate cannot remain limited to cities' structural development; it also needs to take into account the notion of preserving, further developing and increasing the capacities of urban parklands. In terms of climate and social aspects, green and open spaces are the necessary counterbalance to density and mixed usage. Sustainable urban development relies on climate-adapted development of open spaces.

We are already clearly seeing that cities are being exposed to greater fluctuations in climate. During the summer months, intense heat often causes great distress to urban populations, as does the high concentration of pollutants in the air. Heavy rain is causing more and more frequent flash-flooding and overflowing drains. Non-indigenous species increasingly coming to inhabit urban heat islands are displacing local flora and fauna. Can this development be contained despite all the processes in place to increase density?

The results of these guidelines offer some hope. They provide cities and communities with potential strategies and methods for overcoming the challenges of climate change, including in densely built-up urban districts. The Bayerischer Städtetag (Association of Bavarian Cities) thanks the Centre for Urban Ecology and Climate Adaptation for addressing this issue.

Bernd Buckenhofer
Executive member of the board of the Bayerischer Städtetag

Summary

The aim of these guidelines is to develop climate-protection and adaptation measures for Bavarian cities using co-ordinated strategies. The sub-project being carried out at the Technical University of Munich’s Centre for Urban Ecology and Climate Adaptation examines how rising temperatures and more frequent heavy rain impact densely built-up and sealed-off urban settlement types such as perimeter block developments and free-standing blocks of flats, as well as historic city centres, and how these impacts can be countered.

The ever advancing climate change leads to association that the need for heat energy, and thus the need to refurbish buildings more energy-efficient, is declining. But the results show that increased thermal insulation continues to be important. In future, however, the summertime need for cooling in buildings and open spaces will increase, thwarting energy-saving efforts in existing buildings. Structural measures such as sun-protection systems outside windows, and green-infrastructure measures to provide shade for buildings and open spaces and cool the surroundings, can help here. Climate-adapted urban development requires protecting existing trees, planting new trees, and adding greenery to building exterior and roofs. This increased greenery will help adapt even densely built-up urban districts to climate change.

Study results show that the challenges of climate change can be overcome, even in heavily built-up urban districts of Bavarian cities! But they require the development and implementation of comprehensive, co-ordinated climate-protection and adaptation strategies and measures. These improve energy efficiency and climatic conditions, while also promoting the quality of life in the open spaces and biodiversity. Relevant measures needs to be initiated right now, as planning and implementation processes take considerable time in urban environments, and trees also grow slowly.

Within the framework of municipal planning sovereignty, targets for climate protection and adaptation must be integrated into the existing town-planning instruments and sectoral plans, and the options for implementing these fully utilised through statutes and support instruments. Integrated approaches require communities to bring together the various sectors of administration, involve players from civil society, and increasingly co-operate between municipalities.

Due to the tremendous pressure to keep expanding settlements in many Bavarian municipalities, it will be important in future to place more emphasis on planning redensification, including in terms of climate protection and adaptation. Further detailed studies must be arranged to examine the impact of such measures on structural redensification. The approach adopted by the Centre for Urban Ecology and Climate Adaptation with regards to studies must thus be continued at many different levels.

Werner Lang Stephan Pauleit

Centre for Urban Ecology and Climate Adaptation, Technical University of Munich

Abstract

There is an urgent need for the development and implementation of integrated strategies for climate change mitigation and adaptation in urban areas. Urban green infrastructure, i.e. networks of urban green and blue spaces that provide multiple ecosystem services, is considered key in this context. The project “Climate protection and green infrastructure in cities” at the Centre of Urban Ecology and Climate Adaptation explored the potential of roof and façade greening, greened courtyards and street trees to achieve climate mitigation and adaptation goals at the same time using a novel, integrated approach. The starting point for the project was an analysis of future climate change impacts in Bavaria, which was used as a backdrop for the following research questions: What is the effect of different green infrastructure measures on the urban microclimate? What is the effect of climate change on different refurbishment strategies for the building stock? What is the impact of green infrastructure measures on biodiversity? How can those measures improve quality of life in urban neighbourhoods? The study covered three different urban settlement types that can be found in Bavarian cities. The last phase of the project included an evaluation of the possibilities and barriers of municipalities for the implementation of urban green infrastructure.

The scientific results of the project were translated into guidelines for urban planners to support them in prioritising their actions for effective climate mitigation and adaptation using urban green infrastructure. These decision processes are often complex and require balancing a range of different interests in the city. Therefore, multifunctional green infrastructure measures which deliver synergies for climate mitigation and adaptation as well as biodiversity and quality of life should be especially supported and implemented.

Key messages for urban planners:

1. Take into account future conditions in today's planning. Extreme heat and weather events are increasing.

2. Even though climate change will reduce heating demand in general, building refurbishment is still essential since heating will remain the largest share of energy demand.

3. To guard against costs and emissions from increasing cooling demands, passive techniques like natural ventilation should be planned.

4. Evaluating green infrastructure from a quantitative and qualitative perspective is important. The well-being of society depends greatly on the provision of ecosystem services by urban vegetation.

5. Green infrastructure cools the urban microclimate and hence improves thermal comfort for pedestrians. Trees have the largest cooling potential as they provide shading and evapotranspiration at the same time. Moreover, they provide habitats and increase biodiversity. The existing tree stock should be preserved and sufficient rooting space for new plantings should be allocated.

6. Green roofs and façades cool the nearby environment by evapotranspiration and shading. They can significantly improve perceived temperature on hot days. Incentive programmes should support their installation and maintenance on private property.

7. Green space also improves infiltration. Especially green roofs have a high rainwater retention potential. It's important to assess the potential for greening sealed surfaces on public property. Incentives for creating more pervious or semi-pervious surface on private property may be accomplished through public programmes such as waiving rainwater runoff fees.

8. Varying demands and potentials need to be considered when designing green and open spaces in cities (e.g. potential for use, biodiversity).

9. City statutes are the most powerful municipal legal instruments at hand. Use legal means to the extent possible, for example with open space design regulations. The landscape plan in particular allows the most room to secure and develop green and open space as a network. Try to obtain appropriate surveys regarding climactic value already in early planning phases.

10. Informal planning instruments such as urban development contracts to determine percentages of green space are an option that should be used more often. Adoption of municipal strategies is recommended for the long-term development of urban green infrastructure.

Planning networks of green and open space with diverse functions and uses as 'green infrastructure' can support climate change adaptation in cities as well as quality of life for their residents.

1 Introduction

Cities are particularly affected by the impacts of climate change: Increasingly frequent heatwaves are much more problematic in cities than in rural areas due to sealing and dense development. Cities also have difficulty cooling down overnight. Several hot days in a row additionally pose a health risk to the urban population, and endanger plants and animals. Heavy rainfall puts pressure on cities' drainage systems and leaves entire streets under water – if not enough ground infiltration or drainage facilities are available.

Cities as a place of action
But cities also provide scope for action: Converting to renewable energy sources and more efficient energy use are urgent and worthwhile steps here. Huge savings can be achieved in greenhouse gas emissions, particularly in existing buildings. In Bavaria, buildings are responsible for around 40% of total energy use and 35% of CO_2 emissions (VBW (Bavarian Industry Association) 2012: p. 242). Households are responsible for around 30% of Bavarian final energy consumption, which is why existing residential buildings particularly need to be rendered more energy efficient (StMWi (Bavarian Ministry of Economic Affairs, Energy and Technology) 2015: p. 241).

Climate change is altering energy requirements for heating and cooling. The current energy and rehabilitation plans still generally do not take into account the influence of climate change. But they could considerably increase energy efficiency, particularly in cities. In addition to climate protection, climate adaptation is another aspect that has already become necessary in cities. Environmental damage, such as altered ecosystems and destroyed buildings due to flooding, requires fast action.

Protection and adaptation
Climate protection and adaptation need to be combined in order to tackle these challenges. While climate protection combats the causes of climate change, climate adaptation seeks to clarify the way we handle the effects. These strategies have so far usually been treated separately. For example, people have been calling for a reduction in greenhouse gas emissions since the late '70s. And most municipalities in Bavaria have established climate-protection measures, whereas adaptation has taken longer to come into focus.

GREEN INFRASTRUCTURE

Urban green infrastructures are multifunctional networks of green and open spaces strategically developed to promote quality of life in cities and adapt it to climate change (Pauleit et al. 2011; EC 2013).

Interdisciplinary guidelines
How can the approaches be combined? Reducing greenhouse gases remains essential, but at the same time, future conditions need to be provided for in current plans. These guidelines are the result of an interdisciplinary collaboration between engineers, natural and social scientists. They cover quantitative studies on the energy efficiency of buildings under the influence of climate change, computer simulations of the climatic effectiveness of revegetation measures, and a qualitative assessment of urban living environments. Based on the simulation results, answers are provided to the following questions: What makes public squares attractive? How can rear courtyards be enhanced? Is it possible to unlock potential for the habitats of flora and fauna in conjunction with climate-adaptation measures? The guidelines only recommend measures included in the legal framework conditions. They thus refer to existing planning instruments, and highlight options for applying these in keeping with the idea of a 'green city of the future'.

Key instrument: Green infrastructure
'Green infrastructure'' is key to climate protection and adaptation. Plants are all-rounders. They fix carbon dioxide, thus directly helping protect the climate. But they also have an indirect effect by providing shade for buildings and cooling their surrounds through water evaporation. As such, they reduce the thermal load and consequently buildings' need for cooling energy. The shading and cooling of urban spaces also help with adaptation, since they combat cities' heat island effect, and significantly increase the quality of the living environments in the city. Coupled with this is the fact that green spaces are urgently required in cases of heavy rain. Unsealed soil absorbs rainfall, taking the pressure of the drainage systems. Plants also absorb water by storing some in the substrate. These measures need to be able to fulfil multiple functions and interests simultaneously. This creates synergies between the city living environments and conservation, but also conflicts such as the 'food versus fuel' dilemma.

Practical reference: Types of settlement structures
All proposed measures and scenarios need to be applicable to Bavarian cities, which is why the guidelines are based on three types of urban settlements which originate in the partner cities of Munich and Würzburg, but which exist right across Bavaria: Munich's Maxvorstadt district as an example of Gründerzeit perime-

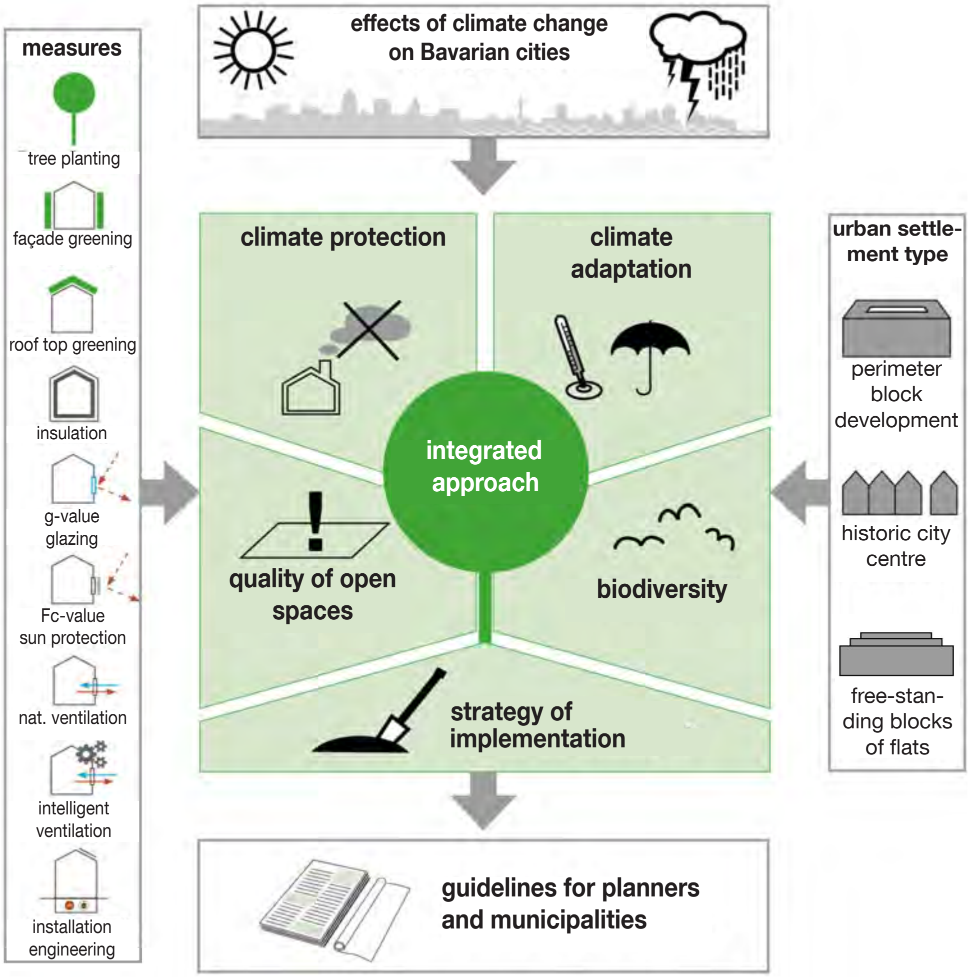


Figure 1: Structure of ZSK sub-project 1: "Climate Protection and Green Infrastructure in Cities"

ter blocks developments, Neuaubing in Munich as a typical free-standing blocks of flats and Heidingsfeld in Würzburg as an example of an historic city centre. Each type of settlement has its own requirements for climate protection and adaptation, and offers different potential for designing urban ecosystems. Three draft designs show the proposed measures and their specific location in the respective type of settlement.

A guide to the guidelines

Chapter 2 demonstrates what climate change means for Bavarian cities and why they are vulnerable. Chapter 3 presents the guidelines' integrative approach (the methods of quantitative analysis and qualitative aspects), and contains interdisciplinary strategies, which are also important for implementation.

Chapters 4, 5 and 6 form the core of the guidelines. They present the three types of settlements, and highlight measures from different perspectives. Each chapter starts with calculations within the urban settlement type, showing why rehabilitation plans need to adapt to climate change. The sections on climate adaptation through green infrastructure present data on the effectiveness of trees, rooftop greenery, and greenery on building exteriors. These calculations are supplemented by qualitative studies which rate the green spaces as open spaces and in terms of their biodiversity. A revegetation project is used as an example to show how existing planning instruments can be used.

The draft design (Ch. 4.5, 5.5 and 6.5) summarises all perspectives of climate protection, climate adaptation and urban ecosystems for each type of settlement. It shows where the measures are location, and how they impact the microclimate. Chapter 7 provides an overview of the legal requirements.

BACKGROUND AND TARGET GROUP

The guidelines are aimed at decision-makers and citizens in Bavarian communities. They present the results of the 'Climate protection and green infrastructure in cities' research project. The project is part of the Centre for Urban Ecology and climate Adaption (ZSK), a joint project at the Technical University funded by the Bavarian State Ministry for the Environment and Consumer Protection. The ZSK consists currently of ten subprojects.

2 Climate change and urban ecology in Bavarian cities

Climate change raises new questions for cities: How can urban ecosystems be incorporated as a climate-adaptation measure for cities of the future, and thus also help be protected? How can residents' health be ensured during times of intense heat? How does climate change impact buildings' energy efficiency? How can greenery and shade be added to public squares? What role do green and open spaces play for residents and biodiversity? Do local authorities have appropriate instruments to solve these issues? Chapter 2 describes the possible effects of global climate change for Bavaria, explains the particular vulnerability displayed by cities, and justifies the selection of three urban settlement types.

2.1 Effects of climate change

Climate change is happening: The average annual temperature is rising, annual rainfall is shifting, and extreme weather events such as heavy rain or heatwaves are becoming more common. Snow cover is declining and the phenological phases are shifting. Climate projections for Bavaria show average annual temperatures increasing by between +1 and +2°C for the near future and +2 to +4.4°C for the distant future (StMUV 2015). The average annual air temperature between 1971 and 2000 is shown in Figure 2.

Regional differences

The strain caused by climate-induced heat stress is one of the focuses of the studies in these guidelines. Two regions with particularly high air temperature have been chosen. The regions around the cities of Munich and Würzburg are at the upper end of the scale in Fig. 2, and are representative of southern and northern Bavaria.

An analysis of the trend in average annual temperatures in the Munich and Würzburg regions is shown in Fig. 3. The study is based on climate projections from the REMO regional climate model (Jacob et al. 2008) for the years 2000 to 2100. The projections show scenario A1B of the Intergovernmental Panel on Climate Change (IPCC 2000). The average annual air temperature from the period 1971 to 2000 from Fig. 2 is added as a reference value.

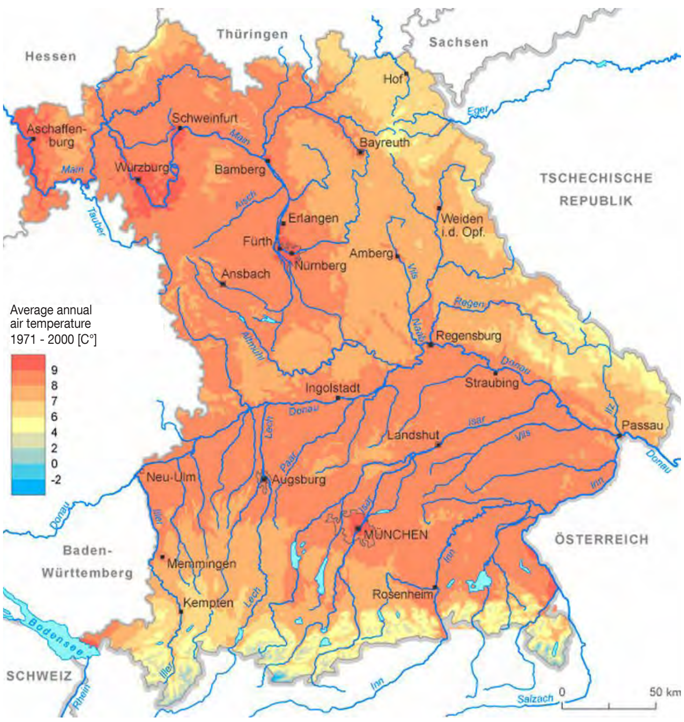


Figure 2: Regional distribution of air temperature in Bavaria 1971 to 2000, own representation after StMUV (2015)

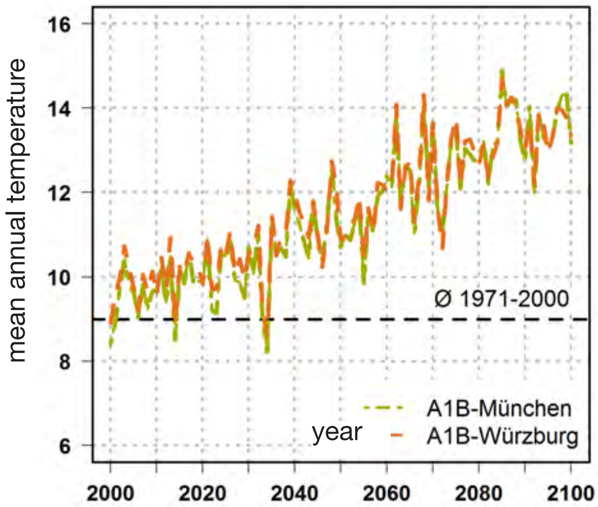


Figure 3: Trends in average annual temperature for the Munich and Würzburg regions for the years 2000 to 2100

Rise in average annual temperature

The results in Fig. 3 show a clear increase in average annual temperatures compared to the reference period of 1971 to 2000. The climate projections in scenario A1B indicate an approx. 5°C increase in average annual temperature, from 9°C today to 14°C in the year 2100, for both regions. These analyses only represent an 'average' increase in global warming, meaning the temperature increase in denser urban areas may be much greater. The results show an urgent need for action in relation to climate-change adaptations for Bavarian cities.

Increase in extreme heatwaves

In addition to the rise in average annual temperatures, an increase in extreme heatwaves is also forecast for Bavaria. These may be represented using 'threshold days'. e.g. a 'hot day'. A 'hot day' has a maximum air temperature of >30°C. An increase of 13 'hot days' per year is expected for Bavaria for the period 2071 to 2100 compared to the period 1971 to 2000. The duration of the extreme heatwaves is also increase dramatically in future (BayKLAS (Bavarian Climate Adaptation Strategy) 2016).

The impact of climate change is particularly dramatic in cities. They heat up much more than the surrounding landscape during the day, and their night-time cooling is reduced. This phenomenon is known as the urban heat island (UHI) effect, and is intensified by the high concentration of energy consumption, as the heat produced during energy consumption is released into the urban space.

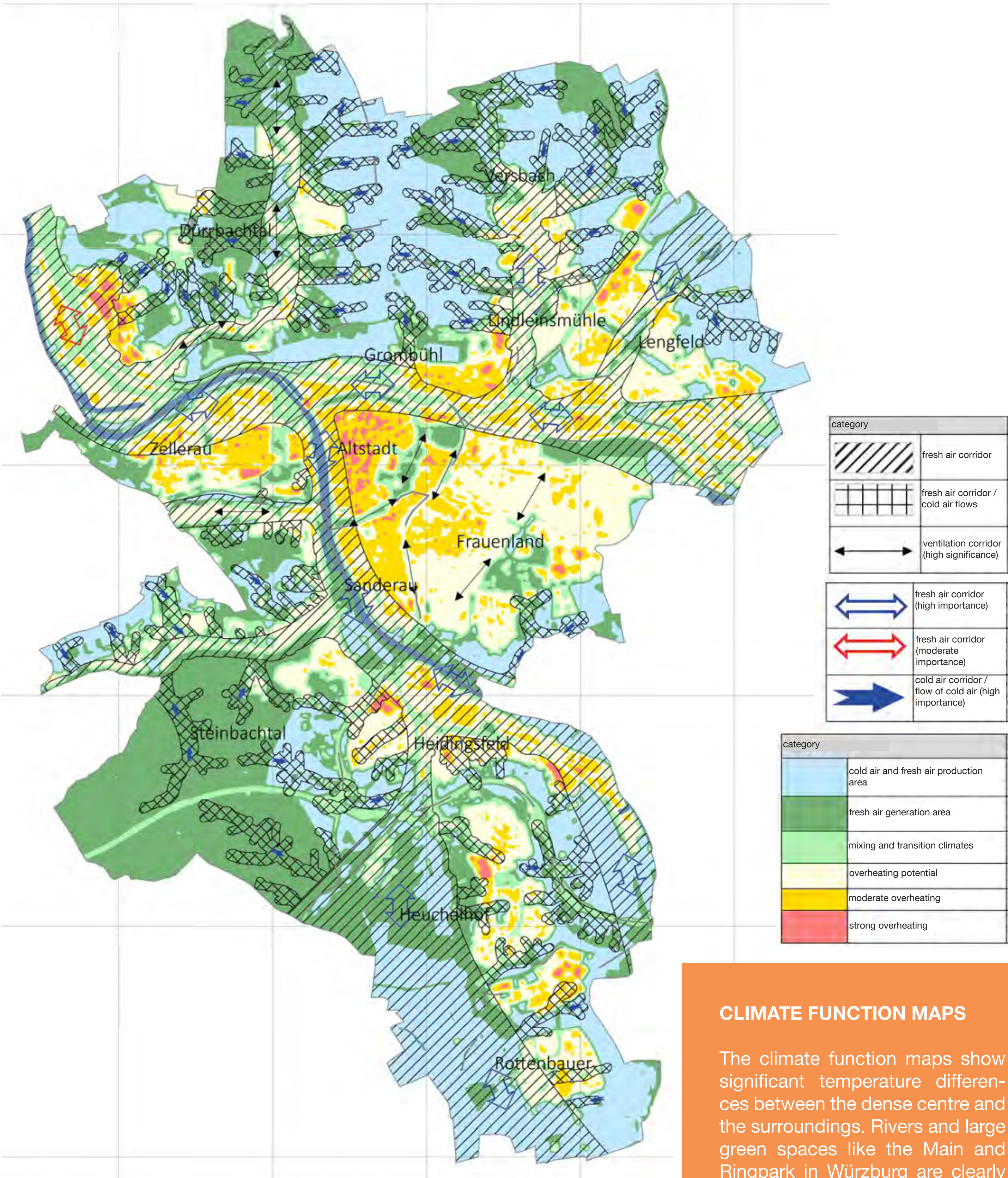


Figure 4: Würzburg climate function map (Burghardt und Partner 2016)

CLIMATE FUNCTION MAPS

The climate function maps show significant temperature differences between the dense centre and the surroundings. Rivers and large green spaces like the Main and Ringpark in Würzburg are clearly visible.

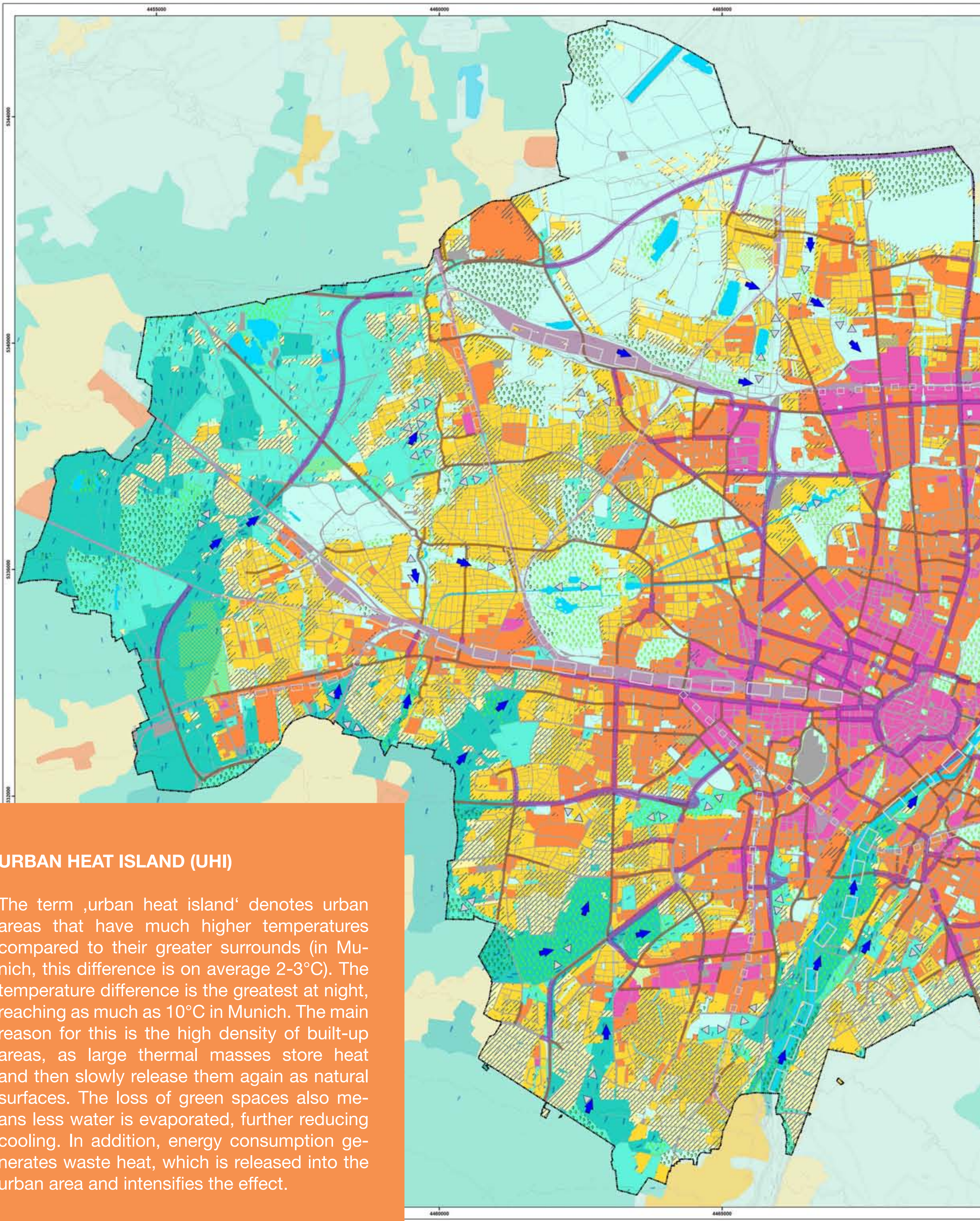
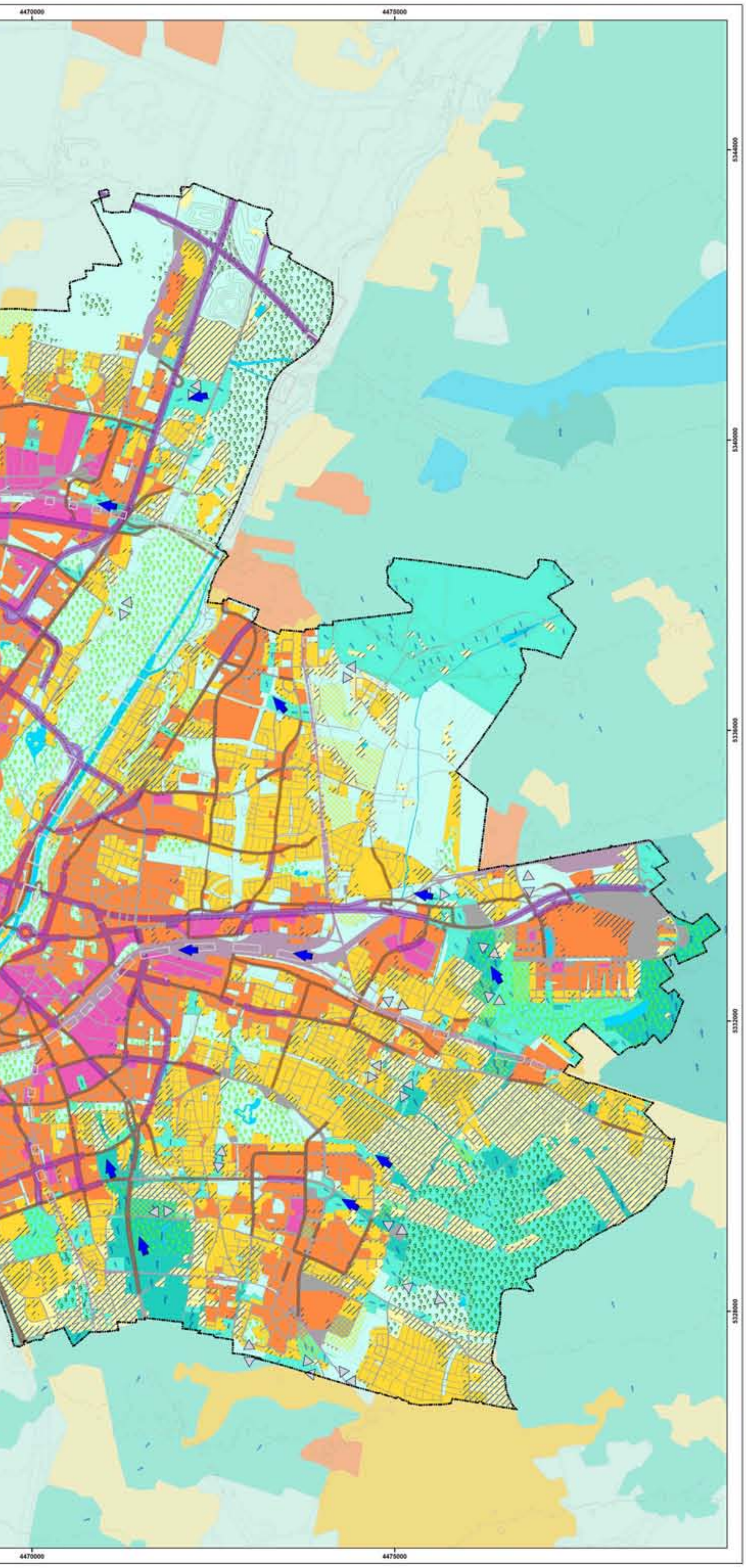


Figure 5: Munich climate function map (Landeshauptstadt München 2014)

URBAN HEAT ISLAND (UHI)

The term ‚urban heat island' denotes urban areas that have much higher temperatures compared to their greater surrounds (in Munich, this difference is on average 2-3°C). The temperature difference is the greatest at night, reaching as much as 10°C in Munich. The main reason for this is the high density of built-up areas, as large thermal masses store heat and then slowly release them again as natural surfaces. The loss of green spaces also means less water is evaporated, further reducing cooling. In addition, energy consumption generates waste heat, which is released into the urban area and intensifies the effect.



Legend

Green and open spaces

cold air generation of green and open spaces

mean flow of cold air per grid cell (m³/s)

city			surrounding area
	very high	> 1500	
	high	900 - 1500	
	moderate	< 900	

green spaces and park areas with importance for recreation during daytime

forest

Builtup areas

Bioclimatic conditions in built up areas

city		surrounding area
	very favourable	
	favourable	
	less favourable	
	unfavourable	

effective area of local air flow systems within built up areas

traffic induced air pollution in built up areas along main roads

high

middle

Air exchange

cold air corridor

modelled cold air flow area

main direction of local air flows in green and open spaces

volume flow high / very high

areas with potential for ventilation impact of main ventialtion corridors

high

moderate

local impact

Other

urban extension area with planned development

water

railway area

streets and open soils

contour line (10 m distance)

City of Munich

2.2 Cities' vulnerabilities

Urban infrastructure, traffic, ecology, energy cycles and material cycles need to increasingly be designed to cater to the altered conditions of climate change (cf. BayKLAS / KLIP (Climate Programme) run by the Bavarian State Government). Cities are more directly exposed to the effects of climate change than rural areas. They heat up faster, cool down less at night, and often have inadequate drainage and ground-infiltration options in cases of heavy rainfall. Plus there are lots of people in a small area. In Germany, approx. 75% of people currently live in cities, and this is set to rise to almost 80% by 2030 (UNESCO 2015). Munich's population grew by 10.1% just in the period from 2010 to the end of 2015 (City of Munich 2017: p. 18), and the BBSR (German Federal Institute for Research on Building, Urban Affairs and Spatial Development) rates all major Bavarian cities as 'growing' or indeed 'experiencing above-average growth' (BBSR 2017). Space, particularly in growing cities, is under pressure; living space and infrastructure such as streets, underground cables and drains compete with the need for green and open spaces.

Figure 6: Hot days on the rise in Munich (AZ München 2012)

Figure 7: City residents increasingly suffering from heat stress (SWR 2015)

Heat: A risk to young and old
Prolonged heatwaves in particular pose a risk to health. Sealed surfaces and dense development mean cities also store the heat overnight, affecting night-time periods of rest and putting a strain on city residents. Those especially vulnerable are infants and the elderly, as they tend to suffer the most from circulatory problems and dehydrate faster. They are often also less mobile, and thus find it more difficult to access parks. The reason the risk to the elderly is so significant for city planning is because of the ageing population that is resulting from demographic shifts; while there is expected to be 17% fewer children and adolescents in Germany by 2030, the 65+ age group is set to rise by approx. a third (Destatis 2011).

Figure 8: Residential street under water (photo: ZSK sub-project 1)

More frequent flooding
Cities are also particularly vulnerable to heavy rain. Ground sealing dramatically changes the rainwater drainage system. Rainfall usually drains superficially – which previously used to help clean cities. The drains collect the water underground and transport it away as quickly as possible. This usually centrally organised system reaches its limits when rainfall volumes cease to be calculable, and exceed the drainage system's existing capacities. If, in cases of heavy rainfall, the volumes of water can no longer drain properly and rivers overflow, we end up with a destructive force such as those seen during the recent flood disaster in Bavaria in mid-2016. The floods cost several people their lives, and destroyed infrastructure, buildings and livelihoods.

Figure 9: Heavy rain overloads urban infrastructure (BBK 2013)

Figure 10: Highly sealed surfaces heat up the city (photo: ZSK sub-project 1)

Impacts on flora and fauna

The spatial options for local storage and ground infiltration are limited in densely built-up urban districts, and require new, multifunctional solutions such as rainwater storage on vegetated rooftops. Climate change is intensifying this problem, as these events are set to increase (Chapter 2.1) and also affect flora and fauna. Rising temperatures are altering phenology in plants, affecting food supplies for animals, and displacing species areas northwards and to higher altitudes. Non-indigenous species coming from warmer regions are increasingly inhabiting urban heat islands, while some native species are leaving their habitats. Some of the affected native plants and animals have the potential to colonise new areas.


Figure 11: Green spaces are a source of recreation and shelter (photo: ZSK sub-project 1)

2.3 The challenge for three urban settlement types

The structures found in cities differ from district to district. The structural features can be classified as types of urban settlements (Roth 1980).

Climate change and building structures
The effects of climate change, such as heat and heavy rain, can vary greatly depending on the structure. The degree of sealing, the surface quality, the building height, distance between buildings, building orientation and even the building materials used all affect heat balance in urban areas. Unlike unsealed surfaces, vegetation and bodies of water, sealed surfaces heat up more in the daytime sunlight, and store the heat for much longer. Flooding caused by heavy rain is primarily the result of a lack of backwater and infiltration options due to the high degree of sealing (Steinrücke et al. 2012).

For the cities of Jena and Cologne, modelling studies carried out by the German Meteorological Office show that the densely built-up urban settlement types with a high degree of sealing are particularly affected by heat. ‘Summer day’ (maximum daytime temperature >25°C) and ‘hot day’ (maximum daytime temperature >30°C) thresholds are recorded particularly often in perimeter block developments, free-standing blocks of flats, industrial/commercial areas and terraced housing estates (Grothues et al. 2013; Hoffmann et al. 2014). The climate function maps for the cities of Munich and Würzburg support these results; the least favourable areas from a bioclimatic perspective are predominantly located in inner-city districts (cf. Chapter 2.1).

Affected urban settlement types in Bavarian cities
In order to apply climate-adaptation measures in the most targeted and effective manner possible, the differences in settlement typology need to be taken into account during planning. Three types of settlements have been selected for these guidelines: Perimeter block developments, free-standing blocks of flats and historic city centres. These three types are typical of densely populated districts in Central European cities.

A GIS analysis conducted as part of the research project showed that the selected urban settlement types also exist in Bavaria’s eight largest cities: Munich, Nuremberg, Augsburg, Ingolstadt, Regensburg, Würzburg, Fürth and Erlangen. While the local characteristics differ, key structural features can be compared across city boundaries. Taking into account local differences, the conditions from the study areas can be applied to other cities with residential districts featuring the same type of settlement.

Study areas
In the partner cities of Munich and Würzburg, these types of settlements exist in high-density districts relevant to climate protection and adaptation. The following districts have been chosen as an example for the studies in these cities: Maxvorstadt in Munich is a typical perimeter block development. Neuaubing in Munich’s outskirts has the characteristic features of free-standing blocks of flats, while Heidingsfeld in Würzburg has been used as a model for an historic city centre.

The project analyses show that the Gründerzeit perimeter block development in Maxvorstadt and the historic city centre of Heidingsfeld are some of the most densely built-up and intensively sealed urban structures with a very small percentage of green spaces. The heat island effect is increased by the high volume of buildings and poor ventilation. At the same time, there is very little open space for vegetation measures.

With its large high-rises, Neuaubing is relatively lightly built-up, and has a high percentage of green spaces providing lots of scope for climate-adaptation and protection measures. At the same time, it is a place where a lot of people are potentially affected by the impacts of climate change live in a small area.

Specific residential blocks from the study areas, and which were representative of the district and urban settlement type, were selected as part of a quantitative analysis. Their most important structures and parameters are summarised in Fig. 13 and Tab. 1, and are described and examined in Chapters 4, 5 and 6.

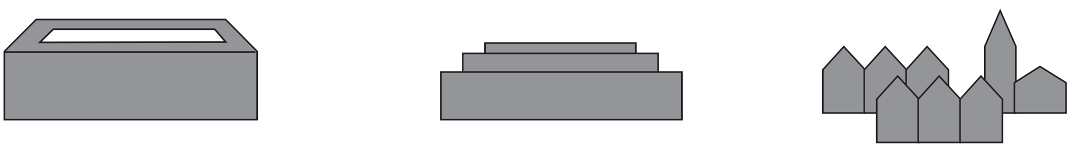


Figure 12: Selected urban settlement types: Perimeter block development, freestanding blocks of flats and historic city centres

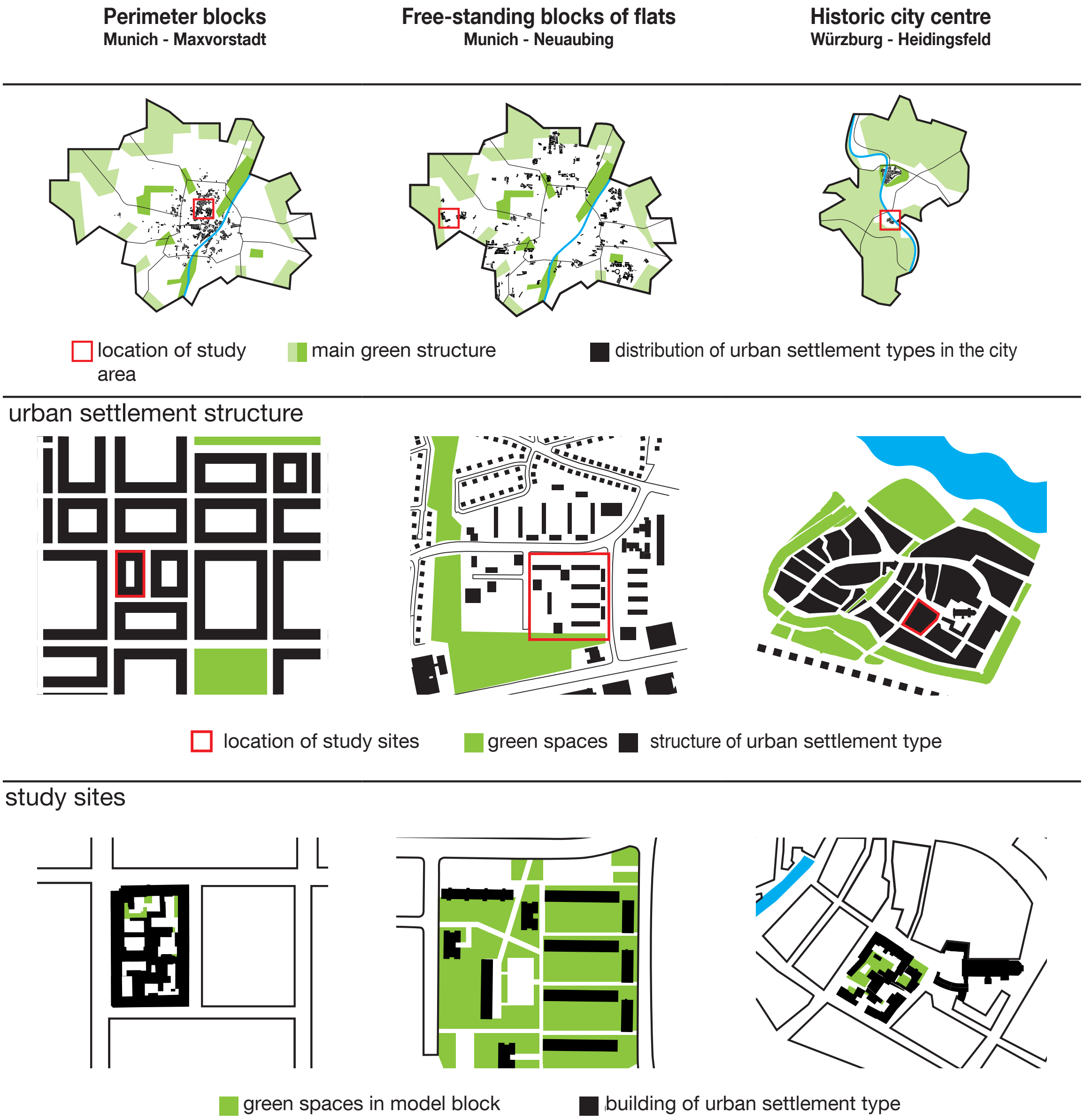


Figure 13: Aerial photograph of the selected urban settlement types (own analysis on basis of geodata of the city of Munich)

Table 1: Index numbers (mean values of all blocks of the urban settlement type in quarter)
(own analysis on basis of geodata of the city of Munich)

	Perimeter blocks	Free-standing block of flats	Historic city centre
Degree of sealing			
	81.2 %	35.0 %	86.2 %
Built up areas			
	62.3 %	21.5 %	61.1 %
Amount of vegetation			
	18.9 %	65.0 %	13.9 %
Floorspace index (only valid for each model)			
	3.0	0.8	1.2


°C
CO_2
§

3 An integrative study of climate protection and adaptation

Climate-protection and adaptation strategies affect various disciplines; the planning processes bring together various player interests. The guidelines have an interdisciplinary structure. Chapters 3.1 and 3.2 present simulation results. They explain how rehabilitation concepts with increases in energy efficiency help protect the climate, and illustrate the impacts of vegetation measures on the exterior microclimate.

Chapters 3.3 and 3.4 focus on the quality of green and open spaces. Cities function as a habitat for plants, animals and people, giving rise to dependencies and conflicts. Conflicting interests and spatial requirements will be addressed, as will overarching issues of climate-oriented urban development.

3.1 Protecting the climate through energy efficiency

Bavaria's climate policy is tackling the challenges of climate change through climate protection and adaptation (see BayKLAS 2016). The top climate-protection objective is to reduce greenhouse gas emissions, primarily by developing renewable energy sources and increasing energy efficiency.

Energy efficiency means minimising energy consumption in order to reduce emissions. In Bavaria, approx. 40% of energy consumption goes towards water heating, as well as heating and air-conditioning for buildings (StMWIVT (Bavarian Ministry of Economic Affairs, Energy and Technology) 2013). Making existing buildings more energy-efficient is thus important for achieving climate-protection goals, as it offers a high potential to save on greenhouse gas emissions.

Climate change influences these potential savings, which is why we need to examine how it impacts the current rehabilitation schemes. After that, the concepts must be expanded to include measures that reduce the negative effects of climate change. The analysis is conducted using a thermally dynamic building simulation. The urban settlement types explained in Chapter 2.3 are used as examples of buildings in Bavaria. Climate change is analysed using the climate projections from the regional climate model (REMO) presented in Chapter 2.1. The projections for the IPCC scenario A1B can be divided into four periods: Period 1 from 1971 to 2000, period 2 from 2001 to 2030, period 3 from 2031 to 2060, and period 4 from 2061 to 2090.

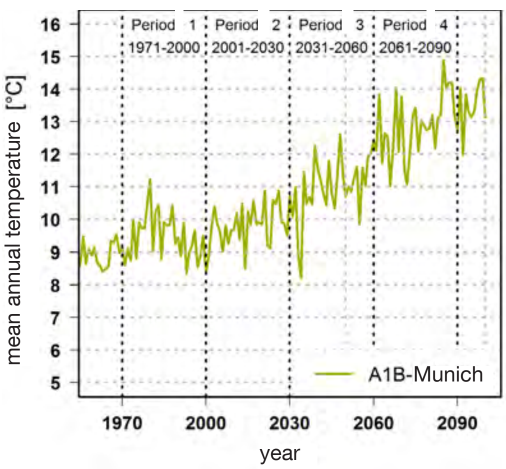
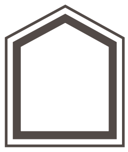


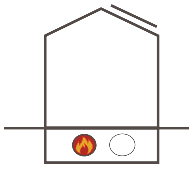
Figure 14: The climate projections split into four periods



Rehabilitation schemes
Building shells – The influence of climate change on current rehabilitation schemes is analysed using two sets of measures for building shells and two sets for systems technology. The EnEV (German Energy Saving Ordinance) package represents the building-shell parameters for energy-efficiency rehabilitation based on the 2014 EnEV. The EnEVPlus package represents building-shell parameters geared to passive house standards. The heat transmission coefficients for the building-shell rehabilitation measures are shown in Tab. 2.

Table 2: Heat transmission coefficient for rehabilitation measures on a building shell

measure	EnEV [W/m2K]	EnEVPlus [W/m2K]
insulation outer wall	0,24	0,15
insulation roof	0,24	0,15
insulation floor	0,30	0,15
transmission window	1,30	0,80



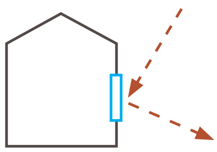
Systems technology –
The rehabilitation measures for systems technology stipulate that it must be possible for heat energy requirements to be met with low greenhouse gas emissions. Buildings are thus heated with low-emission wood pellets. Cooling must be taken into account in the building models in order to quantify the effects of climate change. This involves distinguishing between inefficient cooling in the 'Moderate' scenario and efficient cooling in the 'Ambitious' scenario. Inefficient cooling denotes a compression refrigeration machine that does not meet its electricity requirements through renewable energy. In an efficient cooling scenario, 60% of electricity requirements are met by renewable energy, and a brine/water heat pump is used as a generator. The aim of examining these two scenarios is to analyse the influence of efficient/inefficient building cooling.

Table 3: Combination of measures for reduction of overheating of buildings or potential cooling requirement

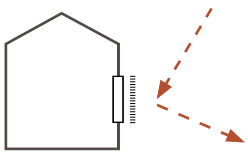
combination of measures	glazing g-Value [-]	sun protection Fc-value [-]	natural ventilation
option 1 - glazing and night ventilation	0,35	-	night ventilation (manual)
option 2 - sun protection and night ventilation	0,60	0,25	night ventilation (manual)
option 3 - sun protection and automated and natural ventilation	0,60	0,25	smart ventilation (automated)

Adapting rehabilitation schemes to climate change

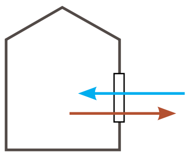
The influence of climate change can be quantified based on the rehabilitation schemes presented for building shells and systems technology. Thereafter, measures countering the negative effects of climate change, such as the potential increase in cooling requirements, must be assessed. The focus here is on reducing overheating in buildings. The following measures are examined:



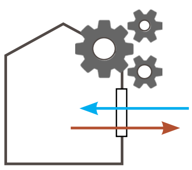
Glazing – Adapting the total energy transmission ratio of glazing (g-value) reduces solar rays from penetrating the building, and thus also reduces the potential for overheating.



Sun protection – Exterior sun protection (sun screens) also regulate the penetration of solar rays into the building. A reduction factor for the radiation (Fc) defines the effectiveness of sun-protection measures.



Night ventilation – Natural ventilation, such as opening windows, cools a buildings' interior. Night-time ventilation measures involving opening windows between 11pm and 6am during summer are thus analysed.



Smart ventilation – Smart ventilation sees windows controlled automatically. The control reacts to internal and external temperatures; if the internal temperature is higher than 26°C and the external temperature lower than the internal temperature, the window is opened.

Combining the measures

The reduction in building overheating and the potential need for cooling is analysed in three combinations of measures. The combinations are classified based on technical expense/effort involved:

Variant 1 can be implemented without any additional changes to a conventional rehabilitation scheme, as windows and glazing are generally replaced. The potential for night ventilation can also be utilised in existing buildings.

Variant 2 includes installing sun protection in combination with night ventilation.

Variant 3 is the most technically elaborate combination. Natural ventilation is automated, and sun protection is also taken into account. Tab. 3 presents the parameters of the combinations of measures.

3.2 Climate adaptation through green infrastructure

Climate adaptation to more frequent and extreme heatwaves is very important. It can be tackled in the following ways: Technical measures such as automatic shading on buildings or vegetation measures provide regulation thanks to their ecosystems (Brink et al. 2016). In town planning, vegetation measures are also known as green infrastructure (Gaffin, Rosenzweig & Kong 2012). This includes parks, trees, and vegetation on roofs and building exteriors that make up the urban ecosystem (Bolund & Humhammar 1999).

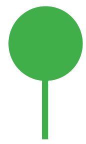
Climate regulation through vegetation
The vegetation measures have a regulating effect, as they can provide shade, evapotranspire, and influence air flow. The shading, which depends on the leaf area density, impacts both air mass and surfaces whose heat reflection is reduced outside. The evaporation rate is made up of the leaves' transpiration and the evaporation of the plant substrate.

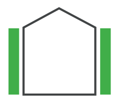
The regulating activities differ according to the type and location of the measures. Trees provide shade for outdoor areas and façades, as well as evaporate water and thus cool the nearby surrounds (evapotranspiration). Adding greenery to building exteriors particularly provides shade to the underlying façades, while evaporation cools the nearby surroundings. Vegetation on rooftops particularly lower surface temperature and reduce the building fabric's ability to store heat. They also provide cooling through evapotranspiration. Above all, however, they store rainwater, and provide a useful buffer in times of heavy rain. All three measures can be implemented in existing districts.

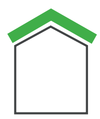
Modelling the microclimate
The three vegetation measures – trees, façade vegetation and rooftop vegetation – are each modelled in two quantities for these guidelines with the help of the ENVI-met simulation program. The study areas correspond with the 'study areas' (have been presented in Chapter 2) and are representative of the urban settlement types. All conclusions can consequently be applied to urban districts with similar structural features.

Figure 15: Virginia creeper façade greening (photo: ZSK sub-project 1)

Vegetation scenarios
In the realistic scenarios, the measures are applied where they are deemed technically and spatially feasible: Vegetation on flat roofs, street trees and façade vegetation on side of the street ideally exposed to the sun, trees spaced min. 10 m apart, and vegetation on 2/3 of the façade areas (Pfoser et al. 2013). In contrast, the maximum scenarios illustrate extreme situations in which the entire public space (except streets) can theoretically have vegetation added. Only one species is used in the respective measures; the trees planted are Norway maples (Acer platanoides), a typical street tree, rooftops are extensively vegetated with grass, while building exteriors are covered in a ground-based vegetation known as Boston ivy (Parthenocissus tricuspidata).







For hot days (>30°C), analyses are conducted at 3pm (wintertime) at a height of 1.4 m (humans' centre of gravity). The Physiological Equivalent Temperature (PET) is the parameter used for analysing the thermal load outdoors. It encompasses the effect of the meteorological parameters of air temperature, wind, humidity and radiation temperature on humans outdoors in one value – apparent temperature – in °C. Tab. 4 shows humans' thermal sensations:

Table 4: Human thermal sensitivity based on PET, own representation after Matzarakis, Mayer and Iziomon (1999)

PET	Themal sensitivity	Thermophysiological load
18-23 °C	cosy	-
23-29 °C	lightly warm	slight
29-35 °C	warm	moderate
34-41 °C	hot	strong
> 41 °C	very hot	extreme

Figure 16: Extensive roof greening (photo: ZSK sub-project 1)

Chapters 4.3, 5.3 and 6.3 show the average PET for each urban settlement type for the entire study area, as well as heat maps presenting the spatial distribution of the heat load. Each chapter has an overview graph reflecting the results of all vegetation scenarios, and compares this graph to the thermal load of the current vegetation situation in today's climate conditions. This illustrates the potential of various measures to counteract the future effects of climate change with green infrastructure.

Figure 17: Norway maple trees planted along the street (photo: ZSK sub-project 1)

3.3 Urban living environments

Human habits are always shared by certain animals and plants, particularly in urban areas. Biodiversity contributes significantly to the quality of urban open spaces. Communities should thus always think of both biodiversity and the quality of open spaces when designing urban living environments. Draft designs play a key role here. They integrate different perspectives from specialist disciplines and local players into spatial concepts, and paint informative pictures of urban living environments which are easy to convey to policymakers and the public.

Multifunctional measures

Climate-protection and adaptation measures play several roles in urban areas: In addition to their primary function of minimising buildings' energy requirements and regulating the microclimate, they also significantly impact the quality of urban living environments. Rehabilitation, tree-planting, and vegetation on rooftops and façades offer the following potential for designing urban living environments:

Energy-based rehabilitation

Many species of bird and bat use cracks, recesses and holes on and in buildings as places to reproduce and rest. Unrendered brick walls (e.g. fire walls) serve as habitats for cavity-nesting wild bees and wall plants. Improving the energy efficiency of buildings often involves hermetically sealing roofs and façades, resulting in building-dwelling flora and fauna visibly losing their habitats. Rehabilitating the building shell, however, also enables new habitat elements to be integrated, e.g. in the form of façade-integrated or added cracks and crevices for bats or nesting aids for birds and wild bees.

Rehabilitation measures are also always an opportunity to redesign the building shell. The choice of façade materials impacts the cityscape and quality of life. Façade openings generate new links between interiors and exteriors, while additive elements such as balconies can also create private living spaces. They can each be used and have vegetation added individually. If the load bearing capacity of the roof permits, roof rehabilitation and extension enable new open spaces to be created in densely built-up urban districts.

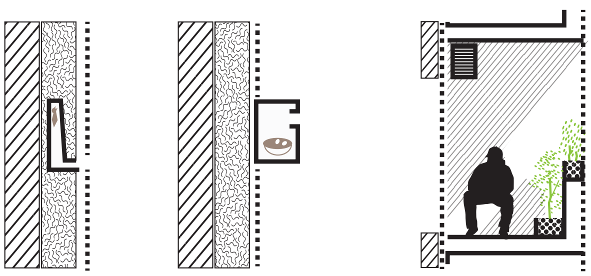


Figure 18: Integration of bat roosts and nest boxes into façade insulation (left), additive façade elements, balconies as living space

Tree-planting

Trees are one of the most precious parts of urban living environments. They structure the urban area, enable the clearings around their trunks to be used and serve as visual points of reference, and create pleasantly shady spaces under their canopies. Their foliage and blossoms aesthetically enhance the townscape. Their scent, the way they change with the seasons, and their noise as they rustle in the wind are a feast for the senses. Tree canopies also provide an untroubled habitat for many animals. Leaves, blossoms and fruit serve as food, while hollows, broken branches and crevices in the trunk provide resting spots or places to breed. Some species, such as squirrels, use thick 'enclosed' canopies to migrate through the city.

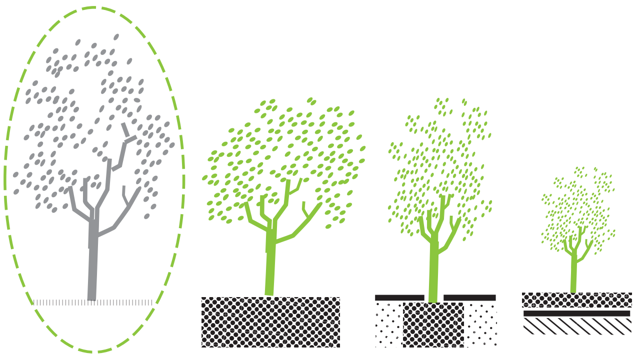


Figure 19: Preservation of existing trees (left), trees in green areas, trees in surfaced areas, trees with substructures (right)

The older the wood, the more valuable it is. The main aim is thus to protect cities' trees and tend to them appropriately. New locations with adequate space for vital development must also be created. The ideal species and species combinations are those who make the existing trees more robust, and which also help the local fauna. Depending on the location and requirements, it may be viable to use many species and varieties which are also suitable for highly sealed urban sites exposed to heavy thermal loads.

Rooftop vegetation

Rooftops are generally hardly used and relatively difficult to access. Adding vegetation to them can significantly increase the diversity of urban living environments. Different types of vegetation can be achieved, depending on substrate quality, layer thickness and water supply. From extreme dry grass, to different types of lawn, to humid biotopes (urban wetlands) or intensively tended rooftop gardens, a wide range of aesthetic and ecological effects are possible, subject to roof incline and load bearing capacity of the roof. This variability needs to be maximised when adding vegetation to rooftops.

Set up suitably, rooftop greenery can create self-supporting habitats for many species of animal. Special accessories such as deadwood (branches, trunks), waterholes or nesting aids (for birds or wild bees) increase the roofs' value to local fauna. When viewed from above, rooftop biotopes considerably enhance the cityscape and facilitate a unique experience of nature. Accessible rooftop gardens, especially in densely built-up urban districts, offer still largely untapped potential for establishing semi-public common areas and private retreats in the open air.

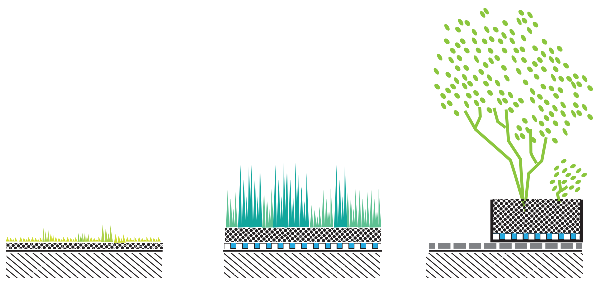


Figure 20: Extensive green roof (left), retention roof with intensive greening, rooftop terrace with plant tubs (right)

Façade vegetation
Adding greenery to building exteriors, particularly in densely built-up areas, offers vast, largely untapped potential for creating urban living environments. Various vegetation systems are possible, depending on the building fabric, location, and aesthetic and ecological benefit. While ground-level root areas are required for ground-based vegetation involving creepers, façade-based systems can be created even without this – albeit with great technical expense and effort.

Greenery-clad façades are space-saving measures that add life to locations, particularly in densely built-up, intensively sealed urban areas. Combining them with balconies, pergolas or arcades is one way of creating pleasant recreational areas. Lignifying creepers provide self-supporting reproduction and rest sites for open-nesting bird species, small mammals and insects. Many woody climbers also serve as rich sources of food for a number of animals. When adding vegetation using modular systems, herbs rich in nectar and/or pollen should be used. The nesting sites of building-dwelling species can also be integrated.

Design principles for urban living environments
One characteristic of urban spaces is the way they intertwine buildings and vegetation over a very small area. Type and distribution shape a district's identity and quality as a living space. The relationship between them varies according to urban settlement type, and must be taken into account when designing urban living environments.

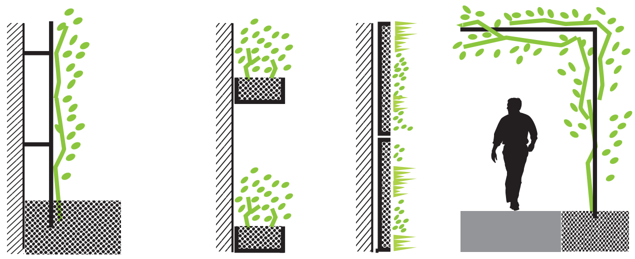


Figure 21: Ground-based façade greening (left), façade-based greening with traysystem, modular façade greening, pergola (right)

Small-scale city structures result in a specific mosaic of light and shade, drought and moisture, and heat and coolness that enables many different life forms to co-exist. This mosaic must be utilised through varied application of the measures.

Finally, it is important to ensure the accessibility of urban living environments for humans, animals and plants. Depending on their mode of mobility, actors have differing requirements for the way their living environments are interconnected. The distinction between spatial and functional interlinking must thus always be borne in mind. A 'green corridor' is not a functional connection per se for every actor; streets in urban areas are important operating spaces for people, whereas animals like squirrels get around the city via thick 'enclosed' tree canopies in laneways. Streets are often deadly barriers for lizards or frogs, and flying species such as birds move around more or less independently of linear corridors.

Chapters 4.3, 5.3 and 6.3 present the habitats resulting from measures implemented on buildings, in streets and in courtyards of the respective urban settlement types. The spatially specific draft scenarios in chapters 4.5, 5.5 and 6.5 show how the measures can be precisely located in the existing district based on functional and qualitative aspects, and be differentiated according to location and type.

3.4 Integration into urban development

The 'sustainability principle' in the German Federal Building Code (BauGB) places great responsibility on urban development, calling on it to pursue climate-protection and adaptation targets. While the proposed measures are not new per se, they are more important than ever in times of a changing climate. Climate-friendly urban development cannot be achieved with one single regulation. In addition to specific rules during the planning stages, it is also important to have long-term strategic approaches that identify and take into account the correlations between the effects of climate change and trends such as population growth and developments on the job market.

Figure 22: Open spaces cool inner-cities and make cities liveable as living environment for human beings and animals (photo: ZSK sub-project 1)

It's all about the correlations

Climate change necessitates interdisciplinary co-operation. It affects and connects almost every area of life – from health, to the economy and environment, to education and social affairs. Interweaving community land-use plans with higher-level plans such as regional planning is also becoming more important. Because thinking strategically means rethinking correlations. For example, keeping cold-air source areas clear requires co-ordinating with neighbouring communities and supra-local plans. Intercommunity co-operations can serve as strong leverage for climate protection and adaptation here. Three areas are particularly important for climate-friendly urban development: Open spaces despite redensification, mixed-use districts, and alternative mobility concepts.

Preserving and creating green spaces

The need for green infrastructure is being reassessed

Figure 23: Examples of vegetation / greening on adjacent buildings, such as garages and transformer substations (photo: ZSK sub-project 1)

Figure 24: Façade greening (photo: ZSK sub-project 1)

in view of the urban heat island effect (cf. Chapter 2). Green spaces have an effect on air quality and thus on the health of city residents. Having local green spaces can also generate economic benefits resulting from increased attractiveness. Green components on buildings have a particularly positive effect on land value if they are not isolated, and instead help shape the overall look of the surroundings. Large green structures and parks can serve as local recreation areas, and even help reduce traffic if they replace long drives into the surrounding area. Green and open spaces also help ventilate urban areas, which can in turn influence buildings' energy consumption.

Mixed use
Preserving or creating green spaces as part of urban development involves ensuring mixed use. Given the increase in traffic and the heavy use of the surrounding area, there once again needs to be greater awareness of small-scale mixed use needs when planning for climate-protection and adaptation objectives. The focus here is on a mix of functions. Access and transport routes, for example, need to be shortened, and urban life made more attractive. It must also be possible for people to live, work and consume in a confined area. There needs to be social mix that encourages stability and security.

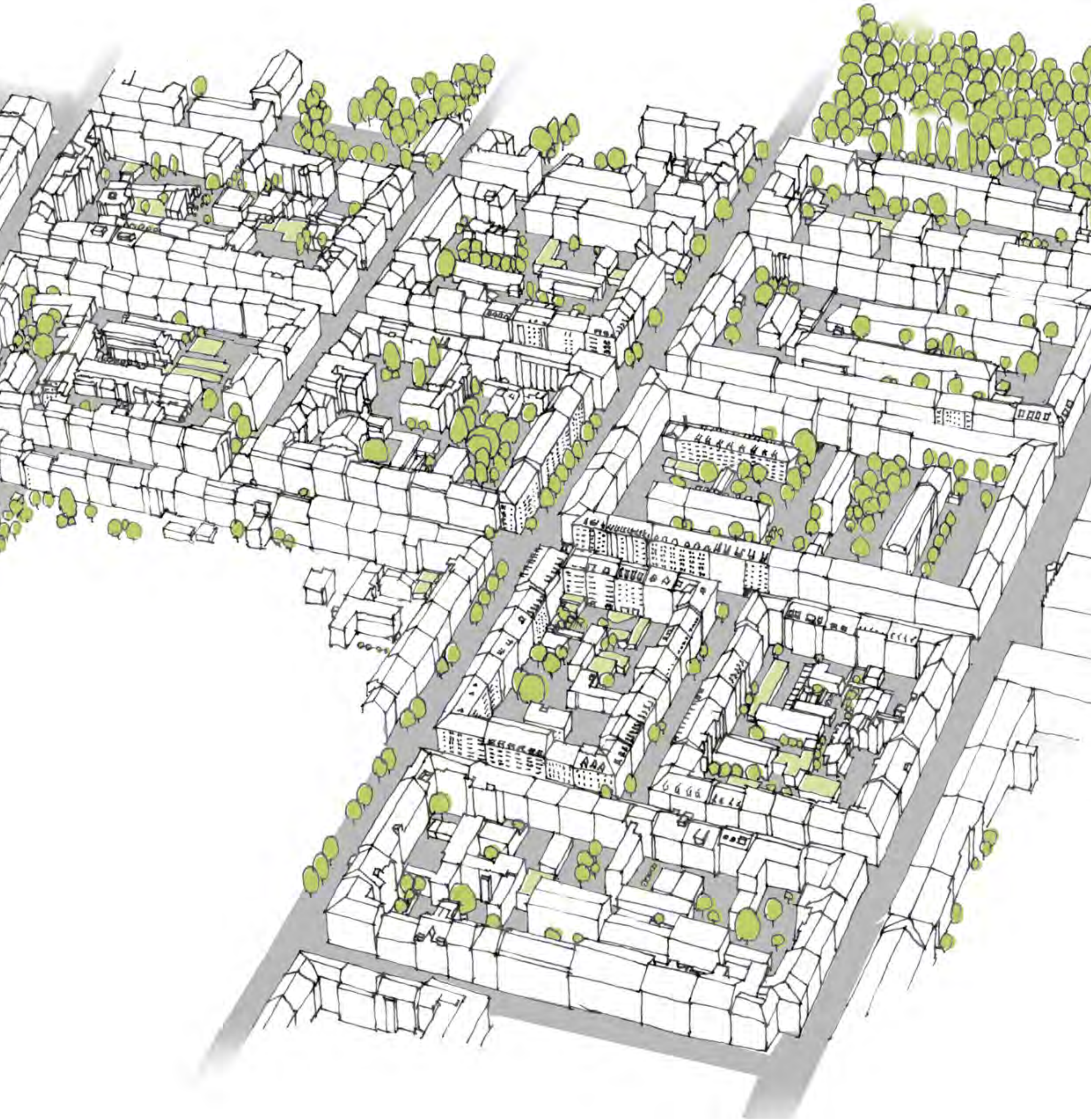
Figure 25: Alternative mobility concepts are part of climate-oriented urban development (photo: ZSK sub-project 1)

Figure 26: Gärtnerplatz, Munich: gastronomy, shopping and dwelling in confined spaces characterize urban sense of life (photo: ZSK sub-project 1)

More mobility – less traffic
Small-scale mixed use goes hand in hand with alternative mobility concepts. Climate-protection and adaptation measures cannot be totally implemented in cities unless there is a change in transport policy. Sustainable urban development needs to include alternative mobility concepts such as developing public transport, cycling networks, access to fast regional bike routes and attractive footpaths. This can be supported by approaches such as the 'compact city'.

Same laws – distinct settlement types
The legal framework conditions in the metropolitan area do not differ according to the urban settlement types followed by these guidelines. But the three structural types – perimeter block developments, free-standing blocks of flats and historic city centres – have their own requirements. Depending on development structure and the location of the metropolitan area, monument protection, distances between buildings, and transport access provide various sources of potential for climate-oriented urban development.

Application to the urban settlement types
Selected climate-protection and adaptation measures and their effectiveness are presented in Chapters 4.4, 5.4 and 6.4. The feasibility of each respective vegetation measure is examined as an example of a particular urban settlement type: Tree-planting in perimeter block developments, rooftop vegetation in free-standing blocks of flats, and façade vegetation in historic city centres.



4 Perimeter block developments

Districts containing perimeter block developments are defined by an orthogonal road network. In terms of traffic, the streets are either main streets or side streets, and at a microclimate level, they run either north-south or east-west. Most of the 5 to 7-storey buildings are from the Gründerzeit period. The solid line of structures acts as a barrier between busy streets and quiet interior courtyards, which often have little vegetation and are generally highly fragmented as a result of walls and adjacent buildings. Many different microclimatic situations arise within the perimeter block developments due to their small-scale structure. Districts featuring such developments often border high-density city centres, their concentrated, orthogonal structure being sporadically interspersed with squares of stand-alone buildings or public green areas such as parks and cemeteries.

In the study area of Maxvorstadt in Munich, perimeter block developments make up 32% of the total area, and have an average sealing rate of 81%, with a built-up area of 62%. The district only has very sparse vegetation; the average percentage of green spaces is 19%. The vegetation that does exist consists of random rows of trees in streets and various wood elements and flower beds in rear courtyards.

4.1 Protecting the climate through energy efficiency

The influence of climate change in the ‘perimeter block development’ urban settlement type is examined using the rehabilitation concepts shown in Chapter 3.1. Fig. 27 presents the study site for this analysis.

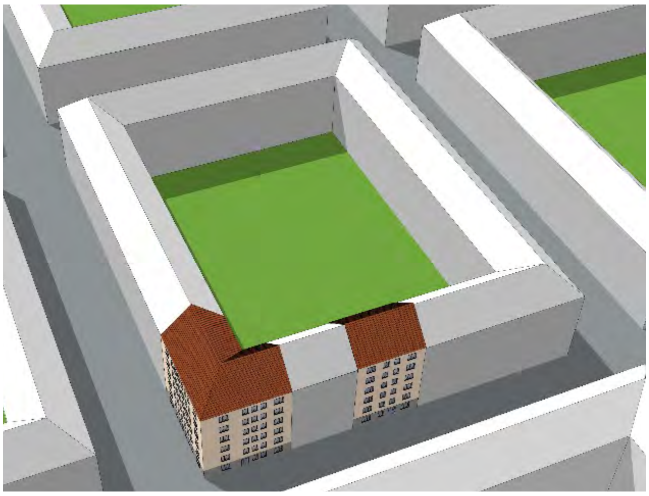


Figure 27: Study site for the ‘perimeter block development’ urban settlement type with its characteristic buildings corner and middle house

The effects of climate change

Fig. 28 shows the average net energy demand per period for the entire study area in Maxvorstadt. The net energy demand is split into the thermal energy requirement (orange) and the cooling requirement (blue). In general, the clear trend is that the thermal energy requirement will decline in future and the potential cooling requirement will increase.

The percentage denotes how much of the net energy demand is constituted by the cooling requirement. Perimeter block developments have the lowest energy requirement compared to the other urban settlement types. This is due to its compact structure and the resulting low external area of the buildings. Most of the walls are on the neighbouring buildings, meaning only minimal heat transmission. During the summer months, however, this low heat transmission also causes buildings to overheat, thus resulting in a higher potential need for cooling. Comparing the two rehabilitation concepts with the results of the existing structures, as in Fig. 28, shows that rehabilitation for energy efficiency will continue to be essential in future. Rehabilitation under the EnEV or EnEVPlus reduces energy requirements by more than half.

Rehabilitating building shells in accordance with EnEV reduces the heating demand in the fourth period, i.e. in the period from 2060 to 2090, by approx. 14 kWh/m^{2}a. This corresponds to approx. 30% of the current thermal heat requirement from period 1. The potential cooling requirement when rehabilitating a building shell in accordance with EnEVPlus increases by approx. 8

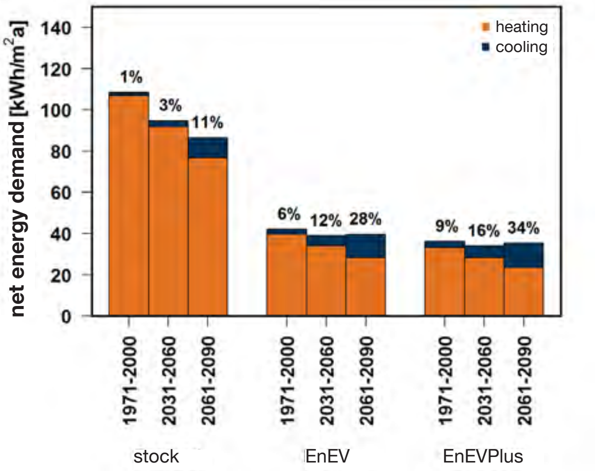


Figure 28: Average net energy demand per rehabilitation period in the Maxvorstadt study site after EnEV an EnEVPlus

kWh/m^{2}a in period 4. Both rehabilitation options involve a cooling requirement of approx. 30% in period 4. This illustrates that minimising cooling is important in further reducing the net energy demand.

The results in Fig. 29 demonstrate that, despite a stag-

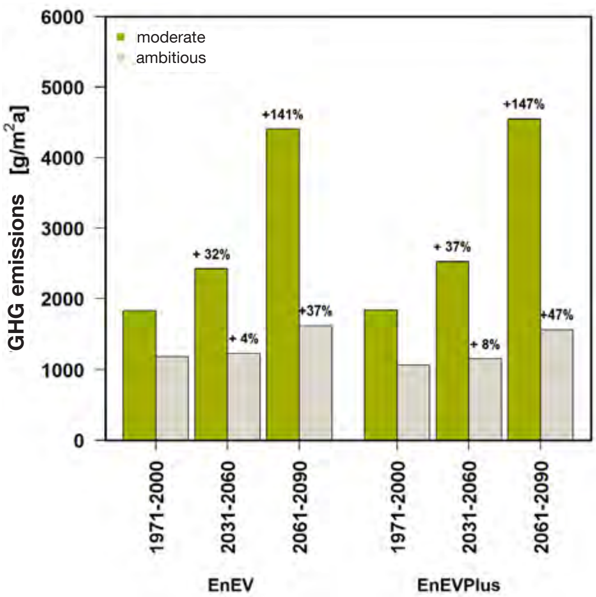


Figure 29: Future average GHG emissions in the Maxvorstadt study site

nating net energy demand, GHG emissions rise considerably when cooling is inefficient (Moderate). This rise is due to the increased need for cooling; GHG emissions in period 4 are twice as high as in period 1. The negative effect of climate change is clear. The results of efficient cooling show that planning ahead can reduce the rise in GHG emissions (Ambitious), which is why the option of cooling buildings efficiently must be taken into account in current rehabilitation concepts.

Measures Building-shell measures counteracting a potential need for cooling are assessed below. The comparison is based on three combinations of measures geared around the effort and expense involved in technical feasibility. V1 is the variant with the least effort/expense, variant V2 is the middle, and V3 is the most elaborate/expensive. Chapter 3.1 contains details on the measures.

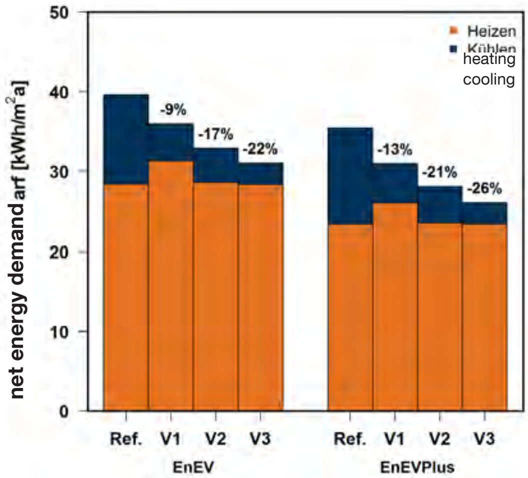


Figure 30: Reduction in net energy demands for the period 2061 to 2090 by climate adaptation of the rehabilitation measures

Fig. 30 shows the influence of the combinations of measures on the net energy demand during the period 2061 to 2090. The reduction in total energy transmittance by replacing glazing in variant 1 (V1) has a negative influence on the thermal heat requirement. Sun-protection glazing reduces solar radiation entering the building even in winter, increasing the thermal heat requirement. The net energy demand can only be reduced by approx. 9%. Climate-adapting the rehabi-

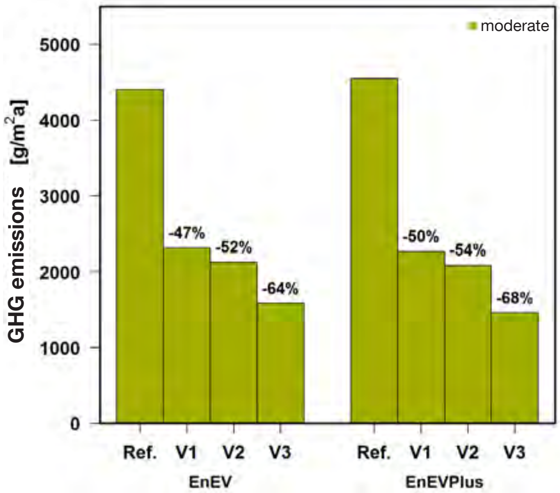


Figure 31: Reduction in greenhouse gas emissions for the period 2061 to 2090 by climate adaptation of the rehabilitation measures

litation plans through exterior sun protection and automated natural ventilation (V3) can reduce the net energy demand for EnEV and EnEVPlus by more than 20%. Fig. 31 illustrates the trend in greenhouse gas emissions for the scenario of inefficient cooling (Moderate). Variant 3 once again achieves the greatest potential saving with almost 65%. Variants 1 and 2, however, also reduce emissions by approx. 50%.

Variant 2 is a good compromise: The combination of external sun protection and night ventilation does not negatively impact the thermal heat requirement, and offers great potential for reducing emissions and the need for useful energy.

RECOMMENDATIONS

- Climate change is reducing the heating demand, causing the potential cooling requirement to rise in perimeter block developments.
- In terms of climate protection, rehabilitation for energy efficiency in perimeter block developments will continue to be essential in future.
- The possibility of efficiently cooling the building through systems technology or building-shell measures should already be taken into account in the current plans due to the long cycles involved in rehabilitation. Inefficient cooling combined with rehabilitation to comply with the latest standards of technology may increase greenhouse gas emissions by approx. 140% at perimeter block developments for the period 2061 to 2090.
- We recommend combining measures consisting of exterior sun protection and night ventilation. The technical effort/expense will be contained, and a 50% saving in potential emissions can be achieved as early as the period 2061 to 2090.

4.2 Climate adaptation through green infrastructure

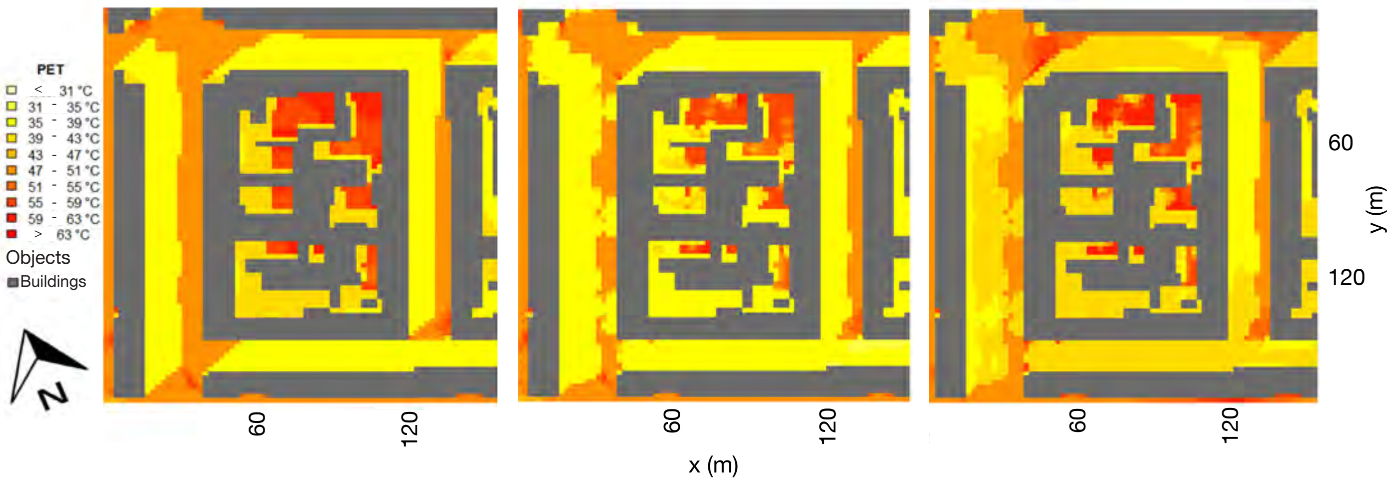


Figure 32: Thermal load at perimeter blocks under current climate conditions without greening (left), under current climate conditions with current greening (middle) and under future climate conditions with current greening (right) at 3 pm on a very hot day in 1.4 m height

The modelling using ENVI-met shows that the exterior of perimeter block developments heats up dramatically on hot summer days. The thermal load on humans, expressed through the PET Index (Physiological Equivalent Temperature), reaches a very high level, particularly in poorly ventilated areas of afternoon sun, such as interior courtyards. Streets and interior courtyards, where buildings and trees provide shade for public spaces, offer the most pleasant conditions, yet still have an apparent temperature of between 35 and 39°C PET (Fig. 32, middle). Climate change means there will be more hot days in future, and their intensity will increase too. This is expressed through higher maximum temperatures, as well as a rise in the overall temperature curve throughout the entire day.

A rising thermal load in outdoor areas

Thermal load will continue to rise at perimeter block developments on more extreme hot days – by on average of 6.3%, i.e. from 41.1 to 43.5°C PET (Fig. 32, right). On a small scale, this increase is apparent across the entire block. But the effects are particularly intense in unshaded interior courtyards outside south-west-facing façades, where the PET will rise to over 41°C PET in already existing hotspots, in turn causing extreme heat stress to humans (Fig. 32, right). The main reasons for the overheating are poor ventilation due to an enclosed design and heat reflection from the façades.

How vegetation regulates heat

A typical block of houses in a perimeter block development has a very high number of sealed surfaces and only a small percentage of green spaces, consisting of street trees and a few shrubs and trees in rear courtyards. The comparison in Fig. 32 (left and middle) shows that existing vegetation reduces the heat load. Tree canopies on streets provide shade and cooling, while shrubs in interior courtyards weaken the localised overheating in very sunny areas. The apparent temperature, for example, is an average of 41°C compared to the 43°C it would be without vegetation (Fig. 32, left). Vegetation measures reduce the thermal load in streets.

Planting trees whose canopies provide shade for large

REDUCING THE EFFECTS OF HEAVY RAIN THROUGH VEGETATION

Vegetation measures can also regulate surface draining after episodes of heavy rain, thereby taking the strain of the drainage system. More intense episodes of heavy rain increase the amount of water entering the drainage system, as the rainwater retention capacities fill up faster in the highly sealed open space. Vegetation measures create additional retention capacities through interception by foliage, infiltrating water-permeable soils, and increasing evapotranspiration rates. Trees primarily play their role by intercepting the rain in their canopies, while rooftop vegetation retains water in its substrate. The surface area of the vegetation measures is crucial to their effectiveness. For instance, rooftop vegetation is the most effective measure for perimeter block developments, as it is easy to add vegetation on the flat roofs of the backyard buildings.

areas and which cool the ambient air through evapotranspiration are particularly ideal for perimeter block developments. The exterior thermal load can be reduced by up to 13% compared to the current vegetation scenario (equivalent to max. 6°C PET reduction), particularly if the trees are placed outside the thermally loaded south-west façades.

Through evapotranspiration, façade vegetation also increases air humidity, which in turn provides cooling. A shaded façade can similarly aid night-time cooling, as it reduces thermal capacity. The apparent temperature may be reduced by up to 10% to an average of 37°C PET.

In contrast, the effects of the extensive rooftop vegetation barely reach the street, instead remaining limited to the space above the building rooftops. The effect at street level reduces the higher the buildings are, i.e. in a perimeter block development, rooftop vegetation on lower buildings offers the most potential in interior courtyards. The thermal load at street level (at pedestrian level) is reduced by 0.5% on average. The evapotranspiration effect is limited to the vegetation's immediate surrounds. Trees are thus of greatest benefit to perimeter block developments, as they reach the furthest into the outdoors and provide shade for sealed areas.

In terms of the anticipated climatic changes, trees and façade vegetation thus have the potential to counteract the effects of climate change and maintain today's climate conditions even in future (Fig. 33). These measures enable thermal load in the maximum scenarios of extreme heat stress to be reduced to strong/moderate heat stress. Adequate ventilation must be ensured when implementing all measures, particularly when planting trees.

RECOMMENDATIONS

- Trees and façade vegetation reduce solar radiation on (sealed) open spaces and façades, and thus reduce heat reflection and storage, especially in areas of afternoon sun. They should be planted as much as possible, insofar as space allows.
- Adding vegetation to lower buildings results in further reduction.
- Adequate ventilation, particularly in rear courtyards and along prevailing wind axes, must be ensured.
- Trees, façade vegetation and rooftop vegetation increases the cooling effects produced by evapotranspiration, thereby positively contributing to climate adaptation.

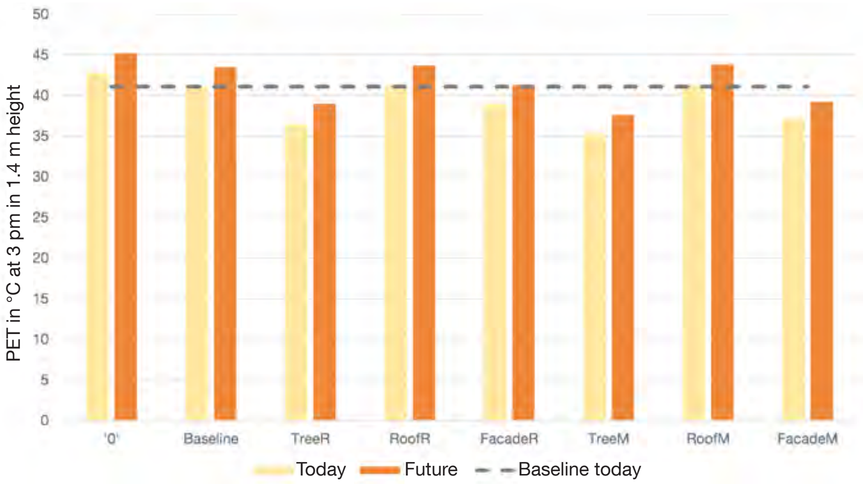


Figure 33: Comparison of PET values for all vegetation scenarios in the perimeter block under current and future climate conditions, the grey line represents the PET-Value of the current greening situation and current climate conditions (PET=physiological equivalent temperature)

4.3 Urban living environments

In perimeter block developments, varying climate-protection and adaptation measures create a diverse mosaic of urban living environments. The main prerequisite for this is the restructuring of traffic areas and the restoration of previously unused rooftop and façade areas. Trees, façade greenery and deep garden beds increase functionality, usage options, and spatial and ecological quality in street areas. Combining woody plants with varying vegetation on rooftops and façades transforms yards into sanctuaries for people, animals and plants. The aim is to link the district to a dense network of busy streets, lush rear courtyards and public green spaces.

Figure 34: Habitats created by grey and green structural elements

Quality of open spaces

Centrally located districts with perimeter block developments are popular residential areas. Commercial ground-floor usage consisting of retail and dining liven up the streets and add urban character to the neighbourhoods. The quality of life and space for pedestrians and cyclists, however, is limited by the dominant vehicle traffic. Public green spaces and squares act as local meeting places, playgrounds and sporting grounds. There are hardly any private gardens or semi-public open spaces, placing pressure on the few public recreational spaces. The lack of private green spaces and the pressure on public open spaces will continue to increase in future. Traffic areas and the high pressure to develop are already threatening existing greenery. And the urban climate will keep intensifying too. Some of the existing vegetation is already at risk. In addition to protecting the developing existing green spaces and vegetation, it is also necessary to create new, vertical green structures in the form of rooftop or façade vegetation in order to ensure quality of life in dense urban districts in future.

Figure 35: In the shade in front of buildings with public used ground-floor are often popular recreation sites (photo: ZSK sub-project 1)

Biodiversity

High-density construction, intensive sealing, and the resulting lack of greenery, as well as the lack of water, generally make perimeter block developments relatively species-poor. Typical animals include adaptable, less specialised 'common species' such as blue tits, great tits, blackbirds and pigeons. On the other hand, some specialists which have adapted to inner-city conditions, and which naturally dwell in relatively warm/cavernous rocky landscapes, such as swifts, various species of bat and wild bee, and wall ferns, also have their habitat here. These use buildings as substitute living environments, and are particularly at risk from energy-efficiency rehabilitation measures. Large areas of existing vegetation, such as cemeteries and parks, form green islands that are home to animals rarely seen in the inner-city. so the scenario in perimeter block developments is this: On the one hand, the habitats of these dwellers need to be protected as part of the work to improve the energy efficiency of building shells, and expanded by adding vegetation to façades and roofs. On the other hand, the different types of vegetation added to buildings, courtyards and streets create additional habitats – including, and most importantly, for flora and fauna that have previously been rarities in this type of settlement.

Figure 36: The great tit is a typical perimeter-block dweller (photo: ZSK sub-project1)

Street-level measures

Trees are the most effective way of cooling streets. They also do important work at perimeter block developments in terms of the quality of the streets as habitats: Their shade creates pleasant areas to rest and operate. They form an organic contrast to architecture, and provide orientation in the neighbourhood. Rows of trees help structure the streets, and protect pedestrians and cyclists from vehicle traffic. For many animal species, trees act as sources of food in the streets around perimeter block developments. They also ex-

Figure 37: View of the streetscape of a N-S-facing main street and a side street with a modular green façade of a corner house in the background (own illustration)

pand habitats upwards and serve as sanctuaries, especially in low-traffic zones.

Where possible, existing trees should thus be expanded. But their need for space for their canopies and roots often conflicts with above-ground traffic areas and underground cable ducts. Street vegetation measures thus frequently require a reorganisation of the above-ground and underground infrastructure. When planting new vegetation, it is important to allow enough room for roots and adequate distance from cabling etc. Tree species suitable for street areas and which are able to cope with the changing urban climate must also be chosen. Site conditions vary depending the orientation and cross-section of main streets and side streets. Tree locations and species must be selected accordingly.

Unsealed street areas are important for localised rainwater management. Surfaces enabling infiltration on parking areas and footpaths absorb surface water. Deep beds, known as rain gardens, can also store and drain away large quantities of excess surface water in adjacent street areas, not to mention the fact that they aesthetically enhance the streetscape and provide habitats for urban fauna.

Building-based measures

The roofs of the surrounding perimeter block development are often sloping and more exposed than those of interior courtyards. They are only suitable for vegetation to a limited extent. Rooftop terraces are recommended for rehabilitations involving roof extensions. On the other hand, the often relatively flat roofs of the adjacent buildings in the rear courtyards offer tremendous potential, particularly in terms of making up for the lack of private/semi-public open spaces and self-supporting habitats. Depending on location, extent, exposure, height and building fabric, communal or private gardens and inaccessible biotopes on rooftops should be combined to create a small-scale mosaic of habitats amongst the high-density perimeter block development.

Figure 38: Cross-section view of a quiet side street with tree planting and green façades (own illustration)

Figure 39: View from a greened balcony to the mosaic of different green roofs of the adjacent buildings, framed by façades covered with climbers; between that shaded common spaces in the courtyards (own illustration)

The façades of the perimeter block development have great potential for establishing additional living environments. Façade vegetation is one alternative, especially in place where, due to technical or spatial reasons, no trees can be planted. Façade-based systems are necessary in streets where the demand for use is high. Modular systems, known as living walls, look aesthetically pleasing but are time-consuming to set up and maintain. Plant species rich in nectar and pollen are recommended, due to the poor ecological conditions in street areas.
Ground-based systems at the base of façades are also suitable for little-used side streets and rear courtyards. They are relatively hassle-free to set up and require hardly any room for roots.

Different species of fast-growing creepers are another suitable option for large façade areas. Balconies should be combined with climbing aids for deciduous creepers. This transforms the façades into vertical gardens, and adds private outdoor living rooms to homes. When carrying out these structural measures on roofs and façades, however, it is important to preserve, and ideally even expand, the habitats of building-dwelling flora and fauna.

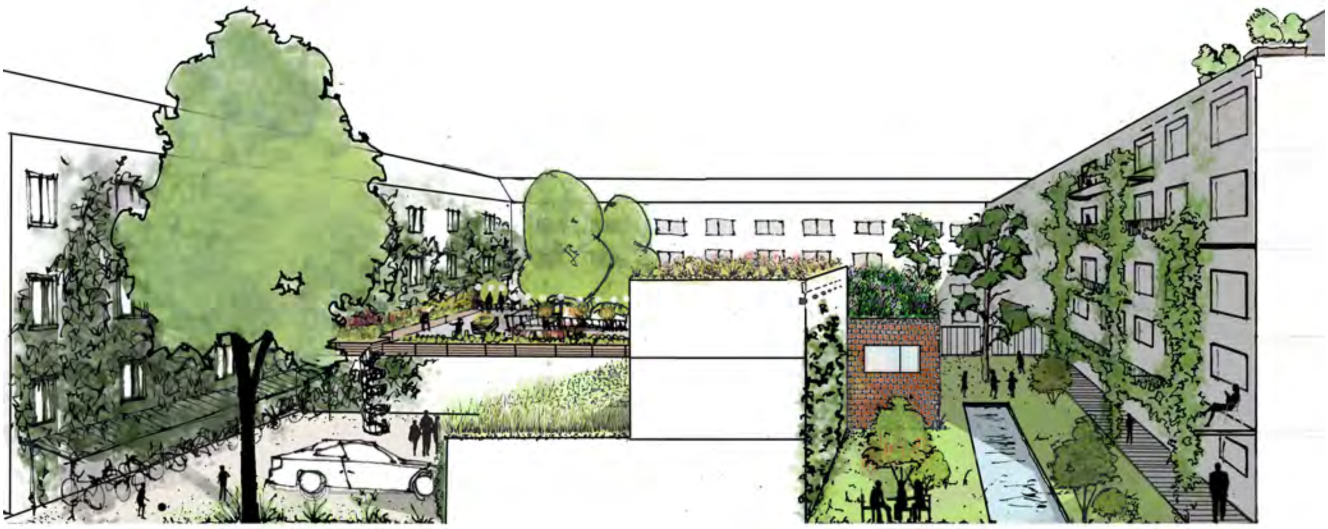


Figure 40: Cross-section view of a perimeter-development courtyard with façade greening, rooftops used as biotope or garden and greened courtyards with trees and open water points (own illustration)

Interior-courtyard measures
The enclosed interior courtyards of perimeter block developments stand in contrast to their lively streetscapes. This notion of being a place of rest needs to be preserved and enhanced. Along with the façade and rooftop vegetation, trees and small gardens in the remaining yard areas transform interior courtyards into lush oases with private or communal open spaces, as well as sanctuaries and habitats for local fauna. Large, full-grown trees particularly impact the microclimate, spatial quality and fauna of rear courtyards.

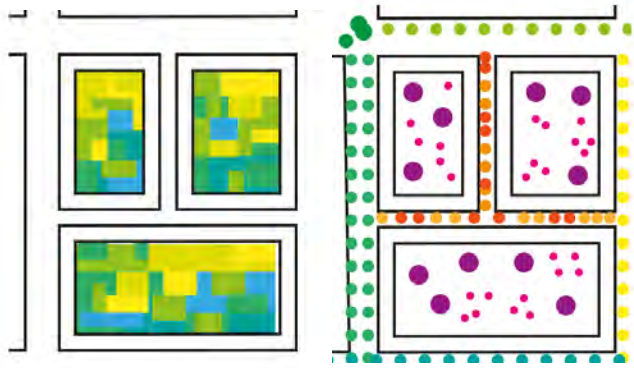


Figure 41: Diversified green spaces and tree locations at a perimeter block development

But they are endangered by parking bays and underground car parks. They need special protection, and more should be planted in areas where there is adequate room for roots.

A thick substrate layer of min. 60 cm on underground car parks enables the planting of shrubs, herbs, shrubs and grasses capable of handling the specific location conditions (flat root zone, low water availability). The building's residents can use these areas of vegetation for recreation.

Above-ground or underground water stores, such as wells or cisterns, need to be factored in as a means of watering the plants during dry periods. Areas of open water are important habitat requirements for many animal species, particularly in inner-city settlements.

Figure 42: Context and connecting of habitats in a perimeter block area

DESIGN OBJECTIVES

To provide various living environments
- Shaded recreation zones and thoroughfares in the public street area
- Communal green spaces on roofs and in rear courtyards
- Private open spaces as a result of vegetation on balconies or rooftop terraces
- Inaccessible biotopes on roofs
- Protected sanctuaries and nesting sites in tree canopies and façade vegetation
- Habitats on buildings

Diversity through vegetation
- Varying rooftop vegetation through different substrate and use
- Varying façade vegetation with different creepers
- Combining various suitable street trees capable of handling the urban climate
- Adding deep beds (rain gardens) to street areas
- Unsealing parking areas and adding sporadic vegetation to yards in the form of large trees
- Adding shrubs to underground car parks

Interlinking within the neighbourhood
- Linearly interlinking the neighbourhood's vast green spaces through the use of tree-lined streets
- Selective interlinking of lush rear courtyards

4.4 Implementation options

Rear courtyards offer the best options for vegetation at perimeter block developments. The enclosed yards form a network of many small open spaces, and can significantly help with city greening. Courtyard vegetation is also important at a social level, since they are often used communally and provide potential for 'urban gardeners'.The potential offered by yards

Figure 43: Rear courtyards offer potential for greening and act as meeting places for neighbours (photo: ZSK sub-project 1)

Climate-related aspects need to be more intensively combined with social aspects when it comes to promoting town planning (cf. 'social cities'). There are often adjacent buildings and garages worth demolishing. If adjacent buildings have to be preserved, owners are advised to assess whether the roofs' load bearing capacity of the roof permits vegetation measures. Issues of heritage listings and monument protection are often less serious here than on main buildings. If the courtyards are used as parks, water-permeable paving is feasible. Partial unsealing is possible through the use of chequer bricks or wide-joined paving stones. As courtyards are almost exclusively private areas, the local government should introduce funding programmes or split wastewater levies to encourage building owners to take unsealing measures.

Figure 44: The potential offered by rear courtyards often cannot be exhausted because of high sealing (photo: ZSK sub-project 1)

Figure 45: Parking bays can be partially unsealed and enable ground infiltration /percolation (photo: ZSK sub-project 1)

Example: Tree-planting

The local government can protect existing trees and shrubs by establishing tree-protection orders. While these can be enacted by the municipal council, they must not conflict with higher-tier plans. These legal regulations define which shrubs are to be protected, and stipulate compensatory measures in the event of unavoidable felling.

The courtyards of perimeter block developments are suitable for planting new vegetation, insofar as they are not built up, unsealing measures are technically feasible, and trees do not prevent use. The local government cannot, however, make unsealing and vegetation mandatory at existing developments, as property protection (Art. 14 of the German Constitution (Basic Law)) gives rise to provisions safeguarding existing standards. The local government should thus

Figure 46: Trees transform public street areas into a nature experience (photo: ZSK sub-project 1)

establish incentive systems with funding programmes or competitions to get building owners onboard with vegetation and unsealing measures. The city of Munich, for example, offers funding programmes for private vegetation measures in courtyards and front gardens, and on roofs or façades, and runs a competition every two years (cf. 'Mehr Grün für München' ('More green spaces for Munich')).

On town-planning grounds, the development plan stipulates 'the planting of trees, shrubs and other vegetation […] for certain areas or for a development area or part thereof, and for sections of structural complexes […]' for new buildings or rehabilitated areas (Section 9 Para. 25a of the German Federal Building Code). In addition to these stipulations, the Bavarian State Construction Code (BayBO) also calls for greenery measures to be taken in undeveloped areas of building land (Art. 7 BayBO). The local government can substantiate these by establishing provisions governing the planting of vegetation at structural complexes (buildings, adjacent buildings etc.) as part of design by-laws or open-space planning.

Small-scale ownership structures

The often very heterogeneous ownership structure must be taken into account when it comes to perimeter block developments. This requires a highly personalised approach in the case of incentive programmes. At the same time, many neighbours benefit from energy-efficiency rehabilitation programmes due to the compact nature of perimeter block developments. Private-law regulations under the Implementation Act to the German Civil Code (AGBGB) must be observed for all vegetation measures. Neighbourhood regulations such as those governing spacing distance and minimum space (Section 7 AGBGB), for instance, must be upheld.

Figure 47: The street areas around perimeter blocks can provide space for trees, if underground infrastructures could be bundled (photo: ZSK)

Car-free side streets

While the most common form of use is residential, mixed use, e.g. ground-floor commercial units, can shorten distances and affect traffic volume. The plan needs to provide scope for flexible, individual solutions in order to comply with the overarching goal of climate-adapted urban development. In relation to alternative traffic concepts, it is also necessary to assess the use of the transport axes that often run parallel, so as to make streets quieter or car-free. This increases air quality, enhances open spaces, and benefits habitats for urban fauna.

Figure 48: Additional buildings are suitable for greening (photo: ZSK sub-project 1)

Figure 49: Example: Garage (photo: ZSK sub-project 1)

4.5 Recommended measures

A measures map contains a combination of the most effective climate-protection and adaptation measures for perimeter block developments (Fig. 50). A draft scenario for space use substantiates the vegetation plan for perimeter block developments, citing recommendations regarding their multifunctionality for urban living environments and their spatial feasibility. A model then shows how the recommended measures would impact the microclimate in the study area (Maxvorstadt).

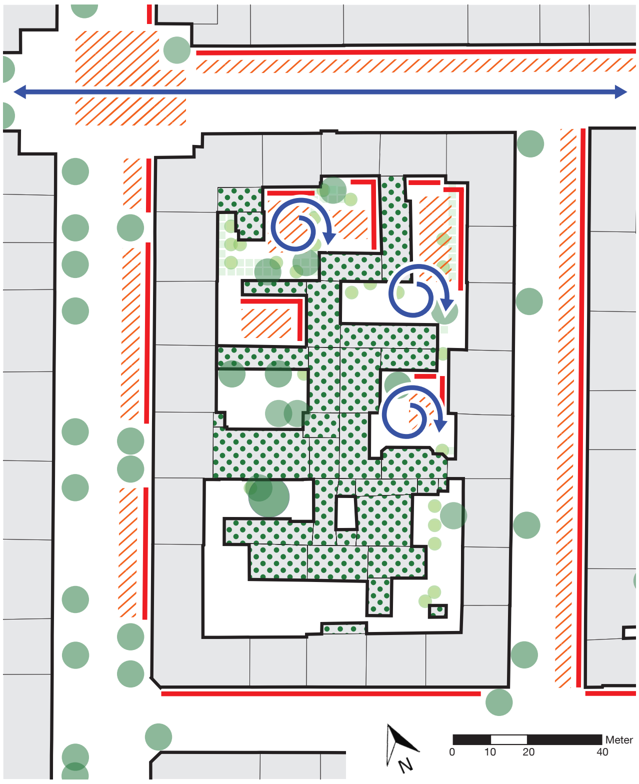


Figure 50: Map locating the measures for climate mitigation and climate adaptation examined in Chapter 4.2

Location of the measures

While the measures to rehabilitate the building shell are designed to be implemented on all buildings, vegetation measures to reduce summer heat stress vary depending on space. When placed in front of façades exposed to the sun, shading helps reduce the amount of heat being reflected into the open space. Very sunny open spaces in streets or rear courtyards must also be given shading or vegetation, so as to prevent surfaces from heating up. Adding vegetation to low and flat roofs wherever possible will also aid with cooling, and increase retention. Inside enclosed building structures such as interior courtyards, it is important to maintain/improve natural ventilation in order to prevent heat from accumulating in the south-west corners of the enclosed structure. Streets and lanes following the prevailing wind direction must be kept clear for air circulation, particularly in the east-west direction.

Draft scenario with concrete measures
... at street level

1 The trees on the north-south main road is supplemented to create an avenue of street trees resistant to urban climates, and which provide shade for the street area and recreational areas outside the east/west façades. The rows of plants are set up to enable infiltration and storage of excess surface water. They serve as boundaries splitting the traffic zone into footpaths, bike paths and roads. Unsealed parking bays for car-sharing are available between the trees.

2 Trees particularly resistant to drought and heat are planted along the previously treeless main roads running east-west to provide shade for the recreational spaces outside the southern façades. So as not to obstruct ventilation, vegetation is only planted on one side, and small-canopy species are used. The row of trees shelters pedestrians and bikes from the vehicle traffic.

3 Very sunny southern and western façades on main roads also receive additional shading. These are modular vegetation or technical shading elements due to the high demand for usage at the base of the façade. Recesses for different types of animals can be incorporated into both façade systems. Modular vegetation offers a particularly wide range of plant species and habitats. As ‘living walls’, they provide an unusual spatial experience and create unique locations in the neighbourhood.

4 In the narrower side streets, the road design will only allow for one row of street trees. Given the streets are quieter areas, clusters of different tree species are planted in the middle of them, transforming a singlefunctional traffic space into a multifunctional place of recreation and movement for residents. The parking bays will also be reduced to the bare essential, unsealed, and arranged between the tree clusters. Deep beds under the trees enable most rainfall to infilt-

Figure 51: Greening scenario on a scale of 1:1000

- rehabilitation of existing buildings for energy efficiency
- surface with high albedo
- water permeable surface
- rain gardens with perennials, grasses, dwarf-shrubs
- Decorative garden on the roof of an underground car park
- Roof surfaces suitable for solar systems
- roof top
- roof top greening type wet meadow
- roof top greening type kitchen garden
- roof top greening type dry grassland
- watering hole/well
- modular façade greening with perennials and grasses
- greening balcony/pergola as vertical garden in planting trough
- ground-based facace greening, self-climbing or with trellis, 15-18 m high

- supplementing tree stock main road north-south with broad-crowned street tree species 1. and 2. order
- new planting of trees main road east-west with narrow-crowned or light-crowned street tree species 2. order
- supplementing tree stock side roads with groups of shrubs different street tree species 2. and 3. order
- supplementing tree stock courtyard with solitary trees 1. order or several small trees 2. and 3. order on roofs of underground car parks
- solitary shrubs in courtyard with different growth habits and seasonal aspects
- woody plant on roof top in planting throughs

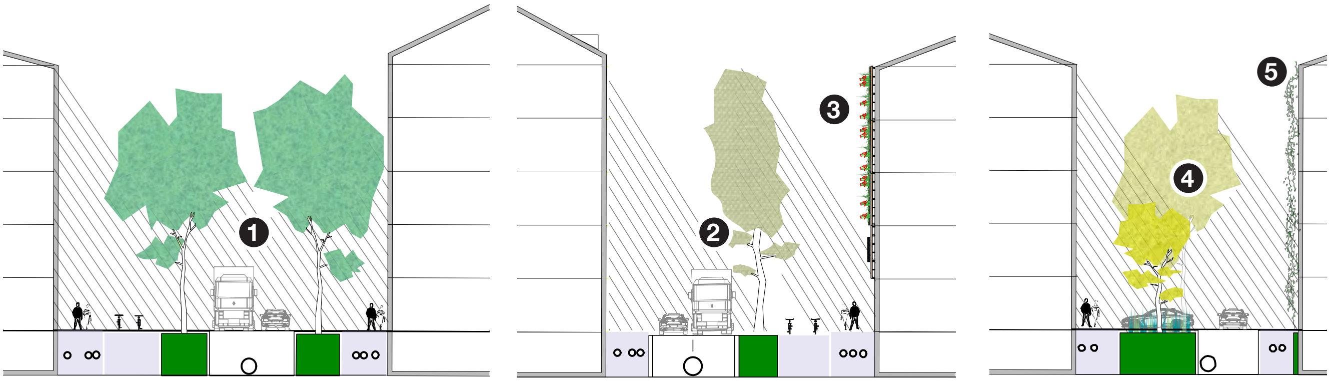


Figure 52: Cross-section of the street areas on a scale of 1:500

rate into the ground in situ. Various grasses, herbs and shrubs with a very high evaporation rate, and which enhance the streetscape as a living environment, are planted in the humid biotopes (urban wetlands). Seating integrated into the borders of the deep beds further improves the area's recreational quality.

5 Vegetation is also added to sun-exposed western and southern façades in the side streets. The low demand for usage at the base of the façade enables ground-based façade vegetation, which improves the quality of the street as a temperate space for playing and recreation and creates additional habitat structures at street-level. Balconies in the quiet streets are transformed back into useable recreational spaces, with vegetation added in the form of pot plants.

... on buildings

6 The energy-efficiency rehabilitation measures on façades take into account the habitats of building-dwelling flora and fauna existing on all buildings, along with habitats for birds, bats and wild bees. Balconies are integrated into the buffer zone of a second façade shell to expand the living area.

7 Due to their slope and extreme exposure, the roofs of main buildings are not given any vegetation. South and west-facing roofs are particularly suitable for solar cells. Roof extensions and terraces are created as part of the redensification process. Ornamental and useable plants are added as vegetation in planters, creating unique recreational sites above the city.

8 The sun-exposed southern and western façades in the interior courtyard are enhanced with ground-based vegetation in the form of vertically growing creepers. These improve the recreational quality of the open spaces, and help reduce heat, noise and dust in the courtyard. Depending on the species, they can also provide food and nesting sites for various animals. A variety of creepers with different coloured leaves and blossoms creates a diverse façade look every season.

9 Adding vegetation to balconies increases the number of shady, private recreational spaces in the interior courtyards. Various creepers climb up trellises. Vertical gardens kept by users in pots can be created in combination with other ornamental or useable plants. The personalised plants result in a very high degree of biodiversity which brightens up the monotone façades in rear courtyards.

... in interior courtyards

10 Adding vegetation to the relatively low roofs in interior courtyards is a very good option for retaining rainfall and creating green spaces in the highly sealed perimeter block development structure. Depending on the building fabric, both extensive and intensive vegetation is added. From dry lawn to marsh, the result is a small-scale, self-supporting mosaic of habitats in the middle of the city that ends up becoming a unique natural experience for residents of the surrounding apartments (when viewed from above). New private or community gardens on accessible rooftops can create recreational spaces that are also used to grow fruit and vegetables (urban farming).

11 Existing trees in interior courtyards are preserved. Additional sites with sufficient root space for large trees are also created in the sun-exposed parts of the courtyard. Their canopies provide shade for vast areas of the hot rear courtyards. Planted a certain distance apart, they enable adequate air exchange. The area under the canopy can be used as a parking spot or as a place of recreation or movement. As such, the trees prevent neighbours from looking in, and act as song-posts, nesting sites, food sources or sheltered sanctuaries for various types of animals. Paved yard areas are minimised and rendered water-permeable in order to enable surface-water infiltration. The tree locations are extensively unsealed. Lawns and plants around the edges increase biodiversity and enable rainwater from the yard to infiltrate into the ground.

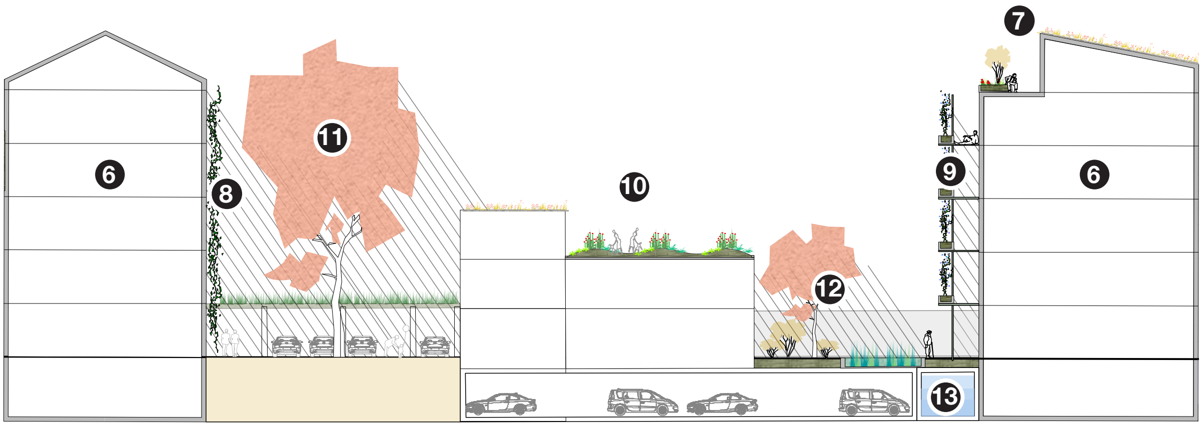


Figure 53: Cross-section of an interior courtyard on a scale of 1:500

12 The roofs of underground car parks are fully covered in vegetation and used as community gardens. A thick substrate and retention mats on the roofing store rain water and enable shrubs to be planted. Only plants requiring small root spaces are used. Combining various shrubs with perennials, herbs and grasses creates highly diverse aesthetic and ecological qualities.

13 Water storage is necessary in order to water the plants during the increasing dry periods. Off-the-ground roof and façade vegetation in particular require continuous watering. Cisterns are provided for this in the underground car parks. Tanks are used for pouring in courtyards and on roofs. They also cool the recreational spaces. Façade-based vegetation should be automatically watered using the building's wastewater (grey water).

Microclimatic assessment of the draft using ENVI-met

Compared to the current vegetation situation, the amount of green spaces increases from 9 to 38.5% in the draft. This reduces the PET by 10.6% in today's climate conditions, and by 4.2% in future climate conditions. At a street level, the shading provided by the newly planted trees particularly reduces small-scale overheating. Façade vegetation and vegetation on balconies reduce reflected solar rays in the sunny rear courtyards; shading from shrubs and single trees also increases the cooling effect. Even under future climate conditions, the draft scenario thus achieves an average thermal load of 39°C PET, which is lower than what is currently being achieved.

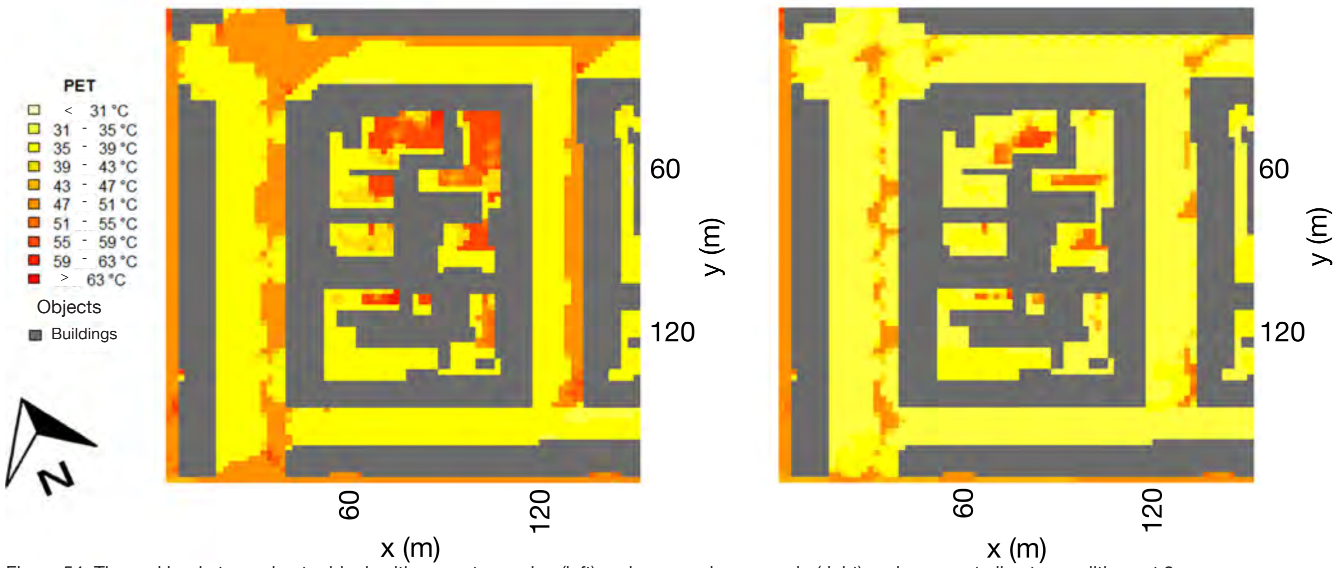


Figure 54: Thermal load at a perimeter block with current greening (left) and as greening scenario (right) under current climate conditions at 3 pm on a very hot day in 1.4 m height

5 Free-standing blocks of flats

Free-standing blocks of flats are characterised by the fact that they are only lightly built up with high-rises. The large residential complexes sit amongst parklands, criss-crossed by vast street areas. The architecture is limited to a few, often identical types of buildings. Some are 3 to 5 stories high and very long, and mostly stand parallel (occasionally also orthogonally) to one another. These structures are broken by tower blocks more than 25 m high, and which have a square base. On average, 35% of the block area is sealed. The building density in Neuaubing is 22%. At 65%, the amount of green spaces is very high. The scene is dominated by vast, often monotonous grassed areas with lots of trees. The residential complexes are only accessible by footpaths. Inside is a central recreational area. The streets feature large parking facilities for the complexes' residents. The streets are very wide, with lots of roadside vegetation. The street area is rarely enclosed by building lines. In addition to the singlefunctional residential complexes are centrally situated local shopping facilities and educational institutions. The residential complexes are surrounded by detached houses, commercial areas, large corridors of infrastructure, and vast green spaces. Despite the location on the outskirts of the city, however, there are hardly any links to the landscape.

5.1 Protecting the climate through energy efficiency

Fig. 55 shows the study area for free-standing blocks of flats. The typical buildings here are highlighted in a detailed diagram. The two buildings represent the main directions – east-west and north-south – of apartment blocks in the study site.

The effects of climate change

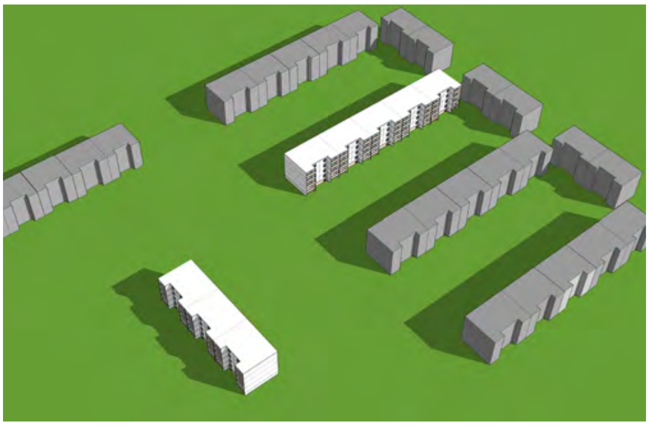


Figure 55: Study site for the ‘free-standing block of flats’ urban settlement type with both main orientated buildings East-West and North-South

Fig. 56 shows the average net energy demand per period for the entire study site for free-standing blocks of flats. The net energy demand is split into the thermal energy requirement and the cooling requirement. The clear trend, even for free-standing blocks of flats, is once again that the thermal energy requirement will decline and the potential cooling requirement will increase.

The cooling requirement’s proportion of the total net energy demand is also shown as a percentage. Free-standing blocks of flats have the highest net energy demand of all the three urban settlement types. This is due to the greater amount of outdoor areas in relation to the air-conditioned areas. The potential cooling requirement falls between the other two urban settlement types. Structural shading from balconies plays a significant role here. For example, optimal shading is guaranteed for south-facing windows even during the summer months. Energy-efficiency rehabilitation offers high potential to save energy, including at free-standing blocks of flats; making building shells more energy-efficient will cover one third of the net energy demand, even in future.

Comparing the results of a rehabilitation conducted in accordance with EnEV shows that the heating demand decreases by approx. 30% from period 1 to period 4. The decrease is caused by climatic warming. In the same period, the potential cooling requirement increases by approx. 9 W/m2/a, making up approx. 25% of the total net energy demand in period 4. This leads us to conclude that, when further reducing energy requirements, it is important to take into account the notion

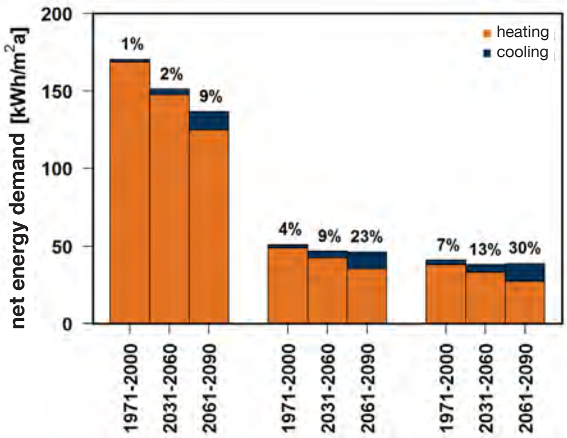


Figure 56: Average net energy demand per rehabilitation period in the Neuaubing study site after EnEV and EnEVPlus

of also minimising cooling requirements at free-standing blocks of flats. The analysis of the net energy demand for rehabilitations under EnEV and EnEVPlus in Fig. 56 shows that the decline in the heating demand and the rise in the cooling requirement roughly cancel each other out. However, these results do not yet take into account how the respective energy requirement arises, nor do they provide any information on possible emissions. Fig. 57 shows the resulting GHG emissions for the Moderate and Ambitious building systems. In the Moderate variant, which corresponds to rehabilitation to meet current standards of technology and additional cooling, the GHG emissions show a sharp increase. The rise in emissions per period is the result of the increasing cooling requirement. As was also the case for perimeter block developments, emissions are expected to double in period 4. This rise in emissions illustrates the negative effects of climate change. The results for the Ambitious version show that the rise in

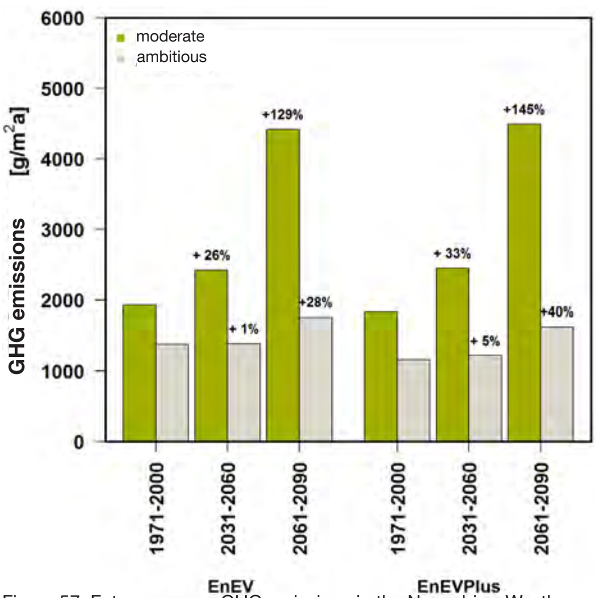


Figure 57: Future average GHG emissions in the Neuaubing-Westkreuz study site

GHG emissions can be reduced by efficiently meeting the cooling requirement. Given that energy-efficiency rehabilitations are only performed every 30 to 50 years, it is important that even current plans take efficient building cooling into account.

Measures

In addition to installing active cooling, passive measures also reduce the potential need for cooling. The combinations of measures presented in Chapter 3.1 are used for a comparison here.

As shown in Fig. 58, the combinations of measures

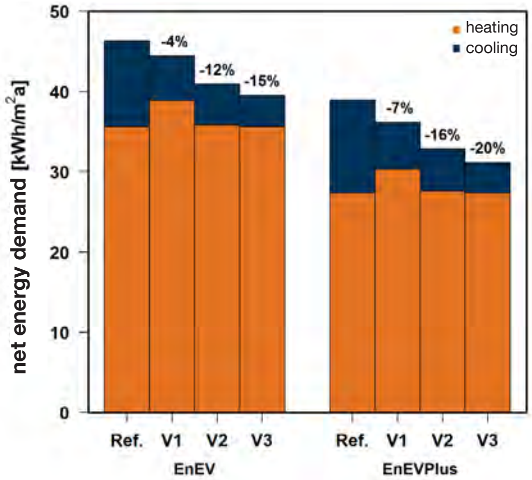


Figure 58: Reduction in net energy demand for the period 2061 to 2090 by climate adaptation of the rehabilitation plan

change the net energy demand for the period 2061 to 2090. Sun-protection glass (V1) also has a negative effect on the heating demand at free-standing blocks of flats. While the cooling requirement can be halved in variant 1, the increase in the heating demand reduces the net energy demand by 4% or 7%. The savings achieved in terms of cooling requirement in variant 2 are similar to variant 1, except that there are no changes in the heating demand. This enables a saving of 12% or 16% in terms of the net energy demand. Variant 3 once again offers the greatest potential for saving.

This is particularly illustrated by the analysis of GHG emissions for period 4, as shown in Fig. 59. With the two rehabilitation plans – EnEV and EnEVPlus, variant 3 achieves an emissions saving of more than 50%. The combination of outdoor sun protection and night ventilation (V2) is also recommended for free-standing blocks of flats. Variant 1 achieves a similar reduction in emissions, provided the heating demand met with low emissions.

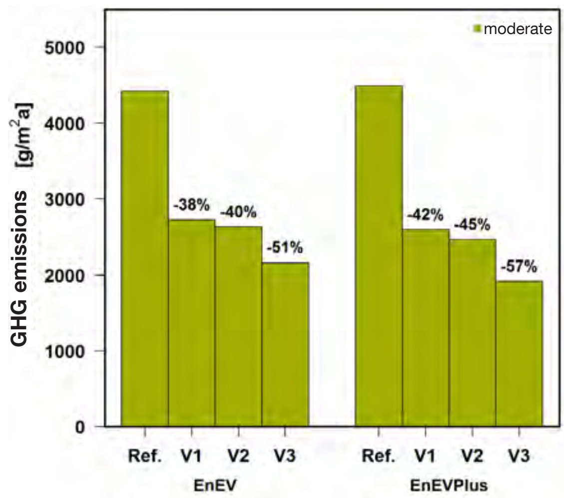


Figure 59: Reduction in greenhouse gas emissions for the period 2061 to 2090 by climate adaptation of the rehabilitation measures

RECOMMENDATIONS

- Climate change is reducing the heating demand and causing the potential cooling requirement at free-standing blocks of flats to rise.
- In terms of climate protection, energy-efficiency rehabilitations will continue to be essential for free-standing blocks of flats even in future.
- Efficient building cooling through systems technology or building-shell measures must be taken into account right from current plans due to long rehabilitation cycles.
- Inefficient cooling combined with rehabilitation to meet current standards of technology may cause greenhouse gases to rise by approx. 130% at free-standing blocks of flats for the period 2061 to 2090.
- Outdoor sun protection coupled with night ventilation is a recommended combination of measures. The technical effort/expense involved can be contained, and 40% of potential emissions could end up being saved even in the period 2061 to 2090.

5.2 Climate adaptation through green infrastructure

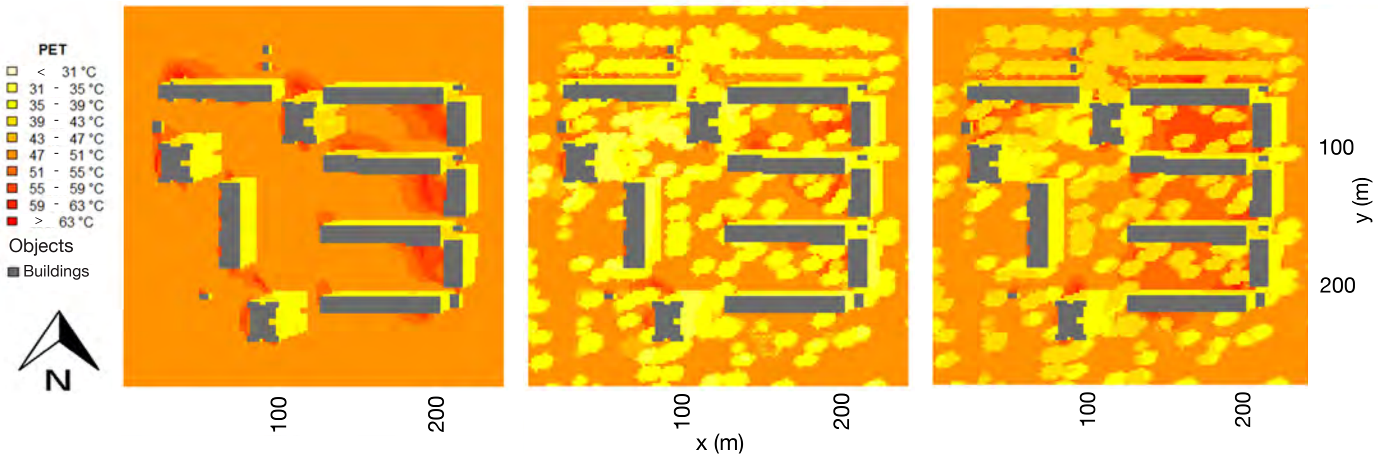


Figure 60: Thermal load at a multistorey block under current climate conditions without vegetation (left), under current climate conditions with current greening (middle) and under future climate conditions with current greening (right) at 3 pm on a very hot day in 1.4 m height

Hot days at free-standing blocks of flats generate a high thermal load outdoors in today's climate conditions. The expansive structural design means there is only limited shading from buildings, and the sunny open spaces heat up dramatically to PET (Physiological Equivalent Temperature) readings as high as 59°C. The open spaces which, in addition to this direct sunlight, also heat up as a result of reflected heat off sunny building façades (facing south-west) are under particular strain. The trees and tree clusters spread across the entire open space form islands with cooler conditions and PET readings of max. 43°C. The average thermal load is higher than at perimeter block developments due to there being less shading in open spaces.

A rise in thermal load outdoors

Increasing temperature extremes are expressed through a higher maximum temperature and a rise in the overall temperature curve throughout the entire day. This leads to an increase in thermal load at free-standing blocks of flats. It rises on average of 5.5%, i.e. from 43.3 to 45.4°C PET (Fig. 60, right). This increase has a particularly strong impact in the areas between the L-shaped free-standing blocks of flats, where the PET reaches maximums of up to 63°C, which humans feel as extreme heat stress (Fig. 60). A lack of ventilation through the buildings in the prevailing wind axes from south-east and reflected heat off the façades are the main reasons for the overheating.

How vegetation regulates heat

Typical free-standing blocks of flats have abundant vegetation and low-density construction. All open spaces between the buildings, without exception, are planted with grass, single trees or clusters of trees. As shown in Fig. 60 (centre), the trees in particular increase thermal comfort outdoors through the shade that they provide. Without the existing vegetation, the apparent temperature would be 48.1°C instead of 43.3°C PET (Fig. 60, left).

Vegetation measures reduce the thermal load outdoors. Trees provide shade and cooling – and are the most effective. The thermal load outdoors can especially be reduced by up to 18% compare to the current vegetation situation (max. 8°C PET reduction) if the trees provide shade for sunny open spaces and south-west façades.

Façade vegetation also increases air humidity through evapotranspiration, thereby providing cooling. The apparent temperature can be reduced by up to 2% to an average of 42°C PET. Compared to perimeter block developments with their high-density construction and average amount of façade areas suitable for adding vegetation, the potential reduction achieved at free-standing blocks of flats is lower when seen over the entire examination area. The actual shading and evapotranspiration, however, is comparable with those at perimeter block developments.

The impact of extensive rooftop vegetation is limited to the space above the buildings' roofs. Although the flat roofs of free-standing blocks of flats are technically well suited to vegetation, their cooling effect in areas occupied by humans, at a height of 1.4 m, is low at just 0.2%, as the greenery on the buildings in the examined free-standing blocks of flats, which are 14 m high, is very far away.

As such, trees are the only option for combating the effects of climate change and maintaining today's climate conditions even in future at free-standing blocks of flats (Fig. 61). The thermal load can be reduced from extreme to moderate heat stress in the maximum scenario.

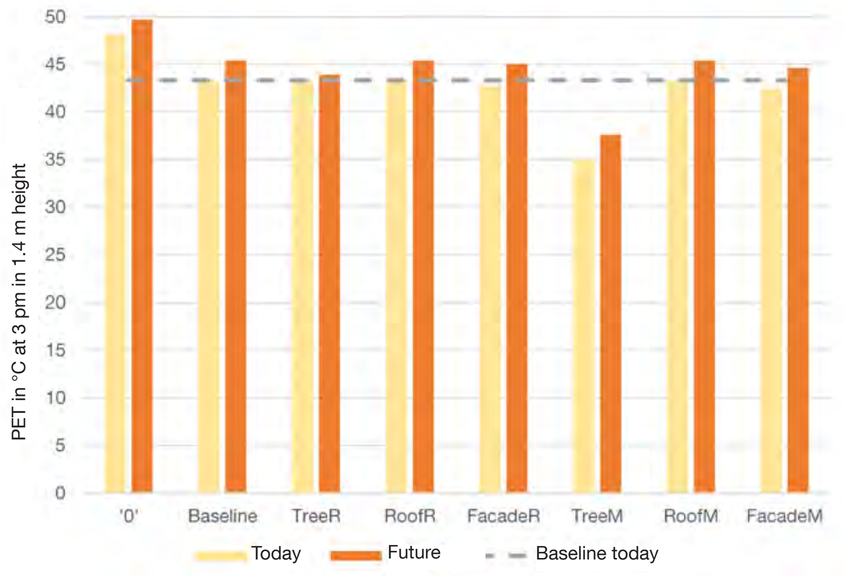


Figure 61: Comparison of PET values for all vegetation scenarios at a multistorey block under current and future climate conditions, the grey line represents the PET-Value the current greening situation and current climate conditions (PET = physiological equivalent temperature)

RECOMMENDATIONS

- Solar radiation, particularly on façades and open spaces exposed to afternoon sun, must be reduced. This reduces the amount of reflect heat, and can be achieved by planting trees and adding façade vegetation, for example.
- Adequate ventilation must especially be ensured, particularly at enclosed structures and along the prevailing wind axes.
- Trees, façade vegetation and rooftop vegetation evaporate water, thereby increasing the cooling effect.
- The combination of shade and evapotranspiration can mitigate increased heat stress.

5.3 Urban living environments

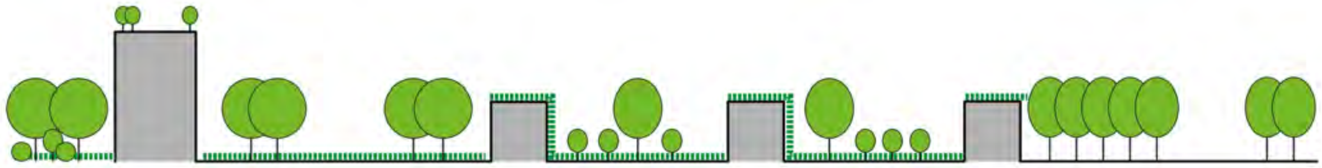


Figure 62: Habitats created by grey and green structural elements

The main task at free-standing blocks of flats is to enhance the social, ecological and aesthetic aspects of existing structures. Establishing a level of differentiation between existing green spaces and traffic areas creates diverse living environments, while adding vegetation to previously unused façade and roof areas broadens the spectrum of high-quality living environments. A number of different districts with characteristic living environments can be formed in relation to the adjacent landscapes and urban structures comprising detached houses, industrial estates and retail centres.

Figure 64: Blackbirds use the lawn at multistorey blocks as a hunting habitat (photo: ZSK sub-project 1)

Quality of open spaces

The vast but homogeneous green-space structure offers little in the way of quality; there is hardly any variety at all. The spaces consist of large areas of manicured lawn and evenly distributed trees, with little diversity of species. The greenery is mostly ‘roadside greenery’ forming a buffer to traffic areas, or is located between residential buildings and is largely unused. Only at the centre of the residential complex are there any recreational spaces or playground facilities, though these are often old. The architecture is limited to its residential function and to the even distribution of identical types of buildings. This means there are no specific points of orientation or identification; there is a lack of unique places and clear boundaries around spaces, and hardly any sound social meeting points for the socially heterogeneous resident structure. The street area is limited to its traffic function, and has none of the qualities of a public space.

Biodiversity

In terms of flora and fauna, free-standing blocks of flats are among the urban settlement types with average species numbers. They are generally more species-rich than inner-city areas, but species-poorer than settlements with well structured green spaces (e.g. old villa districts). Due to its low degree of sealing and large amount of green spaces, this type of settlement provides habitats for many species that are unable to cope with the extremely hot, dry inner-city conditions. If the neighbourhoods are on the edge of the city, they also act as sanctuaries for plants and animals which are no longer able to find suitable habitats, even in the intensively used surrounding farmland. On the other hand, one of the primary reasons the urban settlement type is relatively species-poor is the identical nature of the green spaces compared to the surrounding developments with their well structured gardens. The main problem is the eutrophy of the humus cover combined

Figure 63: The lawn areas between residential buildings are barely used and as habitat only slightly diversified (photo: ZSK sub-project 1)

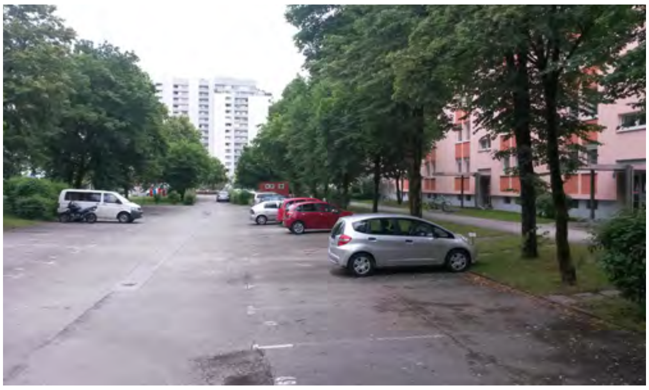


Figure 65: Large car parks at residential complexes dominate the public street area (photo: ZSK sub-project 1)

Figure 66: View of the central recreation space in a residential complex with wetland biotope and recreation areas beneath trees (own illustration)

with frequent mowing. While walking and crawling animal species are exposed to a relatively low collision risk at free-standing blocks of flats, residents and pets are, in principle, able to access all areas of the settlement. This means the disturbance and risk to small mammals, amphibians, reptiles and birds is relatively high.

Street-level measures

More trees need to be added to the existing trees along the streets so as to define the street area, with clearings only to accentuate important areas such as the entrances to residential buildings. This creates a rhythm out of the sequences of different spaces and the clear spatial references.

Large traffic areas must be reduced and partly unsealed. Singlefunctional traffic areas also provide space for alternative modes of transport. A tram track with vegetation, for instance, enables rainwater infiltration and acts as a corridor enabling various flora and fauna to migrate and multiply.

Large car parks on the edge of the residential complexes must be unsealed and covered with water-permeable paving. The surrounding trees should be supplemented with various shrubs to form a small grove without obstructing ventilation. The biodiverse grove structure creates self-supporting habitats. And as green boundaries, they help structure the vast areas between the buildings.

The street provides adequate space for a system of different systems to retain surface water in the paved traffic areas; seasonal retention trenches along the footpath access ways help structure the vast green spaces.

In times of heavy rainfall, they are connected to the retention basins defining the central open spaces. As temporarily flooded areas, they provide special habitats for animals, and have their own unique aesthetic quality when planted with appropriate vegetation.

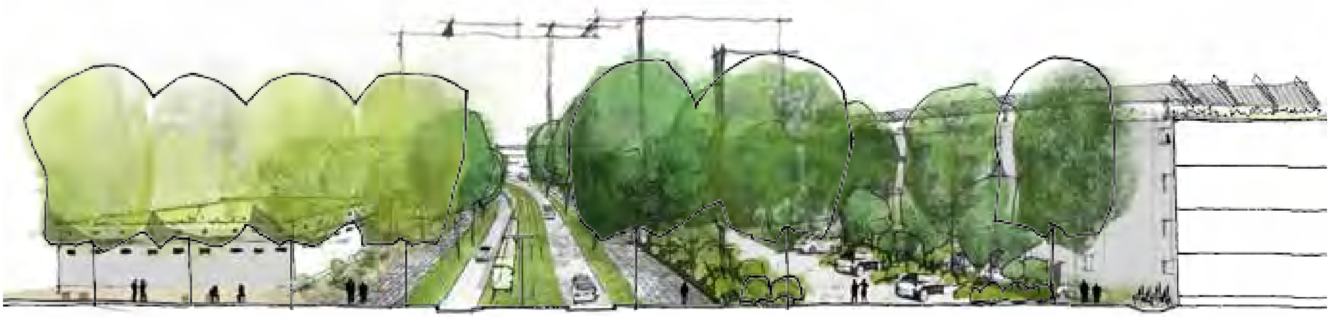


Figure 67: Cross-section of the street area with added trees, greened railway line and unsealed parking lots (own illustration)

Figure 68: Cross-section of private/tenant gardens between multistorey buildings (own illustration)

Building-based measures

The habitats of building-dwelling flora and fauna must be preserved, and ideally expanded, during all structural measures on buildings. The buildings in free-standing blocks of flats also offer untapped potential for vegetation. The façades must be treated differently according to the varying needs of residents, animal species and sun exposure.

Ground-based vegetation can be added all over southern and western façades, which are subject to intense thermal loads. Depending on the type of creeper, this results in food sources and reproduction sites for animals (insects, open-nesting birds, or bats hunting on vertical structures, etc.). During the summer months, vegetation on balconies makes for pleasant, shady recreational spaces. The northern and eastern façades, which are not exposed to such intense thermal loads, do not require vegetation. Façade rehabilitation here should instead incorporate cavity and crevice habitats for birds and bats dependent on an unobstructed approach to the dwellings (e.g. swifts).

The vast green spaces mean it is not necessary to use the flat roofs of free-standing blocks of flats as rooftop gardens. With vegetation added, they act as an additional, cat-free biotope for animals. Rooftop vegetation can also be combined with tilted solar panels, while the roofs of the tower blocks provide unique viewing platforms and can be used as rooftop terraces.

Diversifying the green-space structure

Easy maintenance and development measures enable existing structures to be diversified. This involves defining sub-areas in which usage is intensified/extensified. The spaces between residential buildings may be used intensively as gardens. Private gardens act as the missing link between the homes and the surround-

Figure 69: View of the busy grass landscape and buildings enhanced with vegetation in the background (own illustration)

ing open spaces. The communal areas allow residents to identify more strongly with their residential complex, while the gardens create ties to the surrounding detached houses and create diverse open spaces and a wide range of habitats.

Biodiverse grasslands instead of lawns
Rarely used, peripheral lawn areas should be extensified into biodiverse grasslands. This can often be achieved simply by reducing mowing frequency to 1 to 2 times a year. Removing the topsoil is also recommended for nutrient-rich soils. Fertilizing should be avoided. The complex of extensive grasslands increases the abundance of insects and other invertebrates, which in turn serve as food for birds and bats. The manicured lawn areas are preserved as hunting habitats for certain species such as blackbirds and starlings.

The trees can also be enhanced through selective thickening or thinning to create different spaces, usage options and habitat structures. The result is dense, shady grove or open grassy landscapes with random clusters of shrubs which forge links with the surrounding cultivated landscape.

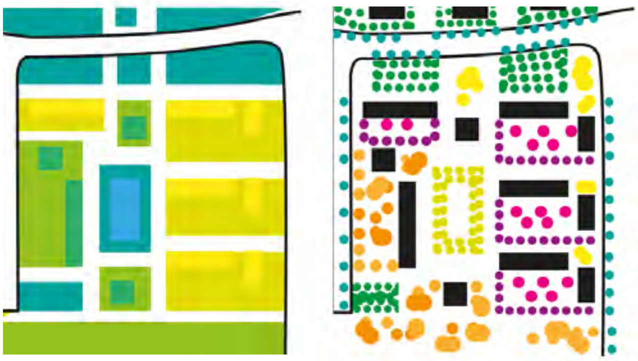


Figure 70: Diversified green spaces and tree locations at a multistorey block

Additional open-space elements such as bodies of water enhance central recreational areas. They also add humid biotopes (urban wetlands) to the range of habitats, and enable residents to experience nature. As central retention basis, they additionally store rainwater for long dry periods.

Figure 71: Context and interlinking of habitats free-standing blocks of flats

DESIGN OBJECTIVES

- Diverse living environments
- Vegetation added to multifunctional traffic areas
- Shady, partially unsealed parking areas with good amounts of vegetation
- Bright and shady recreational areas at residential complexes
- Private gardens and common areas between the free-standing blocks of flats
- Vegetation on balconies
- Extensively managed, biodiverse grasslands
- A system of (seasonal) humid biotopes (urban wetlands)
- Inaccessible dry biotopes on the roofs of the free-standing blocks of flats
- Preservation of habitats on buildings
- Variety by developing existing spaces and diversifying vegetation
- Adding to and thinning out existing trees with typical species from the region
- Extensifying and intensifying the manicured lawn areas
- Diversifying vegetation on façades and roofs
- Interlinking within the neighbourhood
- Creating links to the surrounding settlement and landscape structures by designing the living environments in a characteristic, distinctive manner

5.4 Implementation options

Tower blocks and lower-rise free-standing blocks of flats tend to take up less space than the buildings in perimeter block developments or an historic city centre. Free-standing blocks of flats often still have a lot of room between and even on top of the buildings to add vegetation. In terms of urban climate, the spaces between the buildings should remain undeveloped. Most buildings are purely residential buildings, and there is scope here to provide room for community in the truest sense of the word. In addition to trees and hedges, the areas between buildings can be turned into community gardens or flower beds. Public open spaces or sports grounds are another option. Children's playgrounds in residential districts aid ventilation and, particularly in combination with green spaces and shade, increase the quality and attractiveness of the environment. Open grasslands are suitable for ventilation, though this must be assessed in each case, as trees can often also be planted at free-standing blocks of flats. As free-standing blocks of flats are often on the outskirts of cities, their open spaces can sometimes be connected to the surrounding green belts.

Vegetation on flat roofs

The free-standing blocks of flats, spread in parallel or sporadically, generally have flat roofs and are thus suitable for vegetation. There are many advantages to rooftop vegetation: In addition to climatic functions such as removal of air pollutants, water retention and heat regulation, they also aid biodiversity, noise prevention and social integration (cf. Chapter 4.3, 5.3 and 6.3). Rooftop areas can also be used attractively in semi-public spaces – as private roofs of parking buildings, shopping centres, office blocks or commercial buildings (City of Munich 2012: P. 61). The urban land-use plan can stipulate a percentage of rooftop areas to be reserved for community use.

Figure 73: Roof greening is feasible on flat roofs (photo: ZSK sub-project 1)

The technical aspects must be clarified in advance, particularly in composition of substrates, plant selection, roof sealing and resistance to fire. A general distinction must be made between extensive and intensive rooftop vegetation. If the load bearing capacity of the roof permits, intensive vegetation is possible on roof slopes of up to 15%, while extensive vegetation with suitable substratum can handle inclines of up to 25%. Further details can be found in the rooftop vegetation guidelines published by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL). While building owners need to submit a building application for intensive rooftop vegetation, this is not generally required for extensive vegetation. In Munich, approval is not required for insulation up to 25 cm, and otherwise depends on whether the beams running parallel to the roof ridging have been preserved in the roof truss. The conflict between solar-energy usage and rooftop vegetation calls for innovative solutions. In some cases, photovoltaics (without loss of income!) can be combined with green roofs – and if the situation permits stilting, modules can even be placed on top of vegetation.

Figure 72: Green roofs become veritable oases in the middle of the city (source: LH München 2012)

Funding for existing structures

At an urban level, a register of green-roof potential first needs to be established. This can facilitate implementation, as almost all conservationist assessments of area potential in the past have been case-based. Location, orientation/sun exposure, noise

Figure 74: Conflicts with photovoltaic systems can now be easily resolved (photo: ZSK sub-project 1)

Figure 75: There are options for plants to grow even on small structural elements (photo: ZSK sub-project 1)

and wind conditions are critical factors. Funding programmes should be set up for vegetation at existing structures. Competitions can also provide incentives. The KfW's 'Energy-efficient rehabilitation' programme also subsidises green roofs once they meet the standards as thermal insulation with a maximum U-value of 0.14 W/(m²K). Programmes 151 and 152 or 274 are relevant for loans; programme 430 for grants.

Financial incentives are also possible indirectly by splitting wastewater levies. Around 75% of all German cities already have split wastewater levies (DDV 2017), meaning rainwater and sewage levies are charged separately. Rooftops with vegetation are recognised as unsealed areas. As they can retain up to 95% of rainwater, the rainwater levies drop by up to 1 Euro per sq m and year (e.g. in North-Rhine Westphalia). Municipalities enjoy some financial benefits if drains and rain retention basins are used less.

Requirements for new constructions

Urban rehabilitation and development programmes have been underway since 2013, including in relation to climate protection and adaptation (Section 136 (2) No. 1), because the legal requirements for recognising serious deficits in urban planning have been expanded. For instance, municipalities in urban development areas can stipulate the orientation and height of structures in free-standing blocks of flats to favour aspects such as air flow.

In accordance with Section 9 (1) No. 25 of the German Federal Building Code (BauGB), local governments can establish rules regarding the planting and preservation of trees, shrubs and other vegetation. This relates to green spaces, undeveloped blocks of land and thus private properties, as well as streets and squares, or the addition of vegetation to façades and roofs (BfN (German Federal Agency for Nature Conservation) 2016: p. 58).

(Open-space) design by-laws or open-space planning, which in Bavaria is mandatory either as part of the legally binding land use plan or as an independent set of rules and standards (Section 4 of the Bavarian Nature Conservation Act, BayNatSchG), are also suitable as vegetation regulations. The Munich open-space design by-laws, for instance, stipulate vegetation on garages and adjacent buildings for undeveloped areas of built-up land: 'Pebble roofs and equivalent suitable roofs spanning 100 sq m or more should be permanently covered in vegetation. Fast-growing, perennial creepers should be added to suitable, particularly large outer walls of existing structures, paying special attention to the architectural design. Industrial and commercial buildings are considered especially suitable.'

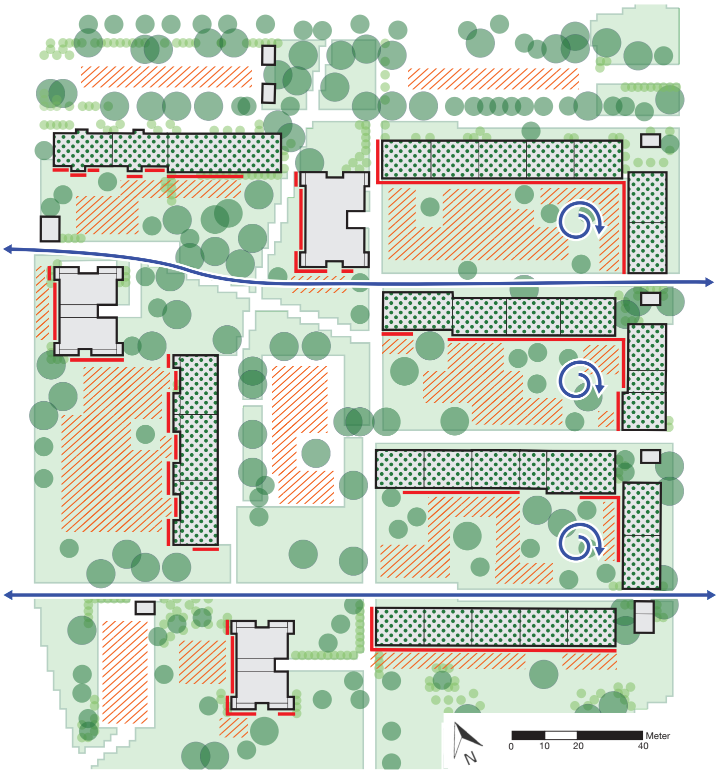
Recognition as compensatory areas

Urban land-use plans can also stipulate rooftop vegetation as ecological compensatory measures under the German Federal Nature Conservation Act. The underlying principle here is that of preserving proportionality. Special requirements or stricter fire-safety rules preventing vegetation often apply to commercial and industrial buildings whose flat roofs tend to have potential as rooftop gardens.

Figure 76: The spaces between buildings in multistorey blocks provide space for vegetation (photo: ZSK sub-project 1)

5.5 Recommended measures

A combination of the most effective climate-protection and adaptation measures for free-standing blocks of flats is shown in the map in Fig. 77. These measures are detailed in a specific, spatial draft scenario for the 'perimeter block development' model area, along with recommendations regarding their multifunctional use for urban living environments and their spatial feasibility. A model below shows how the recommended measures would impact the microclimate in the study area (Neuaubing).



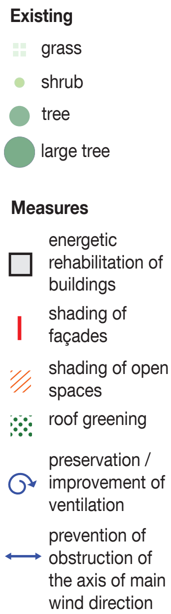


Figure 77: Map locating the measures for climate mitigation and climate adaptation examined in Chapter 5.2

Location of the measures

The technical measures on the building shell must be applied to all buildings. The use of vegetation measures to reduce summer heat stress varies depending on the space. Shading in front of sun-exposed southern and western façades helps reduce the amount of heat entering the building and being reflected into the open space. Open spaces exposed to lots of sun also require shading to prevent surfaces from heating up. And adding vegetation to (ideally) low, flat roofs aids with cooling. Within closed structures, such as the spaces between free-standing blocks of flats, it is important to maintain/improve natural ventilation in order to avoid hot spots. Streets and lanes following the prevailing east-west wind axis should be kept clear for air circulation.

Draft scenario with concrete measures
... at street level

1 Large trees enhance existing trees in street areas. The rows of trees provide shade for sealed traffic areas, and clearly define spatial boundaries. Extensively vegetated roadside trough-trench systems enable surface water to infiltrate into the soil between the trees. The vast street areas are reduced and the parking lanes on the edge are unsealed.

2 A new tram line connects the neighbourhood to the central retail centres and S-Bahn (suburban train) stations. The track is integrated into the middle of the road, with dry lawn added as vegetation. In addition to the lush look, this creates extra food sources and acts as a corridor for many animal species to migrate and multiply.

3 The currently fully sealed parking areas are mobilised for rainwater management, and more vegetation is added to ensure better shading. The existing trees on the edges are combined with various shrubs to form a graduated grove. Large trees provide shade for the parking areas. The existing asphalt surfaces are unsealed and covered with water-permeable paving. Shrubs and trees are planted, and rainwater infiltrated, in the lower planting areas at the expense of a few parking bays. The combination of various local shrubs makes for a biodiverse fringe that serves as a green space in terms of urban planning, and acts as a sanctuary for many animals. The fringe-like structures are similar to the edge of a forest, which creates a richly structured and, depending on the degree of exposure, microclimatically diverse habitat for many different animal species.

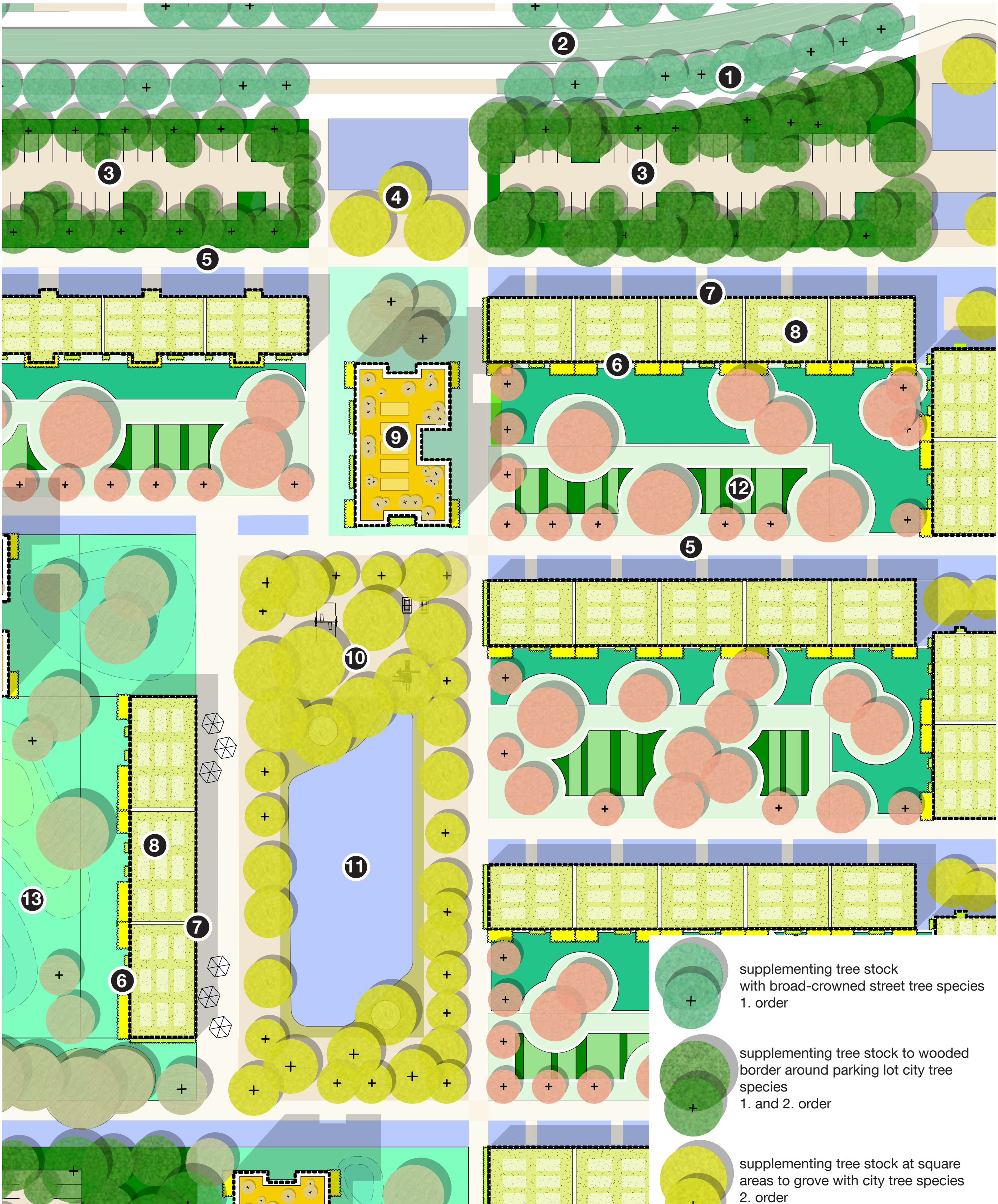


Figure 78: Greening scenario on a scale of 1:1000

- rehabilitation of existing buildings for energy efficiency
- water permeable surface
- lawn
- kitchen garden with beds
- areas for small groves/hedges
- extensive meadow with modelled site
- wet areas for retention
- roof top terrace greened with planting troughs
- extensive roof greening lime stone grassland
- solar roof with roof greening
- greened balcony/loggia
- ground-based façade greening with trellis, 12-15 m high
- supplementing tree stock with broad-crowned street tree species 1. order
- supplementing tree stock to wooded border around parking lot city tree species 1. and 2. order
- supplementing tree stock at square areas to grove with city tree species 2. order
- supplementing tree stock between free-standing blocks of flats with fruit trees
- supplementing tree stock at meadow areas to tree groups with endemic tree species 1. and 2. order

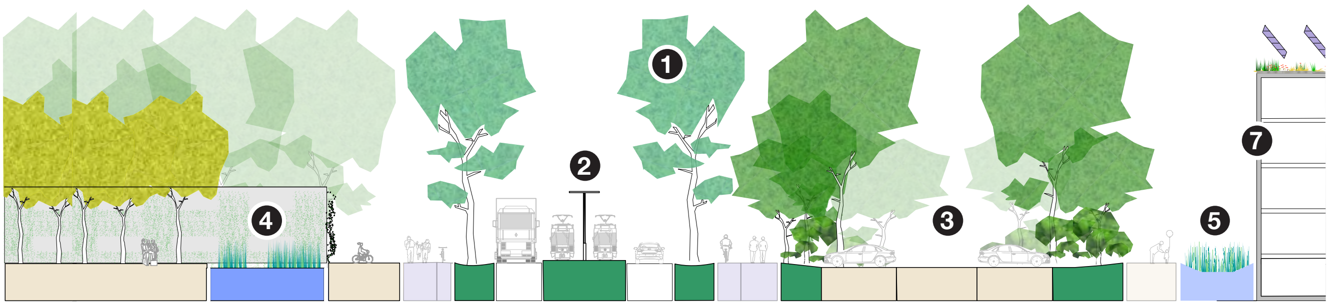


Figure 79: Cross-section of the street area on a scale of 1:500

4 Entrances to the residential complexes are expanded to become squares covered in waterbound paving. Recessed groves of trees define the space far below, creating shady recreation options. At the centre of the square are retention basins planted with seasonal vegetation; these basins enable the infiltration of surface water from neighbouring streets and parking areas. They also create new visual aspects at street level, and provide habitat elements for animals.

5 Seasonal retention trenches are added to the footpaths leading up to the residential complex on the northern side of the building. They collect rainwater from the paved areas, and are connected to the large retention basins at the centre of the residential complex. They look different depending on whether they are dry or overflowing, and, as temporary flooded areas, act as unique biotopes.

... on buildings

6 The southern and western façades, which are exposed to the highest thermal load, are planted with various ground-based creepers. Depending on the type of creeper, these also provide additional visual aspects, as well as food sources and breeding sites for animals such as insects, open-nesting birds, and bats that hunt on vertical structures. Adding deciduous creepers to existing balconies transforms the overheated areas into pleasant, shady recreation areas during the summer months, while still allowing enough light into the apartments in winter.

7 It is important to ensure building-dwelling animals do not lose their habitats during rehabilitation measures. Nesting cavities/areas for building-dwelling birds, bats and wild bees are integrated into the eastern and northern façades, which are under less of a thermal load, as part of rehabilitation measures.

8 Unlike the lawn areas which are mostly shaded by trees, the flat roofs of buildings in free-standing blocks of flats are fully exposed to the sun. Calcareous grass can be planted on the currently intensely overheated pebble roofs without excessive technical effort or expense, establishing a link to the habitats in the surrounding fallow land and railway areas. Stilted solar cells can be placed on top of the roof vegetation, and end up being much more effective on hot days thanks to the cooling from the green spaces below them.

9 Rooftop terrace are created on the roofs of the tower blocks. As a biotope in themselves, they are too exposed and difficult for animals to access. For building residents, however, they provide unique lookout points and a communal recreation area. Potted shrubs provide the necessary shade.

... Diversifying green spaces

10 The trees in the residential complex's central recreation space are thickened into a grove. This creates a shady area underneath them consisting of a waterbound floor covering, which can be used as a recreational space or playground. The interconnecting canopies in turn provide useful sanctuaries and nesting sites for animals.

11 As a unique spatial element, a large body of water accentuates the complex's central recreational area. The humid biotope provides a habitat for many unusual species of animal, including dragonflies, amphibians and waterbirds, and is conducive to observing and admiring nature. The basin can also act as a reservoir to collect water in times of heavy rainfall. On hot days, the water area and water plants additionally cool the residential complex through their high evaporation rate.

12 The spaces between the free-standing blocks of flats are intensified to form gardens. Ground-floor apartments are given direct access to private gardens. Shrubs, hedges and dry-stone walls act as partitions between the garden plots, and enrich the space with additional biotope structures. The existing trees are casually supplemented with fruit trees. Residents on upper floors are offered the central areas as communal spaces or rented gardens. These constitute an additio-

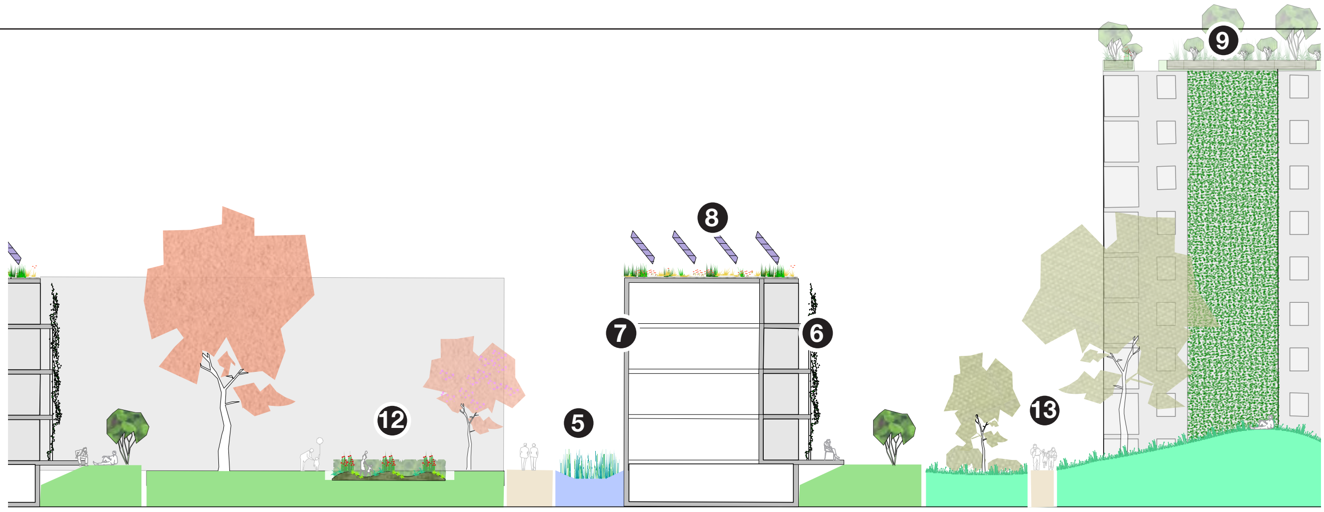


Figure 80: Cross-section of a residential complex's interior on a scale of 1:500

nal private outdoor living space, and enable individual designs for the areas. Having one's own garden allows the multicultural community of residents to express their own landscaping and outdoor customs, which promotes cultural exchange and increase social responsibility for the green space.

13 Based on typical landscape features of the surrounding area, the peripheral green spaces are converted into biodiverse grassland through soil impoverishment and extensified maintenance measures (mowing once or twice a year). Modelling the grounds is also a way of diversifying the site into damp hollows and dry mounds. The shrubs are thinned out or sporadically thickened into clusters typical of the landscape to create well structured, semi-open living environments. The biodiversity here is also increased by local shrubs less resistant to the urban climate, resulting in a landscape typical of the region, into which the buildings are integrated.

Microclimatic assessment of the draft using ENVI-met

The proportion of green spaces in the draft also increases significantly for free-standing blocks of flats – from 55.2% to 74.4%, reducing the average PET by 5.5% under today's climate conditions. In future, however, we will ultimately still be 0.5% off today's thermal comfort level. Shrubs, small trees, façade vegetation and balcony vegetation are all effective in reducing thermal load in this type of settlement. While adding a central water body will absorb solar rays and help with cooling through evaporation, the PET value will barely reflect this.

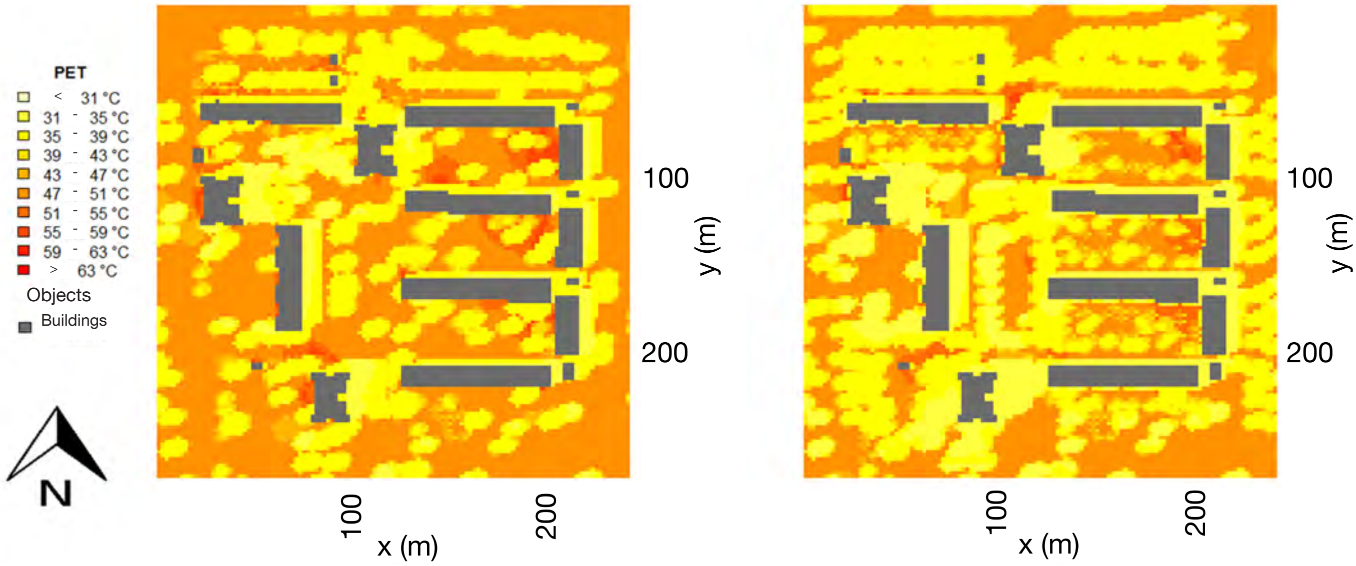


Figure 81: Thermal load at a multistorey block with current greening (left) and as greening scenario (right) under current climate conditions, at 3 pm on a very hot day in 1.4m height

6 Historic city centres

Historic city centres have a compact layout within city walls or the remains thereof. The buildings vary in terms of expanse, height, shape, position and age, and are often heritage-listed. The average structure height is between 10 and 15 m. The historic building structure consists of densely interlaced blocks, whose edges do not follow any clear building lines, and which include lots of offset constructions or gaps between buildings.

Interiors of blocks are partitioned by several buildings and boundary walls. The often narrow, intensely sealed rear courtyards rarely feature any vegetation, and the public spaces form a close-knit network of lanes, streets and central squares. They are heavily used and highly sealed, with only sporadic vegetation in the form of trees, creepers or vascular plants.

The city centre of Heidingsfeld is characterised by very high-density construction and few green spaces. The average degree of sealing is 86%, green spaces 14% and building density 61%.

Large, free-standing historic buildings such as churches and town halls with impressive forecourts or historic parklands mix up the small-scale urban structure. The city is usually criss-crossed by brooks or canals. Some dense city cores are surrounded by a green belt of former fortress complexes. In addition to modern settlement structures, these sometimes also border directly onto typical landscapes such as floodplains or vineyards.

6.1 Protecting the climate through energy efficiency

Fig. 82 shows the study site of the ‘historic city centre’ urban settlement type. The typical buildings – corner, middle and boundary buildings – are highlighted in detail in the figure. The three buildings represent the typical outbuilding scenario in this sort of settlement.

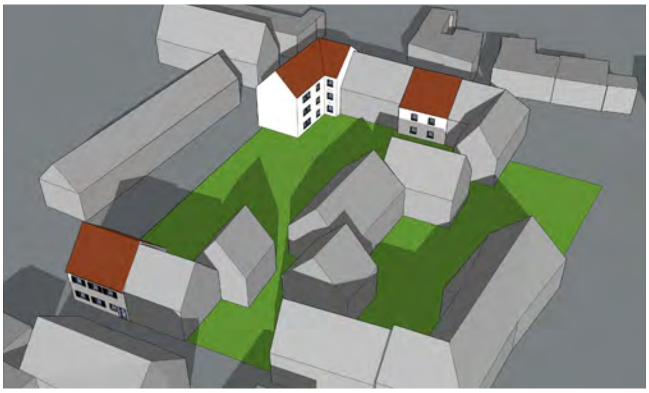


Figure 82: Study site for the ‘historic city centre’ urban settlement type with its three typical buildings corner, middle and side building

The effects of climate change

The average net energy demand per period for the entire study site of the historic city centre is shown in Fig. 83. The net energy demand consists of the need for cooling and thermal heat. In this type of settlement, we once again see that the heating demand will be decreasing in future, while the potential cooling requirement will rise. The net energy demand for historic city centres sits between that of the two other urban settlement types.

The rise in potential cooling requirement is the lowest for historic city centres, primarily due to the shading from surrounding buildings, as these are all very close to one another compared to in the other urban settlement types. Rehabilitation for energy efficiency also offers a high potential for energy-saving in historic city centres. Rehabilitating building shells can indeed cut the net energy demand by more than half. Comparing the urban settlement types shows that rehabilitating building shells significantly reduces the urban settlement type’s influence. Unlike the results for existing building fabric, rehabilitations following the EnEV or EnEVPlus schemes produce similar results in all urban settlement types.

Comparing the results of a rehabilitation following the EnEV scheme shows that the heating demand will decline by approx. 25% from period 1 to period 4. The potential cooling requirement will rise by 25% during this same period. From this, we can conclude that, even in historic city centres, the cooling requirement is important when further reducing energy demand. An analysis of the net energy demand for EnEV or EnEVPlus rehabilitations in Fig. 83 shows that the drop

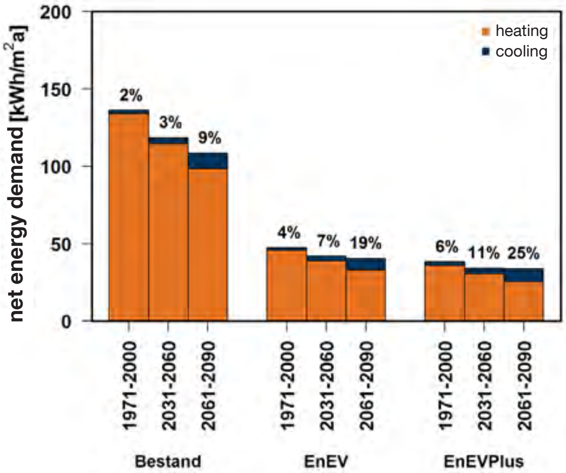


Figure 83: Average net energy demand per rehabilitation period in the Heidingsfeld study site after EnEV and EnEVPlus

in thermal heat requirement is greater than the rise in the cooling requirement. Even in period 4, when the other urban settlement types display a slight increase, the net energy demand for historic city centres drops. This is due to the comparatively lower increase in potential cooling requirement here, which can largely be explained by the fact that the buildings provide shade for one another. This also impacts on greenhouse gas emissions.

Fig. 84 presents the emissions for the Moderate and Ambitious systems technology variants. The increase in greenhouse gas emissions for the Moderate variant is sharp, as is also the case with the other two urban settlement types. But the maximum values are much lower compared to the other urban settlement types. The use of efficient cooling in the Ambitious variant si-

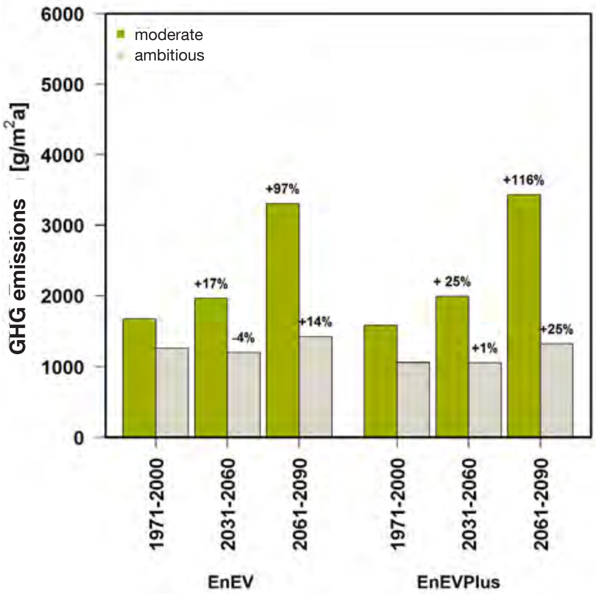


Figure 84: Average greenhouse gas emissions in the Heidingsfeld study site

gnificantly reduces the emissions, as seen at the other settlements, which is why it is important to take into account the option of efficient building cooling right from the current schemes.

Measures

As an alternative to active cooling through systems technology – as per the Moderate and Ambitious scenario –, passive measures on building shells in historic city centres are also analysed. These measures are presented in detail in Chapter 3.1.

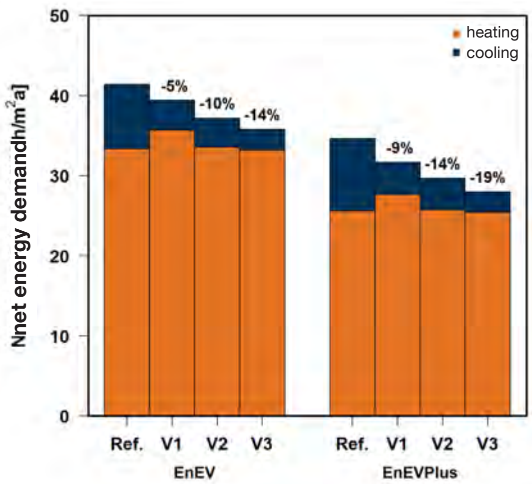


Figure 85: Reduction in net energy demand for the period 2061 to 2090 by climate adaptation of the rehabilitation measures

Fig. 85 shows the potential savings achieved by the measures for the net energy demand during the period 2061 to 2090. Variant 1 has a negative impact on the need for heat energy, even in historic city centres. While it significantly reduces the cooling requirement,

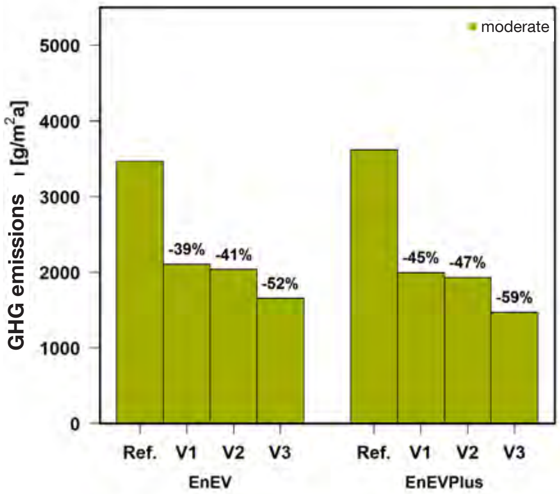


Figure 86: Reduction in greenhouse gas emissions for the period 2061 to 2090 by climate adaptation of the rehabilitation measures

the increase in the heating demand means a net reduction of only 5% or 9% of the net energy demand. Using proper sun protection (V2 and V3) does not trigger any rise in the heating demand in this urban settlement type either.

Combining outdoor sun protection and automated natural ventilation (V3) reduces greenhouse gas emissions by 50% or 60% in period 4 (Fig. 86), roughly corresponding to the amount of emissions in the current period 1. Combining outdoor sun protection and night ventilation (V2) is also recommended for historic city centres, as these measures are a good compromise between input and reward.

RECOMMENDATIONS

- Climate change is reducing the heating demand and causing the potential cooling requirement in historic city centres to rise.
- In terms of climate protection, energy-efficiency rehabilitations will continue to be essential for historic city centres even in future.
- Efficient building cooling through systems technology or building-shell measures must be taken into account right from current plans due to long rehabilitation cycles.
- Inefficient cooling combined with rehabilitation to meet current standards of technology may cause greenhouse gases to rise by approx. 100% in historic city centres for the period 2061 to 2090.
- Outdoor sun protection coupled with night ventilation is a recommended combination of measures. 40% of potential emissions could end up being saved even in the period 2061 to 2090.

6.2 Climate adaptation through green infrastructure

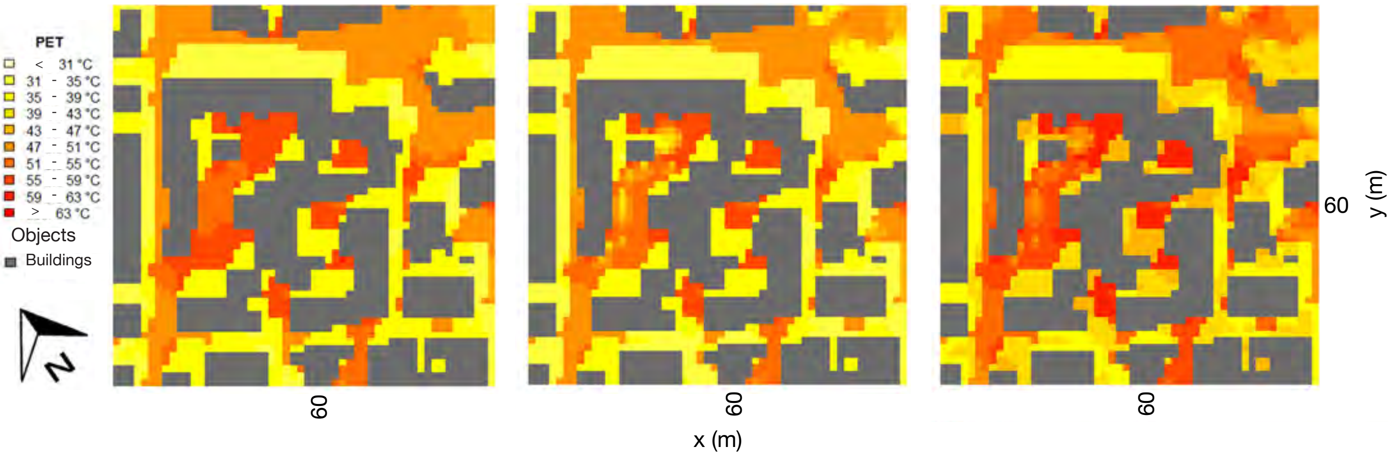


Figure 87: Thermal load in an historic city centre under current climate conditions without vegetation (left), under current climate conditions with current vegetation (middle) and under future climate conditions with current vegetation, at 3 pm on a very hot day in 1.4m height

The Würzburg meteorological data used for the studies in Heidingsfeld show that outdoor areas are subject to high thermal loads on hot summer days. The average PET (Physiological Equivalent Temperature) of 42°C means extreme heat stress for humans.

In this urban settlement type's small-scale development structure, most of the street areas are shaded by buildings, and thus have the most pleasant of conditions, ranging from 35 to 39°C. Enclosed interior courtyards, on the other hand, are where the highest degree of overheating is recorded, due to reflected heat off sunny façades and a lack of ventilation.

A rise in thermal load outdoors

According to IPCC forecasts, climate change will particularly increase the intensity of hot days in Würzburg. The thermal loads will rise by a drastic 11.5%, from 42 to 46.6°C (Fig. 87, centre and right). This increases summertime heat stress across the entire examined area. As was also the case for perimeter and free-standing blocks of flats, the increase is greater in sunny interior courtyards and street areas, resulting in maximum PET values of over 60°C.

How vegetation regulates heat

The small-scale structures of the historic city centre leave hardly any room for vegetation. It is generally impossible to plant trees in the narrow streets, and the gardens of interior courtyards rarely have enough space for large trees. The existing vegetation, consisting of small trees, hedges and shrubs thus only reduce the thermal load by an average of 1°C compared to a scenario without any vegetation (Fig. 87, left and centre). These small-scale green structures mean shading and evapotranspiration have a very limited effect locally. And planting trees provides both shading and evapotranspiration, it is the most effective method. Expressed as apparent temperature, this corresponds to a reduction of approx. 8°C PET or 17.5%.

Planted trees providing shade to open spaces and façades exposed to intense sunlight, particularly those facing south-west, achieve the greatest benefit. Façade vegetation achieves a maximum PET reduction of 14%. Evapotranspiration and shading on the many small southern and western façades reduce temperatures from 42 to 36°C. The effect of extensive rooftop vegetation is primarily limited to the space above the building roofs.

But vegetation on the low buildings of historic city centres can still achieve a higher PET reduction of 1% in street areas compared to perimeter and free-standing blocks of flats. The evapotranspiration effect is limited to the vegetation's immediate surrounds, which is also explains the effectiveness of trees; they have the furthest reach into the outdoor area, where they also provide cooling.

With regards to the anticipated climatic changes, the simulation results show that trees and façade vegetation have the potential to counter the impacts of climate change, and even maintain today's climatic conditions in future (Fig. 88). These measures reduce the thermal load in the maximum scenarios from extreme heat stress to intense/moderate heat stress.

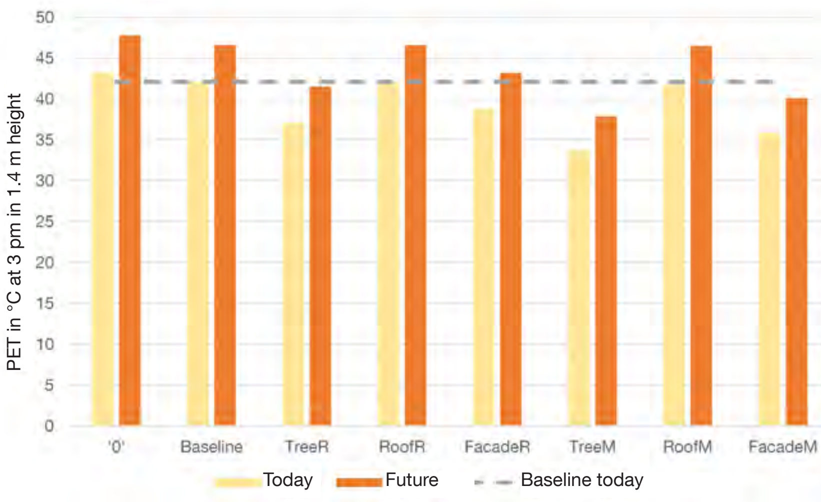


Figure 88: Comparison of PET values for all vegetation scenarios in an historic city centre under current and under future climate conditions, the grey line represents the PET-value of the current situation of vegetation and current climate conditions (PET= physiological equivalent temperature)

RECOMMENDATIONS

- Adding vegetation in the form of trees and façade vegetation can lower solar radiation on open spaces and façades, and thus reduce the amount of heat being reflected back outdoors. Areas of afternoon sun must be given priority here.
- Adding vegetation to rooftops, especially of low buildings, reduces the thermal load in street areas.
- Ensuring adequate ventilation, particularly in enclosed structures such as interior courtyards and along prevailing wind axes, is important.
- Any vegetation in the form of trees, façade vegetation or rooftop vegetation provides cooling through evapotranspiration.
- Strategically combining shading and evapotranspiration helps reduce heat stress outdoors.

6.3 Urban living environments

The spatial density of historic city centres leaves little room for vegetation. Trees can only be planted sporadically, yet they enhance public spaces as places of recreation. Adding vegetation to façades and unused rooftops is one way of creating private recreational spaces and sanctuaries for animals in cramped rear courtyards.
The small-scale structure has the potential to create a huge variety of living environments. And the link to the locations' history plays a key role in the vegetation process; it involves reviving building vegetation compatible with the architecture, as well as traditional forms of open-space design and use. One key pre-requisite for this, however, is reducing space for parked vehicles.

Figure 89: Habitats created by grey and green structural elements

Quality of open spaces

Development and open spaces form an extremely small-scale mosaic of spaces in historic city centres – a mosaic forged over centuries out of the historic requirements of maximum density and usability within the city walls. Lanes, streets and squares are today, however, dominated by (parked) vehicles, and are hardly used as recreational spaces anymore. Fast commuting within the city and good connections to the public transport network are a particular quality of historic city centres.

An awareness of tradition continues to shape townscapes and people's lifestyles. In addition to sound architecture, parts of traditional landscaping also continue to be found in the gardens of rear courtyards. Benches and flowerpots outside buildings are sometimes still evidence of functional neighbourly exchange. Green structures and landscaping elements outside

Figure 91: Gardens within the dense block structure are important places for residents and biodiversity (photo: ZSK sub-project 1)

the city walls have great recreational value, and must be linked more intensively with the high-density city centre.

Biodiversity

In terms of flora and fauna, historic city centres are considered to be extremely species-poor due to the high degree of sealing and sparse greenery. Unlike other types of inner-city settlements, however, they generally have richer structures and offer a wealth of potential living environments. In addition to the species typically found in inner-city locations, there are also 'specialists' which particularly inhabit historic buildings. These include bats, such as greater mouse-eared bats and Geoffroy's bats, as well as birds, namely barn owls, kestrels, house martins and jackdaws. Shade-loving wall plants also grow in shady, humid laneways. Wild bees nest in the joins of old paving or walls in sunny areas. City brooks and walls provide additional habitats, e.g. for dragonflies and lizards. Different types of gardens traditionally play a key role in boosting the biodiversity of historic settlements. In general, flora and fauna in historic city centres are closely linked with surrounding landscape elements such as rivers, lakes and forests.

Figure 90: The quality of public spaces suffers under the dominance of parked vehicles (photo: ZSK sub-project 1)

Figure 92: House martins are typical inhabitants of historic city centres (photo: ZSK sub-project 1)

Building-based measures
All measures taken on historic building fabric must comply with monument protection laws in the historic city centre. The type and extent of vegetation should be geared around the historic townscape and traditional forms of vegetation. Particular attention must also be paid to protecting species when rehabilitating and adding vegetation to buildings. Additional habitats and nesting sites should be created as part of the rehabilitation measures wherever possible.

It is very difficult to add vegetation to the steep roofs of the main buildings. Extensions or adjacent buildings in the rear courtyards, however, are ideal places for rooftop vegetation. Connected to the residential building, they can be used as rooftop terraces or gardens, while relatively undisturbed biotopes on inaccessible roofs can expand the range of habitats.

Figure 93: View of the church square with fountain and central recreational spaces under trees (own illustration)

The greatest potential for climate adaptation in high-density city centres lies in adding vegetation to southern and western façades, which are exposed to intense thermal loads. Small plant areas will suffice to add traditional creepers, such as ivy, Virginia creepers, espalier fruit, grapevines or roses, to the low façades. This form of vegetation works particularly well in narrow laneways or rear courtyards where there is generally little space available.

Measures in public spaces
The space needed by trees in public areas conflicts with the high-density development and parking areas. And yet trees have traditionally played key roles in historic townscapes; large single trees or clusters of trees coupled with a fountain often define prominent squares and act as central gathering places. Wide streets have always been important as meeting places, which are used and enlivened by retail, farmer's markets and festivals. Trees define and shade these places of activity and recreation.

Their locations must be sporadically expanded through sensitive placement within the urban framework in order to ensure qualities in the public space. The choice of location and species must be adapted to local conditions according to space and exposure. Old existing vegetation in public spaces and (historic) gardens and parks already plays a key aesthetic and ecological role, and must be preserved.

The semi-public areas in front of buildings perform a social function in historic city centres: As traditional bench areas, they are a place for neighbours to communicate and engage in recreation. To revive this function, places with development potential should be made accessible so that they can be personalised with planters and flowerpots, and have seating added.

City brooks or canals act as open-space corridors in the high-density urban structure. Their shore areas should most definitely be developed as public open spaces and valuable biotopes. The cramped urban open spaces need to be more closely linked with the large green spaces of the surrounding ring of fortresses, the floodplains and the historic gardens. They will act as climatic refuges in future.

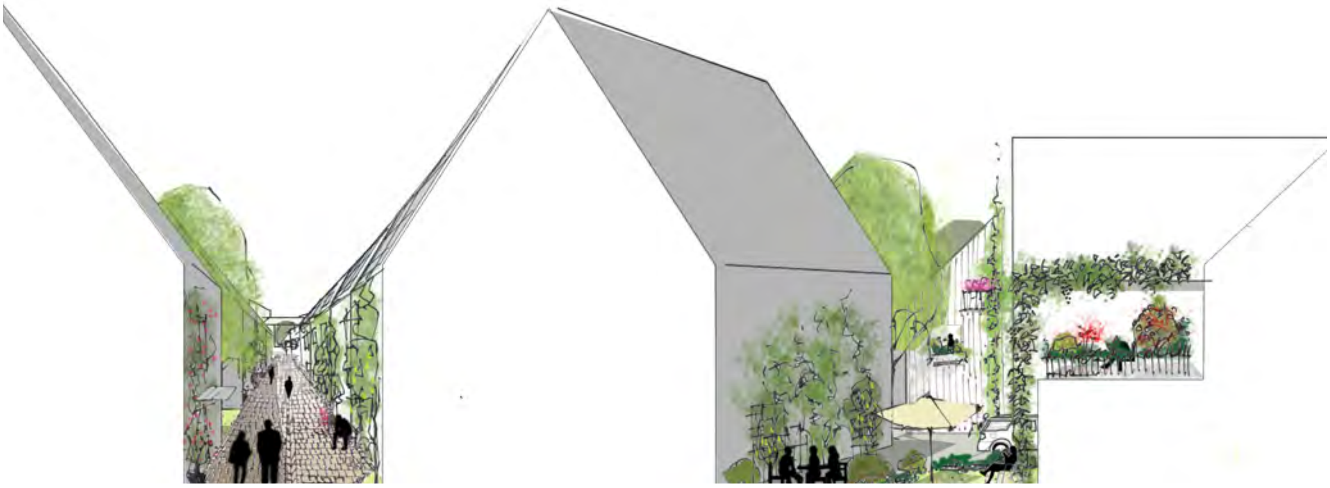


Figure 94: Cross-section views of a laneway with green façades and greened rear courtyard with rooftop (own illustration)

Measures in interior courtyards

Climatically favourable private open spaces can be created in the rear courtyards of historic urban areas. Free-standing walls and pergolas with greenery are a traditionally space-saving and very effective form of vegetation in these very small courtyards. Combined with pot plants, small bodies of water and unsealed areas, the tiny, highly sealed yards can be transformed into temperate, lush oases with a pleasant ambience.

Individual trees can be planted, and fruit and vegetable gardens created, in larger rear courtyards. Landscaping was an important part of historic city centres. Permaculture involving bedding, fruit trees, espalier and vine bowers can be integrated into even the densest of urban structures, though the only way possible to revive this as a garden is if the areas cease to be used as private parking bays.

Figure 95: View of an interior courtyard formerly used as a parking area, which was transformed into a little oasis (own illustration)

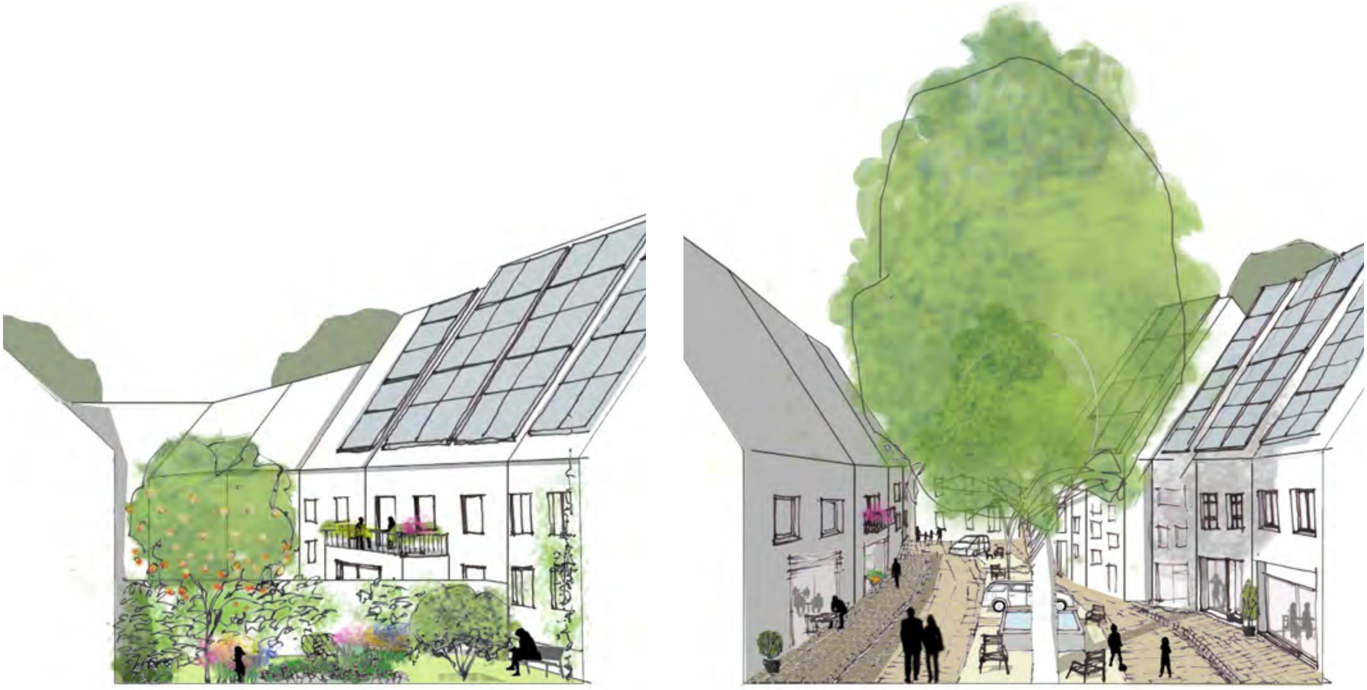


Figure 96: Cross-section view of a greened rear courtyard used as vegetable garden and a wide street area with living zones beneath the trees (own illustration)

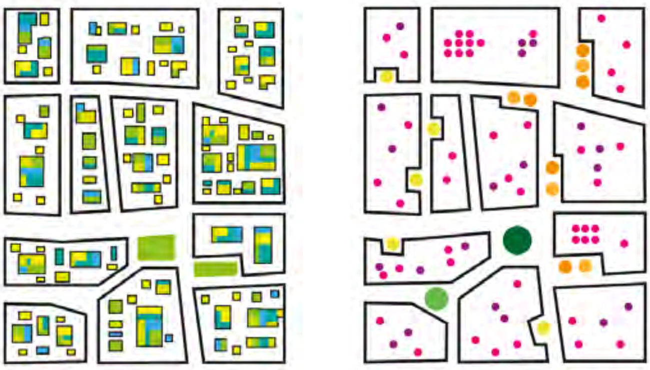


Figure 97: Diversified green spaces and tree locations in an historic city centre

Figure 98: Context and interlinking of punctual, linear and areal habitats in an historic city centre

DESIGN OBJECTIVES

Diverse living environments

- Shaded recreational areas a town squares
- Semi-public areas in front of buildings
- Private ornamental and fruit/vegetable gardens in rear courtyards
- Private sanctuaries on rooftop terraces
- Reviving city brooks and canals
- Sheltered retreats for animals on rooftops, in tree canopies and in façade vegetation
- Preserved habitats on buildings

Diversity through vegetation

- Diversified vegetation on façades, pergolas and walls in the form of traditional creepers
- Sporadic planting of different tree species – depending on space
- Adding vegetation to rear courtyards in the form of traditional ornamental and crop plants
- Extensive vegetation for inaccessible adjacent buildings

Interlinking within the neighbourhood

- Interlinking the small, inner-city green spaces with large surrounding green structures of green belts and/or floodplains

6.4 Implementation options

Figure 99: Greening options in public spaces (photo: ZSK sub-project 1)

The narrow, winding streets and lanes in historic city centres mean there are often no options for unsealing surfaces and planting trees. This makes it all the more important to assess the potential for adding vegetation to rooftops and façades. As the property is protected under Art. 14 of the German Constitution (Basic Law), the local government cannot oblige people to add vegetation to the exteriors of their buildings.

Creating incentives and adding vegetation to façades

That's why it is important to create incentive systems which, above all, encourage private owners to add vegetation. PR work must accompany the positive effects of façade vegetation and highlight the added value through piggyback measures. If, for example, the exterior wall is insulated, painting it the lightest possible colour should increase its albedo value. The impact of the façade vegetation must be calculated right from the start of rehabilitation.

In the case of new constructions, rehabilitations and repairs, regulation options are established in the urban land-use plan: Façade vegetation can be incorporated in the development plan (Section 9 of the German

Figure 100: Climber on a residential building (photo: ZSK sub-project 1)

Federal Building Code) and in project and site-preparation plans as part of open-space planning, or, if necessary, stipulated through vegetation requirements. Similar to rooftop vegetation, local governments can also stipulate the addition of vegetation to façades through (open-space) design by-laws. Landscaping plans/open-space planning for urban areas may include 'green values' (e.g. biotope area factors), such as those introduced by the city of Berlin (Berlin Senate Office 2016). Town-planning contracts are a good way to secure investors. Façade vegetation also comes into play for intervention and compensatory regulations as per Section 8 of the German Federal Nature Conservation Act.

In addition to the exteriors of residential buildings, public and commercial buildings are also options for façade vegetation. Halls, school buildings and production facilities are all suitable places for vegetation. Windowless fire walls and brick walls must be assessed, as walls covered entirely in vegetation offer great potential for collecting dust and regulating the microclimate (Berlin Senate Office 2017). Vegetation measures should also be considered for other structures, such as tunnels, bridges and soundproof walls, as part of climate-oriented urban development.

Figure 101: Along with residential buildings, public structures also offer options for façade greening (photo: ZSK sub-project 1)

Ground-based creepers or trellises

In principle, a distinction must be made between self-climbing creepers and vegetation on trellises. The guidelines issued by the Forschungsanstalt Landschaftsentwicklung Landschaftsbau (FLL e.V.) provide reliable reference points for which plants are suitable and how the relevant maintenance expense is to be calculated. Depending on the specific location conditions, the plants can only be chosen on site. Reservations concerning façade vegetation can often be dispelled, or end up being less important for adjacent buildings.

Monument protection restrictions

Much of the buildings in historic city centres are heritage-listed. While interior rehabilitation measures are not usually critical, major changes to the exterior (windows, façades, dormers, extensions) require approval from the Lower Monument Protection Authority (Untere Denkmalschutzbehörde).

Close dialogue is always advisable as a way of finding solutions for planned rehabilitation or vegetation projects. The legal requirements for thermal insulation are less strict for monuments than for other (old) buildings. The local government should provide building owners with adequate information on financial support, as projects in this type of settlement often involve high costs. Since 2012, for instance, the KfW set up the 'Effizienzhaus Denkmal' funding programme for energy-efficient monuments (KfW 2016). Expenses relating to preserving the building are also tax-deductible over several years through higher write-offs.

Travelling by bike or on foot

The central location means historic city centres are well connected to local public transport. A good mix of residential and commercial shortens access-ways, saves emissions and encourages the use of cycling tracks and footpaths. City centres thus lend themselves to having traffic-free zones and non-built-up public squares. The local government can regulate the parking-space code in the form of by-laws. Retail players should be included in the plans early on, so as not to jeopardise any locations.

Figure 104: Vegetation can be added to parts of structural complexes (photo: ZSK sub-project 1)

Figure 102: Narrow laneways can be shaded by greenery (photo: ZSK sub-project 1)

Vegetation and shading must be provided at public squares as part of urban restructuring measures. Ever since the climate protection amendment, losses of function in terms of urban development can also be claimed if the requirements for climate protection and adaptation have not been met. As such, sails, vegetation and other climate-adaptation measures can all be applied to improve climatic comfort.

Figure 103: An example of vegetation on parts of a half-timbered building (photo: ZSK sub-project 1)

Figure 105: An example of a pergola with vegetation (photo: ZSK sub-project 1)

6.5 Recommended measures

A combination of the most effective climate protection and adaptation measures for historic city centres can be found in the map in Fig. 106. The draft scenario specifies the measures for the study site, plus mentions recommendations regarding its multifunctional use for urban living environments and their spatial feasibility. A model then shows how the recommended measures would impact the microclimate in the study site (Heidingsfeld).

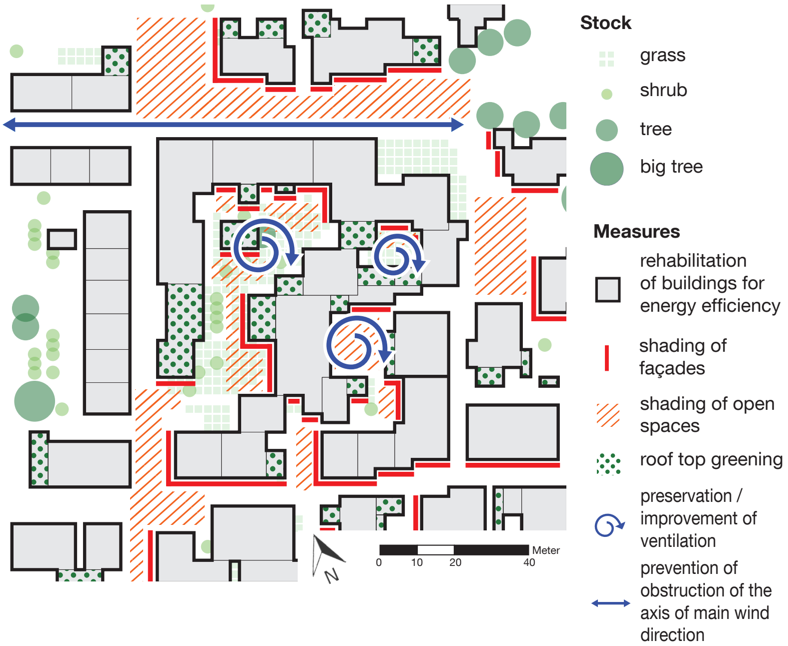


Figure 106: Map locating the measures for climate mitigation and climate adaptation examined in Chapter 6

Location of the measures

The technical building-shell measures should be applied to all buildings. The use of vegetation to reduce summer heat stress varies depending on the space. Shading in front of sun-exposed façades reduces the amount of heat being reflected into the open space. Very sunny open spaces must be shaded to prevent the surfaces from heating up. Vegetation on (ideally) low and flat roofs also aids with cooling. Within enclosed structures such as interior courtyards, it is important to maintain/improve natural ventilation to prevent hot spots. Streets and lanes along the prevailing wind axis should be kept clear for air circulation.

Draft scenario with specific measures
... in public spaces

1 Ground-based vegetation is added to sun-exposed southern and western façades in narrow laneways. Small spaces in the street, where owners plant vegetation, provide enough room for roots. In terms of creepers, we recommend traditional species such as ivy, Virginia creeper, climbing roses, espalier fruit or grapevines which create a link to the historic development and traditional landscaping culture. The areas in front of buildings can also be personalised with flowerpots or planters, while seating in the form of benches or similar revives the public space as a place of communication and recreation.

2 Gaps between buildings or recessed buildings can provide space for trees, including in narrower lanes. This particularly shades exposed south and west-facing recesses and enhances them as places of recreation. Category 2 and 3 tree species are best suited for narrow spaces.

3 Sections of the wider, sunnier street areas are shaded by rows of trees, without this conflicting with the historic townscape. Species with slender or small canopies are ideal, as they require less space for roots and canopies and still enable ventilation. In the otherwise bare street, the trees act as an important place of recreation and social exchange for city residents. Seating is a good idea here, and trees shade parking bays or market stalls without restricting their use. The root zone is protected by wood slices.

4 The fully exposed, sunny squares in front of churches and town halls provide space for large, expansive single trees or striking clusters of trees. Combined with a fountain, they traditionally define the centre of the square. Apart from establishing an historic link, these also cool the surrounds and are particularly useful as water sources for animals. Steps are a good way of integrating different levels into the design or accentuating certain parts of squares. They can also act as seats in the historic city area without the need for additional, disruptive urban street furniture.

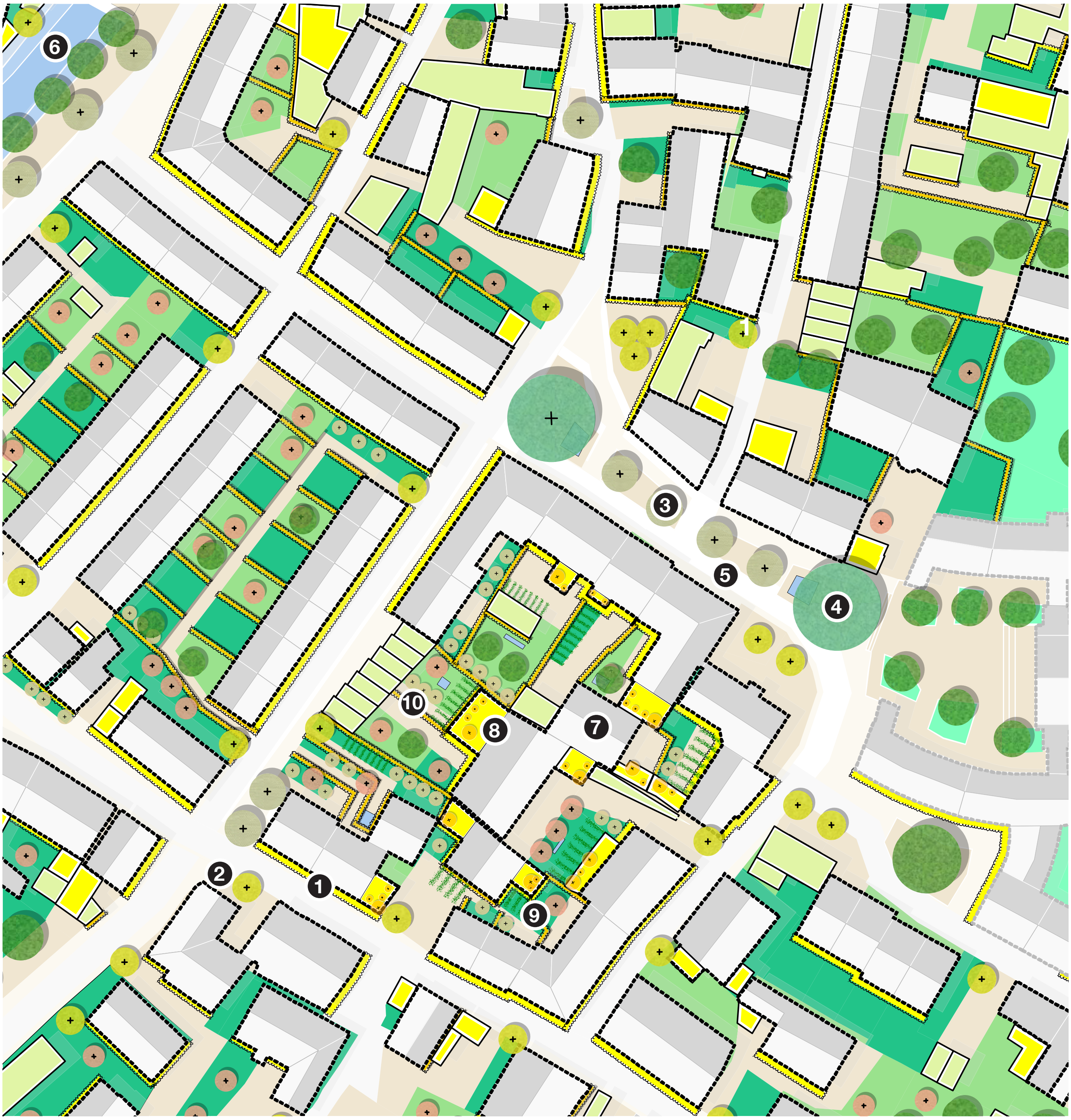


Figure 107: Greening scenario on a scale of 1:1000

- rehabilitation of existing buildings for energy efficiency
- surface with high albedo
- water permeable surface
- waterbound surface
- decorative garden with lawn, perennials and grasses
- kitchen garden with vegetable beds
- historical garden
- Roof surfaces suitable for solar systems
- roof top terrace
- extensive roof greening
- watering hole/well
- ground-based façade greening with traditional climbers or fruit epaliers 3-7 m high
- wall greened with slow-growing climbers or fruit espaliers
- pergola with richly blossoming or fruit-bearing climers
- fruit tree courtyard
- solitary shrub kitchen garden / decorative garden
- decorative shrub roof top terrace in planting pots
- preserving tree stock
- new planting of trees at central squares with broad-crowned, solitary street tree species 1. order
- new planting of trees at streetscape with narrow-crowned or light-crowned street tree species 2. order
- new planting of trees at vacant lots with narrow-crowned or slow-growing tree species 2. and 3. order

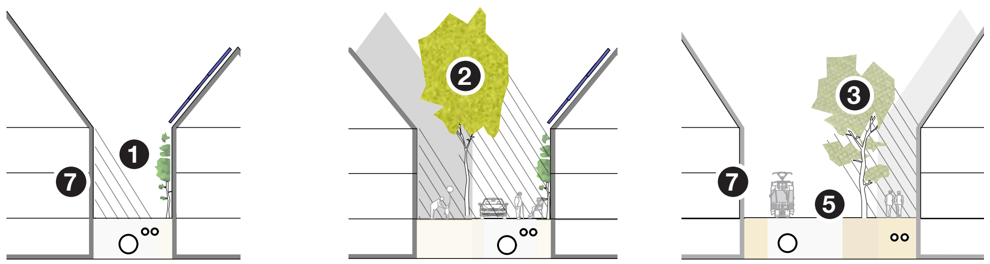


Figure 108: Cross-sections of characteristic types of street areas on a scale of 1:500

5 The surface quality of the streets and squares plays an important role. Natural stone cobbles establish a link to the historic importance of the public spaces, while large sections of grouting/joins and an unbound design reduce the run-off coefficient. Together with a pale surface, this also reduces overheating in these areas. Waterbound paths are traditional paving methods and are typical of the recreational areas underneath the trees. They decrease the degree of unsealing, and overheat much less than asphalt surfaces. Some animal species, such as sparrows and mining bees, even take advantage of the fine sandy surfaces.

6 The city brook is revived as a pleasant public space for strolling. The bed is widened and planted with trees suitable for the location. The shore areas can be used as a 'sponge park' to retain water and regular flooding. Terraces with water-storing substrate are created and planted with fast-evaporating vegetation. The water in the zone area is filtered and very slowly released into the brook.

... on buildings

7 Energy-efficiency rehabilitation of buildings preserves/replaces the habitats of building-dwelling flora and fauna. Additional habitats and nesting aids also created for typical bird and bat species. Traditional forms are largely to be used when designing façade surfaces. New façade materials or wide windows with technical shading systems are only used for buildings at special locations with public functions, such as libraries.

8 Rooftop terraces are created on easily accessible extensions and garages, insofar as the building fabric permits this. They add private outdoor recreational spaces to the relatively dark, cramped living areas. Grass, shrubs and small trees are grown in pots or planters. Extensive lightweight rooftop vegetation on inaccessible or structurally less load-bearing roofs on adjacent buildings add new dry biotopes to the range of habitats in historic city centres.

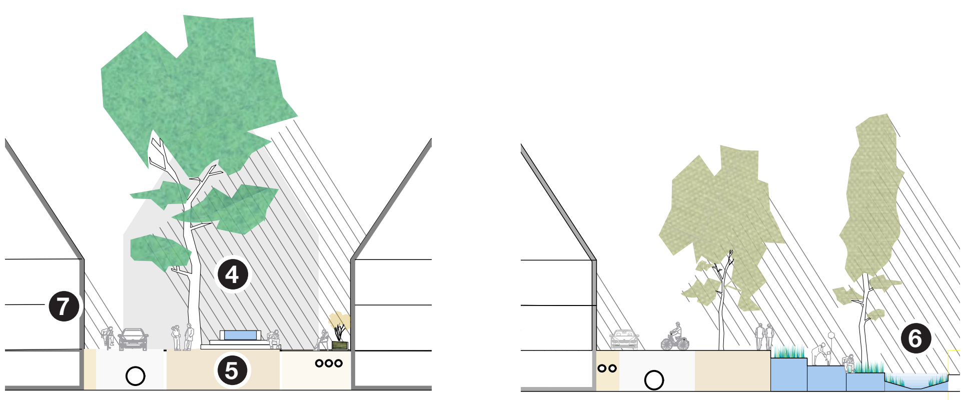


Figure 109: Cross-sections of a square and the city brook on a scale of 1:500

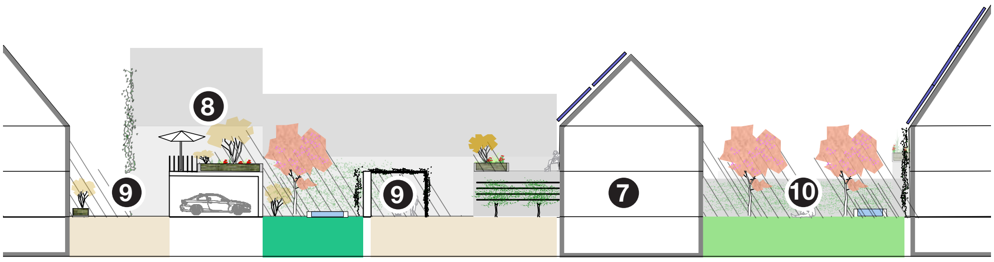


Figure 110: Cross-section of a block's rear courtyards on a scale of 1:500

... in interior courtyards

9 Vegetation is added to south and west-facing façades and free-standing partition walls in narrow rear courtyards in the form of crop plants, such as grapevines, kiwi fruit and espalier fruit. Richly blossoming ornamental plants, such as wisteria or clematis, particularly enhance the aesthetic effect of courtyards. These creepers are also suitable as vegetation on traditional, very effective shading elements including arbours and pergolas. Combined with surface unsealing, pot plants and small areas of water (fountains), tiny, largely sealed courtyard areas can be transformed into temperate, lush oases that provide a pleasant ambience for both humans and animals.

10 Larger rear courtyards enable trees to be planted and fruit & vegetable gardens to be created. Gardens with flower beds, nut trees, fruit trees, espalier fruit or grapevine arbours revitalise traditional landscaping. Along with the productive aspect, the wide variety of shrubs, herbs and grasses in fruit & vegetable gardens mean a wide range of visual scenes and habitats for animals.

Microclimatic assessment of the draft using ENVI-met

The draft design increases the green spaces from 11.3 to 37.2%. This simultaneously lowers the thermal load from an average of 42°C to 36.5°C PET, corresponding to a reduction of 13.1%. Under future climate conditions, a 2.1% reduction will be achieved compared to today, though this continues to be an extreme load. In the street area, the thermal situation is improved through façade vegetation and, if more space available, sporadic tree plantings. Pergolas provide shade to open spaces in interior courtyards. Shrubs, small trees and extensive vegetation on low flat roofs further enhance the cooling effect. The church square remains an overheated area in the draft, with no further vegetation added for aesthetic reasons.

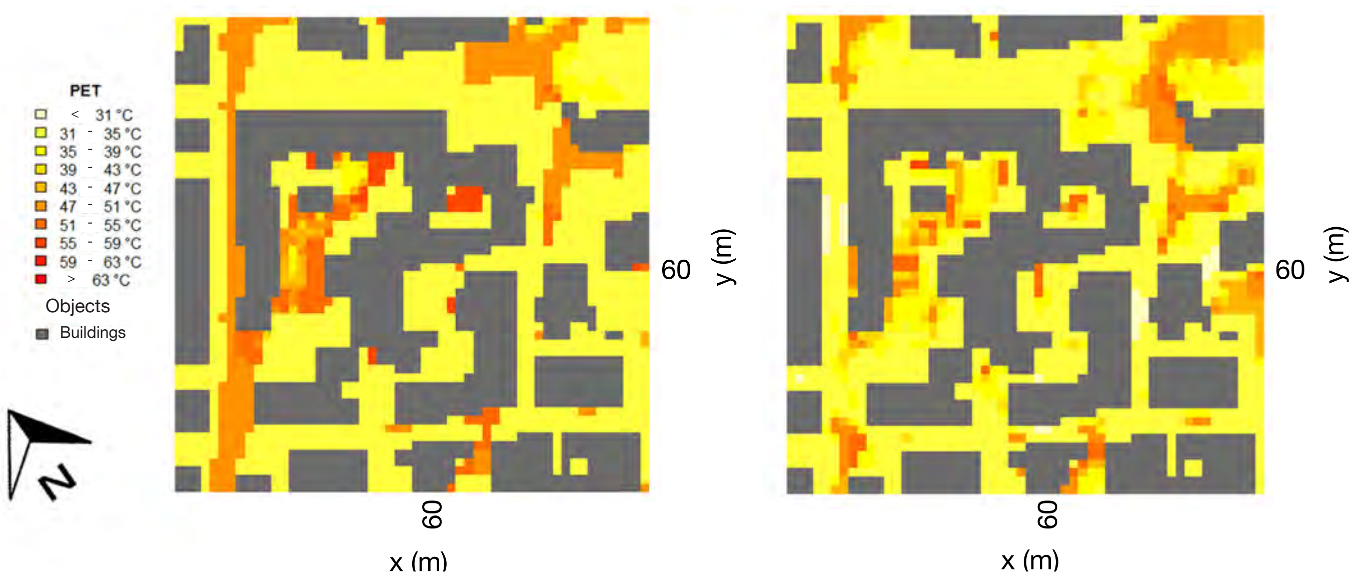


Figure 111: Thermal load in an historic city centre with current vegetation (left) and as greening scenario (right) under current climate conditions, at 3 pm on a very hot day in 1.4 m height

7 Means of implementation

Under Section 1 (5), Section 1 (6) No. 7 and Section 1a (5) of the German Federal Building Code (BauGB), climate protection and adaptation need to be taken into account when weighing up considerations. Since the 2011 and 2013 amendments, there have been more options to justify climate protection and adaptation. But as the phrasing in the BauGB remain relatively unspecific, it is important for climate-oriented urban development to use and combine the individual instruments in a targeted manner. Tables 5 to 7 show which references and bases are relevant to green spaces, biodiversity and the notion of influencing development from a climate perspective.

General principles remain important

It is a challenge to always gear short-term, everyday planning decisions to the long-term objectives and strategies of climate-friendly urban development. Shared general principles such as 'climate communities' or 'energy-efficient cities' can strengthen interdisciplinary co-operations. Collective identification boosts public perception and facilitates participation. Climate objectives must be mentioned early on in the planning process. And in town-planning competitions, they need to be part of the initial requirements.

Using formal planning instruments offensively

Based on the planning authority in Art. 28 of the German Constitution (Basic Law), local governments essentially have access to the land-use plan (Section 5 BauGB) and the development plan (Section 9 BauGB) as planning instruments. Although the options for influencing have increased since the 2011 amendment, the needs, especially in growing cities, conflict with opposing interests and are difficult to assert in simplified or accelerated processes (Section 13 and 13a BauGB). The landscaping plans and open-space plans (in Bavaria part of the land-use/development plan) must thus be used offensively along with the land-use and development plans. This protects green spaces, defines compensatory areas, preserves open spaces and keeps them free from development right from the preparatory land-use plan.

A lot of overlap with specific laws

Climate-related arguments particularly need to be weighed up in terms of conservation, water, soil, energy and building code laws. Landscape planning is a product of conservation, and there remains overlap between conservation and planning laws to this day, such as the blocking of nature reserves and protected landscapes development, wildlife conservation as a possible barrier to planning, and the intervention regulation (Section 13 ff of the German Federal Nature Conservation Act (BNatSchG)). Specific energy-related provisions for the planning processes are becoming increasingly relevant. Section 9 (1) No. 23b BauGB, for instance, enables set areas to be designated for the production of electricity and heat using renewable energy.

By-laws provide room to manoeuvre

The fact that climate protection and adaptation is not a mandatory community task is problematic. By-laws are an effective means of combating this. The City of Munich, for example, passed a resolution to reduce the threshold, established in Section 13a BauGB, for exempting areas of up to 20,000 m^2 from the conservationist compensatory regulation and environmental impact assessment to 5,000 m^2. (BFN (German Federal Agency for Nature Conservation) 2016: p. 169). Tree protection by-laws which protect trees and shrubs once they reach a certain volume, and which stipulate mandatory replacement planting, are important for preserving greenery. It is advisable to formally establish reference values for green and open spaces in growing cities through green-space standards. Design by-laws (based on the German Federal Building Code) can regulate the vegetation and garden design of structural complexes, enabling the community to influence the design of buildings (such as roofing or materials) and properties. Equally important are open-space design by-laws which relate to undeveloped areas of built-up properties. These may stipulate water-permeable ground covering, as well as vegetation for buildings, façades and adjacent buildings. Information on the location, size, condition, equipment and maintenance of children's playgrounds (Section 9 (1) No. 22 BauGB) similarly unlocks ways to add vegetation to neighbourhoods. By-laws also govern the number and quality of parking bays, thus significantly influencing the area potential for greenery measures.

Special urban planning legislation

Urban rehabilitation, development and restructuring programmes boost options for climate protection and adaptation (Section 136-171 BauGB). Since the 2011 amendment, it has also been possible to justify losses of function in terms of the climate-protection and adaptation requirement. Measures such as thermal insulation and energy production plants based on renewable energy sources, as well as those aimed at adaptation (planting trees/shrubs, vegetation or shading elements at public squares) are thus justifiable.

Informal planning instruments

Town-planning contracts (Section 11 BauGB) enable new construction or rehabilitation projects to be influenced. Local governments can conclude contracts with developers, establishing efficiency standards for buildings or vegetation, and even determining the choice of plants (binding contract). Informal planning instruments are gaining importance due to their greater flexibility.

Disclaimer: The following tables only aim to convey the meaning of German laws but they do not represent an officially authorised translation.

Table 5: Relevant references for green spaces (selection)

Aim	Reference		Content
CREATING AND MAINTAINING GREEN SPACES	Gerneral Regulations BauGB	§ 1 (5) BauGB	The task of urban development planning is to promote climate protection and adaptation, especially in urban development
		§ 1 (6) Nr. 7 BauGB	When preparing urban development plans, the effects on animals, plants, soil, water, air, climate and the interactions between them must be considered.
		§ 1a (5) BauGB	The requirements of climate protection should be taken into account through measures both to mitigate climate change and to adapt to climate change.
		§ 1a (3) BauGB § 135a BauGB	Compensation areas or measures on base of the Federal Nature Conservation Act
		§ 2 (4) BauGB	Requirement for environmental impact assessment
	Preparatory land-use plan Representations in the preparatory land-use plan	§ 5 (2) Nr. 2b BauGB	Provision of facilities that counteract climate change, in particular areas for the generation of electricity and heat from renewable energies.
		§ 5 (2) Nr. 2c BauGB	Provision of facilities or other measures which serve the adaptation to climate change
		§ 5 (2) Nr. 5 BauGB	Green spaces such as parks, allotment gardens, sports fields, playgrounds, campsites, bathing areas and cemeteries
		§ 5 (2) Nr. 7 BauGB	Water bodies, docks and areas of water designated for supply and distribution purposes, and spaces to be kept clear in the interests of flood control and to control drainage
		§ 5 (2) Nr. 9 BauGB	Areas for agriculture and woodlands
		§ 5 (2) Nr. 10 BauGB	Areas for measures to protect, maintain and develop topsoils, nature and landscape
	Binding land-use plan Designations in the legally binding land-use plan or in the project and infrastructure development plan	§ 9 (1) Nr. 10 BauGB	Preserving areas from soil sealing and use of these areas e.g. to preserve and connect biotopes
		§ 9 (1) Nr. 14 BauGB	Areas for retention and infiltration of rainwater
		§ 9 (1) Nr. 15 BauGB	Green spaces such as parks, allotment gardens, sports fields, playgrounds, campsites and bathing places
		§ 9 (1) Nr. 18 BauGB	Areas for agriculture and woodlands
		§ 9 (1) Nr. 20 BauGB	Areas or measures to protect, maintain and develop soils, nature and landscape
		§ 9 (1) Nr. 25a BauGB	Planting of trees, shrubs and other plantings
		§ 9 (1) Nr. 25b BauGB	Bindings for the planting and the preservation of trees, shrubs and other plantings as well as water bodies.
	Landscape plan and green ordinances	§ 9 (3) Nr. 4e BNatSchG § 4 (2) BayNatSchG	More detailed definition of aims regarding the protection, quality improvement and regeneration of soils, water bodies, air and climate. Landscape plans are obligatory in Bavaria. They are the most important base for defining the requirements of nature protection and landscape conservation.
	Federal nature conservation	§ 1 (3) Nr. 4 BNatSchG	Air and climate have to be protected; this applies especially to areas with favourable impacts on air quality or climates such as areas for the generation of fresh or cold air or air ventilation corridors
	Urbanistic contracts	§ 11 BauGB	e.g. contracts with investors or land owners for green and open spaces within the neighbourhood to improve microclimates and the quality of open spaces
	Framework plan and urban planning designs	§ 1 (6) Nr. 11 BauGB § 140 BauGB as framework planning	Urban development strategies or other adopted urban plans (e.g. for climate protection) are to be considered in urban land use planning. This includes also e.g. plans for climate protection and adaptation. Guiding visions provide the strategic orientation and they can contribute to cross-sectoral collaboration
	Special Urban Planning Legislation	§ 136 BauGB § 171a, 171b BauGB funding of urban planning 171e BauGB (social city)	Urban rehabilitation, development and restructuring programmes to address deficiencies in urban development: Plans, which mitigate the urban heat island effect, can be recognised as a justification for such measures. Likewise areas, in which possibly no deficiencies in urban development but energetic deficiencies exist, can be improved within the scope of urban reconstruction under § 171a-d BauGB or as a building retrofit. Contingency funds aim to activate private resources for the development of designated regeneration areas.
	Urban planning regulations	§ 178 BauGB	e.g planting order for private land owners by decree
	Ordinance law	Art. 28 (2) GG	Design by-laws for the greening and planting design of built structures: By-laws for open space design (e.g. position, condition and size of children`s playgrounds), tree preservation order § 12 (2), § 37 (2) Nr. 3, § 45 (1) Nr. 4 BayNatSchG
	Pre-emptive rights	§ 24 BauGB § 25 BauGB	Securing access to areas, especially to promote climate adapted urban development in built areas
	Competitions	Incentives	Awareness raising, motivation quality assurance within neighbourhoods and between local authorities
	Funding programmes	Incentives	E.g. façade design, courtyard greening, roof gardens
	Splitted fees for rainwater	Incentives	Separation of locally retained and infiltrated rainwater from treated water: Relieves private households and provides incentives for private greening measures.

Table 6: Relevant references regarding biodiversity (selection)

Aim	Reference		Content
PROMOTION OF BIODIVERSITY	General regulations BauGB	§ 1a (2) BauGB	Sparing use of land and property, compliance with the regulation for soil conservation
		§ 1a (3) BauGB	Compensation regulations of the nature conservation law have to be processed in urban
		§ 1a (4) BauGB	Increasingly EU-law is in force in the field of environmental protection and nature conservation (e.g. Birds directive and FFH directive)
		§ 1 (6) and (7) BauGB	Biodiversity as a consideration in urban development planning: „approach of integration“ for environmental protection in the BauGB: During the preparation of the development plans the interests of environmental protection have to be considered, including nature and landscape conservation, especially the effects on animals, plants, soil, water, air, climate and the interactions between them as well as the landscape and the biological diversity and the aims of conservation, and the objectives and purposes for the protection of the Natura 2000 areas in accordance with the Federal Nature Conservation Act
		§ 2 (4) and § 2a BauGB	environmental report as a part of the preparation of the development plans
	land-use plan	§ 5 (2) Nr. 10 BauGB	Representation of areas for measures for the protection, the maintenance and the development of soil, nature and landscape
	Legally binding land-use plan	§ 9 (1) Nr. 20 BauGB	Designation of areas for measures for the protection, the maintenance and the development of soil, nature and landscape
	Federal nature conservation	§ 1 (1) Nr. 1 BNatSchG	Nature and landscape have to be protected in both settled and non-settled areas so that the biological diversity is safeguarded permanently. Such protection shall include management, development and, as necessary, restoration of nature and landscape
		§ 1 (4) Nr. 2 BNatSchG	For purposes of outdoor recreation, suitable areas for recreational purposes, in terms of their properties and location, are to be protected and kept or rendered accessible, particularly in settled areas and areas close to human settlements.
		§ 1 (5) BNatSchG	Extensive, largely unfragmented landscape areas are to be protected against further fragmentation. Re-use of already developed, built-up areas, ..., is to have priority over use of open land outside of settlement areas. Transport routes, power lines and similar projects are to be routed, designed and combined in such a way that fragmentation and use of the landscape, and adverse effects on the natural balance, are avoided or kept to an absolute minimum. ... any unavoidable adverse effects on nature and landscape are to be compensated for or mitigated,....
		§ 1 (6) BNatSchG	Open spaces within and near settlements, including such areas' various components, such as parks, large green spaces and green belts, forests and edges of woods, trees and woody shrubbery, rivers and streams, including their shoreline zones and riparian areas, standing waters, nature experience areas and areas in horticultural and agricultural use, are to be protected and to be re-established in those areas in which they are not present to an adequate extent.
		§ 7 (2) BNatSchG	The law of species conservation distinguishes between specially protected species (BNatSchG § 7 Abs. 2 Nr. 13) and strictly protected species (BNatSchG § 7 Abs. 2 Nr. 14)
		§§ 14-17 BNatSchG	Intervention regulations: The local authorities are obliged to assess if there is an intervention, whether it can be avoided or minimized, whether a compensation is required or whether the intervention, if it cannot be compensated, needs to be objected because of environmental protection concerns
		§ 30 (2) BNatSchG	Parts of nature and landscape that have special importance as biotopes shall be legally protected
		§ 34 (2) BNatSchG	Natura 2000 areas require special protection
		§§ 39-41 BNatSchG	General protection of wild living animals and plants
		§ 44 (1) BNatSchG	Prohibitions concerning the law of species conservation need to be considered when preparing legally binding land-use plans. These regulations are in place for specially protected and certain other animal and plant species.
	landscape plan and green space ordinances	§ 4 Abs. 2 BayNatSchG	As base of urban development planning the landscape plan is integrated into the land-use-plan in Bavaria already since 1982 (so called primary integration) and partakes in its legal effect. The local requirements and measures for realization of the aims of nature conservation and landscape management need to be represented in landscape plans as part of the preparatory land-us-plan.
	Urban planning contracts	§ 11 BauGB	Contracts with project developers or property owners e.g. for the creation of suitable green and open spaces for the promotion of habitats.
	Framework plan and urban planning designs	§ 1 (6) Nr. 11 BauGB § 140 BauGB as framework plan	In urban development planning, urban development plans or other approved plans have to be considered. This may include biodiversity strategies.
	Strategic guiding visions	Conventions e.g. biodiversity convention	Municipal guiding visions should recall in planning processes the promotion of biodiversity as a mandatory component of "climate-friendly" urban development and these concerns should be considered in the weighing processes of urban development planning.
	Ordinance law	Art. 28 (2) GG	Landscape plan/Green Space Ordinance (§ 8-12 BNatSchG). Obligatory in Bavaria (§ 4 Abs. 2 BayNatSchG); Landscape planning is the most important technical basis for the proper consideration of the requirements of nature conservation and landscape management. Design by-laws for the greening and planting design of buildings (basis: building regulations), tree preservation order (§ 12 (2), § 37 (2) Nr. 3, § 45 (1) Nr. 4 BayNatSchG)
	Competitions	Incentives	Awareness raising, motivation, quality assurance between and within neighbourhoods as well as between local authorities.
	Funding programmes	Incentives	e.g. for façade design, courtyard greening and roof gardens or the support of societies and associations, education in schools etc.

Table 7: Relevant references relating to the influenceability of development structures (selection)

Aim	Reference		Content
CLIMATE ORIENTED EXERTION OF INFLUENCE ON BUILDING DEVELOPMENT	Binding regulations in the legally binding land-use plan or in the project plan and the infrastructure plan	§ 9 (1) BauGB	Type and extent of utilisation for buildings
		§ 9 (2) BauGB	Specifications of construction methods and position of buildings
		§ 9 (3) BauGB	Minimum and maximum size of building plots
		§ 9 (4) BauGB	Parking spaces and garages outside of permitted building zone e.g. underground
		§ 9 (10) BauGB	Level of soil sealing: preserving areas from development and use of areas which have to be preserved
		§ 9 (14) BauGB	Areas for the retention and infiltration of rainwater
		§ 16 (3) BauNVO	(Site occupancy ratio, floor space ratio, cubic index or cubic capacity, number of full storeys, height)
		§ 18 BauNVO	Height of buildings
		§ 19 BauNVO	Permitted base area, building setbacks, building lines, building boundaries
		§ 20 BauNVO	Full storeys, floor space ratio, floor space
		§ 22 BauNVO	Open or closed construction
		§ 23 BauNVO	Plot area to be built on
	Urban planning contracts	§ 11 BauGB	Contracts with project sponsors or land owners e.g. for creating suitable green areas and open areas for recreation near housing areas and for local climate regulation with quantitative and qualitative standards
	Framework plan and urban planning designs	§ 1 (6) Nr. 11 BauGB § 140 BauGB as framework plan	Definition and interweaving of strategic aims in climate policies: density, preservation of open spaces, type of use, mobility plans, accessibility of local public transport
	Special Urban Planning Legislation	§ 174 BauGB § 171a, 171b BauGB Financial Support for Urban Development 2010, Art.11	Urban rehabilitation, development and restructuring programmes to address deficiencies in urban development. Plans, which mitigate the urban heat island effect, can be recognised as a justification for such measures. Likewise areas, in which possibly no deficiencies in urban development but energetic deficiencies exist, can be improved within the scope of urban reconstruction under § 171a-d BauGB or as a building retrofit. Contingency funds aim to activate private resources for the development of designated regeneration areas under §177 BauGB.
	Strategic guiding visions		Guiding visions can promote sense of identity. Well ventilated cities improve the citizen's quality of life during periods of heat.
	Ordinance law	Art. 28 (2) GG	Design constitution Design Constitution of Open spaces (e.g. Position, Condition and Size of Children's playgrounds)
	Pre-emptive rights	§ 24 BauGB § 25 BauGB	Securing Access to areas in Order to exert influence within existing contexts on climate-suitable urban Development in stock
	Certifications and awards	Incentives	Quality assurance e.g. through DGNB, LEAD, Cradle2cradle, etc. as well as citywide competitions and memberships: Energy Award, Climate Alliance, Mayors Adapt, Town twinning, etc.

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5 Bavarian State Ministry for the Environment, Health and Consumer Protection
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7 Bavarian State Ministry for Economic Affairs and Media, Energy and Technology
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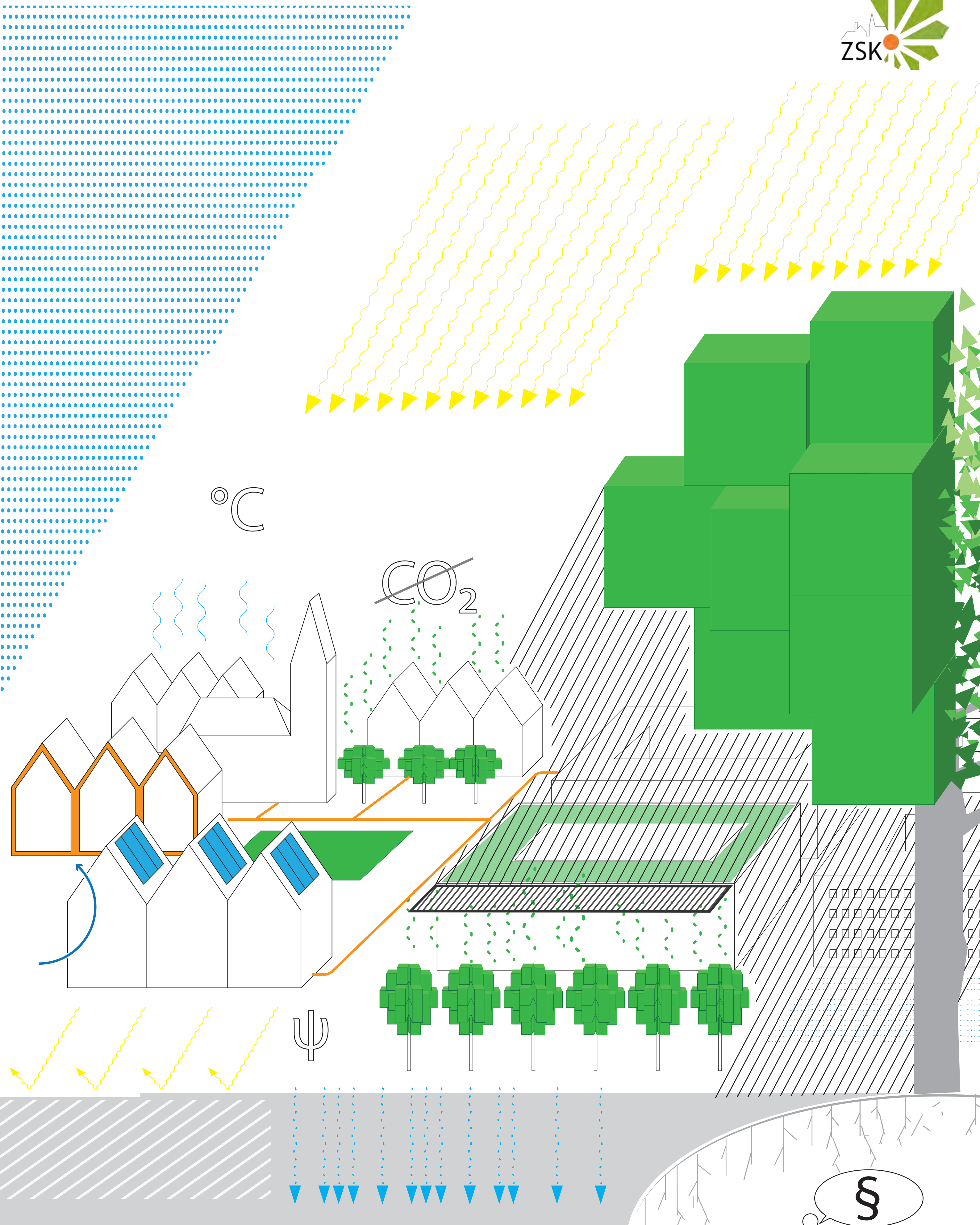

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