Urban Heat Island Strategy
City of Vienna

CENTRAL EUROPE COOPERATING FOR SUCCESS.

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Urban Heat Island Strategy
City of Vienna

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Owner and publisher: Municipality of Vienna, Vienna Environmental Protection Department – Municipal Department 22

Project coordination: Jürgen Preiss, Christian Härtel

Environmental Protection Department – Municipal Department 22

Project manager: Christiane Brandenburg

Institute of Landscape Development, Recreation and Conservation Planning, BOKU Vienna

Project co-manager: Doris Damyanovic

Institute of Landscape Design, BOKU Wien

Project implementation and authors:
Christiane Brandenburg, Doris Damyanovic, Florian Reinwald,
Brigitte Allex, Birgit Gantner, Christina Czachs

Co-authors: Ulrich Morawetz, Dieter Kömle, Martin Kniepert

Institute of Sustainable Economic Development, BOKU Vienna

Graphics and layout: Florian Reinwald

Institute of Landscape Design, BOKU Wien

Revision: Florian Kraus

Green4Cities GmbH

Translation and English Editor: Blanche Cameron

Environmental Design, The Bartlett School of Architecture, UCL

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Foreword

Ulli Sima

Vienna Councillor for the Environment

Vienna is one of the first cities in Europe not only to research the possible consequences of climate change and actions against heatwaves, but beyond this to develop this strategy with practical actions and set concrete initiatives. This Urban Heat Island Strategy for Vienna (Vienna UHI Strategy) developed by the Vienna Environmental Protection Department MA 22 is not a mere declaration of intent – it is being implemented step by step.

Taking action against urban heat islands also helps to provide an even better quality of life in Vienna: there is more greenery in the city, more public spaces for leisure activities and open bodies of water. Some actions have a small-scale effect on the inner-city, such as greening the façades of the MA 48 headquarters on Margaretengürtel. There are also large-scale initiatives, such as a whole series of new parks, for example the seven-hectare Helmut Zilk Park next to Hauptbahnhof/Vienna Central Station, three parks totalling over eight hectares in Seestadt Aspern, the 240-hectare recreational area of Neue Lobau or the approximately 1,000 hectares of Norbert Scheed Forest. Together, these do not just make Vienna 'cooler' – these actions also improve living space generally for citizens of this city.

Since actions to improve the urban climate take place at a range of levels (climate, nature conservation, landscape planning, urban planning, architecture, etc.), responsibility for implementation is shared by various departments and partners of the City of Vienna. Information share and interdisciplinary cooperation, with correspondingly effective guidelines at the various levels (e.g. urban development plan, competitions or various mission statements and programmes for climate protection and urban development) are all important requirements for the successful implementation of the Vienna UHI Strategy.

Foreword

The phenomenon of urban heat islands – significantly higher temperatures in densely built-up areas – will continue to increase as a result of global climate change, unless urban development actions are taken to reduce the trend. The impacts of climate change can already be felt in Vienna: between 1961 and 1990, there were on average 9.6 heat days per year at over 30˚C. By 2010, this had risen to an average of 15.2 heat days per year.

The Urban Heat Island Strategy – Vienna UHI Strategy – was developed by Vienna's Environmental Protection Department MA 22, in collaboration with scientific experts and numerous specialist departments of the City of Vienna. The starting point was the Central European Urban Heat Islands Project, a collaboration between the European cities of Bologna, Budapest, Freiburg, Karlsruhe, Ljubljana, Modena, Padua, Prague, Stuttgart, Warsaw and Venice, as well as Vienna. It became clear that, despite many activities already agreed, further efforts were needed to adequately address the negative climate impacts of urban heating.

Building on this, the City of Vienna has now drawn up this strategic action plan. Work on the strategy has in many ways been 'work in progress': many of the actions described here have already been initiated and implemented.

The Vienna UHI Strategy is a key foundation for proceeding successfully along this path. It not only describes in detail different ways to cool the urban heat island, it also provides accurate information on the effectiveness of specific actions on climate in the city and residential areas. It also shares the benefits and possible challenges to implementation, not least the anticipated costs of construction and maintenance.

Thus, the Vienna UHI Strategy serves as a useful stimulus and decision-making tool for planning and design projects, both large and small, to make the city more liveable in the light of the impacts of climate change.

Karin Büchl-Krammerstätter

Director of Vienna Environmental Protection Department

Contents

'Green' and 'blue' infrastructure – green space and water – measurably reduce the UHI effect.

1. Introduction – UHI in Vienna

As the number of people living in cities increases, dealing with urban heat islands is not a luxury. In 2005, around half the global population was living in urban areas (Alcoforado and Andrade 2008). By 2050, according to Schlünzen (2012), around two thirds of all people will be urban. This change will also happen in Vienna. The population forecast for Vienna envisages an increase over the coming decades from 1.8 Million currently (Statistik Austria 2014) to 2 Million by 2030 (MA 23 2014). The impacts of this are ever-increasing urban development, inner-city densification, and the loss of permeable open greenspace, in turn leading to an increase in temperature differences between the city and surrounding areas. These changes will be exacerbated by global warming. According to Kuttler (2011), the number of days and the periods and intensity of urban summer overheating are expected to increase (Kuttler 2011, 7). Between 1961 and 1990, Vienna experienced on average 9.6 heat days per year; → from 1981 to 2010, the number of heat days rose to 15.2 per year (ZAMG 2012).

Vienna's Department of Environmental Protection MA 22 has been working on the issue of heat in the city for over 15 years. As well as basic studies, strategy papers have been produced and in 2002 active information gathering started. This included preparing climate studies, providing a climate assessment and climate function map based on thermal imaging, and the physical implementation of actions such as green space networks, green roofs, living walls and rainwater management.

High temperatures can have negative impacts on the health of urban citizens. Older people with little social contact and low socio-economic status especially (Wanka 2014) suffer from heatwaves, as well as the chronically ill and children. Mortality and morbidity are affected by heat, the quality of sleep is reduced, wellbeing and productivity are reduced (Lebensministerium, 2012). The last point in particular plays an important role for the urban population as a whole, since cities are places with high productivity across all sectors.

There is agreement that, amongst other things, more urban green infrastructure → (parks, street greening, etc.) or blue infrastructure → (open bodies of water, streams, etc.) as well as increased albedo → in urban areas can contribute to a reduction of the urban heat island effect. But open and green spaces are under particular pressure due to increasing demand for land and the costs of maintenance, the tense economic situation of communities and to some extent the low acceptance of green infrastructure. Thus, in addition to the many positive functions of green and blue urban infrastructure →, it is necessary to highlight their importance to urban climate, and to discuss the tools with which actions can be implemented and permanently secured.

1.1 The UHI effect – urban heat islands in the city

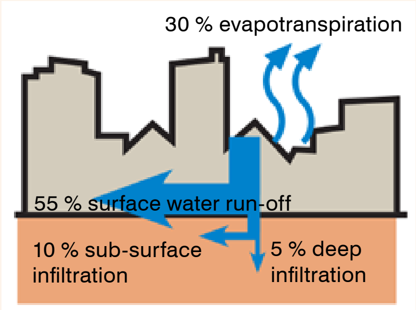
Urban settlement areas are very different in many respects from surrounding rural areas, including climate aspects such as precipitation, wind conditions and temperatures – the result being the so-called urban heat island.

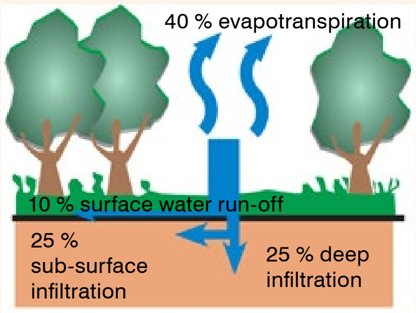
These urban heat islands are defined by the temperature difference between city and the surrounding area – a phenomenon that has been recognised since the 19th Century (Howard 1820). According to Oke (1981), the temperature difference between city and countryside can be as high as 12˚C (in Eliasson 2000, 31). Even within cities, temperature differences can occur in different districts, depending on the level of green and blue infrastructure as well as the degree of permeability (Böttner et al. 2012).

The primary reason for the emergence of urban heat islands is development on permeable greenspace (Kuttler 2011). Natural open spaces mainly consist of vegetation cover and moisture-absorbing soils, so some of the solar radiation received is used in the evaporative processes of transpiration →, which in turn contribute to neighbourhood cooling. In addition, undeveloped areas heat up less than built-up areas, due to shading and evaporation → by the vegetation.

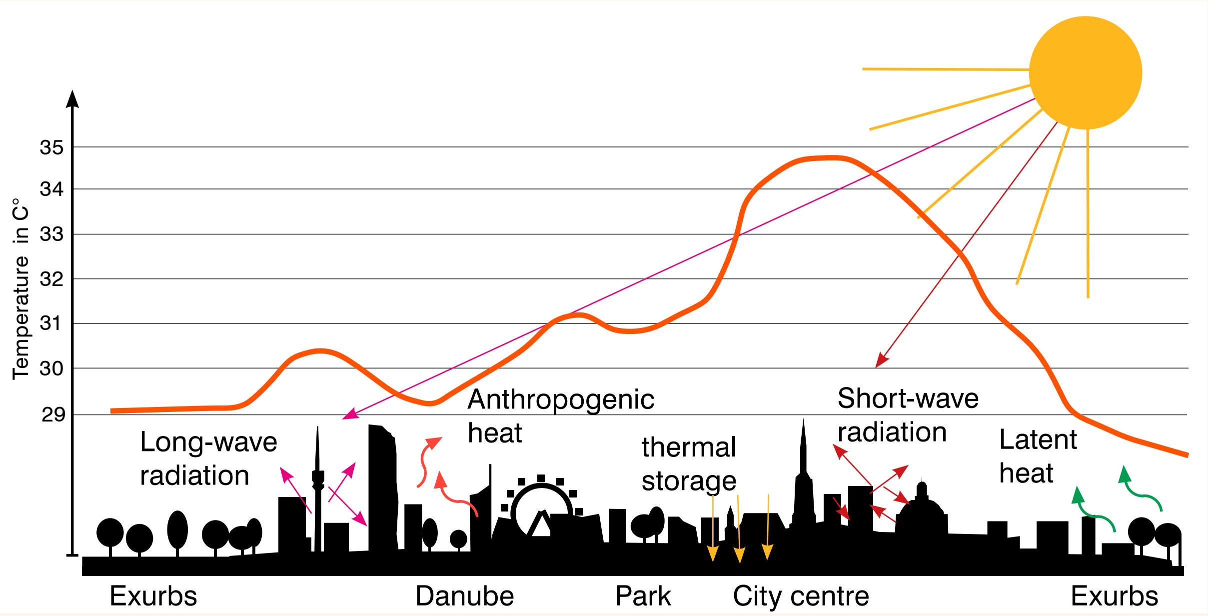
In contrast however, built-up areas are usually constructed with heat-absorbing materials, which are often also impermeable to water. Rainwater runs off quickly, so it is not retained for evaporation and thus evaporative cooling is essentially reduced. In addition, heat-absorbing surfacing can be increased by the geometry of the building. Vertical façades absorb both direct sunlight and radiation reflected from other building surfaces.

Due to the geometry of the buildings, and the low sky view factor → often associated with them (how exposed urban open spaces are to the sky), urban air circulation and long-wave radiation are further impeded (Kuttler 2011).

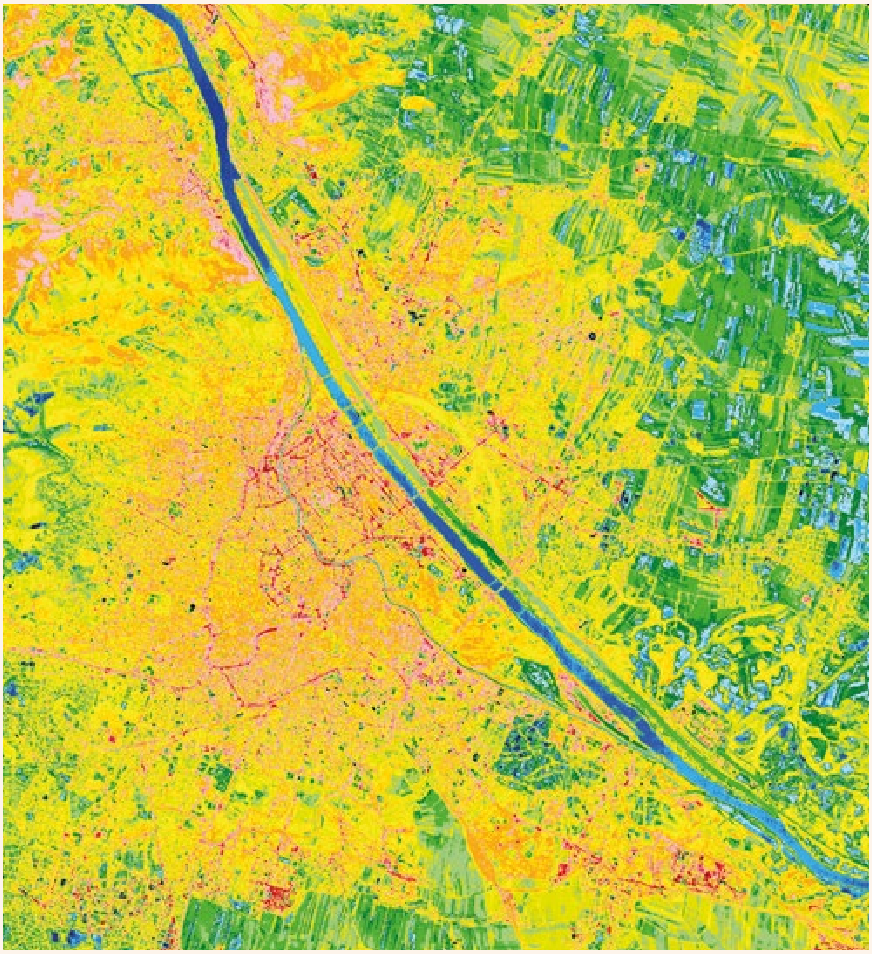




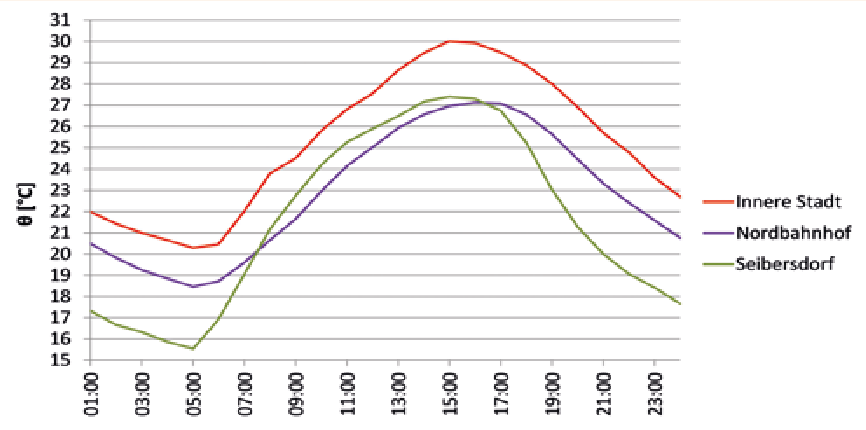
Comparison of evaporation in urban areas (above) and rural areas (below)



The energy budget of built-up areas and the UHI effect



Thermal image of the city of Vienna and surrounding countryside in the evening. The differences between the urban agglomeration and cooler rural areas are clearly visible.



The graph illustrates the average hourly temperature distribution on a typical day in summer 2012 – it shows two areas of Vienna being studied: Innere Stadt/City Centre and Nordbahnhof/North Station (see also Chapter 5.2) as well as a rural area in Seibersdorf for comparison. The results clearly show there is a significant microclimate difference between the areas, with high temperatures in the inner-city clearly visible.

Thus, exposed and low or non-reflective surfaces (i.e. areas with a low albedo) such as, for example, dark-coloured ground surfacing and roofs may be up to 50°C warmer than air temperature (EPA 2008a, 2).

Other factors that amplify the urban heat island effect include the reduction and fragmentation of urban greenspace and the production of waste heat in industrial processes, air-conditioning systems and motor vehicles. In addition, construction increases irregular surfacing, causing a reduction in wind speed. In many cases, development also prevents cooler air flow from undeveloped neighbourhoods into built-up areas.

The isotherm map of a built-up urban area (see adjacent figure), clearly shows the characteristics of the urban heat island and the contours of developed areas and 'hot spots' such as impermeable parking lots and industrial areas, but also 'cold spots' such as parks, agricultural areas and bodies of water. Generally, it can be assumed that temperatures increase from the outskirts towards the city centre.

In terms of time, the largest heat island effect can be observed on calm and cloudless summer nights. Building materials generally have a high thermal mass, meaning they act as a heat store and radiate heat to their surroundings after sunset, usually until morning.

In non-urban landscapes however, the earth's surface is cooled at this time, since a cloudless sky encourages heat to radiate and the initial temperature is also lower than in built-up areas.

1.2 The development of the Vienna UHI Strategy

The Vienna UHI Strategy was developed through cooperative dialogue with (and for) the planning and project development departments of the Municipal Authority of Vienna together with external experts.

First, a comprehensive international literature review was carried out to identify actions that could contribute to reducing Vienna's urban heat island effect. These actions were assessed for, amongst other things, impact on micro- and neighbourhood climates, on quality of life and biodiversity, and economic costs. This assessment was carried out by experts from a range of disciplines (e.g. meteorology and ecology) and with the various planning and project development departments of the Municipal Authority of Vienna. Three workshops in 2013 and 2014 identified and analysed good practice examples from the City of Vienna, discussed practical implementation and responsibilities of the various actions and developed further transdisciplinary solutions.

Another important aspect of the project was to test and demonstrate possible actions for implementation at various management levels, areas of activity and tools for city planning and urban development in Vienna. Close coordination between city administration officers was also essential. The Vienna UHI Strategy project was part of the Central European Urban Heat Islands Project – development and application of actions and adaptation strategies to minimise the global phenomenon of urban heat islands. The aim of the project was to minimise summer overheating in cities and urban areas and develop actions for adaptation and reduction of overheating in central Europe (more information is available here: http://eu-uhi.eu/)

1.3 Aims of the Vienna UHI Strategy

Vienna's UHI Strategy contributes to reducing the urban heat island effect in Vienna, thus minimising negative health and other impacts. The aim of Vienna' UHI Strategy is to demonstrate various actions and their implementation that reduce heat in the summer months, to make them a priority for future urban development. The actions described should be implemented as soon as possible, to prevent the urban heat island effect increasing. They will also help with tackling the challenges posed by climate change, thus improving Vienna's climate resilience.

Vienna's UHI Strategy shows there is a wide variety of possible strategic and technical measures, by which micro- and neighbourhood climates can be improved, with varying effects on quality of life, construction and maintenance costs. Securing and extending green infrastructure for example is an effective action by which the urban heat island effect can be reduced, while improving quality of life for city dwellers and promoting urban biodiversity.

Vienna's UHI Strategy aims to show planners, architects and the relevant administrative departments which actions can be implemented within their sphere of influence, which policy instruments at what level are available, and what potential impact each action has. This means that actions to reduce UHI can be selected and implemented early on in different planning and urban development processes.

Austrian Climate Change Assessment Report 2014

In Austria, the temperature has risen by about 2°C since 1880, 1°C of which is since 1980, with a further increase in temperature of around 1.4°C on current levels expected by the middle of the 21st century. The temperature increase is caused by anthropogenic emissions and activities.

More information on the Austrian Panel on Climate Change website: www.apcc.ac.at

Good practice examples such as the MA 48 office building are important models for Vienna

1.4 Structure and application of the Vienna UHI Strategy

The primary target group are the employees of Vienna Municipal Authority's planning and urban development departments, with whom the Vienna UHI Strategy was first developed. However, external planning consultancies, developers, planning advisors and urban planning stakeholders, anyone preparing competitive open space or architectural designs can also understand the City of Vienna's objectives in this section of the Vienna UHI Strategy, as well as practical options for implementation.

Content and structure of the Vienna UHI Strategy

The most important approaches and actions for UHI-sensitive actions in city planning and urban development are set out in a structured way in the Vienna UHI Strategy. It contains practical actions for implementation in urban planning and design as well as various exemplar case studies and planning stages. In this way, the various challenges of UHI-sensitive urban design – from the strategic spatial development of the city as a whole, to detailed planning and design of streets, squares or buildings – should be taken into account.

Chapter 1 – Introduction – UHI in Vienna

The first chapter presents the urban heat island effect – its causes and its impacts. Based on the results of two research projects by ZAMG and the Vienna Technical University, current and future pressures on Vienna as a result of the UHI effect are set out.

Chapter 2 – Urban heat islands and city and nature conservation planning

The second chapter presents the various areas of actions, levels of control and planning processes by which UHI-sensitive urban planning can be implemented. Based on legal and strategic foundations in climate-sensitive urban planning, the areas for action – from city-scale to individual buildings, and actions from masterplanning to project design and policy options – are described in brief. Based on legal and strategic foundations in climate-sensitive urban planning, the areas for action – from city-scale to individual buildings, and actions from masterplanning to project design and policy options – are described in brief.

Chapter 3 – Strategic actions for climate-sensitive urban planning

The third and fourth sections show different actions and options for action at the strategic large-scale, as well as on the practical building level. The detailed description and evaluation of actions should help to assess the potential and effectiveness of each action. In addition, the benefits and challenges of implementing each action are set out. Understanding the capabilities of each action and highlighting their direct impacts can help with urban planning discussions and considerations. It also supports quality assurance in the planning and implementation of projects.

Strategic actions for climate-sensitive urban planning are given in the third chapter. These include appropriate, applicable city-wide policies and approaches. The spectrum ranges from maintaining urban air flow and connecting open-space networks, to ways of adapting city structure and settlement patterns, and protecting and expanding green and open spaces.

Chapter 4 – Practical actions in planning and project design

The actions described in the fourth chapter include practical technical and structural approaches to reduce heat stress in the city. They start at the practical planning and project design levels. One priority is protecting and developing green and blue infrastructure; but it also describes actions, for example, in the design and planning of public open spaces, buildings or public transport.

Chapter 5 – Areas of action and implementation case studies

In the final section, areas of action and implementation case studies are identified. Examples of ways to raise awareness about UHI, information and public engagement are presented, as well as examples of possible implementation based on exemplar case studies in two Viennese city districts and at two planning levels. The two case studies illustrate where and how UHI-sensitive urban planning and development can happen in different planning processes and projects.

The conclusion comprises a reference section giving basic planning information on Vienna's climate, further literature and information, and a glossary with definitions of terms.

Structure of the Vienna UHI Strategy and focus of each chapter

UHI and urban planning

- Areas of action, levels of control and options for action
- Legal and strategic frameworks for climate-sensitive urban planning

Strategic actions

- Strategic actions for climate-sensitive urban planning
- Examples, information and basic principles

Practical actions

- Practical actions for urban planning and project design
- Examples, information and basic principles

Implementation

- Areas of action and implementation case studies
- Examples and implementation options at planning level

References

- Further information
- References and sources

About FOCUS-I
Future of Climatic Urban Heat Stress Impacts

Project management:
Central Institute for Meteorology and Geodynamics (ZAMG)

Researchers:
Koch Roland, Matulla Christoph, Nemec Johanna, Zuvela-Alosie Maja

Clients:
Federal Ministry for Transport, Innovation and Technology (BMVIT), Climate and Energy Fund within the »ACRP 2nd Call« (Austrian Climate Research Programme)

Project Partners
German Meteorological Service, City of Vienna Departments MA 18 and MA 22

Further information:
Zuvela-Aloise et al. (2013): Future of Climatic Urban Heat Stress Impacts – Adaption and mitigation of the climate change impact on urban heat stress based on model runs derived with an urban climate model

ZAMG project website: www.zamg.ac.at/cms/de/forschung/klima/stadtklima/focus-i

1.5 UHI und Vienna's city climate – the 'FOCUS-I' project

Project management: ZAMG (Maja Zuvela-Aloise, Roland Koch)

This project carried out high-resolution climate simulations of future heat stress on the City of Vienna, analysing the effectiveness of possible urban planning adaptation strategies to reduce heat stress in densely populated areas. Possible improvements to buildings and open spaces by increasing the proportion of vegetation and water bodies, unsealing impermeable surfaces and upper-level and roof-level albedo were simulated, to create a scientifically rigorous basis for urban planning to support a sustainable, future-orientated city.

Heat stress in Vienna

The dynamic urban climate model MUKLIMO_3 (DWD) → was used to study the development of the urban heat island. It models temperature curves for potential summer days to identify thermally-sensitive areas of the city. The numerical model was validated via a series of real-time climate monitoring stations across the city, as well as mobile measurements gathered by a bicycle-based data campaign. Both the modelling and in situ measurements show a steep rise in air temperature across the city, attributable to different land uses and partly also topographical conditions. Particularly high levels of heat stress were detected in the city centre, as well as in residential and industrial areas on flat terrain.

UHI in Vienna and future development

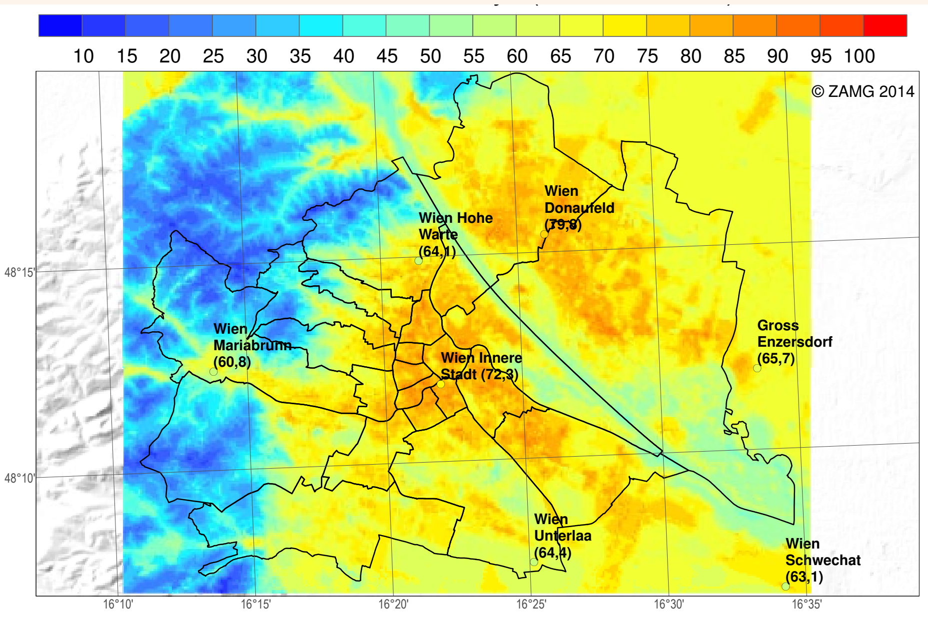
Future climate predictions come from modelling based on various baseline scenarios for greenhouse gas emissions, which in turn depend on population growth and patterns of consumer behaviour, as well as on the economy and politics (IPCC 2007, 2013). However, since modelling future climate is subject to considerable uncertainty, these are not climate forecasts but possible climate scenarios. A set of future climate scenarios for Vienna, based on various regional climate models, shows an increase in the average annual number of summer days in the coming decades. For the period 2012-2050, a moderate annual increase in the range of 0 to 25 summer days ($T_{max} \geq 25$ °C) is expected, compared to the reference simulation (1971-2000). A possible increase of around 20 to 50 additional summer days per year is projected for 2071-2100.

Different scenarios

Regarding urban planning strategies, the MUKLIMO-3 → experiments suggest that adaptation actions need to be applied at a large scale to achieve any significant reduction in urban heat stress. This combined with the targeted implementation of various small-scale actions such as an increase in greenspace (+20%), reducing building density (-10%) and unsealing impermeable surfaces (-20%), could also have significant positive impacts.

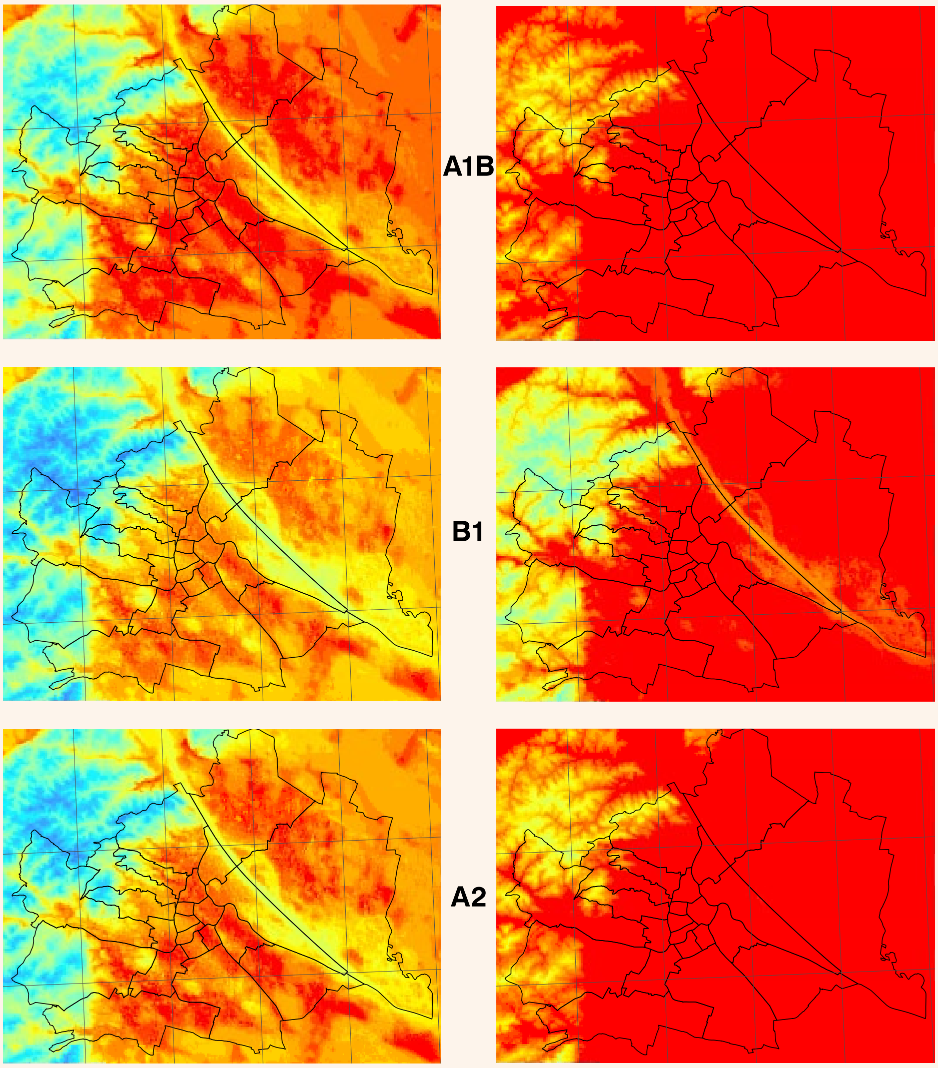
Thus, the consequences of global warming for the city could be partially mitigated. Furthermore, modelling shows that due to topography, predominant atmospheric circulation (north-west and south-east winds) and various urban structures, the same adaptation actions applied in different neighbourhoods would have different impacts. For example, an increase in green area factor (+30%) in the inner-city has a greater cooling effect on the local environment than the creation of greenspace in outer districts.

Average number of summer days (T_{max}≥25°C) in Vienna and surrounding areas for the reference period 1981-2010



Mean number of summer days (T_{max}≥25°) 2021-2050

Mean number of summer days (T_{max}≥25°) 2071-2100



Simulation of the average number of summer days in Vienna and surrounding area for the period 2021-2050 (left) and 2071-2100 (right) with underlying climate scenarios: IPCC scenarios A1B, B1 and A2 from UBA-REMO based on ECHAM5 simulations (Jacob et al. 2008). The various IPCC 2007 scenarios represent different demographic, social, economic, technological and ecological global development trends. Differences between more economically orientated scenarios (A) and more environmentally orientated scenarios (B) are striking. Over time, the IPCC and the whole scientific community have adopted what is known as the lead scenario, considered the most realistic – the A1B scenario. The IPCC report in 2013 produced new definitions for future scenarios.

About the Urban Fabric & Microclimate Project
Urban Fabric + Microclimate – Urban Fabric Types and Microclimate Response – Assessment and Design Improvement

Project management:
Institute of Urban Design, Landscape Architecture and Design, Department of Landscape Planning and Garden Design, Technical University of Vienna

Researchers:
Richard Stiles; Katrin Hagen; Heidelinde Trimmel, Beatrix Gasienica-Wawrytko

Clients:
Federal Ministry for Transport, Innovation and Technology (BMVIT), Climate and Energy Fund within the ACRP 3rd Call (Austrian Climate Research Programme)

Project partners:
Energy Department, Austrian Institute of Technology (AIT); Institute of Strategy and Management of Landscape Development, Technical University of Munich

Further information:
Stiles et al. (2014): Urban fabric types and microclimate response – assessment and design improvement. Final Report. ACRP 3rd Call. TU Vienna. Download www.urbanfabric.tuwien.ac.at.

1.6 UHI and Vienna city districts – the 'Urban Fabric and Microclimate' project

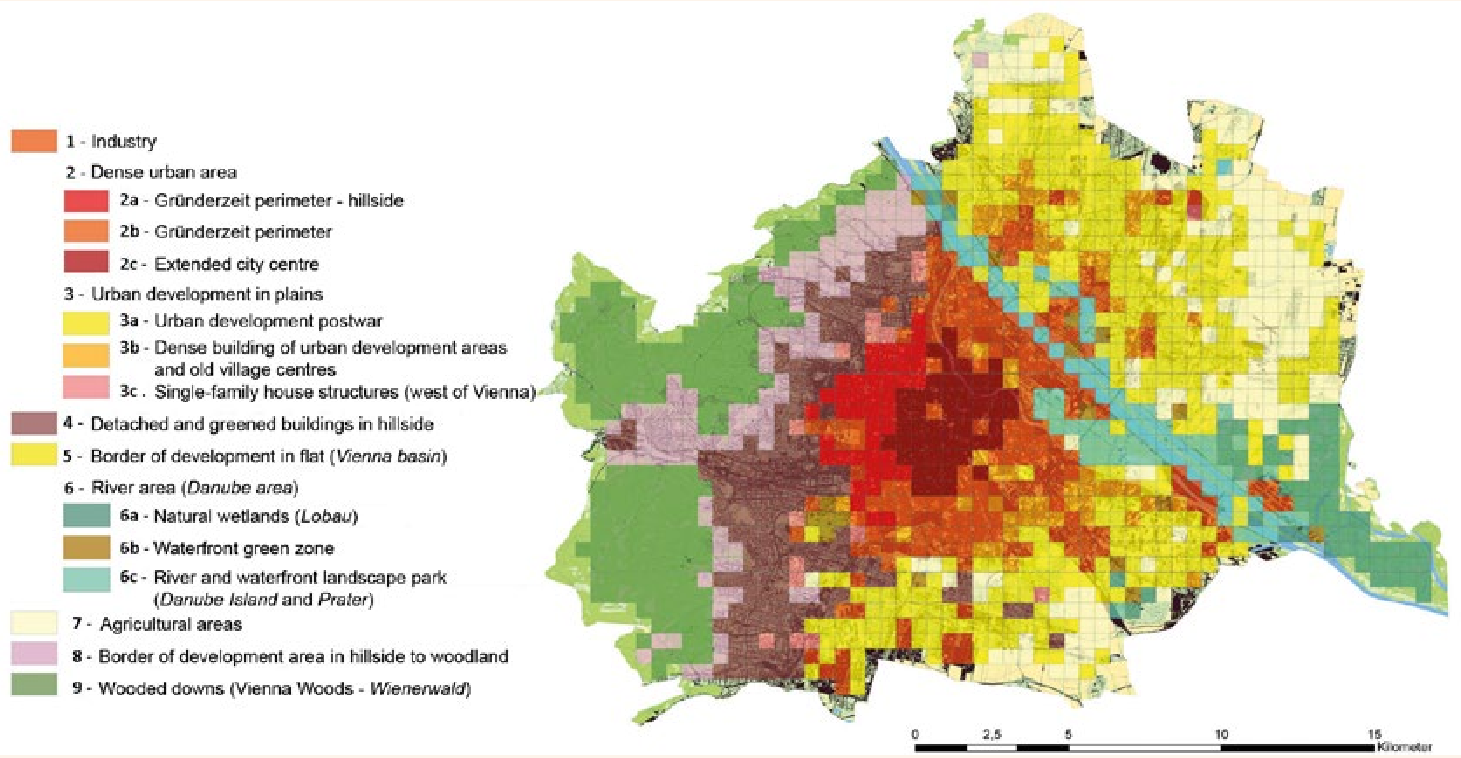
Project lead: TU Vienna, Institute of Urban Design, Landscape Architecture and Design (Katrin Hagen, Beatrix Gasienica-Wawrytko)

One of the aims of the 'Urban Fabric and Microclimate' project (Urban Fabric Types and Microclimate Response – Assessment and Design Improvement) was to find out to what extent small-scale urban structures influence the urban heat island effect as well as other climate characteristics. The aim was to develop strategies that can alleviate negative impacts at a local level. Another focus of the project was the characterisation of urban morphology and landscape in order to understand the interactions better between urban open spaces and microclimate. Using the example of Vienna, climate-critical urban space situations were identified, and practical open space design actions proposed that would counteract local overheating during summer months. For this, urban space types were identified, so design actions could be tailored to different urban spaces and open space structures. The project was run in collaboration with MA 22.

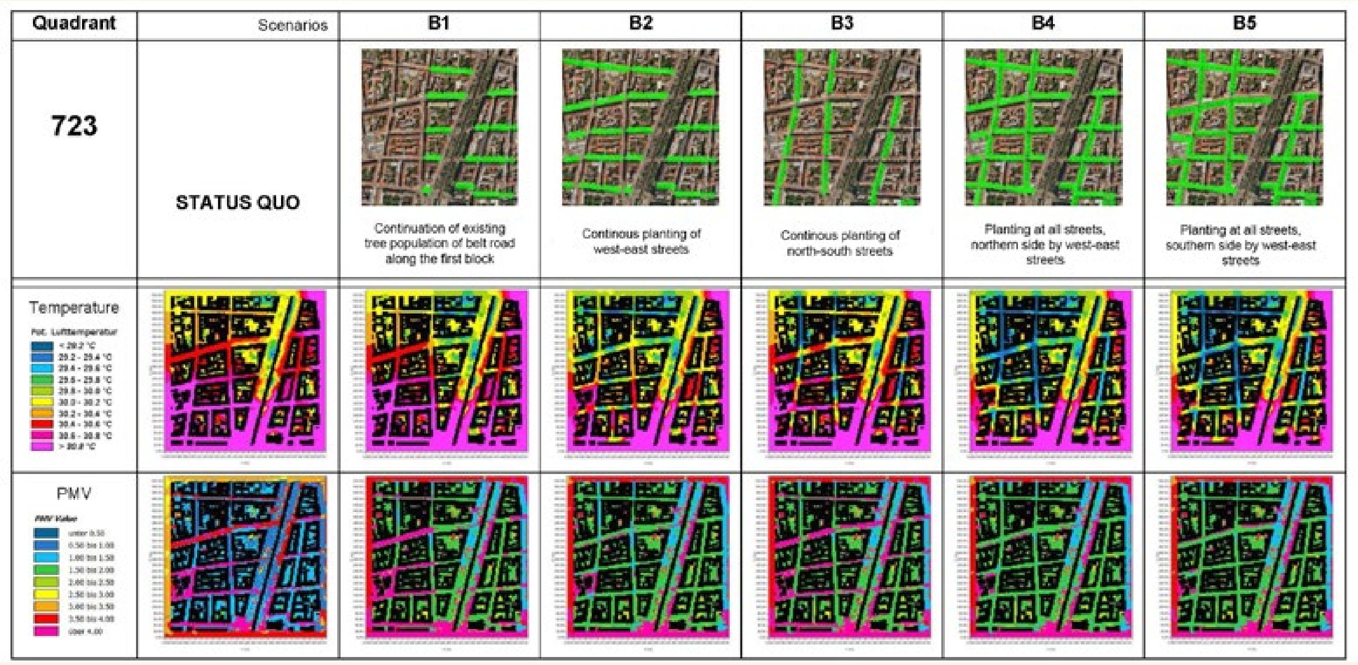
This intense professional exchange took place within the framework of an international expert advisory board from research, city administration and planning sectors who met at key project phases in Vienna to discuss interim results and next steps for the project.

Urban space categorisation

The categorisation of urban spaces was based on a wide variety of climate-related data sets. Data was collected and digitally processed, then cross-referenced with the Statistics Austria database, to be able to generate information for each 500m x 500m quadrant.



The nine different types of urban space which differ in terms of their typology, topography, climate, vegetation-related features, and the proportion of impermeable surfaces and water bodies. Actions and their impacts were then simulated for selected quadrants (see illustration on the next page).



The images show the results of a simulation of different versions of tree planting. The differences in air temperature and PMV →▤ values on highways are clearly visible, depending on the number and location of trees planted in the simulation (blue = cooler, to violet = hotter).

The data required for the analysis were grouped into four themes and a two-step cluster analysis was carried out. This meant the data could be correlated, so that conclusions could be drawn about similar conditions in other urban areas. The result is a map that divides the entire urban area into nine urban space types (clusters), revealing an overarching structure of climate-related factors and their relationships. Further research focused on the urban space types that would be hardest hit by climate impacts. Foremost amongst these were the densely built-up areas of the original city structure, as well as urban expansion areas to the south and over on the other side of the Danube.

Urban space types and UHI

Further research aimed to analyse particularly climate-critical urban space types by means of sample quadrants and the development and investigation of practical design actions to improve the microclimate. Findings for the individual quadrants can be seen as examples of respective urban space types and should therefore be transferable to other Central European cities with comparable urban structures.

Critical urban space types and possible design actions

A total of five quadrants were chosen for further characterisation and modelling. These include a description of small urban structures and different open space typologies. Real-state simulations were carried out which helped identify climate-critical areas within the quadrants. Specific design actions were developed for existing open space structures, and their impacts on microclimate analysed using the ENVI-met 4.0 simulation program →▤ (Bruse 1999).

The focus was on unsealing impermeable surfaces, tree planting and green roofs. In assessing the simulations, special emphasis was placed on PMV (Predicted Mean Vote) as an index for thermal wellbeing, as well as on climate factors such as wind speed, average radiant temperature, air temperature and humidity. A great advantage of the programme was the option to map the results of individual parameters on the respective areas of the urban plan. In addition, mean values and daily patterns of air temperature, wind speed and so on were analysed for each individual action.

Planning recommendations

Project results are summarised in a catalogue of actions. This breaks down planning recommendations according to the respective design actions and provides general information as well as specific detail on urban spatial aspects. It is important to highlight that street trees were the most effective of the design actions studied. There are particular aspects to be considered during the planning process, such as which side of the street trees are planted (tree planting is more effective on the eastern side of the street), tree canopy and distance between trees.

Actions to reduce urban heat islands often share benefits with projects in environmental protection and nature conservation, such as 'Netzwerk Natur' (Nature Network), Vienna's species and habitat protection program.

Information and awareness-raising among Vienna's citizens is important.

2. Urban heat islands and city and nature conservation planning

In Vienna, a climate-sensitive approach and actions to adapt to climate change have long been strategically embedded. Urban climate protection is reflected in the City of Vienna's spatial planning, environmental protection and nature conservation planning instruments, as well as in more informal processes. Reducing urban heat island effects and implementing forward-looking urban development that helps prevent urban heat islands are a long-term and cross-cutting issue. A wide range of sectors, control levels and planning processes are either affected or influence the implementation of actions. Therefore, aspects of climate change adaptation are reflected in many of the City of Vienna's programmes and activities, often combined with other environmental protection goals.

2.1 UHI areas of activity – building knowledge and taking action

Vienna's UHI Strategy sets out three areas of action to encourage greater consideration of the urban heat island issue. Awareness-raising amongst the public and relevant planning experts is needed first. Information and communication and an increase in skills in the city administration help to mainstream issues related to UHI. It is crucial – especially in a rapidly growing city – to think ahead about structural, strategic and large-scale urban actions, to have a beneficial and sustainable influence on the urban climate. In the course of any urban development project, practical technical and structural actions can be taken to counteract urban overheating.

Building knowledge and skills

Heat in the city affects everyone. Basic awareness-raising is needed amongst members of the public and relevant planning experts, to highlight that everyone can do something about it. The City of Vienna has been providing information about impending heat stress since 2010. The Public Health Department together with the Central Institute for Meteorology and Geodynamics provides preventative information about upcoming heatwaves →▤ on this website and in the local media (http://www.wien.gv.at/gesundheit/sandirektion/hitzebericht.html). Advice is also available on personal actions to take in heatwaves →▤ on this link and on the City of Vienna's Health Service Department (MA 15) website (www.gesundheitsdienst.wien.at).

Awareness-raising and skills development in Vienna's planning and development departments are also important. As part of the City of Vienna's environmental protection and spatial research, important databases and guidelines for managing and preventing urban heat stress have been set up and practical projects implemented in climate change adaptation and research projects (see Chapter 6).

Act strategically and proactively

Long-term actions like a green and open space network strategy to help create and distribute cool air, or expanding the city's tree stock, must be planned in advance and strategically embedded. These approaches should be considered at an early stage in the planning process. Applied at city-scale or when planning new settlement areas, these actions can help to reduce urban heat stress in the long-term. Appropriate actions and their effects are described in Chapter 3 Strategic actions for climate-sensitive urban planning (p. 26 onwards).

Take practical steps

In every urban planning and development project, practical actions can be taken to avoid neighbourhood or building-related heat stress. In the planning and design of individual buildings, streets, green and open spaces, meaningful steps can be taken to increase amenity and quality of life. These actions, their feasibility and impacts are described in detail in Chapter 4 of Vienna's UHI Strategy, 'Practical actions in planning and development' (p. 46 onwards).

2.2 UHI reduction as a planning and environmental protection strategy

The various instruments that affect urban climates, as well as strategies and regulations for managing the phenomenon of urban heat islands, is very broad. These range from international treaties like the UN Climate Convention to nationwide approaches such as the Austrian Strategy for Climate Change Adaptation, country-specific approaches, federal and provincial laws, guidelines, practical planning instruments, planning aids and programmes, some of which are briefly described on the following pages. What all these programs have in common is that their application by Vienna was different – under various management leaders, central departments were involved and collaborated.

Increasing the climate resilience of cities as a Europe-wide strategy

The EU strategy on adaptation to climate change (2013) makes it clear that adaptation actions as well as climate protection actions are needed, to overcome the challenges of climate change. From the European Commission's point of view, ‚it is cheaper to take early, well thought-out adaptation actions than to pay the price later for not adapting.' (COM 2013, 2). The aim is to increase climate resilience → – the ability to withstand the impacts of climate change – in Europe.

‚It is cheaper to take early, well thought-out adaptation actions than to pay the price later for not adapting.'
COM 2013

Green infrastructure especially →– such as farmland, forestry and parks – is considered central, as it is ‚more cost-efficient and sometimes easier to implement than relying on grey infrastructure alone' → (COM 2009, 6).

The Austrian Strategy for Adaptation to Climate Change

The Austrian Strategy for Adaptation to Climate Change (2012), adopted by the Council of Ministers (2012) highlights that, in addition to actions to limit the rise in global temperature, appropriate and timely adaptation actions must be taken. The negative impacts of heatwaves → on health and the importance of actions to reduce these are explicitly emphasised in the Austrian strategy (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 5). In particular, green and blue infrastructure → in densely built-up areas can help to reduce bioclimatic impacts on the public. It is important to consider systematically the effects of climate change at all planning levels (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 118f).

Vienna is on course to becoming a climate-resilient city

Vienna's Environmental Protection Department MA 22 has been promoting green roofs and green façades for many years. The sustainable use of rainwater, rainwater management, especially to increase evaporative cooling, is also the subject of numerous studies, specialist conferences and public outreach work.

The sustainable use of rainwater (rainwater management), particularly to increase evaporation, is the subject of numerous studies, specialist conferences and public outreach work.

Positive effects are also being felt through the ÖkoKauf/EcoBuy scheme for sustainable procurement and ÖkoBusinessplan/EcoBusinessPlan, a collaborative project between the Environmental Protection Department and the Chamber of Commerce to advise companies on ecological actions. These programmes and projects all come under Vienna's Smart City Strategy and its Climate Protection and Adaptation Programme (KliP II).

Vienna's Smart City Framework Strategy and the urban climate

Vienna's Smart City Framework Strategy, adopted by Vienna City Council in 2014, is a long-term umbrella strategy to 2050, to be implemented with staggered, specific targets subject to continuous checks (MA 18 2014d). The central objective is to reduce CO_2 emissi-

STEP 2025 und the urban climate – focus on climate change adaptation

‚In the future, the urban climate function of open spaces, as well as their recreational value, will become more important. They need to be designed to withstand the impacts of climate change and help the city adapt. For the latter, preserving fresh air corridors and cooling areas plays a central role. Equally important are small-scale actions such as increasing permeability, tree planting, shading, rainwater management, and more urban greening, green roofs and façades.‘

(MA 18 2014a, 79)

ons from the current 3.1 tonnes per capita to around 1 tonne (80% reduction from 1990 to 2050). However, in contrast to similar strategies by other cities, the strategy also includes other environmental protection targets, such as reducing private motorised transport from the current 28% to 15% by 2030 or protecting the high percentage of greenspace at 50%, which helps prevent urban overheating.

Vienna’s Climate Protection Programme

Vienna’s Climate Protection Programme (KliP II), approved by Vienna’s Municipal Council, includes alongside the aim of reducing greenhouse gas emissions → actions to reduce and adapt to the consequences of climate change. The programme resolutely addresses urban planning actions. Greening streets, courtyards and roofs, reducing impermeable surfaces and upgrading green and open spaces improve quality of life for the Viennese and reduce the UHI effect (MDKLI 2009, 93). In addition, especially at regional cooperation level, ‚long-term green and open space protection, integrating (regional) green space networks and raising awareness of agricultural products in the urban area‘ are recommended (MDKLI 2009, 105f).

Urban Development Plan 2025 – Urban Greening instead of Air-Conditioning

In the Urban Development Plan 2025 (STEP 2025), increasing urban greening is seen as a core strategy for beneficial impacts on the urban climate. The aim is that ‚climate protection and adaptation to climate change become an integral part of the planning, implementation and development of city neighbourhoods and open spaces‘ (MA 18 2014a, 85). The creation of quality open and green spaces, the greening of roofs and façades and the planting of trees and avenues are highlighted specifically as contributors.

One initiative especially – Urban Greening instead of Air-Conditioning – should help to identify particularly affected areas and reduce the urban heat island effect. Climate change adaptation must be integral to planning, to increase the amenity of public spaces and improve the urban climate.

Green and open space standards and the urban climate

City centre networks of green spaces and ‘green corridors’ are especially good at reducing the UHI effect in the city. Green and Open Space Standards create the conditions for effective prevention of urban heat islands by gradually expanding Vienna’s Open Space Network (MA 18 2014b). Technical standards also embed quality standards to supply green infrastructure and ensure green urban areas (see table above). ‘Early greening’, i.e. creating green infrastructure before construction starts (MA 18 2010) as well as connecting green spaces increases quality and ensures adequate greenspace provision. The new planning instrument of the Local Greening Plan is especially effective for controlling greenspace provision to reduce the urban heat island effect.

GREEN AND OPEN SPACES	CATCHMENT (m)	SIZE (ha)	m²/inhabitant		
Neighbourhood	250	< 1	3,5		
Residential area	500	1–3	4,0	8,0	13,0
District	1.000	3–10	4,0		
	1.500	10–50			
Region	6.000	> 50		5,0	
+ Sportsgrounds			3,5		
+ Green space per workplace			2,0		

Open space standards, taken from Green and Open Space Standards (MA 18 2014b, S 84)

Securing agricultural land via the Agricultural Structural Development Plan

Vienna's Agricultural Structural Development Plan 2014 (AgSTEP 2014) aims to protect and preserve the city's approximately 6,000 hectares of agricultural land. Key objectives are the ‚preservation (safeguarding) of the management of agricultural land in Vienna in accordance with green space planning and the further development of environmentally friendly (sustainable) agricultural production' (MA 58 2014, 5). The demarcation and conservation of 'agricultural priority areas' supports the sustainable protection of areas that provide cooling.

The Nature Conservation Act protects greenspace

The protection of greenspace and wildlife areas also includes urban climate aspects → since climate is directly influenced by the natural environment (Vienna Nature Conservation Act §3, para. 2). The protection of areas under the Nature Conservation Act is important for the sustainable protection of greenspace and its climate function in Vienna. The core objective 'protection of and care for nature' supports the protection of urban ecological functions of green infrastructure and thus the climate impacts of these areas.

2.3 UHI as a consistent strategy – implementation at all levels

Implementing these strategic planning guidelines to reduce the UHI effect can take place at different levels. To combat the phenomenon of urban heat islands effectively, it is crucial to consider UHI-related issues at all stages and aspects of urban design and development and therefore also at all planning levels. The urban heat island effect is already established as a concept in Vienna's spatial planning instruments, environmental protection and nature conservation planning as well as in informal instruments.

Pilot actions, research projects and guidelines

- ***Mapping green roof potential***
  Green roof potential mapping provides information on which roofs are suitable for greening (MA 22).
- ***Green space monitoring***
  The size, condition and development of green areas in Vienna's urban area have been recorded every five years since 1991 with green space monitoring (MA 22).
- ***Greening roofs and façades***
  Numerous greening buildings pilot and research projects have been implemented as well as funding given (MA 42 and MA 22)
- ***Guidelines for project implementation***
  Numerous research projects and initiatives in the City of Vienna at different levels of planning have produced further information on options and practical steps that help to reduce the UHI effect (for more details, see p. 93 onwards).

Successful actions and projects that can contribute to the reduction of the UHI effect require early consideration and forward-looking planning.

Vienna UHI Strategy levels of action

As part of the project, the following key actions for the Vienna UHI Strategy were identified:

1. Masterplans and urban design competitions
2. Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA)
3. Zoning and development planning
4. Planning and design of public green and open spaces
5. Collaborative planning process, developer competitions, housing initiatives and public housing
6. Planning and design of public utility buildings
7. Promoting implementation

The hierarchy of planning stages as well as the timing of individual instruments in the context of the planning process must be taken into account when implementing actions. The various interfaces and connections between individual instruments require integrated, inter-departmental planning and coordination.

Strategic decisions are made at the masterplanning stage

At mission statement and masterplanning stages, requirements for more detailed planning steps are created. The basic urban fabric, density of buildings and public space – and thus the impact of new urban development areas on the local climate – are defined at this level.

In this early planning stage, (potentially) contradictory urban development aims as well as different public and private interests – such as density of development versus green space designation – are assessed and balanced.

Assessing climate effects of urban development

For large-scale projects, various test methods are used – Environmental Impact Assessment (EIA) → and Strategic Environmental Assessment (SEA) → -. Both test methods examine the effects on protected interests – humans, animals, plants and their habitats, soil, water, air and climate, landscape as well as property and cultural assets. An EIA is used when approving specific projects that are subject to EIA regulations in accordance with the Environmental Impact Assessment Act. When making environmentally significant decisions within the framework of the planning process, a SEA is carried out as part of the planning permission procedure. The SEA is enshrined in the building code and must be implemented if any significant negative effects are anticipated for at least one protected interest, such as the climate, in the implementation of the new planning permission. The SEA comes before the EIA, as an EIA is only carried out during a specific project planning process.

Land use planning creates conditions for further implementation

Zoning and development planning law sets legally-binding conditions for all subsequent planning and development processes. At this stage, urban density (gross floor area, usable land), what land can be built on, the degree of impermeable surfacing, building types and heights and orientation of buildings are determined. Likewise, UHI-related actions can be established through special provisions. In addition to building orientation and size, regulations can be set such as how much greenspace must be included on the site, tree avenues or groups of trees in traffic zones, as well as greening roofs and façades.

Developing and implementing UHI reduction actions is possible at all planning and design levels.

Adequate greenspace has a beneficial effect on the urban climate

The planning and design of public streets, squares, open and green spaces play a crucial role in implementing actions to reduce UHI, as they determine conditions long-term. The inclusion of UHI-sensitive criteria in competitive contract design briefs is a key approach. The effect of various actions at this stage and how they can be implemented is described in detail in Chapters 3 and 4. Internal guidelines, checklists and guiding principles, some of which contain climate-sensitive aspects (such as the Sustainable Urban Space Checklist), facilitate the implementation of actions at this level.

Residential development as a determining factor

Around 35% of Vienna is building land. Of this, 70% are residential and mixed-use areas. Thus, housing has a decisive influence on urban climate conditions. Collaborative planning processes (often in the run-up to zoning procedures or, subsequently, developer competitions) have become established as an important planning procedure at district planning level. Through an intensive exchange between planning teams, the City Council and the public, green and open space provision in particular can be qualitatively improved and co-ordinated through cross-sector coordination.

In Vienna's Strategic Preliminary Assessment of the Environmental Impact of a Planning Application, microclimate is a separate assessment category, in addition to other environmental protection interests. With this instrument, sites and construction projects can be assessed at urban planning stage for their environmental impact in a comparable and comprehensive way. This is to ensure that all environmental issues are taken into account when deciding between different planning options. At this level too, new issues can be addressed and incorporated into urban development in the form of pilot projects to serve as models for further projects.

Public buildings as a model for climate-sensitive building

The City of Vienna can have an impact on commercial property developers and contractors through its own sphere of influence or a 'role model effect'. All Vienna City kindergartens, schools and education campuses as well as office buildings and other urban buildings come under this category. Quality standards are already being defined, for example, in Spatial Layouts (Raumbuch) (MA 34 2014) or Energy-Conscious Construction Criteria for Service Buildings in Vienna (Kriterienset energiebewusstes Bauen für Dienstleistungsgebäude in Wien) (MA 20 2012). These guides contain many UHI-related issues and actions, such as effective solar shading or reducing cooling demand caused by outdoor temperatures as required by the building code or avoiding large-scale glass structures because of overheating.

The ÖkoKauf Wien/EcoBuy Vienna checklists also contain important requirements as do the Green and Open Spaces Working Group Planning Guidelines.

Thus, the Greening Façades Guide (Leitfaden Fassadenbegrünung) highlights the climate impact of green façades on the city and buildings, the Guideline on Floor Coverings (Richtlinie Bodenbeläge) proposes permeable surfaces to improve the urban climate and the ÖISS (Österreichische Institut für Schul– und Sportstättenbau – Austrian Institute for School and Sports Buildings) Ecological Criteria in School Construction Guide confirms that shading is an important factor for open spaces in schools.

A multitude of actions – city-wide and small-scale, by local authorities and private individuals – together make it possible to reduce the UHI effect

Creating incentives for private individuals

Grants can create incentives for individuals or institutions. For example, Vienna's City Garden Department (MA 42) has been successfully funding the greening of roofs, as well as courtyards and façades, since 2003. This also enables control of quality and effectiveness of actions on the microclimate. Thus, for example, green roof grants depend on the depth of substrate and growing medium, and also the quantity of climate-active plants.

Vienna's ÖkoBusinessPlan/EcoBusinessPlan and the Vienna Chamber of Commerce organised a series of events on different topics for Viennese companies in cooperation with the Ministry of Agriculture, Forestry, Environment and Water Management and respACT 2014. The aim was to deepen the environmental know-how of Viennese companies and to suggest ecological and social actions for businesses, for example awareness-raising events, such as Nature-Based Solutions to Improve the Urban Climate, or Greening Roofs and Façades: Benefits and Subsidies.

2.4 Policy options – incentives or regulations?

Part of the project looked at economic issues and possible (future) instruments and options for action by the City of Vienna. When implementing solutions at different planning stages, the same questions are always asked: who is responsible, who benefits and who pays for it? From an economic point of view, urban temperatures are a 'good' with special characteristics. First, the 'consumption' of this good is not tied to a specific 'purchase' but belongs to everyone equally (inclusivity). Secondly, this good is not 'used up' upon 'consumption' but is – although perhaps only in theory – infinitely available (non-competitive). In the terminology of environmental economics, this good is thus considered a 'public good'.

Cooling as a public good

While the provision of private goods can be organised by markets or price points, these mechanisms cannot be applied to public goods. Its stock is far more vulnerable to external impacts from other production and consumer decisions (such as real estate or motor vehicle markets) as well as legal conditions (such as building regulations or parking space management). Local heat stress may, for example, result from a private interest in converting a greenspace into a hard surface car park. Unlike the greenspace, the car park can generate income through rental. There is no incentive for individual private decision-makers to maintain or protect a specific temperature range, even if they themselves and many others are affected by higher temperatures – an example of market failure.

Looking for new solutions

Vienna has a wide range of options across the spectrum of environmental economics that it can refer to for its urban development. Many varied approaches can currently be seen in Vienna. Most do not explicitly refer to UHI but to other public goods (air quality, peace, security and so on) but they do allow for possible (future) options for action. In general, achieving the desired effect relies not on a single most effective action but on a combination of actions.

Information and encouragement: Options to encourage voluntary action include good practice examples (e.g. green roofs on public buildings), labelling (e.g. energy certificates for electrical appliances) or information on how local urban heating can be reduced. The effectiveness of these calls to action depends on the people with the power to implement them being convinced either of low implementation costs or high personal benefit.

Grants and taxes: In contrast to voluntary actions, grants and taxes provide financial incentives. The effectiveness of actions depends on whether affordable interventions (high-impact subsidies or tax rates) create changes that actually reduce local urban heating. The most effective way to achieve this is performance-based subsidies or taxes for direct impacts on local urban heating. This requires a measurable (or at least estimable) indicator of local urban heating clearly attributable to individual actors. Such an indicator is currently not available.

Alternatively, activity-based grants and taxes can be used. This requires quantifiable actions by those involved, such as building and maintaining a green façade. The level of support or tax must be high enough, in absolute terms and relative to the total cost, to influence the behaviour of the target group.

Another option is conditional subsidies: if grants are being given to pursue aims other than reducing local urban heating, UHI-related requirements can also be imposed (e.g. conditions on new building grants). Its effectiveness relies on funded projects actually having an impact on local heating and ensuring that compliance with conditions can be checked cost-effectively – also long term.

Organised market solutions: Trading certificates for local urban heating or activities that have an impact on it might be possible if it were measurable, attributable and legally required. Trading would also have to be limited to actors within a given area, to prevent heat in one district being reduced at the expense of heat in another. A cost-effective trading system is currently hard to imagine.

Collective decentralized activities: While a certificate trading system aims to create an artificial market for the public good of 'cooling', collective activities can turn the public good into a 'club good' (only members of the 'club' can consume the commodity). For example, if a group of households around a courtyard club together to green the courtyard and reduce local heating, the dilemma of how to provide the public good can be overcome. This requires that local heat generation can be reduced by the actions of the club's members and those who are not members (and therefore do not participate in the activity's costs) can be excluded from the benefits. In practice, however, it is difficult to exclude those who do not want to participate from the benefits of reduced heating. One way to identify the necessary framework conditions for the creation of 'club goods' is participatory processes.

While the provision of private goods can be organised via markets or price points, such mechanisms cannot be applied to public goods like cooling.

Laws and regulations: Minimum standards (e.g. minimum 'green' area such as Vienna's Green and Open Space Standards, MA 18 2014b) or restrictions on the use of resources (e.g. traffic restrictions on hot, windless days in UHIs) are the easiest options to implement. Their effectiveness often depends on whether differentiation is possible with respect to the effect on local urban heating. In addition, actions that give incentives to reduce local heating are meaningful.

Government action: Government action can be effective, if the impacts of local urban heating and cost of prevention through public buildings, green infrastructure, urban planning and so on are included.

3. Strategic actions for climate-sensitive urban planning

Strategic actions for climate-sensitive urban planning include city-wide effective, applicable approaches for reducing urban heat stress. The protection and development of green infrastructure →▤ plays an important role here. The EU's Biodiversity Strategy to 2020 calls for the European Union to harness the potential of green infrastructure and its ecosystem services. Green Infrastructure is included in the European Union's new Multiannual Financial Framework (2014-2020) and is intended to support nature conservation as an integral part of spatial and urban planning. Green infrastructure has the advantage over grey infrastructure – i.e. technical solutions – of providing ecological, economic and social benefits simultaneously. Above all, it also contributes to climate resilience and supports actions to adapt to climate change. In particular, this includes reducing the heat island effect through evapotranspiration. ‚Working with nature to create green infrastructure in urban areas, such as biodiversity-rich parks, greenspaces and fresh air corridors, can help mitigate the urban heat island effect' (COM 2013). ‚Fresh air instead of air-conditioning – a good investment' is the central approach here, and also demonstrates the financial advantage that green infrastructure has of being highly effective and adding value for society (ibid.).

As well as actions promoting green infrastructure such as networking open spaces or protecting and expanding existing open spaces, strategic actions also include information on how to adapt the urban fabric and urban development areas. Approaches such as lighter-coloured buildings and surface materials and reducing impermeable surfaces can have a substantial effect when applied city-wide. Vienna can make a significant contribution to reducing urban overheating.

3.1 Assessment methods

Based on a comprehensive review of national and international scientific literature and the analysis of good practice examples, possible actions were identified that could contribute to reducing the urban heat island effect in Vienna. Identified actions were jointly assessed, under the coordination of MA 22, with the involvement of experts from various disciplines (meteorology, vegetation ecology etc.) as well as from other departments of the City of Vienna (MA 18, MA 19, MA 20, MA 21, MA 25, MA 42, MA 45, MDBD, MDKLI, WUA).

Evaluation of actions

Evaluation was based on the following categories:

- Microclimate, mesoclimate
- Biodiversity, people's quality of life
- Construction and maintenance costs

A multi-level, categorised review key was developed for the evaluation. There were three potential grades for benefits, as well as a grade each for possible negative effects or no effect at all. An evaluation based on measuring results or costs had to be partially omitted as not all actions had values for all categories.

To ensure the comparability of all actions and to visualise the evaluation in a spiderweb diagram, the gradations in individual categories were given a numerical value. Spiderweb diagrams for individual actions graphically show their influence on microclimate →, mesoclimate →, biodiversity and people's quality of life as well, as construction and maintenance costs.

Actions were assessed under the following categories: climate, biodiversity and people's quality of life at the following levels:

3 Significant improvement
2 Improvement
1 Slight improvement
0 Negligible effect
-1 Deterioration

The category economic efficiency (construction/maintenance including opportunity cost, lifespan: 10 years), actions were assessed by the relevant departments (MA 42, MA 49, etc.) under the following grades:

3 Very low/no cost
2 Low cost
1 Medium
-1 High/very high cost

Example of a spiderweb diagram for street greening: two-sided avenue of trees

How to interpret a spiderweb diagram

When reading a spiderweb diagram, the higher the category rating is, the better. The spiderweb diagram above shows that street greening on both sides of an avenue significantly improves the microclimate →, represents a minor improvement to the mesoclimate →, and in turn enhances biodiversity and people's quality of life. Construction costs however are very high, while maintenance costs of the double-sided avenue are estimated as medium.

A direct comparison between evaluations of actions in Chapters 3 and 4 is not possible. The assessments of actions in Chapter 3 relate to city-wide strategies and those of Chapter 4 to individual projects.

Description of actions

The following pages describe individual actions and their impact on the UHI effect. Evaluation of economic, ecological and social factors was carried out by the department responsible, the climate impact of individual actions was assessed by a climate expert. Descriptions of individual actions include:

Clear assessment based on spiderweb diagram: Actions included the categories microclimate, mesoclimate, biodiversity, people's quality of life, construction and maintenance costs, and are presented in the form of spiderweb diagrams.

Description of actions and explanation of effectiveness: Effectiveness and reasons for it are set out for each action.

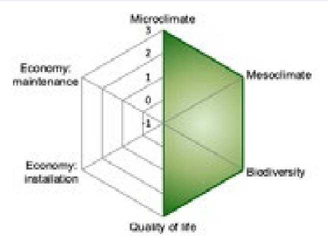
Presentation of possible actions: Individual actions can be implemented in different ways. These are described and the effectiveness of each shown on the spiderweb diagram.

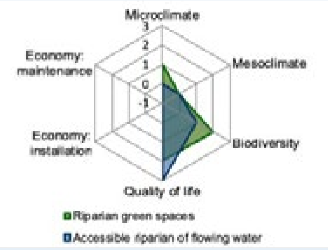
Benefits and challenges: Actions often benefit other City of Vienna strategic objectives for spatial development too. But sometimes there are also conflicting aims.

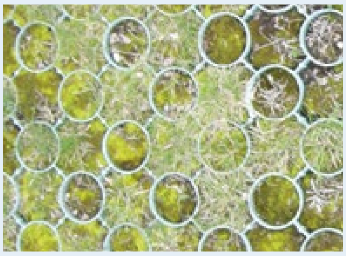
Guidance relevant to the implementation of the action: At these levels, an action is given special consideration - by providing relevant information, specifications or legal arguments.

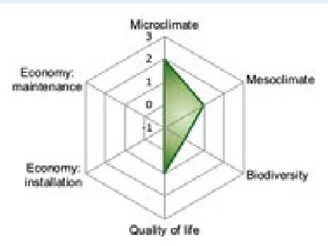
Good practice examples and further information: In addition, practical examples and further information are given for individual actions.

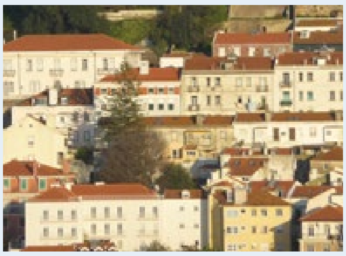
3.2 Overview and comparison of actions











3.3 Preservation of urban air flow and open space networks

As well as ecological aspects, the interaction of the city's various greenspaces is important for generating and distributing cool air. Connecting cooling areas to the dense inner-city, especially via networks aligned to prevailing winds, supports inner-city ventilation. In addition, to connect green spaces, attention should be paid to the topography of the City of Vienna as a whole (cool air flows, inclines), as well as surrounding areas.

Aims of promoting urban ventilation and open space networks

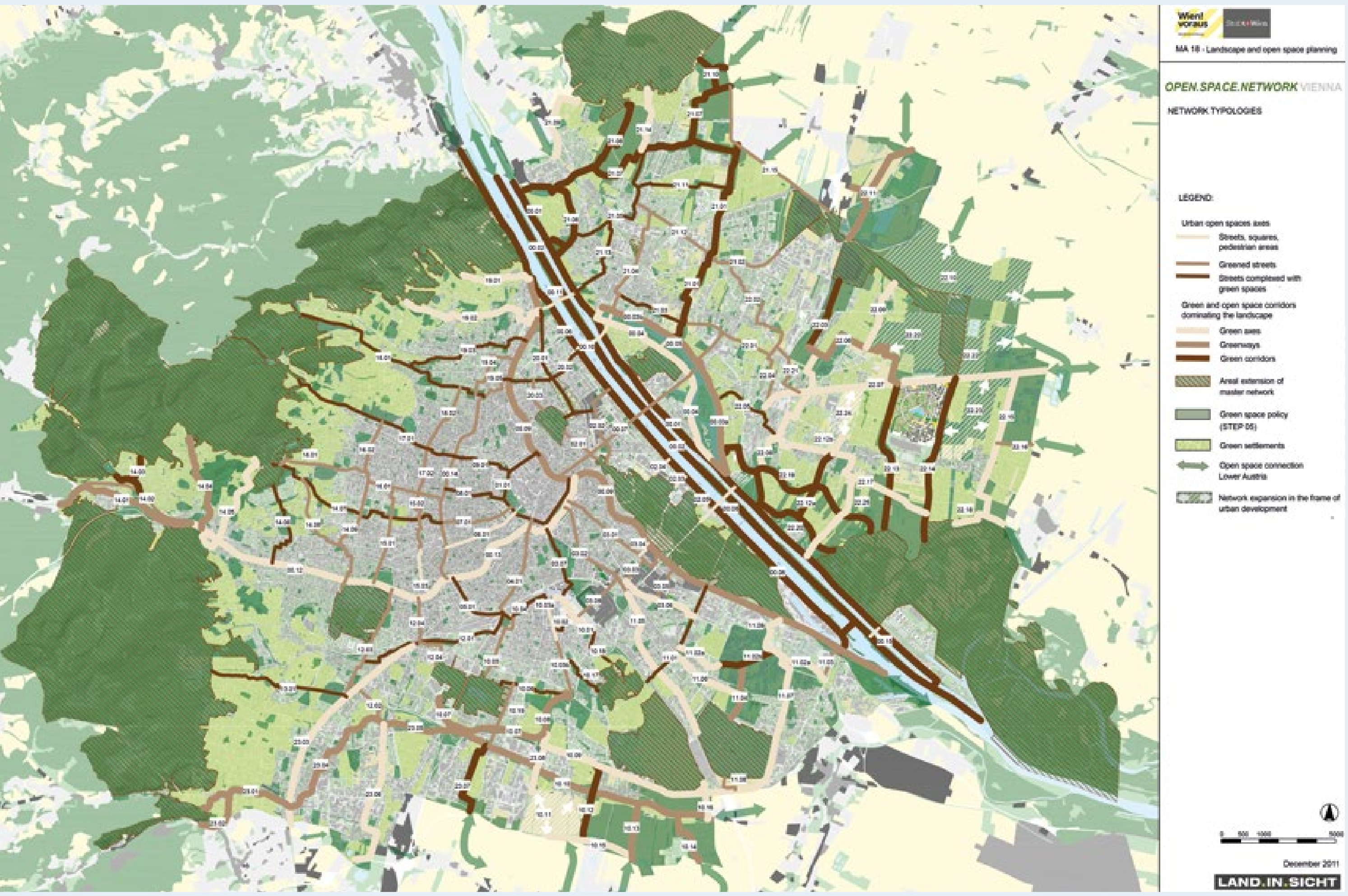
- Open space networks connecting the city and its periphery to rural areas generating cool air such as agricultural and forestry areas. Promoting urban air circulation
- Improving urban ventilation and encouraging and improve ventilation channels and cool air corridors
- Improving fresh and cool air supply from the Vienna Forest

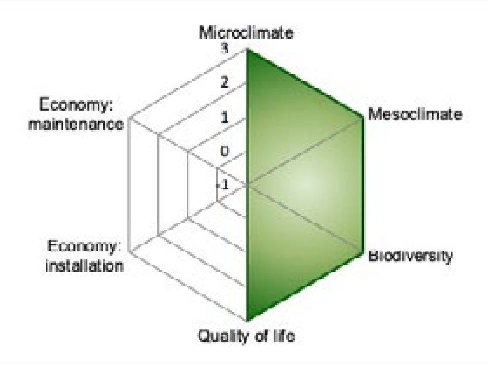
Important, appropriate city-wide actions to achieve these goals

- Open space networks connecting to areas generating cool air
- Greenspace with a water element and their potential benefits
- Avoid contour-parallel development on slopes/hillsides

Vienna Open Space Network

Within the project scope of MA 18's Vienna Open Space Network (Frei.Raum.Netz. Wien), a primary network of priority green and open space connections with city-wide significance was identified. The long-term protection of an open space network and interconnections also helps reduce the UHI effect





Spiderweb diagram: see explanation on p. 25

Description of action

The creation and maintenance of undeveloped axial corridors connected to surrounding areas can support urban airflow and ensure the supply of cool, fresh air. Large, interconnected agricultural and forestry areas in particular can generate cool air. Thus, particular attention should be paid to the topography of the surrounding area (slopes/hillsides promote airflow, forested and un-forested greenspace promotes the generation of cool air, etc.).

Greater networking of urban green and open spaces to protect and create air flow corridors helps freshen inner-city air. Protecting or creating these regional and local air corridors not only helps to bring in cool air, but also to remove polluted air. It is important these networks are as smooth as possible, so as not to slow down the air exchange (e.g. meadows, water bodies, streams, railways or wide streets). A minimum width of ten times the height of adjacent buildings (minimum 50m) is recommended for local air corridors (Schwab & Steinicke 2003, Commission for Air Pollution Control in the VDI and DIN 1988).

Existing greenspaces can be connected by grass verges or green routes and corridors along streets. An example of this is the dedicated green corridor from Bisamberg/Marchfeldkanal to the Old Danube, implemented in several stages and which fulfils important urban ecological functions (fresh air corridors and air quality).

In particular, networks aligned with prevailing winds are a key focus. Vienna primarily experiences north-westerly winds, caused by the 'jet effect' where the Danube breaks through between Leopoldsberg and Bisamberg. In hot summer months, the Puszta winds occur. This south-easterly wind brings warm air fronts from the Hungarian lowlands to Vienna. When this happens, it is almost impossible for regional air corridors to reduce air temperature. In this situation, small-scale actions such as shading, lighter-colour surfaces and especially evaporative cooling can help.

Benefits

- Protecting agriculture and forestry use and biodiversity
- Increasing recreational and amenity by networking inner-city open spaces with outlying areas
- Continued implementation of the Vienna Open Space Network
- Improvement of green and open spaces
- Creation of new connections for non-motorised transport

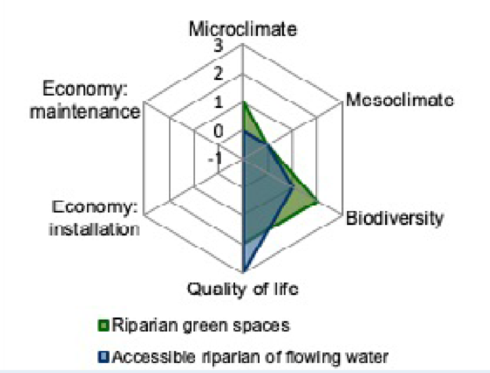
Challenges

- Competing urban planning aims (e.g. density, urban fabric, population growth) as well as existing structures in air corridors and transport routesn
- Competing interests in uses of real estate
- Urban-rural cooperation

Guidance relevant to implementation

Forestry Act, Nature Conservation Act, Forest Development Plan, planning guidelines, competitions and tenders, masterplans, Urban Area Management (SUM), Eastern Region Planning Community (PGO), Public Space Strategy, Urban Development Plan, Green and Open Space Standards, Land Use and Development Plan

3.3.2 Action – Greenspace with water bodies and potential benefits



Spiderweb diagram: see explanation on p. 25

Description of action

Water has a high heat storage capacity, so can help reduce temperatures – especially in large, deep, still water. Daily fluctuations are lower: at night it is warmer, but during the day much cooler. From upwards of around 1 hectare, water bodies have a significant effect on temperature and humidity in their environment (Schwab & Steinicke 2003).

Due to their smooth surfaces, water bodies also function well as air corridors along which air cooling can occur. Increasing green and open spaces along waterways or by protecting their edges from development can help with cool air flows.

The city's existing rivers are usually characterised by well-built, straight embankments and the flow rate is mostly uniform and high. A nature-based design of these waterways and their riparian zones can greatly enhance them, both as recreational areas for people and for urban biodiversity. The installation, expansion and extension of water-based usable green and open spaces – especially along rivers in dense inner-city areas (numerous examples such as the Danube Canal, Wienfluss, Liesingbach, some of the streams of the Vienna Woods, etc.) can also help UHI-sensitive adaptation. This action improves people's quality of life while also promoting urban air flow.

Benefits

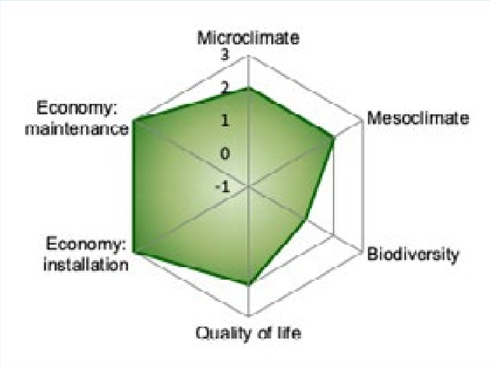
- Increasing quality of life and wellbeing
- Creation of new/additional inner-city or settlement-based recreational and amenity space
- Benefits for biodiversity

Challenges

- Maintenance intensive
- Maintaining water quality
- Can be difficult to create sufficient greenspace along waterways, especially in densely built-up areas

Guidance relevant to implementation

Urban Development Plan, Green and Open Space Standards, Forest Development Plan, Zoning and Development Plan, green space regulations, water regulations, Parks Strategy



Spiderweb diagram: see explanation on p. 25

Description of the action

Topographical wind systems such as the downdrafts from mountains and hills are an important factor in supplying neighbouring urban areas with cool, fresh air. They also help remove pollution. Generating cool air flows, especially at night and close to the ground, depends on the size of the sites producing cool air and the gradient. Suitable conditions exist in Vienna especially along the hillsides of the Vienna Woods in the western and northern parts of the city. Terrace buildings on contour form a fundamental obstacle for hill breezes. If it cannot be avoided, then development on hillsides should include maintaining relatively large undeveloped areas of greenspace and wide distances between buildings. Air flow corridors perpendicular to the slope should always be retained, and interconnected open spaces are preferable to separate open spaces which often have impermeable surfaces. Hillside development should always remain low to allow favourable conditions for air flow. This reduces obstructions to cool air corridors and cool hill breezes from the Vienna Woods and facilitates air flow and supply of fresh, cool air to the city. New construction in cool air corridors should not be erected on contour, but in the direction of fall. In such locations, agricultural and low-height vegetated areas should be offset aims for construction projects.

Benefits

- Conservation
- Protecting agricultural use (viticulture and orchards) and biodiversity in the areas around the Vienna Woods

Challenges

- Potentially competing urban planning objectives on hillsides (e.g. density, urban structure)
- Similarly, finding offset sites in sought-after areas can be a problem

Guidance relevant to implementation

Urban Development Plan, Green and Open Space Standards, Land Use and Development Plan, Vienna Building Regulations (including Conservation Area Plans), OEIB (Österrisches Institut fur Bautechenik/Austrian Institute for Building Technology) Guidelines, housing development (developer competitions, Land Advisory Council, 4 Pillar model), planning guidelines (e.g. High-Rise Directive), competitions and tenders

3.4 Adaptation of city structure and urban development areas

Depending on the structure of buildings and open spaces, different parts of the city will heat up to varying temperatures. Surface materials and degree of development – such as building density, impermeable surfacing or trees – are deciding factors (Stiles et al., 2014), affecting shading, wind speed and also heat storage capacity. More structures mean greater surface area, thus increasing heat absorption and also reflected heat radiation.

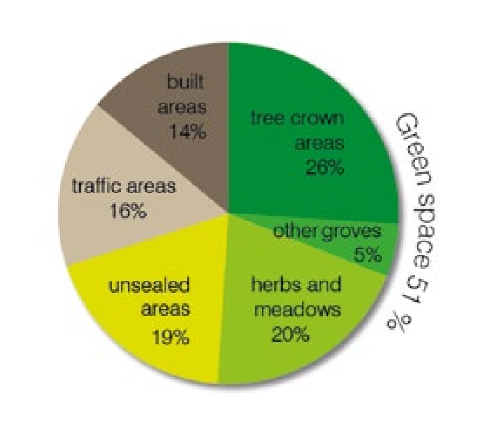
For temperatures that support citizen wellbeing, night-time cooling is especially important. In streets and open spaces in built-up areas, the Sky View Factor → determines both radiation input and potential night-time radiative cooling. The factor relates to the proportion of the visible horizon, determined by the width of the area and building height. The smaller the factor, the lower the night-time cooling potential.

Objectives for optimising city structure and street orientation

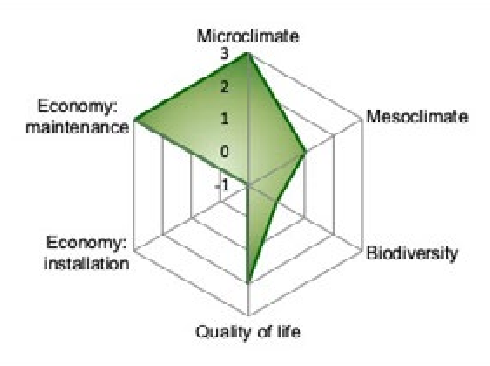
- Improving urban cooling and fresh air circulation by optimising street orientation
- Increasing the amenity of streets
- Preventing (local) overheating of streets
- Optimising building form and orientation to reduce local overheating

Important city-wide solutions to achieve these goals

- Consideration of street orientation and street intersections
- Optimisation of building form and orientation



More than half of Vienna's urban area, covering around 214 km², is still greenspace. Tree canopies account for the largest percentage



Spiderweb diagram: see explanation on p. 25

Description of action

The alignment of streets, their intersections, features and vegetation as well as the height and condition of adjacent buildings all have a direct influence on microclimate → and thus on residents' thermal comfort. The location and orientation of streets in relation to prevailing winds and air flow in built-up areas also has an impact on the city's climate as a whole. Both must be taken into account when creating new streets or redesigning existing ones.

Areas of wide streets, especially if aligned to prevailing wind directions, are important for urban air flow. It is important that wide streets have adequate design and vegetation features for cooling (trees, shading, permeable verges, etc.). Another advantage of wide streets is better night-time cooling due to improved Sky View Factor → and air flow.

As the cooling effect of shading by buildings is lower on wide streets than on narrow ones, shading features are very important for amenity. Street trees are best for this. When setting objectives, it should be noted that north-south-orientated streets are especially exposed to the sun around midday.

Over the course of the day, west-facing façades will heat up the most. Thus, tree planting will be most effective on the east side of the street.

For wider, less densely developed north-south orientated streets, installing a central avenue (two rows of trees with pedestrian access down the middle) in the centre of the street is recommended, to ensure shading for neighbouring buildings during the day. Streets running in an east-west direction receive most sun during the day. Tree planting on the sides is therefore particularly effective, especially an avenue of trees on the northern side of the street is crucial, to shade south-facing house façades (Stiles et al., 2014).

In dense districts with narrow streets, shading by buildings is an advantage, but night cooling does not work as well due to poorer ventilation, lower radiative potential and more buildings giving off heat. Tree planting for additional shading and evaporative cooling is seldom possible in narrow urban spaces. However, greening façades can provide great cooling potential. With a proportionately high percentage of green façades, the perceived temperature [PET] → can be reduced by up to 12˚C in best case scenarios (see also p. 88).

Benefits

- Passive building cooling
- Increased internal thermal comfort in buildings
- Increased amenity of urban open space

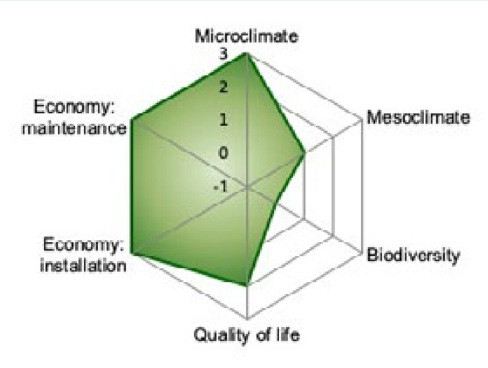
Challenges

- The orientation and design of streets is subject to numerous practical factors (topography, urban circulation routes and networks, street hierarchies, area zoning, etc.) that must be balanced against UHI-related requirements. Optimal assessment can only be made by experts using an appropriate empirical approach (e.g. modelling).
- Focusing exclusively on climate factors could – as in modernist urban planning (sun-orientated terraced buildings etc.) – lead to considerable problems in urban performance.

Guidance relevant to implementation

Urban Development Plan, Vienna Accessibility Standards, Land Use and Development Plan, Vienna Building Regulations, Pavement Regulations, planning guidelines, MA 42 Street Greening Policy, competitions and tenders, Public Space Strategy

3.4.2 Action – Optimisation of building structure and orientation



Spiderweb diagram: see explanation on p. 25

Description of action

In densely populated urban areas, night-time cooling is significantly lower, due to heat storage capacity of buildings and high levels of impermeability.

As well as surface materials, colours (see solution on p. 36) and neighbourhood planting (see solutions on p. 47), the specific alignment of buildings (building spacing, solar exposure, shading, orientation, etc.) has an impact. It also affects the internal thermal comfort conditions of buildings.

However, all aspects of building orientation and urban structure must be considered and calculated on a case-by-case basis, since local factors such as wind direction, gradient and topography need to be taken into account. One option is the simulation of different building types and solutions (see section 5.2 p. 84 onwards and section 5.4 p. 92 onwards).

It is important, when solar exposure cannot be avoided, that solutions are put in place to reduce the thermal load. It is also important to value green infrastructure, with better climate impact on larger, connected courtyards than smaller, separated courtyards (Stiles et al. 2014).

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Benefits

- Similar aims as passive building cooling
- Improved internal thermal comfort conditions in buildings during summer months and reduced energy consumption from air-conditioning.

Challenges

Support for passive solar gain by buildings and districts in winter months can reduce heating costs and CO_2 emissions, but can also be a contradictory aim. A comparison of total energy bills (warm and cold months) would be useful, as would seasonally-adaptive technical solutions (e.g. shading devices, solar cooling, cooling storage).

Guidance relevant to implementation

Urban Development Plan, Land Use and Development Plan, Vienna Building Regulations (including Conservation Area Plans), OEIB guidelines (OEIB 6), support for housing development (developer competitions, Land Advisory Board), planning policies (e.g. High-Rise Directive), competitions and tenders

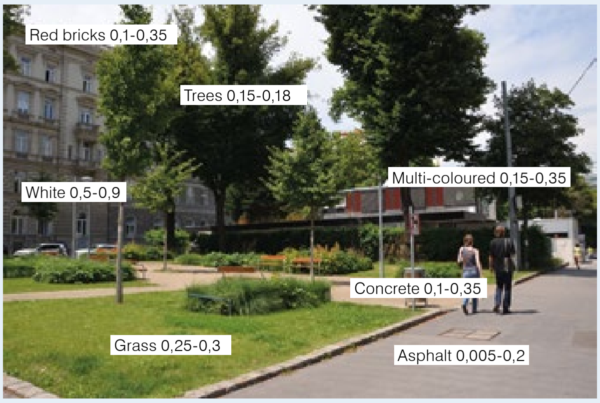
3.5 Lighter-coloured building and surface materials and increased permeability

Transport routes (16%) and developed land (14%) account for almost one third of Vienna's area (MA 22 2010). These surfaces store or reflect the incident solar energy, depending on their surface and material properties.

The albedo →▤ (from the Latin albus, meaning white) is the level of light retro-reflectivity, i.e. the reflectivity of light by different-coloured surfaces. It is represented by a number between 0 and 1 (all incident light is reflected). Darker-coloured surfaces tend to have a lower reflection rate than lighter-coloured surfaces. The heat absorbed also increases the surface temperature of these materials. With highly reflective materials, however, care must be taken to ensure that the re-radiated energy does not impact on other buildings, which would then be heated by this indirect radiation. As well as reflectivity, the thermal emissivity of a material also affects heating. Areas with a high radiation capacity stay cooler, as they can release heat more quickly. Thermal storage capacity or thermal mass is another important property of surface materials. Many building materials such as steel or stone have a high thermal mass. Inner-city areas can store twice as much heat as surrounding rural areas (EPA 2008a). Thermal mass combined with a low Sky View Factor, especially in densely built-up areas, means that stored heat is difficult to radiate back into the atmosphere at night.

Water permeability continues to decline in parts of Vienna, due to urban growth and building streets or buildings on permeable surfaces (MA 22 2010). This is also accompanied by a reduction in evaporating surfaces. The evaporation of water can help to reduce temperatures, as water can store a lot of energy, released in the form of evaporative cooling during transition to a gas. By using porous surface materials, the albedo →▤ of a surface can be reduced and evaporation increased. In addition, porous surfaces also improve infiltration (see also rainwater management actions, p. 67).

Austrian hail insurance also highlights the need to raise awareness of the topic of soil improvement. ‚With more efficient use of space and transport planning today, we can help shape the climate of tomorrow and negative impacts of environmental events such as surface water and river flooding, drought, etc. can be minimised.' (Austrian Hail Insurance).



Albedos of different urban surfaces

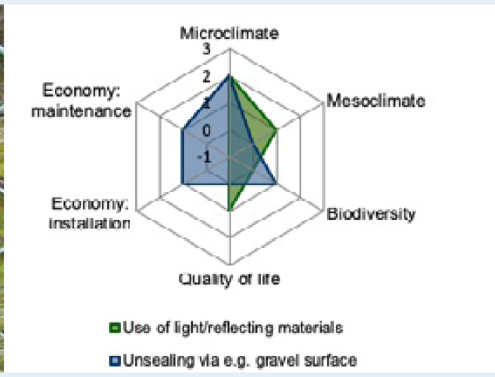
Aims for lighter-coloured building and surface materials and increased permeability

- Increasing the albedo of surfaces and parts of buildings with lighter colours
- Reducing heat storage
- Unsealing impermeable surfaces and increasing evaporation

Important, relevant city-wide actions to achieve these aims

- Lighter surface colour and unsealing of impermeable pavements in open space
- Lighter surface colour of buildings

3.5.1 Action – Lighter colour and increased permeability of surfaces in open space



Spiderweb diagram: see explanation on p. 25

Description of the action

Dark surfaces and floor coverings lead to greater heat absorption in public open spaces and transport zones on hot days. The stored heat is given off at night and prevents cooling, especially in densely built-up areas.

The use of light-coloured and reflective surface materials with a low thermal mass and gradual replacement of existing dark surface materials in open spaces and transport zones should be encouraged. In particular, mastic asphalt (albedo 0.15 →), which is very common in Vienna, leads to unfavourable local and wider urban overheating and should be avoided, to help with UHI adaptation. The aim is to reduce asphalt and metal surfacing (in the case of appliances, street furniture, etc.) in favour of light concrete surfaces, slabs or paving (concrete, natural stone) or crushed stone roof decks (water-bound, resin-bound). Also (dark) metal surfaces such as benches can heat up considerably.

Besides colour, material structure determines thermal properties. Hard surfaces are often impermeable to water. Permeable surfaces help with water evaporation and infiltration and tend to heat up slightly less during the day than asphalted areas – depending on the design and type. Unsealing to increase evaporation and rainwater infiltration can be applied to a variety of areas, such as parking lots, courtyards, driveways, etc. Unsealing can be achieved by the use of permeable asphalt, gravel, gravel turf, or grass paving (Vienna EcoBuy/ÖkoKauf Wien 2011, Stiles et al. 2014).

A combination of lighter colours, rough surfaces and porous materials helps reduce surface temperatures and the amount thermal energy stored and supports rainwater management.

Benefits

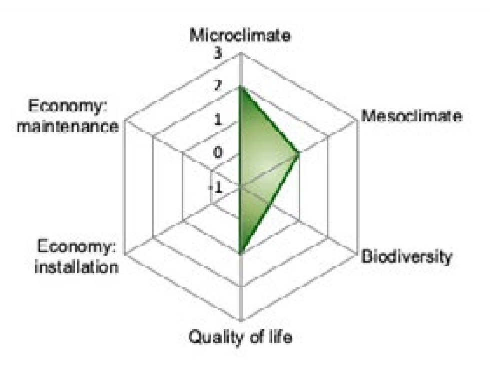
- Improved amenity in public open spaces, better quality of life in densely populated residential areas
- Many light-coloured surface finishes (e.g. sandstone paving, gravel ballasted roof decks) are also able to absorb and evaporate water (additional cooling) and, in contrast to petroleum-based asphalt, can be reused after deconstruction (sustainability)
- Increased visual attractiveness of public open spaces in tourist areas

Challenges

- Many surface materials, such as paving, are more expensive to produce than asphalt, but can be reused after deconstruction
- Due to increased reflection, light-reflective surfaces can heat adjacent buildings, especially ones with dark surfaces
- Permeable surfaces do not always meet accessibility criteria
- Permeable surfaces are often not always as structurally appropriate for traffic areas as asphalt. They are therefore most appropriate as a replacement in car parks.

Guidance relevant to implementation

Vienna building regulations, Pavement Policy, urban development plan, land use and development plan, competitions and tenders, Green Space Policy, Public Space Policy, housing subsidies (4 Pillar model, developers‘ competitions, etc.), masterplans, land use regulations, EcoBuy Vienna/ÖkoKauf Wien Planning Guideline ‘Open Space Surfacing’



Spiderweb diagram: see explanation on p. 25

Description of action

As with ground surfaces in open spaces, dark building surfaces on hot days lead to high heat absorption. Reflectivity, thermal mass and thermal emissivity determine the thermal properties of a building. Stored heat is released at night, which prevents densely built-up areas from cooling down. Using light-coloured surface materials with a low thermal mass is recommended on all exterior parts of a building. On roofs especially, so-called 'cool roof' materials can be used (EPA 2008c). These have a higher reflectivity and dissipate the heat more quickly to the environment than conventional materials. When combined with other building-related actions such as external shading devices or façade greening, the thermal input into a building can be reduced and internal thermal comfort increased. The action should only be applied if it does not conflict with greening a building, as the only positive effect (reflection of radiation) cannot compete with all the multifunctional benefits of vegetation actions (biodiversity, habitat, water storage, etc.)

Benefits

- Reduction of energy consumption for air conditionings
- Improvement of internal building climate
- Increased quality of life and liveable space

Challenges

- Possible conflict with monument protection and urban design
- Restriction of architectural freedom
- Lighter-coloured roof surfaces are not yet common (cost factor)
- Target conflict with high energy efficiency and need for winter solar heat gains

Guidance related to implementation

Vienna Building Regulations, OEIB guideline, OEIB-3, OEIB-6, competitions and tenders, support for housing development (developer competitions, regulations, 4 Pillar model, etc.), masterplans, land use regulations

3.6 Protection and expansion of green and open spaces

Vienna has a distinctive framework of green and open spaces, but they are unequally distributed due to different densities and urban structures. Different vegetation characteristics, size and distribution of green and open spaces influence their beneficial climate impact both in the area itself and neighbouring areas.

STEP 2025
Green Space Policy

Norbert Scheed Forest / North-East Vienna Forest

The Green Belt around Vienna is protected to secure green and recreational areas for the fast-growing north-east of Vienna. The project idea is based on three principles:

- *Nature space and habitat for wildlife (biodiversity)*
- *Leisure and recreational areas for people*
- *Long-term protection of city-related agriculture*

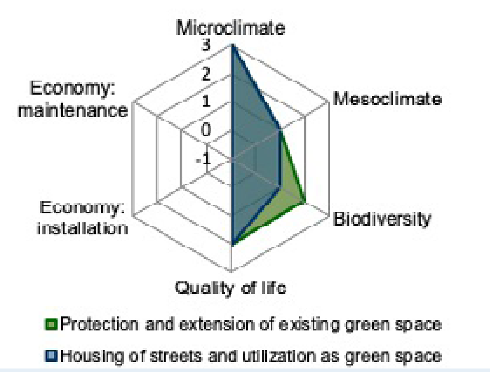
Councillor Ulli Sima: ‚A North-East Vienna Forest would also provide big climate advantages for the city. Everyone would benefit from this new green lung.‘

Objectives of protecting and expanding green and open spaces

- Protecting existing green and open space assets, particularly in the light of growing pressure to develop for urban density, and increasing climate stress
- Protecting agricultural and forestry land
- Beneficial impact on local climate and achieving (significant) cooling, beyond the immediate environment of the green and open spaces
- Increased evaporation and cooling as well as air quality improvement
- Encourage and achieve synergies with strategic objectives of the City of Vienna, such as increasing urban biodiversity and supporting water absorption

Important city-wide actions to achieve these goals

- Conservation and enhancement of green spaces
- Construction of parks
- Protection of existing and planting additional forest land



Spiderweb diagram: *see explanation on p. 25*

Description of action

The preservation, enhancement and expansion of existing urban green and open space infrastructure has been advancing in Vienna for a long time and is helping to improve local microclimates, especially in densely populated areas. The effect on the local climate depends on previous use: if previously it was an agricultural area and is to become a large park in a new urban development area, some small local climate improvement through additional tree planting may occur. Significant improvement happens only when impermeable surfaces are transformed into green space. Existing parks can be adapted to reduce urban heating, for example, by integrating neighbouring streets, selecting resilient tree species (see action on p.44), planting more shade trees especially along transport axes, improving irrigation or shading devices.

Opportunities exist to increase green space assets, by expanding existing parks or extending existing green spaces, as well as developing new opportunities to create urban green space such as closing vehicle traffic routes.

Benefits

- Maintaining and expanding existing green and open space assets for a growing urban population and improving the situation in inner-city areas with below-average access to open space
- Increased water absorption, delayed water run-off
- Increased amenity
- Fine particulate filtration
- Increased urban biodiversity

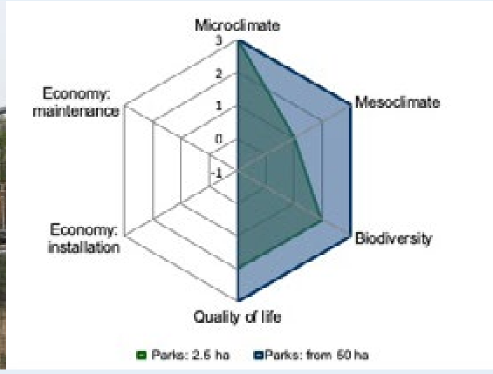
Challenges

- Scarcity of space, and economic attitudes to land use in light of a growing urban population
- Changing vehicle routes to green and open spaces, while desirable from a planning, sociological and climate point of view, has great potential for political and social conflict

Guidance relevant to implementation

Urban Development Plan, Green and Open Space Standards, Land Use and Development Plan, Vienna Open Space Network, competitions and tenders, Playground Policy, Forest Development Plan, Land Use Regulations, Parks Regulations and Policy

3.6.2 Action – Creating parks



Spiderweb diagram: see explanation on p. 25

Description of action

Parks have a beneficial effect on the urban climate, as they promote evaporation with irrigation and heat up less than impermeable areas. Parks have a measurable cooling effect on the urban environment → from around 2.5 hectares. From 10 hectares upwards, around twice the surrounding area will experience beneficial environmental impacts. An even more pronounced climate impact can be felt by parks and green spaces over 40 hectares (some literature is only available from 50 hectares) (Mathey et al., 2011, 38). In contrast to smaller actions, large green areas of 50 hectares or more have a greater effect over distance and also influence the city-wide mesoclimate →.

Whether several larger green and open spaces or many smaller ones are better for the urban climate → cannot be answered with complete certainty. A simulation of Dresden showed that achievable cooling effects are larger for larger areas (in this case 31.5 hectares) than for the same area divided into several small parks (Mathey et al., 2011, 83). This approach has been practiced in Vienna for some time. For economic reasons and to protect sustainable resources, large central parks were the preferred choice when creating policies or masterplans for many urban expansion projects, including Central Station/ Hauptbahnhof, North Station/ Nordbahnhof, Northwest Station/ Nordwestbahnhof and Aspern Seestadt. Some of these parks have been implemented in recent years or are currently under construction, for example Helmut Zilk Park, Bednar Park and Seepark in Aspern Seestadt.

On the other hand, smaller open spaces distributed evenly throughout the city have the advantage that they can be accessed faster and more easily by users, and heat stress can be reduced locally. Fringe impacts – i.e. benefits to neighbouring urban spaces - are also greater. It is therefore important to achieve area-wide greening across neighbourhoods.

The action applies both to urban expansion and development of existing urban space. Development areas close to the city centre which were not previously green space (e.g. railway stations, industrial plants, etc.) are ideal. Temporary UHI-related uses should also be sought for reclaimed brownfield or cleared sites.

Benefits

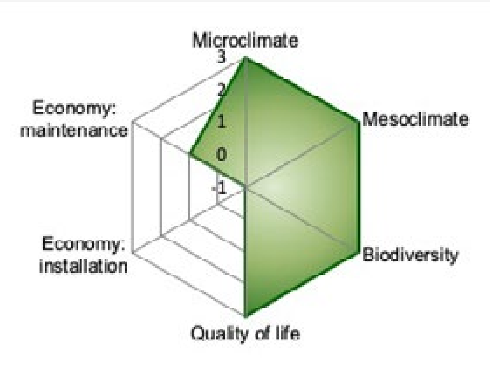
- Creation of new (over-arching) recreation and leisure areas for a growing urban population
- Increasing biodiversity, creating ecological stepping stones for movement
- Intercepting rainwater and reducing the burden on the drainage system

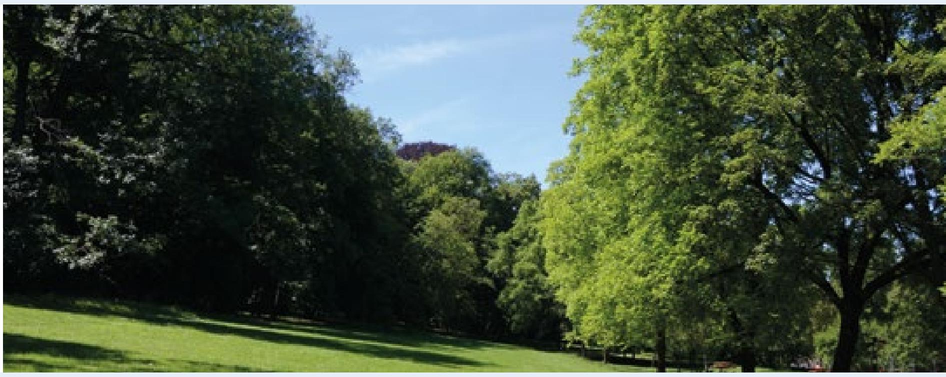
Challenges

- Intense pressure to use dwindling real estate assets to build social and affordable housing presents a key conflict of objectives. However, in view of social and ecological sustainability, creating district-based medium-sized parks in Vienna has also become established as an important asset in urban development.
- Large-scale parks are in competition with the creation of housing in a growing city in terms of availability and usability of land. The creation of new parks by creating traffic flyovers is an option in areas where there is virtually no potential for new parks, but such developments are very expensive.

Guidance relevant to implementation

Urban Development Plan, Green and Open Space Standards, Zoning and Land Use Plan, masterplans, competitions and tenders, Parks Policy, Green Space Regulations





Spiderweb diagram: see explanation on p. 25

Description of action

Forests produce cool air very effectively, contributing to daytime cooling through the slow release of cool air. ‚Forest cooling ranges from 0.6 $m^3/(m^2$ h) to well over 20 $m^3/(m^2$ h)' (Schwab & Steinicke 2003, 28).

Extreme heatwaves rarely occur within forest areas, due to their large extent of shading. Unlike treeless open land, forests are less susceptible to dehydration because trees can tap deeper water supplies than other plants through their extensive root system. Forests also contribute to improving urban air quality through their ability to produce oxygen, store CO_2 and filter the air.

Vienna has about 8,000 hectares of forest. These areas and their tree stock are to be sustainably protected. Careful combining of tree species, mixed-growth control to promote stability and the introduction of natural regeneration all underpin the development of climate-resilient forests.

Creating additional forest areas and extending existing ones can be done by converting fields, meadows and brownfield sites.

Every year, the City of Vienna's Department of Forestry and Agriculture (MA 49) plants new forests. Vienna's forest grows by 50,000-100,000m^2 per year. The new forests improve people's quality of life. They provide a healthy urban climate, are places of recreation and provide new wildlife-rich habitats (MA 49).

Every year, all interested and committed Viennese citizens are invited to take part in the reforestation campaign and help create a new forest.

Benefits

- Creation of new recreational areas and relief of high-quality nature conservation areas (e.g. Lobau)
- Conservation areas for wildlife
- Biodiversity

Challenges

- Competition for space with urban planning aims for urban growth (e.g. land use for residential development); competition with urban agriculture and reducing Vienna's potential for self-sufficiency (e.g. fruit, vegetables)
- Potential conflict with land owners who want to sell at building land prices
- In addition, forest areas should not be created in cool air corridors as they would hinder air flow
- Designating forest function as recreation may reduce its value

Guidance relevant to implementation

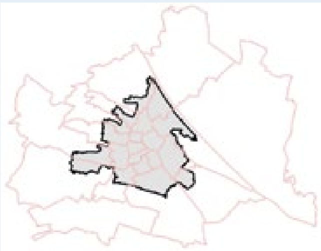
Forestry Act, Nature Conservation Act, Forest Development Plan, Vienna Building Regulations, Air Pollution Regulations, Public Space Policy, Zoning and Development Strategy, various environmental strategies, Hunting Act

3.7 Conservation and expansion of (street) tree stock

Trees have a beneficial impact on urban climate →▤, as they promote evaporation from rainfall and their shaded areas heat up less. As a result, they influence local climate and thus provide important urban cooling. This applies both to trees in urban settings (street trees, park trees, etc.) and to larger wooded areas on the outskirts, which act as sources of cooling. But they are also exposed to various demands. Thus, when selecting tree species, their resilience →▤ to these demands should be considered.

There are around 180,000 trees in Vienna's dense urban core

(Green Space Monitoring MA 22, 2005)



The MA 42 maintains 87,246 public street trees alone

(MA 42, 2013)

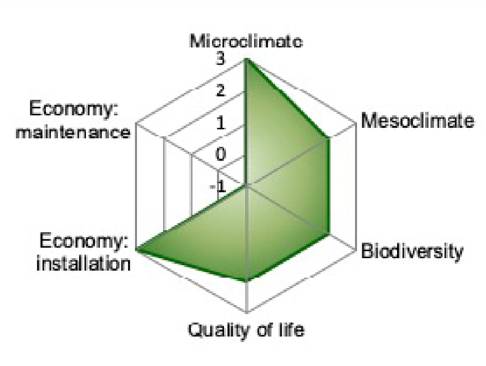
Tree species	Quantity
Maple	25,106
Lime	14,850
Horse Chestnut	10,837
Ash	6,596
Plane	3,515
Ornamental Cherry	3,004
Robinia	2,620
Hornbeam	2,377
Other	18,292
Total number	**87,246**

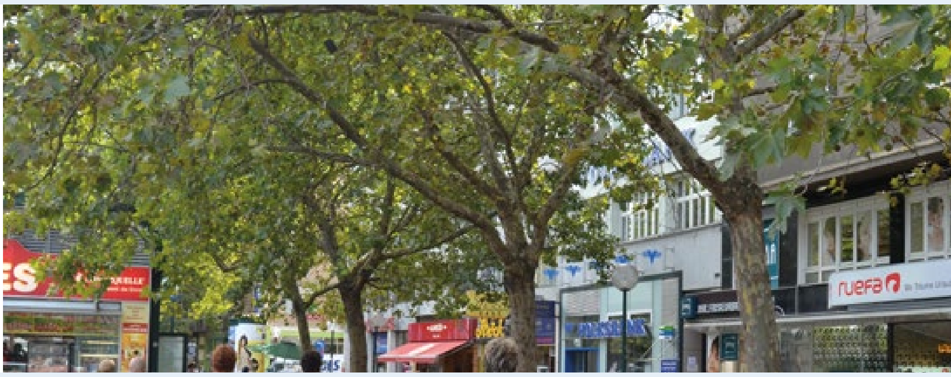
Aims to protect and expand the (street) tree stock

- A sustainable (measurable) protection of current Viennese tree stock; in particular, street trees and trees in parks and housing should be a priority. This includes maintaining or improving tree health through committed care and maintenance actions.
- The aim is to increase the urban tree stock – especially in densely populated urban areas – by planting and expanding tree avenues and tree-lined streets, as well as planting trees in parks, courtyards, green spaces, squares and playgrounds.
- Also relevant is adapting Vienna's tree stock – especially inner-city street trees and amenity trees – to the increasing demands of climate change and increased UHI effect from urban growth. The aim is to create a robust and resilient tree stock.

Important, relevant city-wide actions to achieve these aims

- Protecting Vienna's tree stock
- Selecting appropriate and climate-adapted tree species
- Expanding the tree stock through new tree planting





Spiderweb diagram: see explanation on p. 25

Description of action

Compared to other cities, Vienna has a very large tree stock, playing an important urban climate →▤ role. Protecting the current tree stock is already having a moderate effect on micro and mesoclimates →▤.

Trees in urban areas are exposed to a multitude of anthropogenic impacts and stresses, which in some cases pose extreme challenges to plants, damaging them and often killing them. The most important stress factors for trees are increasingly dry conditions and overheating, due to low substrate (e.g. small tree grates) and increasing vehicle pollution. A weakened immune system often means trees are more vulnerable to pest infestation. Inner-city urban heat islands make this problem worse. Against the background of Venna's growing population, many urban trees are overburdened with increased construction activity or impermeability.

The protection and support of Vienna's tree stock can be helped by more UHI-related maintenance measures, replacement and new planting, and putting irrigation systems and tree protection measures in place. Tree replacement should only be species appropriate to climate and site (see p. 44).

Climate impacts on trees depend very much on their size and health. It is particularly important for trees to reach an optimal age and that this is not overruled by ever-stricter liabilities.

Benefits

- Protecting city districts or public spaces with increased quality of life and amenity
- Maintaining or improving urban climate
- Increasing water retention, delaying water run-off
- Improving biodiversity
- Giving structure to the urban landscape
- Filtration of particulate matter

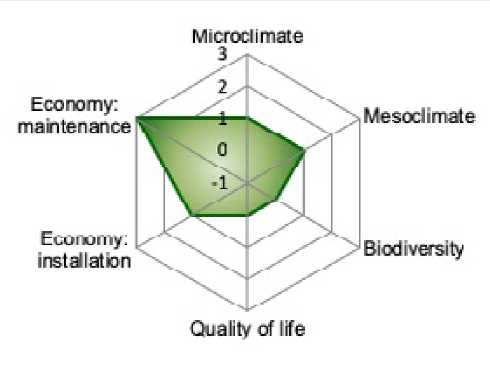
Challenges

- Any construction and urban densification leading to loss of urban trees
- Competing for space with other public space functions and facilities

Guidance relevant to implementation

Forestry Act, Vienna Tree Protection Act, Forest Development Plan, Vienna Building Regulations, Air Pollution Regulations, Land Use and Development Plan, Street Tree Guidelines, Housing Development (4 Pillar model, developer competitions, Vienna Design Advisory Board, Green Field Design Guidelines), Street Café Guidelines, Public Space Policy

3.7.2 Action - Selection of appropriate tree species



Spiderweb diagram: see explanation on p. 25

Description of action

Vienna's climate scenarios are based on rising summer temperatures and lower rainfall, with related burdens increasing the stress on urban trees. To protect and expand the tree stock, drought and heat tolerance should be considered. Selecting and applying resilient, adaptable and especially heat and drought-tolerant tree species for parks, housing estates, tree lines, avenues and all other outdoor areas, as well as in any forestry development. UHI adaptation through tree species selection has a moderate effect on micro- and mesoclimate →, as it improves tree health and resilience. Many tree species used in Vienna's streets or parks or for historical reasons, are only partly meeting these requirements and should therefore be replaced by appropriate trees if they die.

In addition, trees improve an air quality, as they absorb air pollution via the stomata of their leaves. This includes nitrogen oxides, ozone, sulphur dioxide, carbon monoxide and other volatile organic compounds (Matzarakis, no year). Trees lower the air temperature and thus also the potential for ozone to form (Menke et al., 2008). Overall, ozone content tends to reduce with absorption by trees, but some trees also emit volatile organic compounds to varying degrees (see in detail Matzarakis, no year).

Benefits

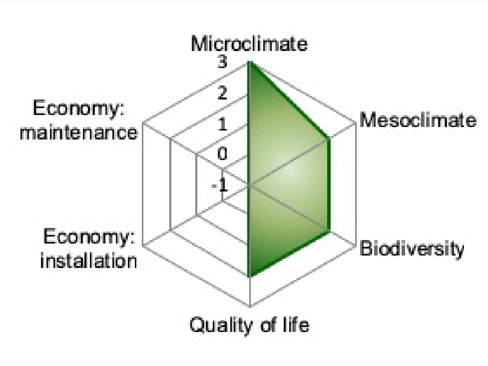
- Protection and improvement of city districts or public spaces with increased quality of life and amenity
- Maintaining or improving urban climate
- Protecting street and park tree stock

Challenges

- Ongoing optimisation of species selection, and also technical training on tree planting is needed to use appropriate trees that can withstand adverse factors such as heat, drought, pests, spatial and historical requirements, as well as meet spatial, climate, cultural-historical, ecological and traffic needs.

Guidance relevant to implementation

Forestry Act, Vienna Tree Protection Act, Forest Development Strategy, Vienna Building Regulations, Air Pollution Regulations, Street Tree Guidelines, MA 42 Street Greening Policy, support for housing development (4 Pillar model, developer competitions, Vienna Design Advisory Board, Green Space Standards), Street Café Guidelines, Public Space Policy, Nature Conservation Act



Spiderweb diagram: see explanation on p. 25

Description of the action

As well as protection, the expansion of the urban tree stock – especially in densely populated inner-city areas – is important for a cooler climate. Particular consideration should be given to implementing and expanding trees lines and avenues along streets and new plantations in parks, green spaces, courtyards, squares and playgrounds, but also creating new forests (see p. 52 onwards for more detail). This increases evaporative cooling and reduces temperatures at street level due to shading.

As well as impacts on temperature, more trees filter more air pollutants such as particulate matter and polluting gases. However, it is important to check the precise selection and arrangement of trees so as not to create a 'tunnel effect', since narrow tree avenues on busy streets can obstruct air flow and thus increase both pollutant concentrations and increased air temperatures due to lack of ventilation (Menke et al., 2008).

Benefits

- Protecting and improving city districts or public spaces with increased quality of life and amenity
- Maintaining or improving urban climate
- Increasing urban biodiversity

Challenges

- Competing with car parking for space
- Restriction of other uses in squares and parks
- Possible unwanted light reduction on lower buildings storeys along streets
- Possible increase in real estate prices due to environmental value
- Increased maintenance and care due to street freeholder liability
- Existing street furniture

Guidance relevant to implementation

Forestry Act, Vienna Tree Protection Act, Forest Development Strategy, Vienna Building Regulations, Air Pollution Regulations on air pollution damaging to forests, Street Tree Guidelines, support for housing development (4 Pillar model, developer competitions, Vienna Land Advisory Board, Green Space Standards), Street Café Guidelines, Public Space Policy, STEP, Land Use Strategy, Nature Conservation Act

4. Practical planning and design actions

Technical measures for climate-sensitive urban planning include practical technical and structural approaches to reduce heat stress in the city. These happen at a practical project planning level and enable UHI-relevant design and planning of public open spaces and buildings. Vienna's planning process started adopting some of these practical actions some time ago. However, there is still a need to develop, including awareness of how to combine actions for more impact. However, it should also be noted that combining actions can also create counterproductive situations, such as trees planted in narrow streets obstructing air flow or daylight reduction along neighbouring façades.

However, the actual effects of actions on climate are often difficult to assess without technical modelling. There are simulation tools that can help planning processes at different scales in the future, after an appropriate development phase. One focus will be protecting and developing green → and blue → infrastructure. The actions proposed serve primarily to increase outdoor amenity and include street greening, provision of drinking water and water features, as well as active and passive cooling of buildings. Adequate shade and seating in open spaces, as well as cooling public transport and associated traffic facilities can also increase wellbeing on hot days.

Chapter 3.1 explains in detail the methods and approaches used to develop, describe and assess each action. When assessing individual actions (see the spiderweb diagrams), it should be noted these assessments (microclimate, mesoclimate, costs, etc.) relate only to individual project level.

4.1 Overview and comparison of actions

4.2 Increasing greening in streets and open spaces

Green infrastructure such as street greening, greening courtyards and brownfield sites, are important components of the city and help reduce the urban heat island effect. One of the benefits of plants is shading the ground and building façades and evapotranspiration. Irrigated plants have higher evaporative capacity. Below large-canopy trees, ground surfaces heat up less and therefore release less heat back into the environment at night. Other benefits include water absorption, absorption of carbon dioxide and particulates, and increasing urban biodiversity.

Aims of increasing greening in streets and open spaces

- Improving the microclimate
- Increasing evaporation and cooling and improving air quality
- Attractiveness of the cityscape
- Encouraging and delivering synergies with the City of Vienna's strategic objectives, such as increasing urban biodiversity and increasing water absorption

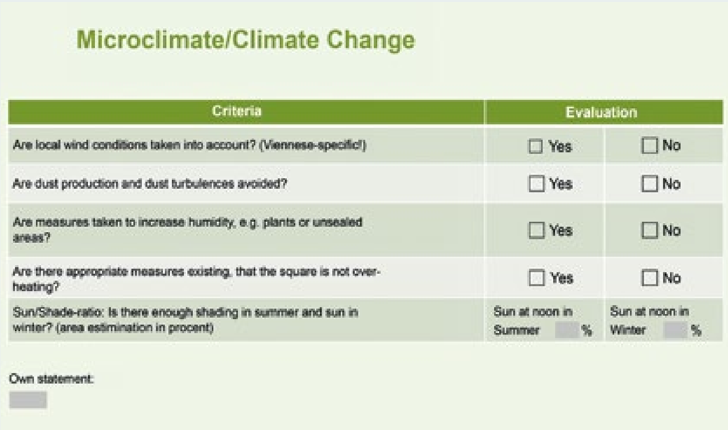
Actions particularly suited to achieving these aims

- Street greening: single or double-sided avenue
- Street greening: single trees
- Street greening: hedgerows
- Street greening: grassland and meadow areas
- Allowing spontaneous greening
- Small-scale greening such as courtyard greening
- (Temporary) use of urban brownfield sites
- Green walls
- Mobile greening

Guidelines and Checklist for Sustainable Urban Space (MA 22)

The checklist makes it easier to plan and design urban spaces. It serves as a decision-making tool for competitions juries, magistrates, district politicians, architects, planners, project teams, area administrations and interested members of the public. An important component of the checklist is the Microclimate/Climate Change chapter.

The guide gives important information such as requirements for tree planting, appropriate tree species and an excerpt from the checklist, Green Space Quality Categories for Sustainable Urban Space (MA 22 2011).



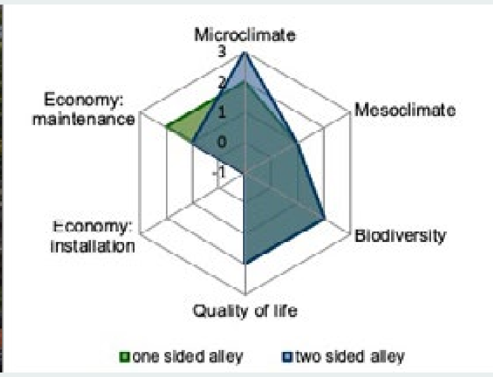
Microclimate/Climate Change

Criteria	Evaluation	
Are local wind conditions taken into account? (Viennese-specific!)	☐ Yes	☐ No
Are dust production and dust turbulences avoided?	☐ Yes	☐ No
Are measures taken to increase humidity, e.g. plants or unsealed areas?	☐ Yes	☐ No
Are there appropriate measures existing, that the square is not over-heating?	☐ Yes	☐ No
Sun/Shade-ratio: Is there enough shading in summer and sun in winter? (area estimination in procent)	Sun at noon in Summer %	Sun at noon in Winter %

Own statement:

Part of the checklist for Sustainable Urban Space

4.2.1 Action – Street greening: single or double-sided avenue



Spiderweb diagram: see explanation on p. 25

Description of action

This action consists of three variants: a street with deciduous trees forming a double-sided avenue, an avenue with trees planted on only one side of the street, or an avenue down the middle of the street.

Trees can reduce street heating. The shaded area under the trees heats up less, shaded surfaces store less heat and night-time radiation is reduced. Climate impact is based on 80% shading and 20% transpiration →▤ (Shashua-Bar & Hoffman 2000, 234). The literature gives the daily evaporation rate of a tree (e.g. beech or lime tree) as 500 litres of water and the increase in relative humidity from 30% to 60%; heat absorption is 300,000 kcal (Ermer et al 1996 in Mathey et al. 2011). Modelling shows the air directly under the trees is cooler by up to 10°C, and even in surrounding areas temperatures can be up to 3°C lower (Brandl et al. 2011). Climate impact comes from the size of the canopy, which is why primarily large-canopy, tall deciduous trees should be used (Kuttler 2011). The action's effectiveness thus depends on the age of the trees. Furthermore, choosing the right location is important, as well as which side of the street the trees are planted (see action 3.4.1 p. 35; Kuttler 2011). The microclimate →▤ is improved for single and double-sided avenues.

All variants of this action cause a slight improvement of the mesoclimate →▤ in the planting area.

If there is already street furniture in the planting area and an automatic irrigation system is planned, then installation costs can be very high. Maintenance costs for a single-sided avenue or central avenue are considered low, and medium for a double-sided avenue. The site criteria and estimated costs for construction, maintenance and technical requirements of the trees would be coordinated with Vienna City Gardens Department.

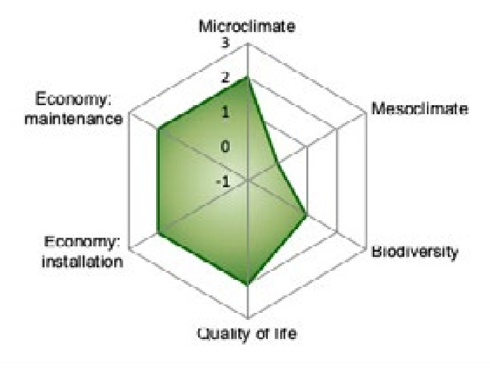
The MA 42 tree register, publicly available online, currently contains around 100,000 trees in public spaces. Maintaining and expanding avenues where possible is a priority. Avenues are generally protected under the Vienna Nature Conservation Act; special protection status is granted to avenues which are protected by law as a natural monument.

Benefits

- Increased water absorption, delayed water run-off
- Positive impact on biodiversity
- Helps to structure the urban landscape
- Increased amenity
- Filtering particulate matter
- Reduction of wind speed
- Pleasant daylight conditions in shaded areas

Challenges

- Tree planting in streets with built-in components such as water/power lines is difficult and expensive
- Streets are an extreme location for plants (pollutants, lack of water) so plant selection is important, also because of predicted temperature increases
- Obstruction of fresh and cool air flow
- Possible obstruction of ventilation and concentration of air pollutants (vehicle emissions) in double-sided avenues – avoid closed canopies (Kuttler, 2011); night-time cooling may also be prevented with dense crown closure (Bongardt, 2006 in Mathey et al., 2011)
- Lack of space (including distance from façades)
- Awareness-raising and knowledge of planners needed
- Security checks to comply with right-of-way holder liability
- Preserving airspace profile
- Competition with vehicle parking
- Soil compaction in tree grates because of vehicle parking, use of tree grates for route relocation
- Unintentional shading of buildings



Spiderweb diagram: see explanation on p. 25

Description of action

This action is suited to locations where planting only individual trees is possible because of street furniture or a narrow street intersection.

Even individual trees can play an important role in local street climate. Shaded space under trees heats up less and the amenity of street open space is more pleasant. Large-canopy trees have a stronger micro-climate effect. The specific impacts of tree planting are described in detail on p. 44 – it should be noted however that the impact of individual trees is much smaller than of tree groups or avenues.

This action does improve microclimate → and mesoclimate → but has only a minor impact.

Construction and maintenance costs are considered low. However, the presence of existing street furniture and the need for irrigation systems can increase costs.

Depending on the location, a single tree may have greater significance for the inhabitants than its climate impact alone would suggest, such as on small squares or at the entrance to public facilities.

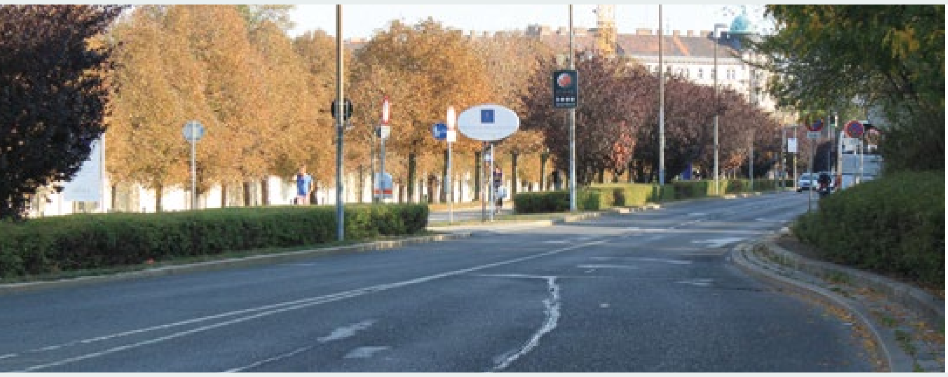
Benefits

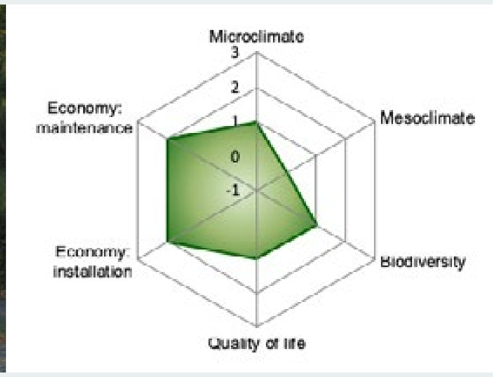
- Increased water absorption, delayed water run-off
- Positive impact on biodiversity
- Helps to structure the urban landscape
- Time spent in open streetscapes under trees will be more enjoyable
- Filtering particulate matter
- Reduction of wind speed
- Pleasant daylighting conditions in shaded areas

Challenges

- Tree planting in streets with built-in components such as water/power lines is difficult and expensive
- Streets are an extreme location for plants (pollutants, lack of water) so plant selection is important, also because of predicted temperature increases
- Obstruction of fresh and cool air flow
- Lack of space (including distance from façades)
- Awareness-raising and knowledge of planners needed
- Security checks to comply with right-of-way holder liability
- Preserving airspace profile
- Competition with vehicle parking
- Soil compaction in tree grates because of vehicle parking, use of tree grates for route relocation
- Unintentional shading of buildings

4.2.3 Action – Street greening: hedgerows





Spiderweb diagram: see explanation on p. 25

Description of action

This action relates to planting rows of shrubs or hedges along streets. General conditions in the urban realm (e.g. existing installations such as electricity or gas pipes) can often mean planting trees is impossible, difficult or costly. Shrubs, rows of shrubs or hedges can be an alternative to trees. Shrubs also provide benefits similar to trees, including shading, increased evaporation, water absorption and air quality improvement, just not to the same extent. If shrubs must be removed for example to repair street furniture, it is easier than trees, as shrubs are faster and cheaper to replace. But maintenance is more expensive.

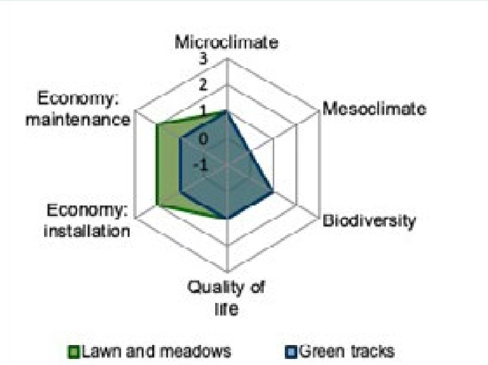
This action leads to a slight improvement in microclimate →, but the impact on mesoclimate → is negligible.

Benefits

- Increased water absorption, delayed water run-off
- Positive impact on biodiversity
- Urban design aspects

Challenges

- Streets are an extreme location for plants (pollutants, lack of water) so plant selection is important, also because of predicted temperature increases
- Maintenance, littering, especially for ground cover
- Maintenance measures such as hedge trimming often difficult because of moving and stationary traffic
- Awareness-raising and knowledge of planners needed
- Competition with vehicle parking
- Lack of space (e.g. distance of planting from façades)
- Visual obstruction to parallel foot or cycle paths



Spiderweb diagram: see explanation on p. 25

Description of action

Grass or meadow street verges should be at least 2m or wider to have an impact on climate. The greening of railway lines is another possibility and can be implemented in several ways.

Grass verges must be maintained and watered to maintain their climate function during dry periods in summer. Creating extensive meadows is preferred where possible. Meadow maintenance with twice-yearly mowing is less than for intensively managed grass lawns. Similarly, reducing mowing creates higher biodiversity and thus also increases amenity for passers-by.

Because of existing installations (gas, power lines, etc.) it is often impossible to plant trees or shrubs. Creating lawns or meadow areas is an alternative in such places. When grass or meadow verges are used instead of impermeable surfaces, daytime surface warming is reduced as well as night-time radiation. Since there is no shading on grass verges, evapotranspiration →▤ is the main climate benefit if soil and vegetation are humid enough (Kuttler 2011).

Tram tracks can be greened using grass or sedum in a substrate or by vegetation mats laid directly in the track bed. Greened tracks have a climate benefit: for example, water evaporates releasing evaporative cooling, the soil surface is shielded from direct sunlight, and the green areas heat up less than asphalt and cool off more at night. In addition, 90% of precipitation that falls on track greening is absorbed by it – in theory every m² of greened track helps cool 44,000m³ of air by 10 Kelvin through evaporative cooling (Grüngleisnetzwerk o.f. (no year)).

This action leads to a slight improvement in microclimate →▤ but benefits to the mesoclimate →▤ are negligible.

On grass or meadow surfaces along streets, greened tram or rail tracks, clearing up litter is a little more complicated than on impermeable surfaces. Sometimes inhabitants consider nature-based green spaces neglected or expect a 'golf course' lawn. However, this changes as soon as neighbours are made aware of the natural management of green areas or even participate in maintenance work themselves. The nature-based Margaret Meadow in the 5th District is a particularly successful example, has been working for several years and is welcomed by residents.

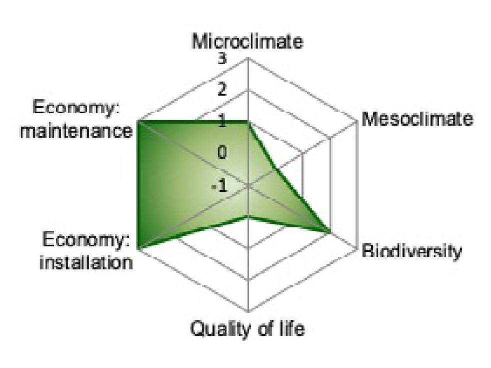
Benefits

- Increased water absorption, delayed water run-off
- Positive impact on biodiversity
- Urban design aspects
- Track greening: noise reduction
- Pollution reduction

Challenges

- Streets present extreme climate conditions for plants – in the case of species composition
- Maintenance, irrigation and cleaning
- Competition with vehicle parking
- Awareness-raising and knowledge of planners needed

4.2.5 Action - Allowing unplanned greening



Spiderweb diagram: see explanation on p. 25

Description of action

Unplanned greening refers to vegetation that evolves naturally, including plants growing from cracks in the stone or asphalt, as well as plants in larger areas such as vacant sites.

For unplanned greening to happen, any heavily-sealed surfaces must be broken up and removed and seeds planted to accelerate greening. As earth is shaded by planting, it does not heat up as much as hard surfaces and thus does not release so much heat overnight. These areas are not irrigated in summer; at high temperatures they risk drying up, meaning reduced climate benefits.

Only limited implementation of trees species is possible on such sites, for example tree which over time achieve protected status under tree protection law. It may also be unclear how long a site will be vacant and how long any unplanned greening will have to become established. In Vienna, the average time sites stand vacant is only around one to two years. This action is deemed to have low impact on microclimate →, negligible impact on mesoclimate →.

Benefits

- Increased water absorption and delayed run-off
- Positive impact on biodiversity - refuge for rare species of flora and fauna

Challenges

- Spontaneous vegetation is sometimes associated with 'untidiness' or 'messy nature', but information, for example an information board on site, may help residents recognise the particular value of such area
- Unwanted use of the land, for example illegal dumping
- Information and awareness-raising measures necessary to increase acceptance
- Invasive plant species can occur or dominate, for example harmful species such as common ragweed *(Ambrosia artemisiifolia)* or giant hogweed *(Heracleum mantegazzianum)*
- Long-term vacancy may mean trees become protected under the Tree Protection Act (Note: refers to trees with a trunk circumference of at least 40cm, measured at 1m height from where root branching starts, and also includes their above and below-ground habitat §1 Vienna Tree Protection Act)
- Lack of space for this action, due to high development pressure on such sites

Spiderweb diagram: see explanation on p. 25

Description of action

The intention is to create intensified (small-scale) green areas as well as unsealed areas for example in inner courtyards and backyards of Wilhelminia-style/ turn-of-the-century buildings.

Inner courtyards can improve the microclimate →▤ as well as residents' quality of life. Courtyard layout is very importance here, as measurements showed large temperature differences between greened and un-greened courtyards. Trees are particularly beneficial – by shading surfaces and façades, and through evaporative cooling. It is not possible to plant trees in all courtyards or backyards, for example if underground garages or other structures are present, in which case mature shrubs or mobile greening can be an alternative.

Results of Vienna Technical University's ZIT Urban Summer Comfort project showed that greening inner courtyards can reduce night-time temperatures as well as lowering temperature peaks during the day. Other influential factors are density of vegetation, type of yard, construction (open or enclosed) and size. For example, measurements during the project of boutique hotel Stadthalle's green courtyard in Vienna showed that a combination of intensive greening and a three-sided courtyard is favourable for the climate (report by Dr. Azra Korjenic, Vienna Technical University, 2014).

As stated, the effectiveness of this measure depends on several factors; however, it improves the microclimate →▤, while its influence on the mesoclimate →▤ is negligible.

Public acceptance of courtyard greening is very high. This is evidenced by numerous green courtyard applications for an MA 22 'natural green oases' plaque. In recent years, around 30 courtyards have been awarded this badge for design and maintenance that meets specific ecological criteria..

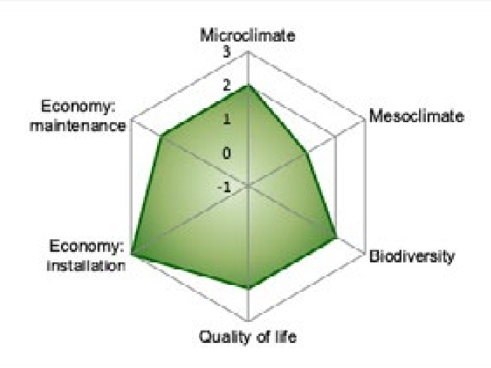
Benefits

- Increased water absorption, delayed run-off
- Positive impact on biodiversity
- Improved quality of life
- Leisure and recreation space
- Privacy
- By combining backyards, creating large-scale semi-public green space

Challenges

- Implementation and maintenance costs must be borne by owners, but there are public sector subsidies
- Different interests of tenants and owners
- Viennese building regulations require a tree to be planted in gardens over 250m²
- Unintended shading of buildings

4.2.7 Action – (Temporary) use of urban brownfield sites



Spiderweb diagram: see explanation on p. 25

Description of action

This measure comprises two variations: using urban brownfield sites for (temporary) purposes, especially climate resilience and adaptation; and creating temporary green space on brownfield sites, for example neighbourhood gardens.

This action differs from the previous action, allowing for unplanned greening, in that more of these rather large (public) areas are available, no longer being used for their original purpose. Another climate-related difference to unplanned greening is the partial irrigation of plants for example, by 'urban gardening'. Climate benefits can result, including shading by trees or vegetation and evaporation, depending on how these sites are designed.

Brownfield sites or vacant lots can be used for different (temporary) purposes: for example, inner-city brownfield sites can be turned into low-maintenance green space or 'urban wilderness'.

How long such sites remain vacant depends on factors such as development interest or soil contamination.

Brownfield sites tend to only impact on climate from around one hectare upwards, reducing temperatures and playing an important ventilation role (Puschner, no year).

Brownfield sites are sometimes considered 'untidy' or 'messy nature'. With appropriate information, such as information panels at the site residents can be made aware of the value of such places.

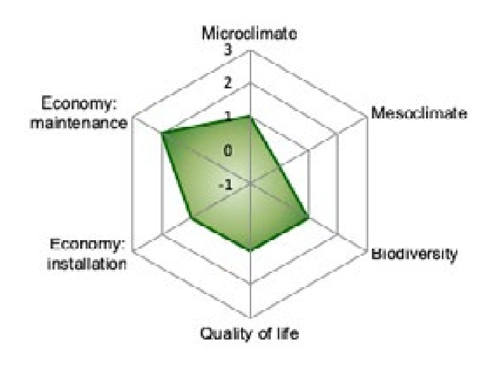
Further information on such areas can be found for example in the 'Gstettenführer'/'Wild Guides' from Vienna's Environmental Ombudsman's Office, or in the MA 22 report 'Growing wild – understanding its value'.

Benefits

- Increased water absorption, delayed run-off
- Positive impact on biodiversity
- Action can support social objectives like neighbourhood gardens
- Additional usable green spaces in the city and residential areas
- Space for ever-increasing demand for 'pick your own' crops
- Mobile greening

Challenges

- Clear communication needed about the period of temporary use
- Rehabilitation after period expires may be necessary
- Liability issues
- Site development pressures



Spiderweb diagram: see explanation on p. 25

Description of action

This action can be implemented in several ways: green walls covered in vegetation, free-standing walls that can support trees growing on the top of the wall, or green walls such as those used as acoustic barriers.

Green walls can be up to 30m long and around 2-3m high, free-standing wall elements with a net green area of about 200m^2 (Eisenberg, 2013). The action impacts are evaporation and shading of surfaces and façades, thus reducing building surface heating and night-time heat radiation.

Greened walls can be used for acoustic protection. They can be implemented and planted in a range of ways. To achieve high-quality acoustic insulation, an acoustic engineer should be involved in the planning process.

This action creates a slight improvement in the microclimate →, while effects on the mesoclimate → are negligible.

Benefits

- Can serve as connecting elements between existing green spaces, for example green walls connecting two parks
- Opportunity for design in the urban realm
- Positive impact on biodiversity
- Positive air quality impacts and possible acoustic protection
- Privacy

Challenges

- Maintenance and irrigation
- Some green walls need contact with the soil so that plants can find nutrients and water after initial maintenance
- Little testing of green walls regarding maintenance, effectiveness, durability, etc.
- Wall elements attached or removable for wall maintenance

Spiderweb diagram: see explanation on p. 25

Description of action

This action uses planters to green open spaces (public streets, squares, etc.).

Due to general conditions in the urban realm (e.g. existing installations such as electricity or gas pipes), tree planting is often impossible, difficult or costly. Mobile greening – i.e. trees, shrubs or herbaceous plants in planters – can be an alternative to planting in the ground. Benefits from shading and thus on the microclimate → depend on plant size, and evaporation performance. As there is no contact with the ground, intensive maintenance and irrigation are required.

This action improves the microclimate → a little but effects on the mesoclimate → are negligible.

Mobile greening is highly valued by residents, and in some cases mobile green spaces are maintained by private individuals, or by businesses on commercial streets.

Benefits

- Urban design aspec
- Temporary, implementable anywhere
- Increased water absorption, delayed run-off
- Positive impact on biodiversity

Challenges

- High maintenance
- Streets are an extreme location for plants (pollutants, lack of water) so plant selection is important, also because of predicted temperature increases
- Frost protection necessary
- Contamination with litter
- Competition with parking space
- Lack of space, narrowing pedestrian access
- Visual obstruction for traffic
- Vandalism

4.3 Greening and cooling of buildings

High temperatures in buildings can be reduced primarily through the following strategies: (1) reduction of solar radiation, (2) prevention of heat storage, and (3) removal of solar gains. Both active cooling systems such as ground-source cooling technologies, solar cooling, etc. and passive cooling methods such as thermal insulation, night-time ventilation or water-based cooling can be used.

Green roofs and façades play a special role, as they reduce summer heating of building surfaces without energy demand. They also improve ambient temperatures through evaporative cooling. In addition, they can help increase urban biodiversity and improve air quality.

Aims of greening and cooling of building

- Improves microclimate
- Increases evaporation and cooling and improves air quality
- Supports environmentally-friendly and passive cooling methods and thus indirect climate benefits
- Supports and achieves synergies with City of Vienna's strategic objectives, such as increasing urban biodiversity and improving water absorption
- Attractiveness of the cityscape

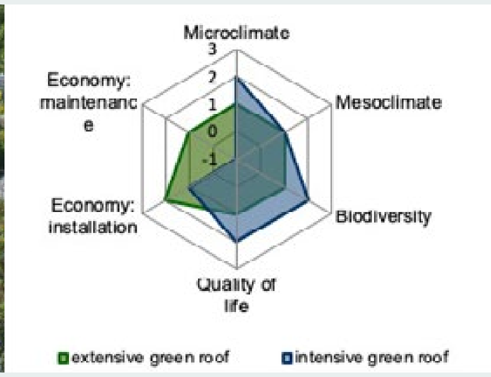
Actions particularly suited to achieving these aims

- Green roof
- Greening façades
- Active and passive building cooling
- Water-based building cooling

Greening Façades Guidelines (MA 22)

This guide helps architects, planners, private individuals, property developers, public institutions and tradespeople to plan and implement façade greening. It gives information on plant species, vegetation engineering basics and legal guidance and standards. The benefits of greening façades on the microclimate are also explained (MA 22, 2013).

4.3.1 Action – Green roofs



Spiderweb diagram: see explanation on p. 25

Description of action

This action includes intensive and extensive green roofs, whose main difference is depth of substrate. However, there are also several intermediate types between extensive and intensive green roofs.

In extensive green roofs, the depth of substrate is about 15cm, planting is usually done with hardy, low-growing plants (e.g. sedums). Extensive green roofs are usually lightweight and are therefore appropriate for many roofs, seldom requiring any structural alteration. Extensive green roofs are low-maintenance but are not appropriate as accessible green roofs.

By contrast, intensive green roofs are characterized by greater depth of substrate and use of grasses, shrubs and trees as planting. However, this means additional structural loading. Intensive green roofs are usually accessible and usable spaces. Both intensive and extensive green roofs should be implemented on all appropriate roofs.

This action reduces the increase in building surface and air temperatures in the immediate vicinity of the green roof. Retaining surface water runoff leads to evapotranspiration → and evaporative cooling. Reduced surface heating reduces night-time heat radiation too. A comparison of different roof coverings shows that black roofing felt reaches the highest temperatures (up to 90°C), light-coloured dry gravel or light-coloured paint significantly reduce temperatures (reduce radiation temperatures by up to 35°C) and planted and well-watered substrates achieve the best results (15°C greater reduction than light-coloured surfaces) (Kuttler 2011). Extensive green roofs improve -microclimate → slightly intensive green roofs improve microclimate → measurably. Both intensive and extensive green roofs achieve a slight improvement in mesoclimate →, when all appropriate roofs on a block are greened. Industrial and commercial buildings are also often suitable for extensive or intensive green roofs.

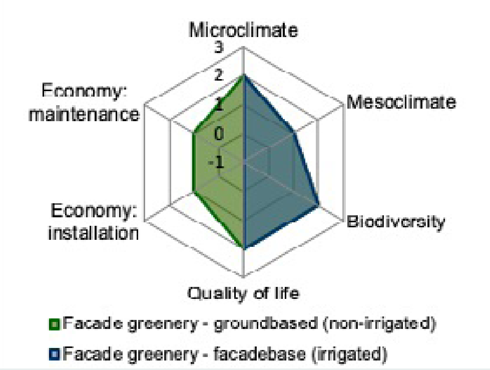
Detailed green roof requirements are usually defined in development strategies. Excluded are buildings where green roofs are difficult or impossible to achieve for technical reasons, conservation areas or roof areas required for lighting, technical installations or roof terraces.

Benefits

- Protects and extends the life of a roof's waterproofing by giving mechanical protection and absorbing UV radiation
- Evaporation of stored rainwater can improve internal climates in summer in rooms directly beneath the green roof
- Reduced burden on urban drainage and sewage treatment plants through rainwater retention
- Improve air quality by absorbing particulate matter
- Replacement habitats for animal and plant species
- Cityscape design
- Creating additional open space for citizens
- Benefits for photovoltaic systems due to cooling effect of green roofs

Challenges

- Conflicting aims: areas suitable for intensive/extensive green roofs are also often appropriate for photovoltaic systems; to avoid problems, integrated planning is recommended
- Occasionally high construction costs
- Maintenance costs depending on green roof plant selection
- Heritage conservation



Spiderweb diagram: see explanation on p. 25

Description of action

This measure includes both ground-based, non-irrigated green façades as well as façade-fixed, irrigated options such as flat systems or with planters fixed to the façade. A variety of plant species are appropriate for greening façades, and a trellis or plant framework may or may not be needed, depending on the system used. It should be noted that weak, cracked or curtain wall façades and plastic-based wall finishes and plasters are not appropriate for free-draining planting.

Building surface and air temperatures in the immediate vicinity of the green façade are reduced. In addition, buildings heat up less in summer and the façade's vegetation also acts as a natural air conditioner. Greening house walls modulates temperature peaks, as it gives additional thermal insulation, and has benefits even in cool periods (MA 22, 2013).

This action improves microclimate →▤ and also slightly improves the mesoclimate →▤. Construction and maintenance costs are classed as medium for ground-based greening and high for façade-fixed systems.

MA 22 is constantly working to improve knowledge about façade greening. Extensive information programs, establishment of an environmental consultancy service, launching grants for façade greening and lastly subsidising numerous pilot projects have increased public acceptance for this action.

Preconditions have been set for greening façades at zoning and development planning levels – for example, the proportion of a façade's surface area, keeping vegetated surfaces free, etc. (see also p. 90).

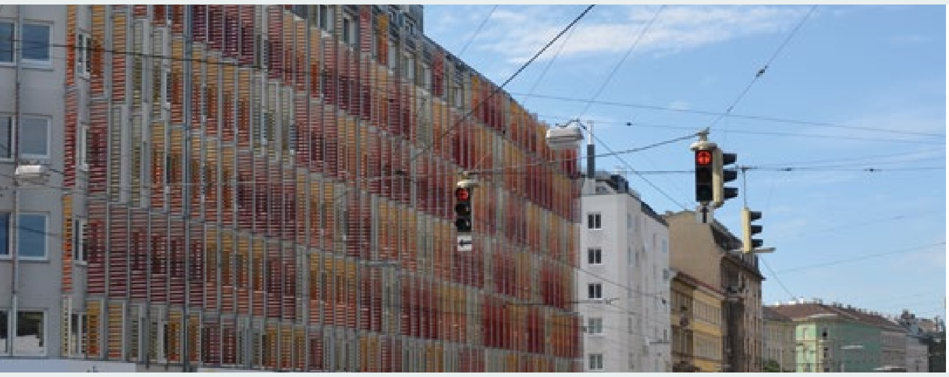
Benefits

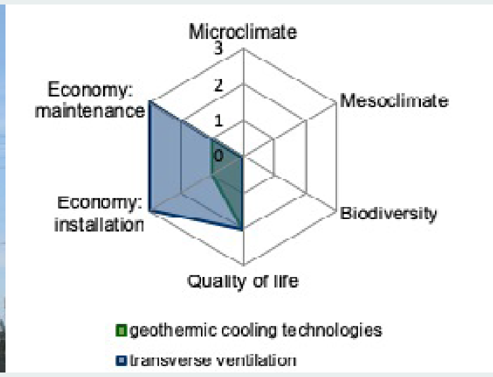
- Thermal insulation
- Air quality improvement, pollutant filter
- Benefits for biodiversity
- Promotes wellbeing and amenity
- Noise reduction (especially reduction of echo effects e.g. in courtyards)
- Protection and enhancement of the building fabric
- Benefits photovoltaic systems due to the cooling effect of façade greening

Challenges

- Need regular maintenance and inspection
- Conflicting aims: surfaces suitable for façade greening are also often appropriate for photovoltaic systems - façade greening and photovoltaic systems can easily be combined; integrated planning is recommended to avoid problems
- Heritage conservation
- Irrigation in non-earth-based façade greening

4.3.3 Action – Active and passive building cooling





Spiderweb diagram: see explanation on p. 25

Description of action

On hot days, the air conditioning is switched on. However, this type of building cooling demands high energy consumption. Avoiding buildings overheating in summer saves energy and is sustainable, for example through appropriate architectural solutions and passive building cooling approaches. Passive building cooling such as cross-ventilation and night ventilation, the cooling potential of outside space can be exploited with little or no technical input. Other passive measures include thermal insulation or thermal refurbishment as well as shading devices on buildings (exterior shading devices such as external roller blinds or sliding shutters, as well as shading roof surfaces for solar cooling for example with photovoltaic systems). Reducing the proportion of glazing and glass on a façade reduces the thermal input into the interior of the building and reflected radiation.

By contrast, there are alternative 'active' cooling technologies that should only be used if passive cooling is insufficient or not possible. Active cooling technologies include controlled domestic ventilation (mechanical ventilation systems), solar cooling (solar thermal systems for winter heating and summer cooling), ground-source cooling ventilation systems, geothermal cooling technologies and thermal mass activation such as concrete core activation. None of the action options mentioned above have any effect on the micro- or mesoclimate →, to improve people's wellbeing or quality of life. Construction and maintenance costs of active or passive building cooling can only be assessed at an individual project level due to the different approaches.

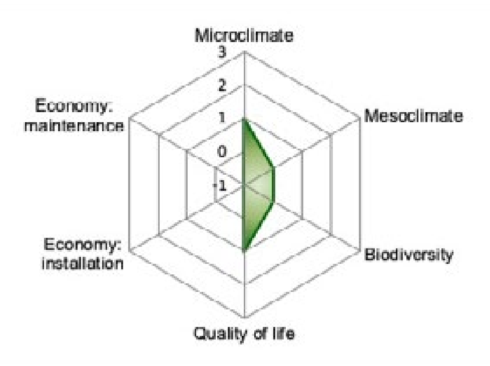
When using cooling technologies, it is important to avoid negative impacts on climate protection (AustroClim 2010) and conventional active air-conditioning should be avoided as much as possible. Shading roof areas with photovoltaic systems for example can also generate energy and reduce building heating, with building occupants benefitting from both. External shading devices on buildings are also often used by residents to reduce heating in living spaces.

Benefits

- Improves people's wellbeing
- Reduces the risk of bird strike by reducing glazing and glass surfaces. Exterior blinds, elements with metal or wooden slats (maximum 10-15cm spacing) also provide good protection against bird strike
- Lower energy consumption and heat output through reduced use of air-conditioning systems
- Energy generation through photovoltaic systems
- Better blackout options at night

Challenges

- Primary groundwork to implement this action should already have taken place in planning stages. Architects and energy consultants are needed to assess options to use external cooling to reduce building heating
- Any potential cooling needs should be thoroughly assessed and evaluated during planning stages and alternative cooling options should be considered
- Target for new construction: no additional conventional cooling should be necessary
- Air-conditioning systems create urban design and local climate challenges (waste heat, noise, etc.)
- District cooling: high energy efficiency, needs infrastructure
- Reducing glazing may contradict the desire for bright rooms
- Heritage conservation



Spiderweb diagram: see explanation on p. 25

Description of action

Much of the direct heat input into buildings comes through the roof, especially with poor insulation. The use of evaporative cooling (adiabatic cooling) is an alternative to complex cooling systems such as air-conditioning systems. So-called 'blue roofs' are a relatively new measure and are appropriate for areas where the climate is warm but not very humid. They usually have two impacts: benefit to microclimate through evaporative cooling and thermal storage, and the retention of water in heavy rainfall events. The term blue roof summarises various technical measures in which rainwater is stored on buildings either as an open water feature, or in or under permeable or other finishes. These actions are not currently widely known about or used in Europe, while in the United States numerous roofs have already been fitted with blue roofs.

Two primary methods exist for the technical implementation of roofs with water cooling or blue roofs. Some systems collect water between two layers of insulating material. At night in summer, the insulated roof-panel is opened and the water absorbs the night cooling – during the day, the cover is closed and the stored night-time cooling is delivered to the building. The process is reversed in winter (Stein & Reynolds 2000 quoted in: Keith 2010).

The second approach stores rainwater in permeable surfaces or – most commonly – in ballast. These blue roofs also serve to capture and slowly drain rainwater during heavy rainfall events. Due to evaporative cooling and a high albedo – if the pools are designed with light colours – they can also have a cooling effect. Costs of a blue roof are lower than for green roofs, but ecological benefits are less marked. Blue roofs are often combined with green roofs. In addition to water absorption benefits in heavy rainfall events and reducing roof surface heating, water aspects can be creatively integrated into green roofs to combine the advantages of both methods.

Water cooling can also be used in buildings in other ways. These include PECW (Passive evaporate cooling walls), a porous ceramic wall standing in water, cooling the environment by evaporating the water. These PECWs can be used in buildings as well as in various urban open spaces such as in squares, at bus stops and so on, or in semi-open spaces like terraces (He & Hoyano 2011). Another way to use water cooling for buildings are so-called water walls. Here, the rainwater collected on the roof is drained through pipes, vertical cooling surfaces (closed or open) over the walls, absorbing heat (this method can also be used for power generation (Keith 2010)).

Also, roof misting can be used, in combination with blue roofs or fed by water tanks. This water cooling approach sprays water on the roofs overnight cooling them, and evaporative cooling takes place during the day.

Benefits

- Water absorption during heavy rain events
- Can be combined with green roofs
- Water walls can also contribute to energy generation

Challenges

- Technology previously uncommon – fear of leaks by architects and clients

4.4 Increasing the amount of water in the city

Providing drinking water

There are over 900 drinking water fountains in Vienna, mainly in parks, playgrounds and markets. In addition, in summer eight mobile drinking fountains in high traffic locations such as Heldenplatz or in Rathausplatz. The locations of all drinking water fountains can be easily accessed on the digital city map of Vienna https://www.wien.gv.at/stadtplan/.

Water is not only vital for the whole living environment and thus also for the human organism; water in the public realm also contributes to human wellbeing and has a cooling effect on the environment at high temperatures, depending on its scale. The proportion of water in Vienna can be increased through many different measures: more water features in the public realm (e.g. drinking water fountains, spray mist, splash pads, fountains, hydrants with spray nozzles), water playgrounds, water bodies in parks, rivers and through integrated rainwater management.

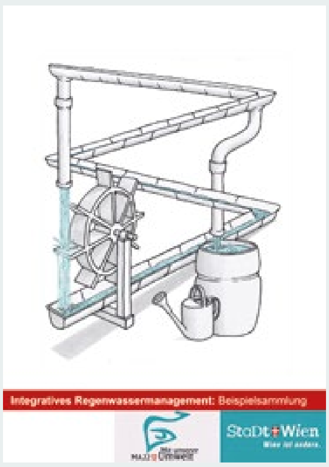
Water bodies create a cooling effect because the energy required for evaporation from the surface of the water is taken from the surrounding air. This energy demand is provided for by warm air released from the environment (Mathey et al. 2011). Moving water (e.g. fountains) generally contributes more to evaporative cooling than standing water bodies. Running water may also be an important ventilation corridor, depending on its location relative to prevailing winds (Mathey et al. 2011).

Aims of increasing the amount of water in the city

- Increasing the quality of outdoor liveability on hot days
- Increasing the attractiveness of urban open spaces (especially for children)
- Increasing evaporation and cooling as well as improving air quality
- Supports and achieves synergies with City of Vienna's strategic objectives, such as increasing urban biodiversity and improving water absorption

Actions particularly suited to achieving these aims

- Irrigation and rainwater management
- Permeability and rainwater management
- Creation of more water installations
- Provision of drinking water
- Increase in the proportion of water bodies
- Opening up/daylighting piped water channels



Integrated Rainwater Management: case studies (MA 22)

The strategy report, Integrated Rainwater Management, describes various rainwater management case studies in Vienna. They not only provide an overview of existing projects but also possible solutions under different framework conditions (MA 22 2010a).

Spiderweb diagram: see explanation on p. 25

Description of action

Different systems for irrigating urban vegetation can be used, such as the installation and use of rainwater ponds, reservoirs or underground rainwater stores (cisterns), or overflow from local groundwater management. Even roof rainwater run-off can be collected to irrigate vegetation, green façades or green roofs.

The maintenance of vegetation and green spaces must be adapted to the increasing heat load. Irrigation will often be necessary to maintain plant functions (evaporation, shading etc.).

To avoid using expensive drinking water to irrigate greenspace, rainwater can be captured, for example in underground cisterns, lakes or reed-bed retention ponds, where precipitation is stored and can evaporate (MA 22 2013). This action improves microclimate →. The mesoclimate → is slightly improved in large-scale implementation.

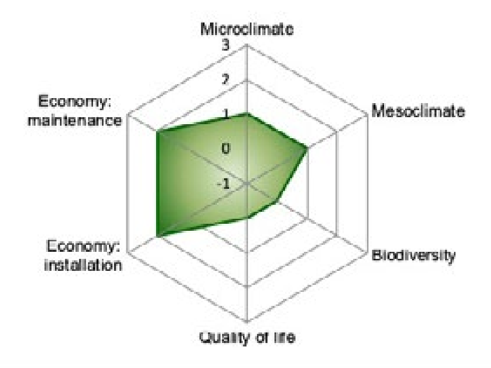
Benefits

- Saves drinking water
- Relieves burden on sewage system and sewage treatment plants
- Water absorption and reduction of runoff for example in heavy rainfall events
- Benefits to biodiversity e.g. from nature-based rainwater ponds
- Mitigates impacts of low rainfall periods

Challenges

- Dominant belief that Vienna has enough drinking water for irrigation
- Structural and precautionary actions necessary
- Decisions on rainwater management should be made as early on as possible – preferably in the planning phase

4.4.2 Action – Permeability and rainwater management



Spiderweb diagram: see explanation on p. 25

Description of action

This action is to promote in situ rainwater evaporation on permeable pathways, gravel lawns, shingle grids, small and large stone permeable paving, bark chippings or other permeable surfaces. Other possibilities include collecting rainwater in retention ponds, basins, swales, lakes or the like, for evaporation and using water-permeable and breathable materials (e.g. permeable asphalt) on a water-impermeable layer for evaporative cooling, for example on pavements. Green roofs can also store rainwater which then evaporates.

The City of Vienna has been implementing permeability and rainwater management for several years. Advantages include: permeable surfaces help with water evaporation and infiltration and heat up slightly less than asphalt for example during the day – depending on design and method used. Permeability can be created in many places, such as parking lots, courtyards, driveways, etc.

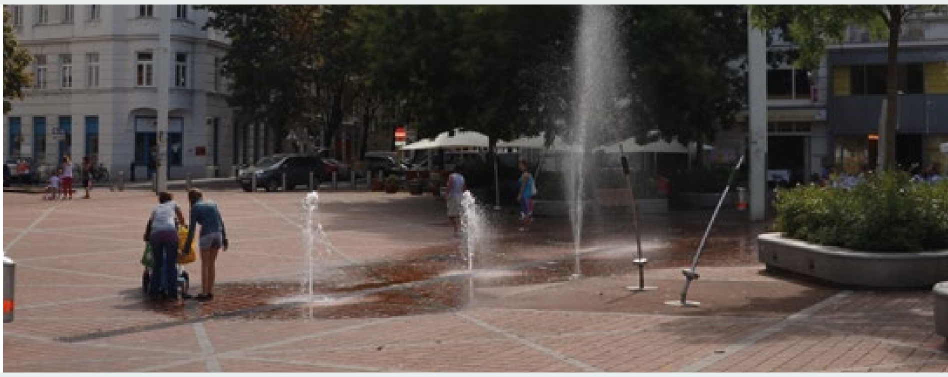
Rainwater management is important not only in the development and planning of large projects such as housing or parks, but it should also be considered in the construction of family homes. Vienna's new building code allows planners to restrict development projects on the volume of rainwater run-off into sewers, and to designate areas where run-off to mains sewerage is prohibited (§5 Para. 4 Vienna Building Regulations).

Alternatives to concrete or asphalt surfaces include surfaces such as gravel lawns, grass pavers and gravel surfaces, which can be used for example on paths or low-traffic access roads. For more heavily used areas, permeable asphalt or porous concrete are appropriate. Wood blocks, timber grids or bark chippings are appropriate for garden paths or playgrounds (MA 22 2013). Water-permeable and breathable materials over a water-impermeable layer can be used for pavements for example, with moisture absorbed in a storage layer and evaporated by capillary action.

Rainwater is collected and distributed in greenspace (e.g. lawns or playgrounds) with rainwater ditch or swale infiltration. In the case of piped or French drain infiltration, perforated pipes can drain rainwater directly through to the subsoil (MA 22 2013). Infiltration ponds allow rainwater to seep into water-permeable embankments above water level, and evaporation also occurs via the plants (MA22 2013). The quantifiable impact of this action is directly related to the size of the installation. However, the evaporation slightly improves microclimate →▤ and mesoclimate →▤.

Benefits

- Relieves burden to the drains in heavy rainfall events
- Helps to mitigate flooding by delaying and reducing run-off
- Provides rainwater to soil, plants and groundwater
- Stabilises local water cycle
- Permeability
- Evaporation improves air quality
- Benefits to biodiversity
- City structure
- Binds particulate matter through increased humidity



Spiderweb diagram: see explanation on p. 25

Description of action

This measure includes the creation of more water installations in public space for example hydrants with spray nozzles, spray mist, splash pads, fountains, etc., as well as designing drinking water fountains to channel any overflow onto soil for gradual infiltration. Another option is to create more outdoor pools and water playgrounds for children and others.

This action increases water evaporation, and water in the public realm also helps contribute to human wellbeing. This action's impact cannot be quantified except on a project-by-project basis.

The City of Vienna operates 54 historic monument and memorial fountains, as well as 10 public swimming pools. The increase in the range of water features and child-friendly outdoor pools primarily improves people's wellbeing and quality of life. Fountains, water hydrants with spray nozzles and other types of running water contribute more to evaporative cooling than still water (Steinrücke et al., 2001). Hydrants with splash pads and sprays also have the advantage of being applicable to most open space in the urban realm, such as water parks and squares.

The evaporation causes a slight improvement to microclimate →▤ but has no influence on mesoclimate →▤.

Construction and maintenance costs will vary depending on the action. One way to reduce costs would be the construction of drinking water fountains through Public Private Partnership (PPP) →▤.

Especially on hot days, water features such as fountains, mist sprays or hydrants with spray heads are popular with the public and help increase amenity in public places.

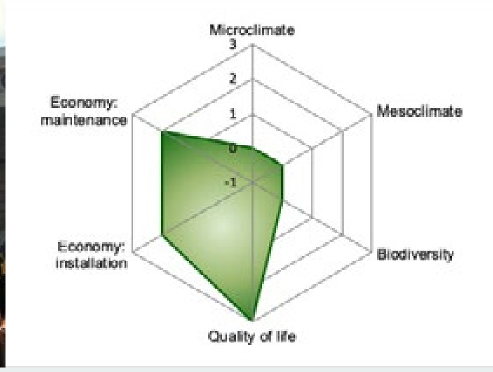
Benefits

- Urban design
- Local rainwater management overflows can be used in urban planning

Challenges

- Compliance with health regulations
- High maintenance costs
- Potentially high construction costs

4.4.4 Action – Provision of drinking water



Spiderweb diagram: see explanation on p. 25

Description of action

This action makes drinking water more available in public open spaces.

Drinking water is essential for people's health and wellbeing, especially in hot weather. Drinking water fountains are thus a valuable action in the urban realm. These should be placed at public transport intersections, in parks, playgrounds and dog walking areas, near cycling infrastructure, etc. The City of Vienna currently operates more than 900 drinking water fountains.

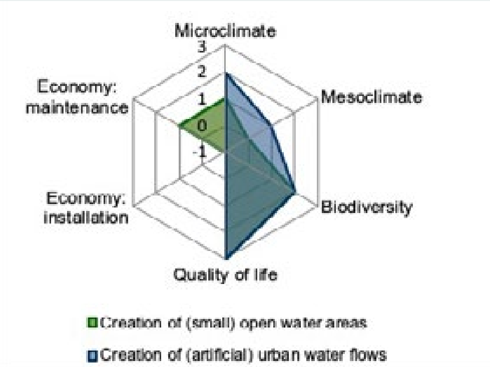
This action is unrelated to micro- and mesoclimate → but significantly improves people's quality of life and health in the urban realm. Construction and maintenance costs for this action are considered low. Drinking water fountains can be permanent installations, set up as mobile drinking water fountains or as temporary water dispensers on hydrants.

Benefits

- Designing drinking water fountains to overflow onto soil for gradual infiltration – also increases wellbeing
- Increases amenity in the public realm

Challenges

- Using hydrants as temporary water dispensers only possible under certain conditions e.g. wide enough pavements
- Needs drainage or infiltration area
- Slippery surfaces



Spiderweb diagram: see explanation on p. 25

Description of action

This action's aim of increasing the proportion of water bodies in the urban realm can be achieved in several ways. Options include creating open bodies of water in e.g. parks or installing or artificially creating running water in the city. Another option is to create large bodies of water storage on the e.g. Wienfluss.

This action's primary impact is the increased evaporation of water. To encourage evaporation in standing water, the design of the bank or riparian zone is important, as vegetation-rich riparian zones are shown to increase evaporation rates and humidity in the area (Mathey et al. 2011).

In weather conditions when horizontal differences in atmospheric pressure are only slight (low-gradient weather conditions →), watercourses can carry layers of air at water level along in the direction of flow and thus form cool-air corridors. According to Hupfer and Kuttler (2006 in Mathey et al. 2011) it has been shown that unobstructed running water in sunny weather conditions with little wind can reduce temperatures by 1K in a 400m radius.

The impact of creating smaller water bodies in parks on microclimate → is considered a minor improvement, and its impact on mesoclimate → as negligible. The impact of creating streams in the urban realm is seen to improve microclimate → and slightly improve mesoclimate →.

Construction costs for standing water bodies are estimated as high, maintenance costs as medium. For flowing water, construction and maintenance costs for this action are considered very high.

The potential for new water bodies is not always available; urban development areas (eg Seestadt Aspern, North Station/Nordbahnhof, Northwest Station/Nordwestbahnhof) offer the best opportunities where new water bodies are often a key consideration. Further opportunities to increase water bodies have been exploited during the renovation of streams, for example in the extensive redesign of the 5.4km section of the Liesingbach between Kledering and the Blumental treatment plant and in the transformation of the Peterbach, the Mauerbach, the upper Wienfluss and the Eckbach. Both flowing and still water bodies are often used by the public for example for recreational activities.

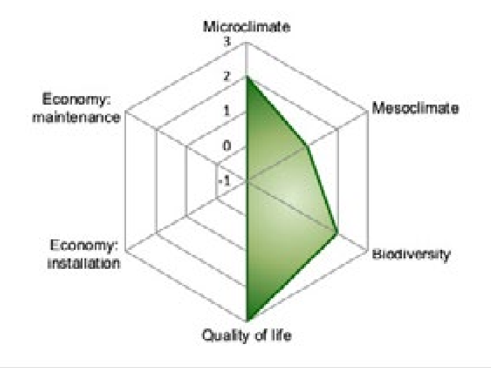
Benefits

- Benefits for biodiversity
- Urban design opportunities
- Improvement of wellbeing
- Water bodies potentially usable for leisure and recreation
- Aesthetic enhancement of the e.g. Wienfluss, as the large body of water is visible and its concrete channel is hidden

Challenges

- Preservation of hygiene
- Requires intensive maintenance
- For water storage ponds, fish ladders needed; changes to flora and fauna
- Potential flood impacts

4.4.6 Action – Opening up piped water channels/river restoration



Spiderweb diagram: see explanation on p. 2

Description of action

This action returns piped water back to the surface, restoring rivers and directing them through urban areas.

The streams of the Vienna Forest are currently mostly only visible in their upper reaches; in densely populated areas they are often enclosed in pipes, channelling the water into the drainage system, the Danube Canal or the Wienfluss. Opening up and restoring piped sections of streams can improve microclimate →. However, this action has negligible effects on mesoclimate →. This action also improves people's quality of life and wellbeing and creates new recreational areas.

Construction and maintenance costs of this action are estimated to be very high.

Benefits

- Running water can provide cool air corridors
- Benefits for biodiversity
- Increased connectivity between habitats
- Creation of an integrated river network connected to surrounding countryside
- Relieves the burden on the drainage system and sewage treatment plants
- Urban design opportunities, upgrading the urban landscape
- Improves quality of life

Challenges

- Space requirements: river restoration projects are often limited by existing infrastructure (services, traffic infrastructure, etc.) or by land ownership
- Costs for river restoration are usually very high. However, there are good opportunities if synergies with other infrastructure measures can be found, such as the restoration of the Liesingbach after the canal was built
- Preserving water quality
- Flood protection
- Maintenance of the waterbed and riparian zones
- Ensuring safety

4.5 Shading open spaces and footpaths

The shading of open spaces and footpaths reduces surface heating, thus leading to a slight improvement of the microclimate and can thereby improve people's wellbeing. However, night-time heat radiation and ventilation may be prevented, depending on the kind of shading.

This action can include the provision of shaded seating under a roof or tree, or permanent or temporary shading attached to buildings (e.g. arcades, awnings) as well as open-air structures (e.g. pergolas, canopies). Some shading is particularly important in large squares, otherwise people avoid them.

Additional benefits of shading include providing shelter in other weather such as rain or snow, as well as potential energy generation when using photovoltaic panels to create shade or mounting them on shading devices.

Aims of shading open spaces and footpaths

- Improving outdoor liveability on hot days
- Improving the microclimate
- Weather protection (rain, snow)

Actions particularly suited to achieving these aims

- Provision of shaded seating
- Shading in open spaces around buildings
- Shading in open-air spaces

Shading in public open space

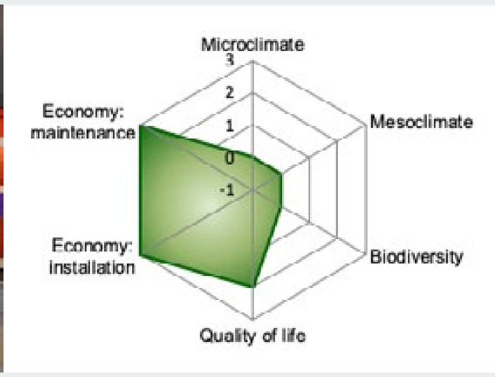

In recent years, numerous projects in the City of Vienna have been implemented to install shading in public open spaces.

- Urban Loritz Platz: A large tensile roof canopy spans and protects individual resting areas and the footpaths between them.

- Robert Hochner Park: A pergola creates shaded seating.

- Fritz Imhoff Park: A new plan was achieved through requests made during a public participation process, and also provides shade to communication areas (MA 27, no year).

4.5.1 Action – Providing shaded seating



Spiderweb diagram: see explanation on p. 25

Description of action

This action can be implemented in two ways: providing shaded seating (e.g. under a roof, awning, tree etc.), or benches on rails so that seating can be moved into shaded areas.

Shaded seating in public space greatly improves amenity and people's wellbeing. Shaded seating is especially important for older people, and not just in hot weather.

Benches on rails especially allow great flexibility – depending on daily or seasonal requirements and depending on the weather, the bank can be moved.

This action has no impact on micro- or mesoclimate →.

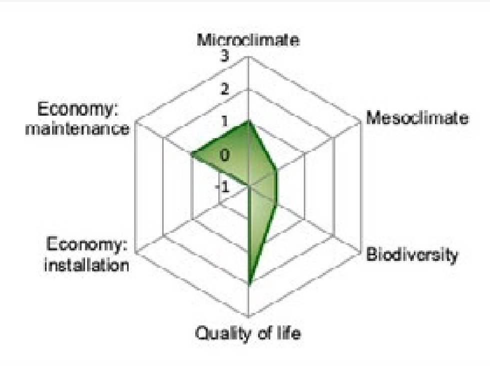
Construction and maintenance costs for this action are considered low or unpredictable.

Benefits

- Increases amenity
- Upgrading of open spaces
- Benches are a mobility requirement for some members of the population, such as older people

Challenges

- Maintenance



Spiderweb diagram: see explanation on p. 25

Description of action

Open spaces around buildings can be shaded in various ways, both through technical and structural approaches. Permanent shading of such open spaces can be implemented by arcades, canopies, covered passages etc., while temporary shading can be provided by adjustable awnings, canopies etc. Shading reduces surface heating and thus also night-time heat radiation.

Adjustable awnings or canopies can be used to create temporary shading of open spaces around buildings at the desired time and do not affect thermal conditions in other seasons.

This action can have a slight improvement on microclimate → but has no influence on mesoclimate →. Construction costs for canopies, roofed passages or similar are considered very high and create temporary shading by adjustable awnings as high. Maintenance costs for both measures are classed as medium. Flexible shading systems especially such as awnings are popular with the public.

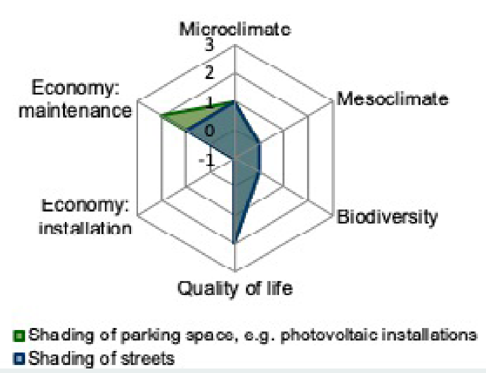
Benefits

- Structural elements protect pavements from other weather conditions such as snow or rain
- Especially beneficial for pedestrians
- Improves people's quality of life and wellbeing in the urban realm

Challenges

- Structural elements may also shade buildings in winter
- Heat build-up and deterioration of air quality through reduced air circulation
- With arcades, special consideration should be given to impacts at ground floor and reduction of usable area
- Shading in large public squares is important, especially primary circulation routes, as otherwise people avoid them
- Charges ('air tax') for awnings etc. could impede uptake

4.5.3 Action – Shading open-air spaces



Spiderweb diagram: see explanation on p. 25

Description of action

This action provides shading in open-air spaces. This can be achieved through photovoltaic systems, pergolas, canopies, gazebos, awnings or similar. Appropriate locations are parking spaces in larger shopping centre car parks, city squares, leisure and sports facilities, etc.

Shading devices can either be permanent installations, or mobile elements such as awnings erected over public squares or streets.

The value of this action is surface shading, thereby reducing heating during the day and reducing night-time heat radiation.

This is an alternative action if planting trees is impossible or not possible to a sufficient degree e.g. because of other installations.

This action has a minor effect on microclimate →▤ but has no effect on mesoclimate →▤.

Public approval for this action is high as shading open-air spaces like city squares increases amenity.

Benefits

- Energy generation if photovoltaic systems are used
- Structural elements provide shelter from other weather (rain, snow)
- Increases amenity on hot days
- Especially beneficial for pedestrians
- Shading in large public squares is important, especially primary circulation routes, as otherwise people avoid them

Challenges

- Reduced air circulation resulting in heat build-up or deterioration of air quality

4.6 Cooling public transportation

Although cooling public transportation has no effect on the microclimate, it has a positive effect on people's wellbeing at high temperatures.

Actions include cooling public transport with air-conditioning systems, passive ventilation options, opening windows etc., as well as air-conditioning and ventilation of underground transport facilities and cooling street-level enclosed stops and shading open stops.

For health reasons, it should be noted that the temperature on public transport should be no more than 5˚C below outside temperature (ORF 2011).

Aims of cooling public transportation

- Improving amenity on public transport as well as in public transport facilities
- Promotion of public transport, with indirect climate benefits

Actions particularly suited to achieving these aims

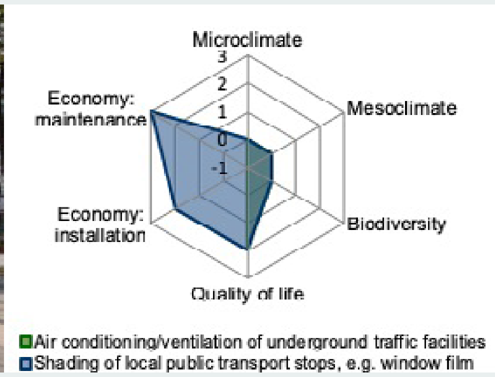
- Cooling street-level and underground public transport facilities
- Cooling on public transport

Geothermal/ground-source cooling

The subway stations Schottenring, Taborstraße, Praterstern and Messe on Line U2 are equipped with geothermal systems so can receive not only heating in winter but also air-conditioning in summer. Wiener Linien/Vienna Lines is thus playing a pioneering role: from an international perspective, this is the first major infrastructure project to use geothermal/ground-source energy with thermal mass absorption technology. During construction, kilometre-long pipes were laid as geothermal absorber elements in the stations' side walls and floor slabs. These remove surplus heat from the stations in summer, passing it into the ground (Wiener Linien GmbH & Co KG 2008).

Geothermal collectors under the floor slab (source: civil engineers iC GesmbH)

4.6.1 Action – Cooling street-level and underground transport facilities



Spiderweb diagram: see explanation on p. 25

Description of action

This action includes the improvement of air-conditioning or ventilation of underground transport facilities (e.g. subway stations) as well as shading open-air stops or cooling underground or enclosed street-level public transport stops → through energy-efficient cooling methods or district cooling.

Shading public transport stops → can be implemented by planting trees and attaching solar protection film to shelters. Energy-efficient cooling methods or district cooling are appropriate in high-traffic subway stations, as long as they are enclosed.

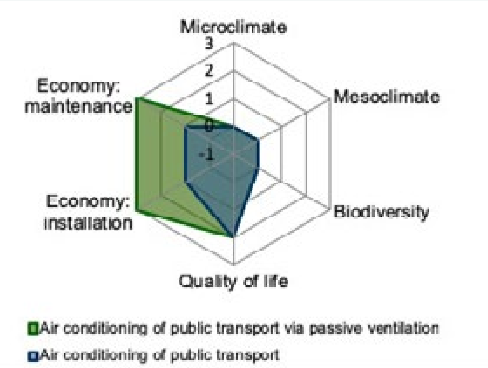
This measure has a beneficial effect on people's wellbeing. It has no direct impact on microclimate → or mesoclimate → in relation to bus or tram shelters. However, planting trees improve microclimate →. Construction and maintenance costs of this action were classed as very high for underground transport facilities, the use of solar protection films at public transport stops being classed as low.

Benefits

- Weather protection (snow, rain) for example at bus or tram shelters
- Making public transport more attractive
- Indirect climate benefits, if more public transport is used
- Shading with trees: expands the tree stock, increases water absorption

Challenges

- Energy demand for cooling, e.g. by subway stations for district cooling
- District cooling: loss of cooling over long transport routes



Spiderweb diagram: see explanation on p. 25

Description of action

This action includes cooling on public transport through passive ventilation options, opening windows or air-conditioning systems and passive cooling by shading with solar protection film.

In Vienna, a large proportion of public transport is already air-conditioned – about two-thirds of buses and about a quarter of trams (ORF 2014).

This action has no influence on micro- or mesoclimate →▤. Construction and maintenance costs of fitting solar protection films on the windows of public transport are classed as very low. Construction and maintenance costs of equipping public transport with air-conditioning systems when new vehicles are purchased are classed as medium.

Cooling on public transport receives wide public approval.

Benefits

- Supports wellbeing and quality of life
- Making public transport more attractive

Challenges

- Cooling with air-conditioning systems increases energy consumption and waste heat in the environment
- Cooling with air-conditioning systems on public transport is not efficient on some routes due to frequently opening doors

Awareness-raising and public information is important for 'individual' adaptation strategies

5. Areas of action and implementation case studies

Raising awareness amongst Vienna's citizens as well as developing the skills of property developers, project developers, architects, planners and city administration planning experts responsible for combatting urban overheating is essential for the successful implementation of Vienna's Urban Heat Island Strategy. The following section presents examples of how UHI-sensitive urban planning and urban development can work.

5.1 Awareness raising, information and promotion of the UHI issue

The introduction to the description below of opportunities to implement actions is from the results of a survey carried out as part of the Vienna UHI-STRAT project. It gives insights into the attitude of the Viennese towards heat in the city, their behaviour in heat waves and their assessment of measures to reduce the urban heat island effect.

Not all consequences of the increasing urban overheating can be solved by planning interventions or structural measures. Initiatives such as Vienna's Coolest Summer Walk or Cool Walks represent other ways to raise public awareness on the issue.

Urban heat affects social groups differently. The STOPHOT project which analysed the impact of heat stress on the elderly – a particularly vulnerable group in relation to heat stress – showed how actions tailored to target groups can be developed and implemented.

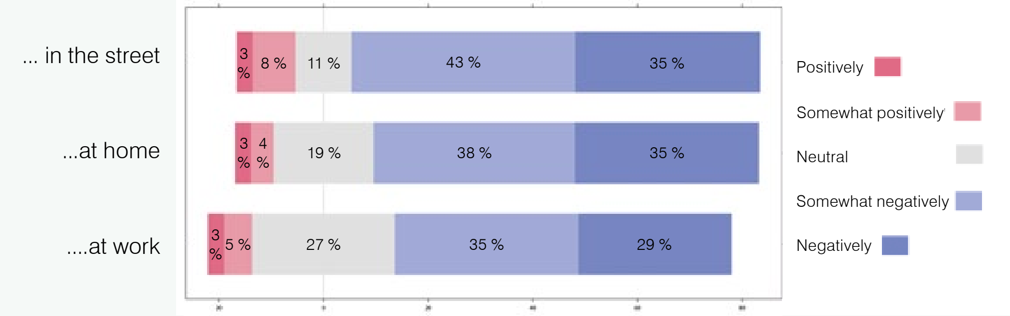
Planning and construction measures to reduce the urban heat island effect can be implemented effectively, if they are coordinated, developed and implemented across departments. In a UHI-STRAT Vienna project series of workshops, collaboration was organised at different levels.

Establishing UHI long-term as an urban planning and development issue also requires skills development in planning practice. The inter- and transdisciplinary, inter-university course Ecological Planning and Building is an example of how this can happen in university education.

5.1.1 Attitudes of the Viennese to heat in the city

Based on 385 responses from a postal survey of Viennese citizens, public perception and attitudes to heat in the city was collated. Almost all Viennese have experienced at least one heat wave. For three quarters of the population, the heat has a negative effect. Especially on the street and in apartments, the heat is clearly noticeable.

How did the last heatwave affect your wellbeing?



What should be done about the heat?

Vienna citizens survey

The survey was carried out in August 2013. Questionnaires were sent to a total of 3,792 Viennese households, of which just over 10% were returned. In order to obtain an approximately representative sample, 27 blocks of flats from differently densely populated areas of Vienna were randomly selected and answers weighted

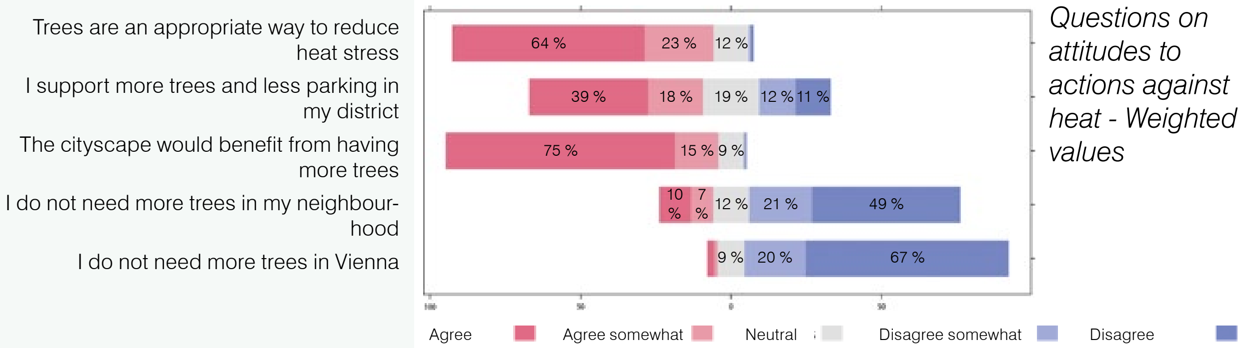
Privately, the Viennese are adjusting to the heat and doing something about it. The most commonly used measures against the heat are: ventilate well at night (88%), drink more liquids (86%) and keep blinds or curtains closed during the day (80%).

Only a minority had the option to leave the city or work less during the last heatwave. Also, only 6% of the Viennese surveyed have personal air-conditioning systems. Around half increasingly used fans.

The actions seen as most effective against heat stress are cooling public transport (64%), drinking water fountains in the city (59%) and street trees (51%). Measures such as lighter-coloured road surfaces, shading pavements or rail/tram track greening have not yet attracted the attention of the city's respondents.

Future actions

The vast majority (86%) consider trees an appropriate action to reduce urban heat stress. Even greater is public approval for the positive effect trees have on the streetscape. The vast majority would like to have more trees both in their own neighbourhood and across Vienna as a whole (70% and 87% respectively). The statement, ‚I support more trees and less parking in my district' found approval from a majority 54%. Only 24% were against it.



Questions on attitudes to actions against heat - Weighted values

Vienna's coolest summer walk 2013

Vienna's Mobility Agency GmbH organized a competition to find the 'coolest summer walk'.

Vienna's coolest summer walk 2013 was along Liesingbach. This initiative raised awareness of the issue of mobility on hot days. A 13-year-old won the competition with his suggestion for a cool summer walk along the Liesingbach.

The proud winner of the competition

5.1.2 Heat in the city affects everyone – public awareness

As the survey revealed, urban overheating is an issue that affects everyone. It is also widely accepted that action needs to be taken to reduce it. Just as climate protection measures are shaped to a large extent by the public and their lifestyle, so individual behaviour changes can support better management of heat in the city. These individual adaptation strategies to reduce bioclimate stress should be addressed quickly, and the public informed about how to reduce harm to citizens' health caused by heat stress.

Cool Walks – awareness of the issue of heat on walks

'Green façades in the Fasanviertel'

As part of the Pheasant Walks Project, running since 2013, tours of the Fasanviertel take place monthly on various issues. The GB*3/11, in cooperation with Vienna's Environmental Protection Department MA 22, organised a walk dedicated to the subject of 'Green façades in the Fasanviertel'. Residents were informed about greening façades and its effects on the urban climate.

'Vienna on foot in the summer'

Within the framework of the Geh-Café/Café-Walks initiative, which focuses on pedestrian access in the city, the District 15 local advice centre together with Vienna's Environmental Protection Department MA 22 organised a walk with the focus on walking in the summer. Participants were informed about impacts on hot days and how they can prepare for them in good time. On the walk, surface temperatures were also measured to show residents how surfaces heat up differently in the city.

5.1.3 Seek synergies and develop skills

To take effective action to reduce Vienna's urban UHI effect, an inter- and multidisciplinary approach is needed. In urban planning, developing skills in dealing with the increasing heat load is important especially to be able to connect with particularly vulnerable groups and to develop tailor-made strategies and actions.

Workshops during the UHI project to discuss actions and embed processes at different planning levels

As part of a series of workshops organised by MA 22 and the BOKU project team, various actions for reducing the UHI effect were discussed across departments and disciplines and their effectiveness assessed.

The various Vienna City Council departments involved were: MD-KLI, MD-BD, MA 18, MA 20, MA 21, MA 25, MA 42, MA 45 and WUA.

The aims of these events were both to raise awareness on the issue of UHI, and highlight and discuss options for action for Vienna, based on urban and nature conservation planning tools. Existing good practice was also shared. The process showed that the trans-departmental and interdisciplinary harmonisation of actions and above all quality assurance on this issue is particularly important. It also became apparent that there are already many existing approaches to establishing and implementing actions to reduce UHI.

Ecological planning and construction

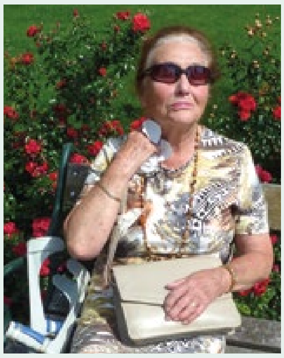
As well as the general public, existing and future planners and architects must also be made aware of the issue of urban overheating and the appropriate skills developed. In the inter-university seminar on planning and construction-related fields of study, organised by MA 22 in cooperation with BOKU and TU Vienna since 2011, students are taught about the issue of ecological planning and construction.

What is special about this seminar is that scientists and MA 22 employees give their expertise to help students with their projects. This allows a multidisciplinary perspective on planning and construction processes. This will also accelerate the implementation of UHI-related actions whose effectiveness is promoted through a coordinated and interdisciplinary approach.

The STOPHOT Project

During periods of heat, one population group in particular suffers from the high temperatures: the elderly. Several studies have already shown the increase in mortality and harm to health of older people in the heat (e.g. Gabriel & Endlicher 2011).

In the future, this situation will worsen with the increase in heat days and a growing number of older people. The aim of the project was therefore to identify actions that



improve the living conditions of older people during hot periods in Vienna. Quantitative surveys of older people (2011/2013) examined heat-risk awareness, perception of the effects of heat and behaviour in the heat.

Survey results show that older people wear lighter clothing during the heat, drink more, carry out chores in the morning or evening and draw the curtains. The majority stayed in their apartment in the heat. However, people who left their apartment in the heat had significantly fewer complaints. When assessing the adaptation measures given, respondents rated the most important as ‚more shade' (e.g. more shaded seating on pavements, more shaded areas in parks, greater shading of public transport stops).

Further information is available online at: http://stophot.boku.ac.at/

Objectives of the Nordbahnstraße-Innstraße urban design ideas competition

In addition to project specifications such as the gross floor area or mix of uses, UHI-related aims and criteria were formulated with city administration experts involved even at this early planning phase. Summary of objectives for the Nordbahnstraße-Innstraße urban development competition:

- Create high-quality green and open space infrastructure for all population groups
- Best possible networking of the new development area with surrounding higher-level green and open spaces (Grüner Prater, banks of the Danube, Augarten, etc.)
- Create conditions for the development of high-quality residential play areas and open spaces
- Protection of ecologically valuable ruderal areas (city wild areas) on Vorgartenstraße as a city biotope, as well as highly usable recreation area (Ökopark/Ecopark)
- Retaining the avenue concept in the public realm
- Consider railway embankments as areas of significant ecological potential
- Maximise permeability
- Integrated consideration of urban climate aspects (sun/shade/wind/humidity).

The winning project of the Nordbahnstraße-Innstraße urban design ideas competition is characterized by a large green space.

5.2 Implementation options at urban masterplanning level

Since planning and implementing large-scale urban design and development projects can take several years, sometimes decades, this strategic level is vital to counteract heat in city neighbourhoods. To be able to implement UHI-sensitive planning and development, early consideration and involvement of experts in this area is recommended, ideally in developing strategic objectives for the masterplan process.

Phases of a masterplanning process

Four phases shape the process of developing masterplans: initial, programming, consolidation and implementation phases (MA 21B 2010), in which UHI-related issues can be introduced and implemented.

Initial phase

In this phase, city policy and urban planning requirements and different expectations regarding future development are identified. Since process structures and participants are defined here, it is crucial to involve people with skills in climate-sensitive urban planning. This phase of the masterplanning process also sets out what basic information and plans, opinions and studies will be gathered. From an urban climate point of view, these include surveying and measuring prevailing winds, air flow paths and cool air corridors, creating local climate models, examining subsoil water permeability, assessing the importance of the area to generating cooling, or examining possibilities for connecting to higher-level cool air corridors.

1. Initial phase

Setting a basic framework/design process. Defining goals, challenges and framework conditions, identifying aims and stakeholders, development of stakeholder, participation and communication plans, clarification of cost issues and timeframe.

2. Programming phase

Bringing expertise and stakeholders together to develop a spatial development plan or masterplan. Development of aims and needs checklist, identification of options or scenarios, development of a structural concept, carrying out competitions or other qualifying processes.

Phases of a masterplanning process
(edited by MA 21B 2010)

Programming

The starting point for planning is often a strategic urban development model that sets out a future development framework. The various interests of city politicians, investors and landowners as well as city administration officers are transformed into basic functional and structural requirements for area development. It is at this phase that urban structure and planning requirements are set that could actively create or prevent local urban heat islands. The aims and guidelines defined here form the strategic framework for further development. The determining factor in establishing UHI-related issues and actions is setting requirements for prequalification procedures or urban planning competitions (see example in adjacent column). Implementing the urban development prequalification process is the final step in this phase.

Consolidation

Translating competition results into practical guidelines, developing realistic technical standards and concrete implementation projects are the focus of this planning and development phase. The preparation of any necessary strategic environmental or ecological impact assessments also offers the chance to introduce UHI-related strategic objectives and practical actions. More in-depth investigation of issues such as any small-scale climate impacts from the proposed construction is recommended here.

The conclusion of this phase is the interface with legally-binding zoning and development planning. Options to embed UHI-related actions at zoning and development planning levels are described in detail in the next section.

Workshop as part of the UHI-STRAT project to discuss the anchoring of measures in the masterplan process

Taking the example of translating the Nordbahnstraße-Innstraße urban planning competition's winning project into urban development guidelines, the possibilities of implementing the UHI-STRAT action catalogue at this level were analysed at a workshop in March 2014 with various departments of Vienna City Council. Discussion of the possibilities showed that most UHI reduction measures can be embedded at this planning phase.

Departmental and interdepartmental discussion of implementation options

This joint feasibility assessment approach has proven effective, addressing many of the important but sometimes conflicting objectives and challenges that have to be balanced during this process.

Topics and questions that can be clarified at this phase:

→ What climate impacts will the proposed project have (see simulation example on p. 89)
→ What actions to reduce the UHI effect can be implemented through the urban planning proposal?
→ Who is responsible for implementation?
→ Which instruments or planning processes can be used to implement the actions?
→ What challenges could there be to implementation?

3. Consolidation

Continue conceptual development. Prepare and coordinate master-plan design, develop delivery strategy. Implementation plan, finance strategy, marketing strategy, quality assurance mechanisms, put planning instruments in place, arranging next planning and implementation steps.

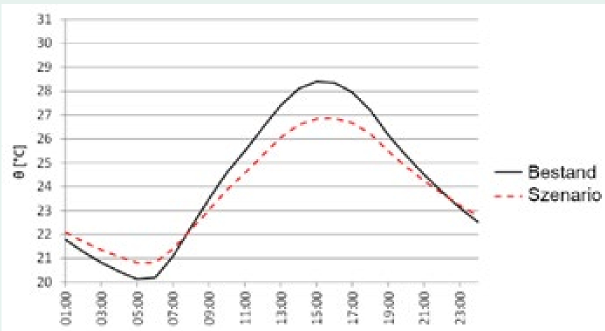
4. Implementation

Ensuring the qualities developed in draft master-plan and delivery strategy. Further guidance or support on the delivery and implementation of concepts for use. Setting up neighbourhood management, monitoring.

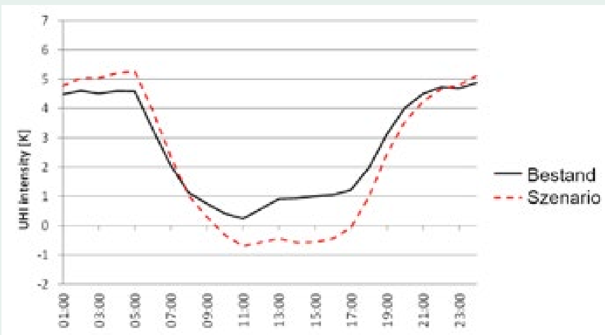
Modelling the climate impacts of the Nordbahnstraße-Innstraße ideas competition winning project

Based on the results of the winning project of the ideas competition for the development of Nordbahnstraße-Innstraße, a former brownfield site, the microclimate impacts of the master-plan were simulated.

The ENVI-met model →▤ before (left) and after (right) of the development of the new district



Comparison of average hourly temperatures over the reference day, existing and post-construction



Average hourly intensity of UHI effect over the reference day, existing and post-construction

According to the development simulation, average air temperatures in the study area increase during the night. This could be caused by a reduced visible sky factor, increase in thermal mass in the area and associated increase in long-wave radiation. During the day, however, a significant reduction in average air temperatures can be observed.

Authors and source: Mahdavi A., Kiesel K., Vuckovic M. – Vienna Technical University, Department of Building Physics and Building Ecology

Implementation

This phase deals with the practical project development of public sector social and technical infrastructure, development of the public realm and investor-led development.

Chapter 4 – Practical actions in planning and project design – describes how UHI-related actions can be implemented at the project design phase and what impact they have on reducing the UHI effect.

5.3 Implementation options in zoning and development plans

The permissible use and development options of a plot of land are legally binding at the level of zoning and development planning. In addition to setting out land use, the zoning and development plan sets construction categories and methods and building regulations, height restrictions and traffic intersections as well as further provisions and 'special conditions' (§5 Vienna Building Regulations). Basically, one has to differentiate between changes of use and structural improvements to the existing stock. There is obviously more room to implement UHI-related actions with changes of use.

However, if significant changes are made to the existing stock, they must comply with current zoning and development plans. UHI-related issues and actions can be embedded via building lines, use requirements or construction categories, as defined in the relevant planning section with regard to city structure, building form and orientation.

Modelling can help produce the most effective design (see following page). Also, practical actions to reduce heat stress such as greening areas, pedestrian routes or arcades can be prescribed. 'Special conditions' (SC), which contain general provisions for the scope of the zoning plan, provide additional options to embed actions to reduce the UHI effect. These include in particular, requirements for landscaping, green roofs, greening façades, rainwater management, permeability, greening courtyards or planting trees.

As the workshop discussions about implementation measures showed, numerous retrofit actions are also possible - aerial view of Karlsplatz and surroundings (above) and actions put forward (below)

Establishing in the plan

As well as regulations restricting building area and form or prohibiting or reducing rainwater run-off into the drainage system, guidelines for street orientation and width from a UHI point of view are particularly relevant. Streets heat up most during the day compared with surroundings. Consideration of street orientation and the form of adjacent buildings shading the street is recommended. Permissible building heights are related to street width and are regulated by the Vienna Building Regulations (§75 Para. 4 Vienna Building Regulations). These regulations do not apply to conservation areas or designated urban development priority areas.

Southern cities have narrow alleys where the sun cannot penetrate. The problem here is heat build-up and only minor night-time cooling due to the low Sky View Factor. Narrow street intersections also do little to help. Designing wider street intersections with green infrastructure can help reduce the UHI effect. Depending on street orientation (east-west, north-south) actions such as planting avenues of trees can help to varying degrees. The alignment of streets should be considered especially in relation to prevailing winds to avoid obstructing air circulation.

Urban greening actions can be stipulated in the zoning and development plan

Aspects such as building height and position, as well as any associated (mutual) shading, must be coordinated for each specific location. General statements are difficult because local wind conditions, topography or supply of green space can be very different.

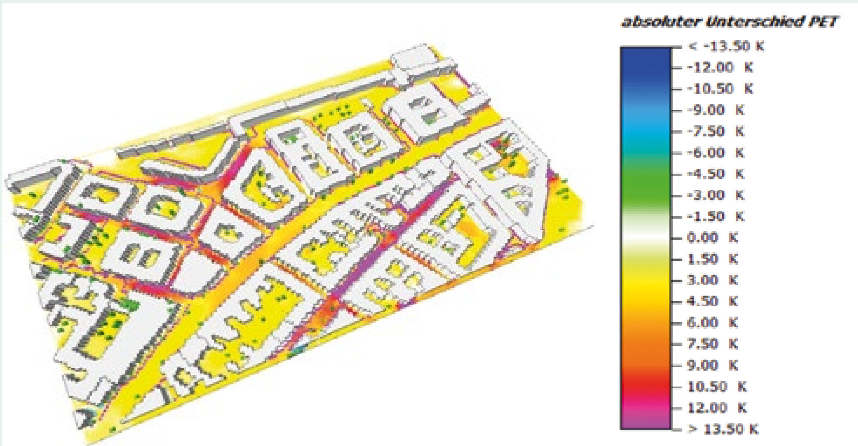
In complex urban planning situations or known climate challenges such as exposure to gusts of wind, microclimate modelling (see adjacent example) of different development scenarios is recommended. (See Vienna's Climate Function Chart in the Appendix on p. 100 for a general overview of the planning area).

Setting 'special conditions'

Requirements for different actions such as green roofs, rainwater management, greening façades or horticultural design as well as the degree of impermeability can be set in 'special conditions'. The following double page gives examples of ways to establish UHI-related actions, based on the requirements of various planning documents.

Requirement computer simulations

To assess the effectiveness of selected adaptation measures on local microclimate conditions, software programs such as ENVI-met → can help. These can simulate how microclimate is affected, depending on the time of day and physical properties of the environment. The mathematical and meteorological algorithms used here are basically the same as those used in predictive global climate change modelling – but are calibrated to the urban climate with much higher spatial and temporal resolution.



ENVI-met model of differences in perceived temperature [PET] comparing greened and un-greened Mariahilferstraße (Source: Bernhard Scharf, BOKU)

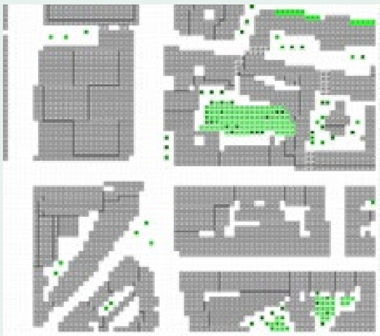
ENVI-met → requires two types of input data: physical (geometric) data and additional parameters such as weather data. Further, information about surface conditions or building materials, soils, vegetation or sources of emission should also be available. Although ENVI-met representations → are subject to certain restrictions regarding size of the study area and resolution, this simulation program can nevertheless provide valuable insights for the assessment of complex climate processes in urban environments.

Simulating retrofit interventions – inner-city example

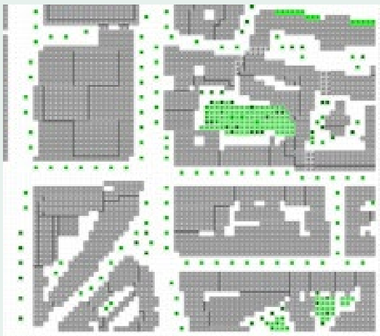
The area studied in ENVI-met simulation → before and after applying adaptation measures.

Three adaptation measures were examined for the inner-city area being studied. These measures were 1) tree planting, 2) green roofs, and 3) a combination of tree planting and green roofs.

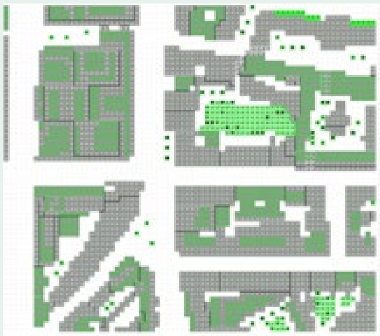
Scenario	Expected benefits
1 - Tree planting	Shading and evapotranspiration, lower maximum summer air temperatures in the street, reduced air pollution
2 - Green roofs	Shading and evapotranspiration
3 - Combination of 1 and 2	hading and evapotranspiration, lower maximum air temperatures in summer, reduced air pollution.



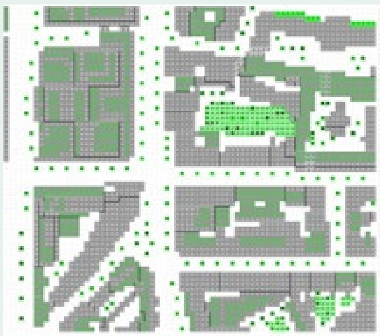
Existing conditions



Scenario 1 – tree planting

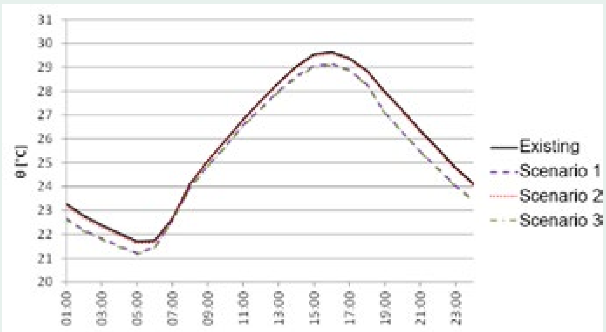


Scenario 2 – green roofs

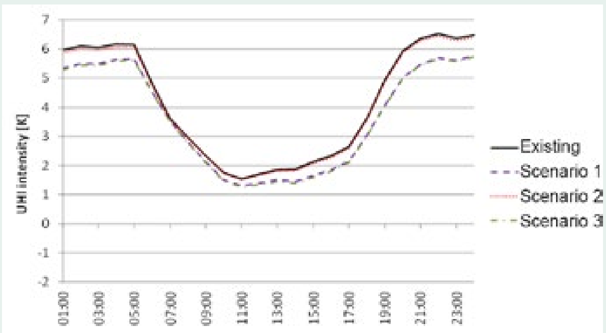


Scenario 3 – tree planting and green roofs

The following diagrams show the differences in climate conditions between existing situation and after implementing individual actions on a reference day. These images were modelled using ENVI-met 4.0 → . The graphs below clearly show the differences in air temperature between existing conditions and after simulating the impact of the selected actions.



Average hourly temperatures over the reference day for existing conditions and the three adaptation scenarios.



Average hourly intensity of UHI effect over the reference day for existing conditions and the three adaptation scenarios.

Results indicate that the different adaptation measures have the potential to reduce air temperature on hot summer days in the area being studied. As expected, the different adaptation measures also are effective to varying degrees. For example, green roofs in this inner-city area have no noticeable effect on street air temperatures, but trees do. Combining the two actions proved to be particularly effective. Looking at temporal patterns showed that differences in evening and night-time air temperature are more pronounced.

Authors and source: Mahdavi A., Kiesel K., Vuckovic M. – Vienna Technical University, Department of Building Physics and Building Ecology

Example of setting conditions for planting **rows of trees** in Special Conditions (SC): ‚On all transport routes whose intersection is entirely within the plan area, [...] action must be taken to plant and maintain two rows of trees. On all transport routes whose intersection is not entirely within the planning area, action must be taken to plant or maintain one row of trees.‘

(Taken from planning document 7990)

Example of setting conditions for **public passages** in SC: ‚In areas designated under SC6, public passages adjacent to traffic zones must have minimum 3.0m head height‘

(Taken from planning document 7598)

Example of setting conditions on **reducing development density and green roofs** in SC ‚In residential or mixed used areas designated under SC4, building footprint may not exceed 50% of the development area. In line with technical standards, all roofs of proposed buildings are to be designed as flat green roofs or terraces, unless they are glass roofs. Technical or lighting services are permitted as required.‘

(Taken from planning document 7254)

Example of setting conditions to establish **façade greening** in SC: ‚In areas designated under SC7 it is determined: on the façade opposite Johannes Fehring Promenade, action must be taken to green the façade to a minimum of 60% of the façade (minus window areas).‘

(Taken from planning document 8033)

Example of setting conditions for **planting groups of trees** in SC: ‚Furthermore action to plant and protect tree groups in Erzherzog Johann Platz, on the corner of Karlsgasse and Gußhausstraße and Karlsgasse - Argentinierstraße as well as in front of No. 11 Wiedner Hauptstraße.‘

(Taken from planning document 7598)

Example of setting conditions for the **construction of an accessible roof terrace with greening** in the SC: ‚The roofs of the penthouse or top floor must be flat roofs and greened in accordance with technical guidance. Laying of roof finishes to allow use as accessible roof terrace up to a maximum of 50% of the roof area, along with installation of any technical and lighting services required is permitted.‘

(Taken from planning document 8032)

Example of setting conditions for **reducing impermeability and planting trees:** *‚In all areas of the development where landscaping is required, action must be taken during groundworks to lay soil substrate to an average depth of at least 1.65m for the planting of trees.‘*

(Taken from planning document 7844)

Example of setting conditions to require **green roofs and tree planting** in SC ‚The garage roofs shall be designed to allow for soil substrate to an average depth of 1.65m. Erection of staircases, lift shafts and other services necessary to the operation of the garage is permitted.‘

(Taken from planning document 7844)

Example of setting conditions to **reduce impermeability of parking** in SC: ‚In areas designated under P SC9 as reserved for car-parking, the erection of structures above or below ground is prohibited. A minimum 30% of surfaces must be permeable.‘

(Taken from planning document 7844)

Example of setting conditions for the construction of **arcades** in SC: ‚In areas designated under Ak öDg, a publicly accessible arcade of the width specified in the plan and minimum 3.0m head height must be provided.‘

(Taken from planning document 7254)

smartKB* project info
Reducing cooling energy demand by optimising building structure, and optimising process and design when planning buildings

Project lead:
Danube University Krems, Department of Construction and Environment, Centre for Facilities Management and Safety, Centre for Environmental Sensitivity and Centre for Building Climatology and Building Services

Project managers:
Christina Ipser, Susanne Geissler, Gregor Radinger, Markus Winkler, Helmut Floegl

Project partners:
SERA energy & resources

Client:
Federal Ministry of Transport, Innovation and Technology (BMVIT) within the framework of the 4th call for proposals, House of the Future Plus

Further information:
Project contents and results can be downloaded from the House of the Future website: http://www.hausderzukunft.at/results.html/id7349

5.4 Implementation options at building level - the smartKB* project

Project managers: Danube University Krems [Christina Ipser, Susanne Geissler, Gregor Radinger, Markus Winkler, Helmut Floegl]

Given predicted climate trends, even at our latitudes we can imagine the increasing importance of cooling energy demand by buildings. Appropriate building structure as a prerequisite in new build and refurbishment projects, as well as appropriate construction methods and planning strategies to minimise cooling demand caused by external conditions, must be seen as increasingly important quality criteria for sustainable buildings. The smartKB* research project aimed systematically to compile measures that could reduce building cooling demand caused by external conditions, and their combination at different action phases.

It focused on the interfaces between buildings and their urban environment, but also the interactions of cooling-related planning and design decisions, which aimed to optimise ecological, economic and user-related building characteristics.

Three levels of action

As part of the project, the systematic compilation of methods and recommendations was initially carried out for measures to reduce cooling energy demand at three levels of action:
(1) Planning appropriate building structure: At the urban planning level, the aim was to describe interactions between building structure and cooling energy demand of buildings, and to draw up recommendations for construction and design. Recommendations were summarized in a 'summer comfort checklist' for municipalities.

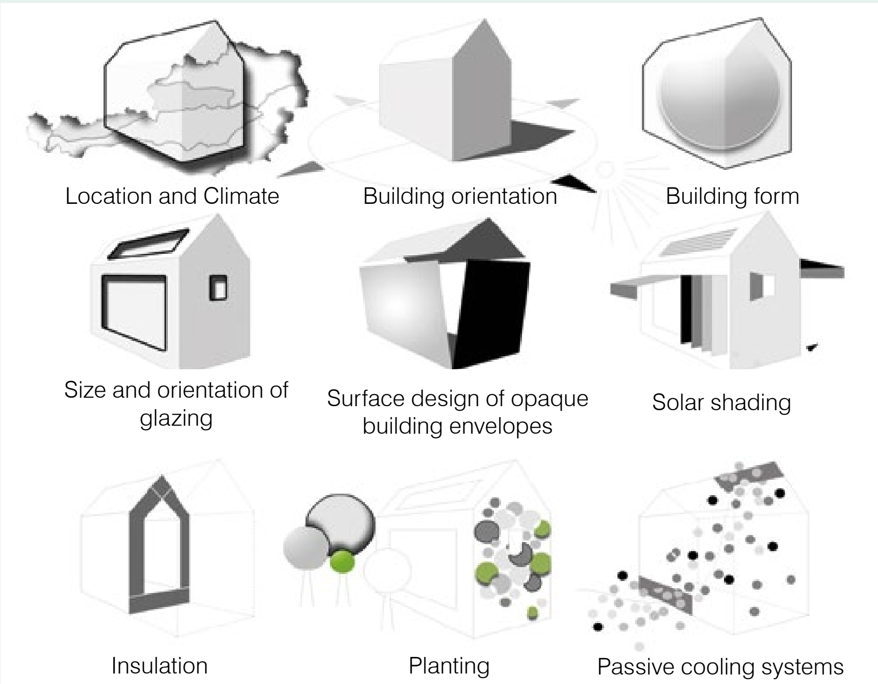


Diagram representing measures to reduce cooling demand in building design and construction

(2) Design strategies and passive measures for summer-friendly and cooling-conscious building design: At the building design stage, primary measures and influential factors to reduce the cooling energy demand of buildings were identified and systematically compiled into design and planning strategies in a comprehensive literature review. Landscapers and builders should be made aware of decisions relevant to cooling requirements during the planning process, by highlighting the most important influencing factors.
(3) Reduction of cooling demand through integrated planning processes: Although experts in the construction industry have been aware of integrated or networked planning methods for many years, planning processes in practice are usually still linear. The interdisciplinary cooperation of relevant project planning sectors - architecture, urban planning, building services, building physics, solar protection, climatology, greening of façades, facilities management etc. – is important from preliminary design phases of a project onwards.

6. Further information

6.1 Further guidance and references

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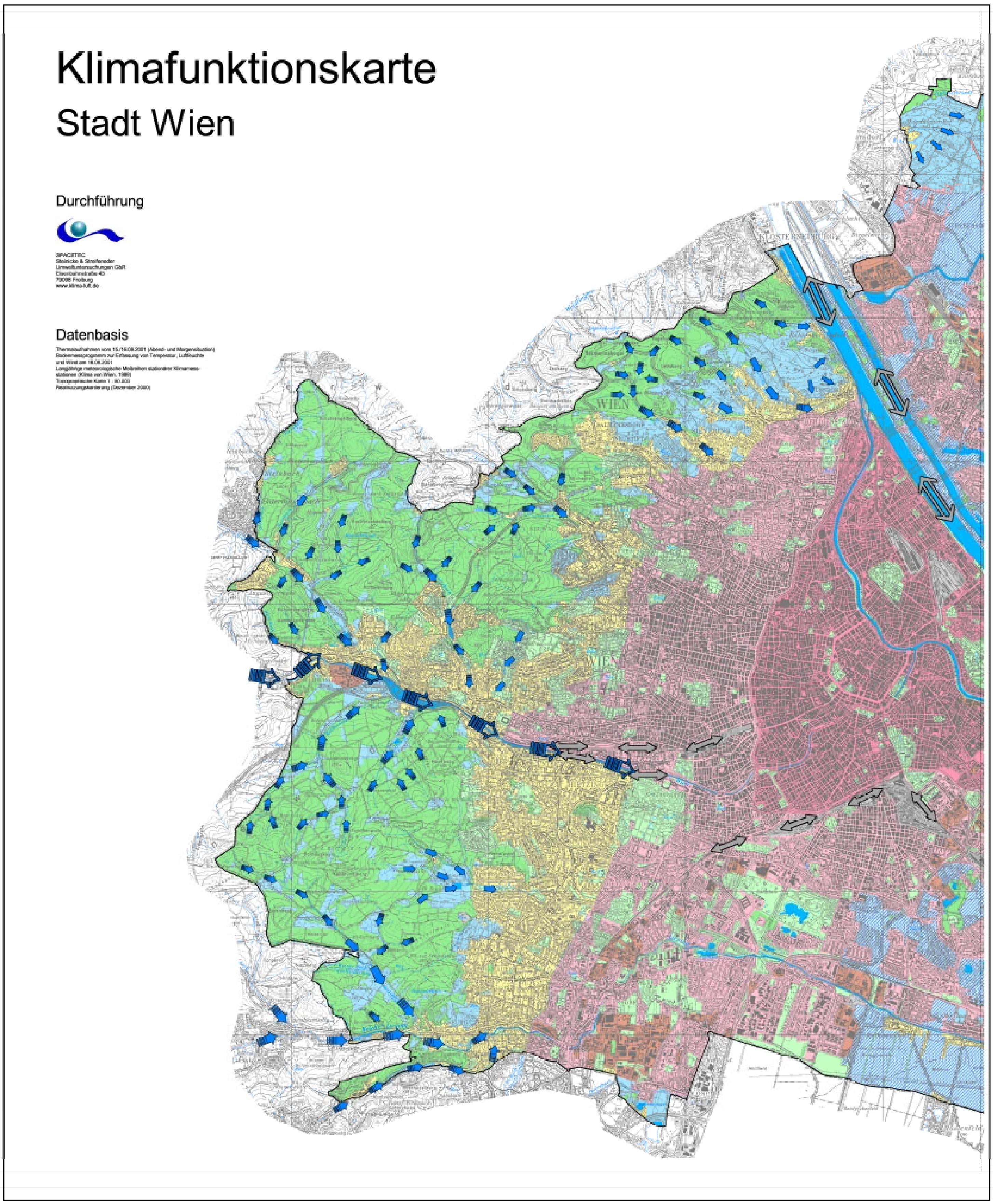
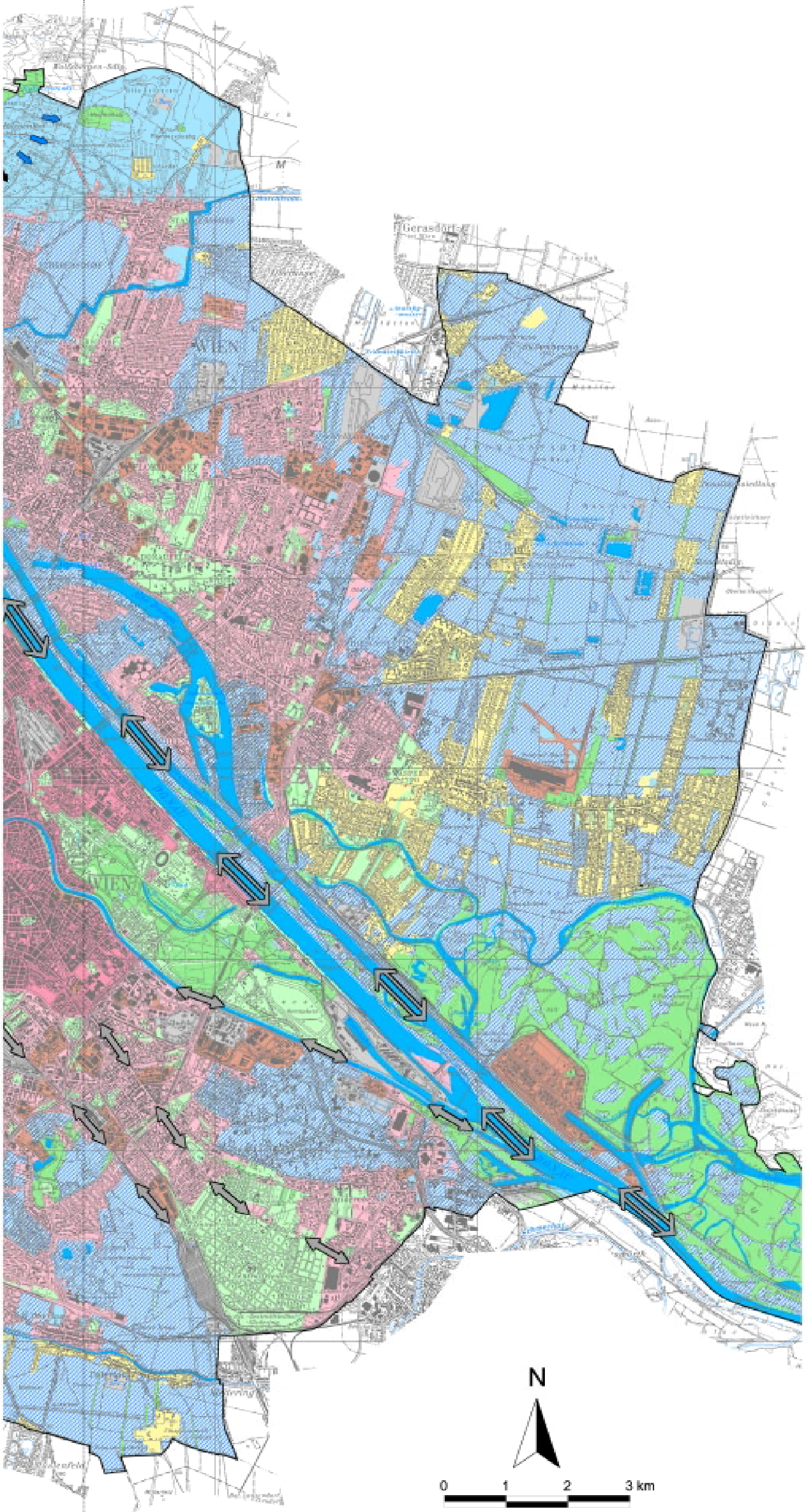
6.2 Vienna Climate Function Map



The Vienna Climate Function Map was developed as part of the Vienna urban climate investigation project. ,The climate function map shows a comprehensive, detailed representation of current thermal and dynamic climate conditions for the City of Vienna area.' (Schwab & Steinicke 2003)



Maßstab 1 : 25.000

Klimatope

Gewässerklima
Wasserflächen haben einen stark dämpfenden Einfluss auf die Lufttemperatur, sie tragen zur Feuchteanreicherung bei und begünstigen den Luftaustausch.

Freilandklima
Die Tagesgänge von Strahlung, Temperatur und Feuchte sind stark ausgeprägt. Es herrschen Windoffenheit und eine intensive nächtliche Kalt- bzw. Frischluftproduktion.

Waldklima
Strahlungs- und Temperaturschwankungen sind im Vergleich zum Freiland stark gedämpft, die Luftfeuchtigkeit ist erhöht. Im Stammraum herrschen Windruhe und relativ hohe Luftreinheit.

Parkklima
Je nach Bewuchs und Größe unterschiedlich stark gedämpfte Tagesgänge von Strahlung, Temperatur und Feuchte sowie unterschiedlich starke Kaltluftproduktion.

Siedlungsklima
Geringfügig höhere Temperaturen, ausreichende nächtliche Abkühlung, relativ guter Luftaustausch, bioklimatisch günstig.

Stadtklima
Mäßig hohe Temperaturen, mäßige nächtliche Abkühlung, reduzierte relative Feuchte, eingeschränkter Luftaustausch, bioklimatisch belastend.

Innenstadtklima
Hohe Tages- und Nachttemperaturen, geringe nächtliche Abkühlung, geringe relative Feuchte, stark reduzierter Luftaustausch, stark turbulentes Windfeld mit Böigkeit und Zugerscheinungen, bioklimatisch stark belastend.

Gewerbe- und Industrieklima
Vergleichbar mit Stadt- und Innenstadtklima, jedoch deutlich höhere Emissionen.

Sonderflächen
Sondernutzungen (Bahnanlagen, Abwasserbeseitigung, Schottergewinnung u. a.), die kleinräumig mit speziellen klimatologisch-lufthygienischen Auswirkungen verbunden sein können.

Belüftungsfunktionen

Regionale Luftleitbahnen
Großräumige Strukturen, die aufgrund ihrer geringen Rauigkeit, ihrer Richtungsgebung relativ zu den Hauptwindrichtungen und geringer Schadstoffbelastung den Austausch belasteter Luftmassen gegen weitgehend unbelastete Luft aus der Umgebung begünstigen.

Lokale Luftleitbahnen
Kleinräumige Strukturen, die den Luftaustausch innerhalb der Stadt begünstigen. Voraussetzung sind geringe Bodenrauigkeit, ausreichende Länge und Breite sowie ein möglichst geradliniger Verlauf.

Nächtlicher kühler Bergwind (Talabwind)
Großräumiges Berg-Talwindsystem mit kühlen, bis zu mehreren Kilometern reichenden Strömungen aus dem Wienerwald während windschwacher Strahlungsnächte.

Intensive Kaltluftabflüsse unterschiedlicher Dimensionierung (Talabwinde)
In topographisch vorgegebenen Strukturen wird die während windschwacher Strahlungsnächte produzierte Kaltluft kanalisiert und talabwärts transportiert.

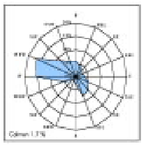
Verzögerte Kaltluftabflüsse unterschiedlicher Dimensionierung (Talabwinde)
Aufgrund von Hindernissen (Dämme, Bebauung), geringem Gefälle oder stark gewundenem Talverlauf wird der Kaltluftabfluß abgebremst.

Flächenhafte Kaltluftabflüsse (Hangabwinde)
An Hängen mit geringer Rauigkeit und ausreichender Neigung fließt die während windschwacher Strahlungsnächte produzierte Kaltluft flächig ab; Mächtigkeit, Geschwindigkeit und Reichweite sind deutlich geringer als bei den Talabwinden.

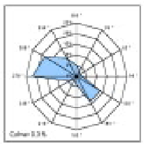
Kaltluftsammelgebiete
Gebiete mit Kaltluftentstehungsfunktion jedoch (aufgrund der geringen Hangneigung) ohne oder nur mit stark eingeschränkten Abflußmöglichkeiten, Gebiete mit Kaltluftsammelfunktion.

Nachrichtlich

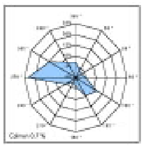
Stadtgrenze



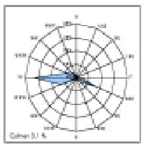
Relative Häufigkeit der Windrichtungen, Wien-Hohe Warte (1951 - 1980)



Relative Häufigkeit der Windrichtungen, Wien-Donauturm (1965 - 1980)



Relative Häufigkeit der Windrichtungen, Wien-[illegible] (1958 - 1980)



Relative Häufigkeit der Windrichtungen, Wien-Hadersdorf (1960 - 1976)

Die Klimafunktionskarte zeigt eine flächendeckende, detaillierte Darstellung der thermischen und dynamischen Verhältnisse des klimatischen IST-Zustandes, und zwar in erster Linie für windschwache, austauscharme Hochdruckwetterlagen. Es werden jedoch auch die auf alle Wetterlagen bezogenen, langjährigen mittleren Windverhältnisse berücksichtigt.

Aussagen zur thermischen Komponente basieren auf den klassifizierten Oberflächentemperaturen, vorhandenen meteorologischen Daten und den Nutzungsstrukturen.

Die dynamische Komponente des Klimas (= Strömungssituation) wird aus der Synthese der topographischen Verhältnisse, der Bodenrauigkeit und den verfügbaren meteorologischen Daten abgeleitet.

Da Vorgänge in der unteren Atmosphäre betrachtet werden, sind die Übergänge zwischen den Flächen fließend, d. h. die Abgrenzungen in der Karte sind nicht als flächen- bzw. parzellenscharfe Grenzen zu verstehen.

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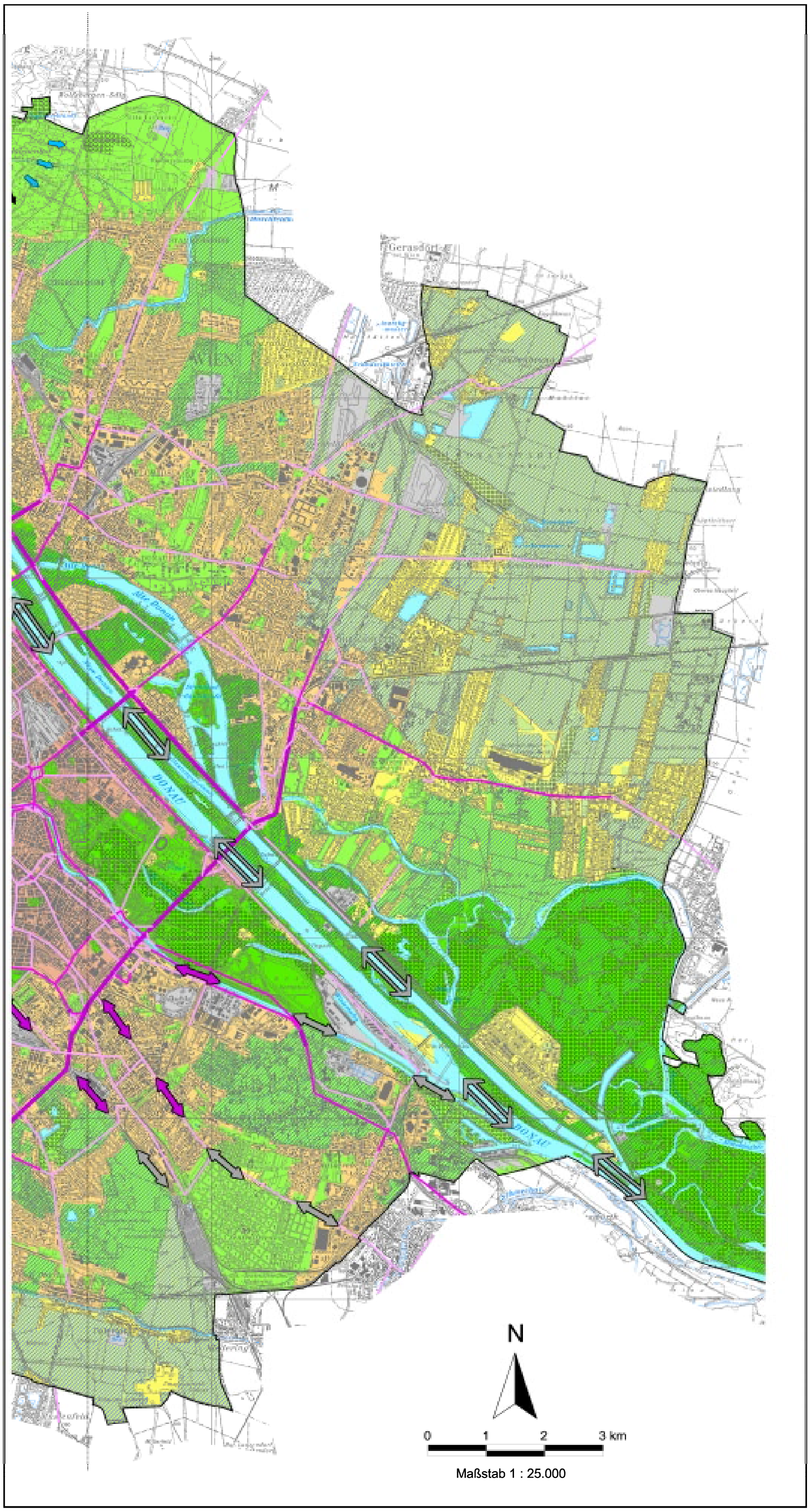
6.3 Vienna Climate and Air Quality Map

The Vienna Climate and Air Quality Map was developed as part of the Vienna urban climate investigation project. ‚In contrast to the largely value-free presentation on the climate function map, the assessment map divides open spaces into several classes according to their climate and air quality benefits, and settlement areas according to their sensitivity to urban densification or expansion.‘ (Schwab & Steinicke 2003).



Freiflächen

Klimatisch-lufthygienische Ausgleichsfunktion | Planungsempfehlung / Entwicklungsziel

- sehr hoch
- hoch
- mittel
- gering

Siedlungsflächen

Empfindlichkeit gegenüber Nutzungsintensivierung und Siedlungserweiterung | Planungsempfehlung / Entwicklungsziel

- hoch
- mittel
- gering

Luftaustausch und sonstige klimarelevante Flächen

- Regionale Luftleitbahn
- Lokale Luftleitbahn
- Nächtlicher Bergwind aus dem Wienerwald
- Intensive nächtliche Kaltluftabflüsse unterschiedlicher Dimensionierung
- Verzögerte nächtliche Kaltluftabflüsse unterschiedlicher Dimensionierung
- Flächenhafte nächtliche Kaltluftabflüsse an Hängen
- Kaltluftsammelgebiete
- Wasserflächen > 1 ha
- Sonderflächen

Vorbelastungen und Konflikte

- Strasse mit hohem Verkehrsaufkommen
- Strasse mit sehr hohem Verkehrsaufkommen
- Strasse mit extrem hohem Verkehrsaufkommen
- Lokale Luftleitbahn

Nachrichtlich

- Waldflächen
- Gewerbe- und Industrieflächen
- Stadtgrenze

Die Bewertungskarte Klima/Luft basiert auf den Aussagen der Klimafunktionskarte für die Stadt Wien. Durch die Einbeziehung von Informationen zur Luftqualität stellt sie die Verknüpfung zwischen den klimatischen und den lufthygienischen Verhältnissen her, wobei in erster Linie die Situation während windschwacher, austauscharmer Hochdruckwetterlagen betrachtet wird. Es werden jedoch auch die auf alle Wetterlagen bezogenen, langjährigen mittleren Windverhältnisse berücksichtigt.

Im Gegensatz zur weitgehend wertfreien Darstellung auf der Klimafunktionskarte werden Frei- und Siedlungsflächen gemäß ihrer Bedeutung als Ausgleichsflächen bzw. entsprechend ihrer Empfindlichkeit gegenüber Eingriffen in einer mehrstufigen Skala bewertet. Daraus lassen sich Planungsempfehlungen und Erhaltungs- bzw. Entwicklungsziele für die dargestellten Flächen und Sachverhalte ableiten.

Die Bewertungskarte Klima/Luft verdeutlicht bestehende Belastungen und Konflikte und ermöglicht eine rasche, qualitativ abgesicherte Beurteilung von Planungsvorhaben.

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6.4 List of figures

6.5 Glossary

→ Albedo

The albedo indicates the reflectance of a material as a percentage of the energy absorbed. It is described by the ratio of reflected to incident light and is a number between 0 (0% = complete absorption) and 1 (100% = complete reflection). Light surfaces (e.g. white brickwork) have a higher albedo than darker surfaces (e.g. asphalt). The higher the albedo, the lower the radiant energy absorbed by the surface. Since the reflected radiation is generally not available for the heating of a solid, a low albedo (i.e. high absorption of the incident light) is therefore usually an indication of the heating of a surface and adjacent air layers (Ranft, Frohn 2004, Climate Service Centre 2012).

→ Climate resilience

See → Resilience

→ EIA – Environmental Impact Assessment

Environmental Impact Assessment is a globally applied instrument of precautionary environmental protection legally established in Austria by the EIA Act 2000. The aim is to examine possible effects of a planned project on the environment before its implementation. Aspects of the environment that can be impacted by a project are people, animals, plants and their habitats, soil, water, air and climate, landscape as well as property and cultural assets. When serious negative impacts of a proposed project are anticipated, which can not be prevented or reduced to an acceptable level, approval must be refused (BMLFU, no year).

→ ENVI-MET

ENVI-MET = ENVIronmental METeorology Simulation Program, a holistic modelling program for simulating energetic-meteorological processes.

→ Evaporation

'Evaporation' refers to the evaporation of water from the soil surface (Ministry of Agriculture, Forestry, Enviroment and Water Management 2012).

→ Evapotranspiration

The term 'evapotranspiration' means the sum of evaporation (evaporation of water from the soil surface) and transpiration (evaporation of water from the flora and fauna) (Ministry of Agriculture, Forestry, Enviroment and Water Management 2012).

→ Gradient-weak weather conditions

A weather condition is called gradient-weak when horizontal air pressure differences are low and air movement is correspondingly weak. In summer, unstable stratification of the air due to solar radiation leads to the formation of local showers and thunderstorms, whereas stable stratification results in sunny weather (Parlow et al., 2010).

→ Green, blue and grey infrastructure

Green infrastructure (e.g. gardens, parks, green roofs and façades) and blue infrastructure (e.g. rivers, ponds, lakes) help prevent the urban heat island effect and thus reduce resulting heat stress (Schwaberger 2012). In addition, they provide many other ecosystem services, such as improving air quality or creating recreational space. While these services are provided by nature at no cost, using grey infrastructure (e.g., roads, rails, sewers, high-voltage grids) is only possible after heavy investment and in a less sustainable manner (Dudau 2011).

→ **Greenhouse gas emissions** Greenhouse gases are gases in the atmosphere that prevent heat from the Earth's surface radiating back into space thus creating liveable temperatures on Earth through a natural greenhouse effect. They occur naturally and in artificial, manufactured form. However, the additional emission of greenhouse gases by human activities (including the burning of fossil fuels) continues to heat the climate, which is why a reduction is required in carbon dioxide, methane and laughing gas/nitrous oxide emissions (MD-KLI, no year).

→ **Heat days** A heat day or tropical day occurs when the maximum daily temperature assumes a value of at least 30°C (ZAMG 2012).

→ **Heatwaves** According to Kysely et al. (2000), a heatwave period meets the following three conditions: at least three consecutive days with a maximum temperature of at least 30°C. Thereafter, the period is regarded as continuous if the maximum of the individual following days does not fall below 25°C and the average maximum temperature during the entire period does not fall below 30°C.

→ **In situ measurements** An in situ measurement is a measurement that is taken on site.

→ **Mesoclimate** 'Mesoclimate' refers to the area between the microclimate and the macroclimate. While the microclimate is mostly influenced by small-scale, local processes and the macroclimate by large-scale processes, the mesoclimate is a mixture of both. Important parameters are terrain, gradient and provision of earth surface. In addition to thunderstorms or weather fronts, many phenomena of the urban climate (e.g. urban heat island) can also be assigned to the mesoclimate (German Meterological Service, no year, a).

→ **Microclimate** 'Microclimate' refers to the specific climate of an area (= atmospheric processes with a horizontal extent up to a few hundred metres), formed in air strata at ground-level and heavily influenced by roughness or thermal properties of surfaces (subsoil, vegetation, development). Differences in terrain or vegetation within a small area can cause large temperature differences. On a summer day an asphalt surface can be several degrees warmer than an adjacent moist meadow. The microclimate is very important to the specific fauna and flora of an area (German Meterological Service, no year, b).

→ **ÖPNV – Public Transport** Public transport provides a metropolitan area and its surroundings with transportation (e.g. buses, trams, underground and overground railways) (BMVIT 2014).

→ **PMV – Predicted Mean Vote** The comfort index, Predicted Mean Vote, developed by Fanger (1970) is an attempt to measure the subjective thermal sensation of a human being. Its calculation includes meteorological parameters such as average radiation temperature, wind speed, air humidity and air temperature, but also different types of clothing (e.g. light clothing, winter clothing) and activities (e.g. sitting, walking, running) (Fanger 1970, cited in Stiles et al., 2014).

→ Perceived temperature [PET]

The perceived temperature or physiologically equivalent temperature (PET) is - in contrast to the meteorologically measured temperature - the one that a person feels subjectively. In addition to air temperature, the radiation energy, wind speed or humidity play a role in how people perceive temperature. These influences are taken into account when determining the perceived temperature.

→ PPP – Public-Private-Partnership

Public Private Partnership is a model of cooperation between the public sector (federal, state and local) and the private sector. It applies to the construction and operation of infrastructure facilities such as for transport, municipal housing, social and health care, water supply or other environmental protection. In addition to its financial capability, the technical skill and performance ambition of the private sector are used to manage public duties (Puwein & Weingärtler 2008).

→ Resilience

Resilience indicates durability, for example of a social or ecological system. It describes its ability and capacity to respond under dynamically changing conditions or disruptions in such a way that its essential functions can be maintained. It thus indicates the resistance or tolerance of a system to interference. In terms of climate, increasing resilience improves adaptability to changing climatic conditions, so that affected areas are better able to adapt to and respond to changes (Schwaberger 2012, Ministry of Agriculture, Forestry, Environment and Water Management 2012, ARL, no year)

→ Roof albedo

See → Albedo

→ SEA – Strategic environmental assessment

Strategic Environmental Assessment (SEA) describes and evaluates the environmental impact of plans and programmes and can be carried out at all stages of strategic planning activities, meaning environmental issues and any additional information for manageers and business decision-makers can be incorporated into the planning process in a timely manner. It helps to give the environment the same importance as economic or social issues. Since environmental damage can be detected and prevented or compensated for early enough, it is possible to avoid high-cost planning errors. By following certain steps (e.g. consideration of alternatives, evidencing, public participation), the planning process becomes more transparent and understandable (BMLFUW 2014).

→ sky view factor

The Sky View Factor (SVF) is a measurement to describe horizonal narrowing for a defined area of open space. It depends on the width of the area and the height of development and determines both the (short-wave) radiation input and the possibilities of nocturnal (long-wave) radiation and thus the microclimate structure of a space. While a SVF of 1 provides a clear view of the entire horizon, a SVF of 0 means no horizon view with air temperatures dominated by long-wave radiation. Smaller SVFs therefore correlate directly with urban overheating (Steemers et al., 2004 cited in Stiles et al., 2014).

→ Summer day

A summer day is deemed to be when the maximum daily temperature reaches at least 25°C (ZAMG 2012).

→ **Transpiration** ‘Transpiration’ refers to the evaporation of water from the animal and plant world (Ministry of Agriculture, Forestry, Environment and Water Management 2012).

→ **Urban climate** The term ‘urban climate’ refers to the strongly modified mesoclimate of cities and metropolitan areas compared to surrounding areas. It is primarily characterised by reduced wind speed combined with increased turbulence, increased rainfall, reduced UV radiation, increased air turbidity (haze) as well as increased air temperatures and the associated development of urban heat islands (Parlow et al., 2010). The thermal component of the urban climate is influenced by topographical location and terrain, extent and density of development, predominant building construction types, surface materials, horizon boundary, proportion of vegetation and water surfaces as well as emissions of anthropogenically generated heat in connection with industry, transport, heating or air-conditioning (Leser 2008 cited in Stiles et al., 2014).

→ **Urban climate modelling program MUKLIMO_3** The term MUKLIMO_3 stands for the 3-dimensional micro-scale urban climate modelling program of the German Meteorological Service (DWD). With this simulation program, the impacts of interventions and changes in the urban system (e.g. adaptation measures to reduce heat stress) can be specifically investigated without physically implementing it. It takes account of building structure and topographical conditions to identify potential heat stress zones (‘hot spots’), both for existing climate and anticipated future climate (LANUV 2010).

6.6 Participants in developing the Vienna UHI Strategy

We would like to thank the following departments for their co-operation and support of the project:

MA 22 – Environmental Protection (Project Coordination)

MA 18 – Urban Development and Planning

MA 19 – Architecture and Urban Design

MA 20 – Energy Planning

MA 21 - District Planning and Land Use

MA 25 – Urban Regeneration and Housing Inspectorate

MA 42 – Vienna City Gardens

MA 45 – Vienna Water

MD-BD – Construction and Technology Department

MD-KLI – Climate Protection Coordination

WUA – Vienna Environmental Ombudsman

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Vienna Technical University – Institute of Architectural Sciences, Department of Building Physics and Building Ecology

Vienna Technical University – Institute of Urban Design, Landscape Architecture and Design, Landscape Planning and Horticulture

Central Institute for Meteorology and Geodynamics (ZAMG)

Urban Heat Island Strategy – City of Vienna