Urban Heat Islands Strategy Plan Vienna – Implementing Urban Green Infrastructure to Reduce Negative Effects of Urban Heat Islands

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Introduction and Background

Urban heat islands (UHI) have been known since the 19th century (Howard, 1820) and describe the difference in temperature between cities and their rural surroundings. This difference can be up to 12°C (Eliasson, 2000, 31); the phenomenon is caused by the transformation of natural surfaces through e.g. soil sealing, construction of infrastructure and buildings. However, differences in temperature not only occur between cities and their adjacent areas, but also within different parts of cities depending on the provision of green and blue infrastructure as well as on their share of sealed surfaces. The situation is further aggravated by a changing climate. Numerous studies state that the number of heat days (maximum temperature of at least 30°C) as well as the number and duration of heat waves will increase worldwide – especially in cities due to their sealed surfaces, building density and lack of green space (Formayer et al., 2008; Bowler et al., 2010). This problem will become even more crucial in the future: in 2005 approx. half of the world population lived in urban regions and this number is predicted to rise by up to nearly two thirds by 2050 (Schlünzen, 2012). Consequences of those growing cities and expanding urban areas are further densification of settlement areas and loss of open and green space; this strengthens the urban heat islands effect even more. Urban heat islands can have negative effects on human health and wellbeing with sensitive groups such as the elderly being especially affected (Allex et al., 2013).

To counteract UHI and their negative effects, the "Urban Heat Islands Strategy Plan Vienna" has been elaborated as part of a Central Europe project (www.http://eu-uhi.eu/, 2011-2014). The aim was the development of a strategy for the City of Vienna to implement open space planning as well as urban ecology measures to reduce the negative aspects of UHI. Within the project, a guideline has been elaborated by the project team and members of the Environmental Protection Department Vienna (MA 22) to support planners, architects as well as members of the Vienna City Administration, to show possibilities of technical and strategic measures against UHI as well as their potential to reduce urban heat, and to point out planning tools and planning levels. The guideline is available online (https://www.wien.gv.at/umweltschutz/raum/uhi-strategieplan.html, in German).

Measures to reduce urban heat islands

Various measures to counteract UHI are described and discussed in literature. As the transformation of natural surfaces and the elimination of evaporation are considered to be a main reason for the development of UHI (Kuttler, 2011), measures focus on the implementation of green and blue infrastructure. Green infrastructure includes e.g. the safeguarding and installation of parks and public green space but also of alleys and single trees, the greening of facades and roofs as well as lawn areas along streets. Of course, the effects of these measures on urban heat islands and human wellbeing vary. Parks on the scale of 2.5 ha have positive cooling effects in close range, whereas parks bigger than 40 ha have distinctive climatic effects on their surroundings (Mathey et al., 2011, 38). The climatic effects of trees are based on shading and transpiration (Shashua-Bar and Hoffman, 2000, 234); the amount of their positive effect on urban climate results mainly from the size of the treetop. Therefore, high-growing, deciduous trees with large treetops should be chosen (Kuttler, 2011). Furthermore, modelling showed that the air under trees can be 10°C lower than in the surrounding area; also in the near range the temperature can be 3°C lower than in the surroundings (Brandl et al., 2011). Blue infrastructure includes soil de-sealing to enhance evaporation, irrigation and rainwater management, the implementation of water installations (e.g. fountains), the establishment of water bodies such as ponds but also streaming water. Moving waters have more effect on urban climate than standing waters (Mathey et al., 2011). However, the effect of waterways such as rivers is not only based on the cooling effect of water, but they also serve as transportation routes for cool air (Hupfer and Kuttler, 2006 in Mathey et al., 2011).

Research design

Numerous heat adaption measures have been identified through an analysis of national and international scientific literature as well as an analysis of practical examples. In close cooperation with experts from various fields (e.g. meteorology, vegetation ecology) and members of the Environmental Protection Department Vienna (MA 22) as well as of other departments of the Vienna City Administration, the identified measures were evaluated according to urban climate (microclimate/mesoclimate), urban ecology, quality of life for humans as well as economy (costs of construction/maintenance).

For the evaluation of the measures, a rating system (positive effects, no effects or negative effects) was developed and tested. The evaluations of the measures concerning the different criteria were visualised in spiderwebs, which also support the comparability of measures. Each measure was described in detail and their potentials for synergies (e.g. rainwater management, positive effects on air quality) were shown as well as their challenges (e.g. required space, heat accumulation caused by hindrance of air circulation).

In total, three workshops with experts from various fields as well as members of the Vienna City Administration were hosted, in which best practice examples in Vienna were identified and analysed. Moreover, the realisation of the measures and the respective responsibilities were discussed. Through the integration of the members of various departments, interdisciplinary solutions were elaborated.

Furthermore, relevant planning strategies and tools for the implementation of the measures to counteract UHI have been identified and evaluated.

Results

Two main fields of action to enhance the consideration of the UHI effect have been identified:

1) Urban infrastructure and large-scale strategic measures to comprise strategies and ideas to reduce heat stress in cities

2) Detailed technical and structural measures to step in the level of concrete projects and to support climate-sensitive design and planning of public space or construction objects

In total, 37 measures (including more than 60 sub-measures) were assessed, and possible implementation procedures on different planning levels – from masterplans over land-use planning down to the concrete building details of e.g. open or green space – were described in detail.

The strategic measures include e.g. safeguarding/expanding the tree stock, safeguarding/expanding green/open spaces, the circulation of air masses within the city and the network of urban green infrastructures, urban structure, street orientation and the albedo of surface materials. The technical and structural measures contain e.g. the construction of roads, green/open spaces, the greening of facades and roofs, the provision and accessibility of water in public space as well as the adaptation of buildings services. Furthermore, awareness raising, information and public relations were identified as a field of action to enhance the consideration of the UHI effect.

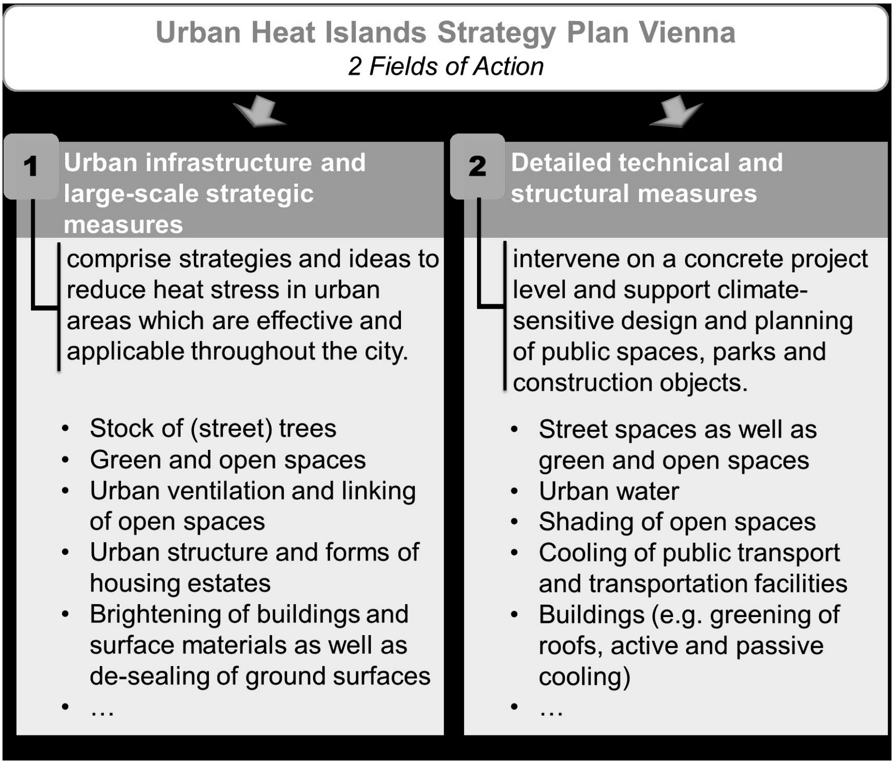

Figure 1. Identified fields of action to enhance the consideration of the UHI effect

The strategic measures include e.g. safeguarding/expanding the tree stock, safeguarding/expanding green/open spaces, the circulation of air masses within the city and the network of urban green infrastructures, urban structure, street orientation and the albedo of surface materials. The technical and structural measures contain e.g. the construction of roads, green/open spaces, the greening of facades and roofs, the provision and accessibility of water in public space as well as the adaptation of buildings services. Furthermore, awareness raising, information and public relations were identified as a field of action to enhance the consideration of the UHI effect.

For example, the measure "installation of parks" (Figure 2, photo 1) differentiates between parks of up to 2.5 ha and parks larger than 50 ha, as their effects on climate as well as their economic restrictions differ. It is obvious that smaller parks have less impact on urban climate, but also have positive effects on biodiversity and quality of life for humans. Both smaller and bigger parks have very high costs for construction and maintenance.

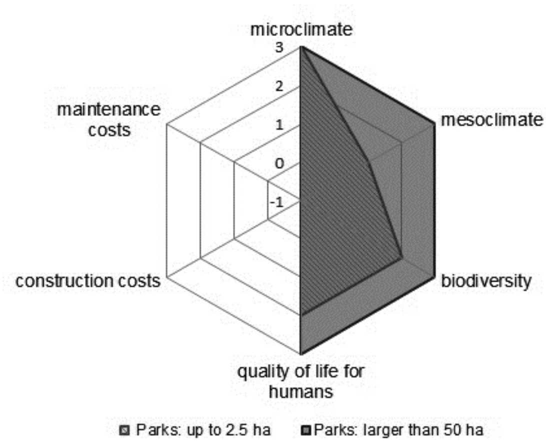

Figure 2. Spiderweb "Installation of parks" *(Ratings for the criteria microclimate, mesoclimate, biodiversity, quality of life for humans: 3 significant improvement, 2 improvement, 1 slight improvement, 0 negligible impact, -1 deterioration. Ratings for the criteria maintenance costs and construction costs: 3 no/very low costs, 2 low costs, 1 mean costs, -1 high/very high costs);* **Photo 1.** *the effects of parks depend on their dimension, but small as well as big parks have positive influence on climate, biodiversity and quality of life for humans; for both construction and maintenance costs are very high (credits: Gantner)*

The measure "increasing expanse of water" (Figure) shows the effect of the construction of (small) water bodies such as e.g. ponds as well as of the construction of artificial watercourses such as e.g. rivers within the city. It can be seen that the implementation of an artificial watercourse has stronger effects on climate than the construction of (small) water bodies, but it has higher costs in construction and maintenance. The effects on biodiversity and quality of life for humans are rated the same – of course, the evaluation may vary depending on the design of the shore and the accessibility. There is high potential for the implementation of water bodies e.g. when planning urban expansion areas (example in Vienna: Seestadt Aspern, photo 2), but also in the revitalisation of rivers (example in Vienna: 5.4 km of reactivation of the Liesing River).

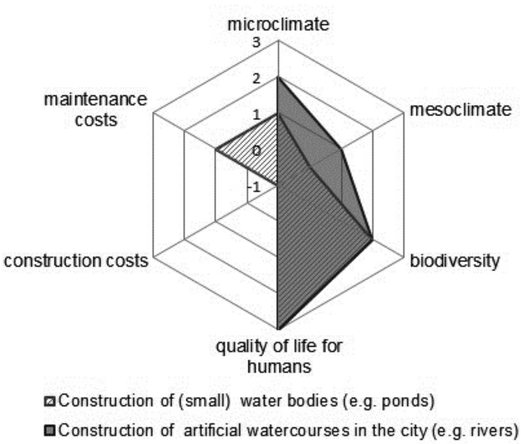

Figure 3. Spiderweb "Increasing expanse of water" *(Ratings for the criteria microclimate, mesoclimate, biodiversity, quality of life for humans: 3 significant improvement, 2 improvement, 1 slight improvement, 0 negligible impact, -1 deterioration. Ratings for the criteria maintenance costs and construction costs: 3 no/very low costs, 2 low costs, 1 mean costs, -1 high/very high costs);* **Photo 2.** *lakes significantly improve quality of life for humans but construction costs are high (credits: Damyanovic)*

The implementation of alleys either on one side of the street or on both sides is visualised in Figure 4. It is obvious that two-sided alleys (photo 3) have a higher effect on the microclimate, whereas the impact on the mesoclimate is the same as in an alley on only one side of the street. While the construction costs of both alternatives are very high, the maintenance costs for the one-sided alley are regarded as lower. The effect on biodiversity and quality of life for humans is rated the same. Challenges are existing built-in components (e.g. power lines, gas) when the implementation is planned on existing roads, and also the fact that streets represent an extreme habitat for trees (e.g. lack of water, pollutants). Furthermore, it has to be kept in mind that the implementation of alleys should not hinder the ventilation of cool and fresh air. Other negative effects of alleys may be undesired shadowing of buildings or the competition with parking space for vehicles. However, besides their positive effects described above, alleys increase water retention and evaporation and structure the urban landscape.

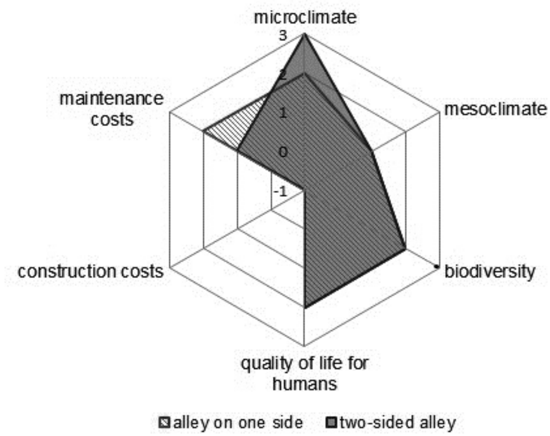

Figure 4. Spiderweb “Alleys” *(Ratings for the criteria microclimate, mesoclimate, biodiversity, quality of life for humans: 3 significant improvement, 2 improvement, 1 slight improvement, 0 negligible impact, -1 deterioration. Ratings for the criteria maintenance costs and construction costs: 3 no/very low costs, 2 low costs, 1 mean costs, -1 high/very high costs);* **Photo 3.** *two-sided alleys have positive effects on microclimate and mesoclimate as well as on quality of life for humans and biodiversity; construction costs are high (credits: Gantner)*

Conclusions

As the results showed, heat adaption measures have to be implemented on all scales and planning levels to meet the challenge of UHI. Heat adaption measures that focus on only one large-scale planning level or measures that are only implemented on a small-scale level are not expedient and effective in a long-term perspective. It is essential to involve city and landscape planners, city administration, politics as well as the population of urban areas. As further growth of cities is predicted, urban areas will merge with their rural surroundings; thus planning across the borders and boundaries of administrative units will be necessary. Besides the strategic and technical measures described in the guideline, awareness raising, information and public relations were identified as an important field of action to enhance the consideration of the UHI effect. As not only sensitive persons such as e.g. the elderly are affected by the negative effects of UHI, the phenomenon is not only an issue for planning but also for society.

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