- Implementation of incentives such as to promote high-performance actions (RIE, Municipalities of Brescia, Florence, Rimini).
- Implementation of procedures such as to highlight the quality/price ratio of each type of action (GF).
- Implementation of bonuses relative to actions which increase the quality of the visible landscape (GF).
- Integration of the indexes with a list of actions which describes, from a qualitative point of view, how to manage specific issues, providing planners with a series of potential solutions (Green Points, GSF).

An analysis of the indexes, in addition to these positive features, also shows some limits. As already mentioned, the indexes analysed show various approaches, relative to the specific urban contexts they are applied to. These indexes are structured in such a way as to promote the implementation of actions with a particular environmental value, but in some cases no solutions which would be equally profitable are envisaged, as summarized in the table below.

	LIMITS
BAF – BERLIN **GSF – MALMÖ** **GF – SEATTLE**	The indexes do not take into consideration actions not focusing on "green areas", for instance Cool Roofs (important in order to lower the heat island effect), capable of exerting a positive effect on the climate and comfort of spaces. They do not quantify a physical measure attributable to a tangible phenomenon.
RIE – BOLZANO **RIE – BOLOGNA**	The indexes only take into consideration the horizontal surfaces of the building lot, excluding the possibility of assessing the contribution of a "green" wall, and not just to qualify the positive effects of the materials used

for building Cool Roofs[5].

They do not quantify a physical quantity attributable to a tangible phenomenon.

In order to overcome these limits, it would be more suitable to implement the above-mentioned features:

- Actions not on "green areas", for instance Cool Roofs, as "high-quality" actions to promote a re-designing of the building lot.
- Definition of specific measurement units attributable to tangible physical phenomena for the calculation of the index, which enable to quantify the environmental sustainability of actions.

5 http://urp.comune.bologna.it/portaleterritorio/portaleterritorio.nsf/a3843d2869cb2055c1256e63003d8c4e/200cfbd63f33a6aac1257671004e6018?OpenDocument

3

DESIGN OF EXPERIMENTAL ENVIRONMENTAL QUALITY INDEXES

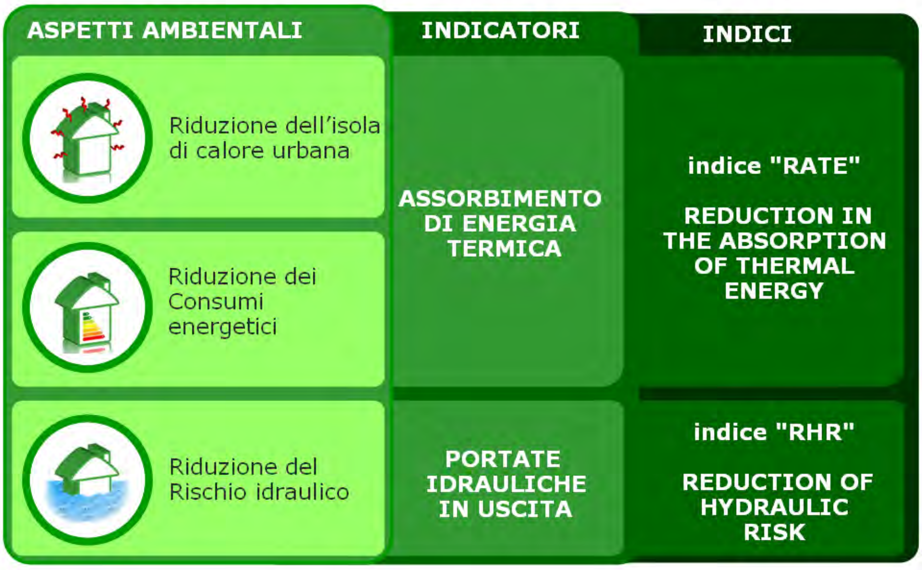
In order to implement the procedures analysed in the previous chapter, it was deemed useful to design calculation methods:

- capable of analysing all the surfaces in the building lot, yards, walls and roof,
- capable of analysing the various types of surfaces, whether green or not,
- capable of keeping the entry of data as easy as in the existing indexes,
- capable of applying the typical approximations of town-planning indexes,
- capable of highlighting environmental performances on the basis of indicators which assess tangible physical phenomena,
- capable of implementing UNI values, procedures already defined by laws or municipal rules.

In order to assess the environmental quality of a building lot, an attempt has been made to design an approach based on technical and scientific consistencies, identifying specific indicators capable of highlighting the physical properties of the building lot which significantly affect the environment. Lest the typical approach of town-planning indexes be changed excessively, it was decided to apply suitable approximations, such as to not complicate the data entry phase performed by users (appointed technicians or owners).

The main environmental features which are affected by the types of actions which can be carried out within a building lot are the effect of a heat island (outside the building), energy saving (inside the building) and hydraulic risk (outside the building lot). As a consequence, on the basis of a technical analysis of these features, the indicators chosen to characterise the building lot are the following:

- thermal energy absorbed by the surfaces (yard, walls, roof), with reference to both the heat island effect and energy saving, which shows the extent of solar radiation withheld by the building lot;
- the amount of water leaving the building lot (yards, roof or any tanks), with reference to the hydraulic risk, which shows how much water due to rainfalls is released into the sewers.



Conceptual framework applied in the designing of the indexes

The specific analysis of the two indicators resulted in two different calculation procedures and, therefore, two indexes. All the algorithms implemented by the indexes are based on validate procedures or procedures being validated by experienced technicians in this field.

In compliance with the preliminary requirement specified above, the complex calculations made in order to calculate the indexes do not make the user's data entry work more complex.

> *Note: The indexes listed below are calibrated in such a way as to be applicable to the Artisan Village, with the approval of the POC MO.W plan envisaged by the municipal administration. It is believed that this experimental application may provide useful assessment elements to extend the application of the indexes to any urban context. In this respect, applications to parts of existing towns are particularly interesting.*

The index was designed in four phases.

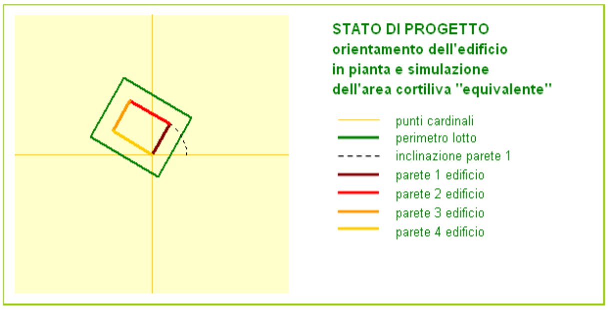
1. In the first phase, a list of building typologies was made, including the typical materials present in the existing context and used for new actions.
2. In the second phase, a physical measurement to be used as an indicator and a calculation method were identified.
3. In the third phase, the technical and physical characteristics of each construction typology and the context necessary to assess the indicator were analysed.
4. In the fourth phase, the typical approximations of town-planning indexes were applied.

3.1
PRODUCT CHARACTERISTICS

The data required for processing the indexes describe the conditions before works (actual state) and the conditions after works (planned state). The following information is required:

- the value of the Land Area in the actual state (which is also attributed to the planned state),
- the SC (covered area) value in the actual state and planned state (they may be different),
- the average height of the volume built in the actual state and in the planned state,
- the length of the longest side of the volume built in the actual state and in the planned state,
- the inclination southward (azimuth) of the longest side in the actual state and in the planned state,

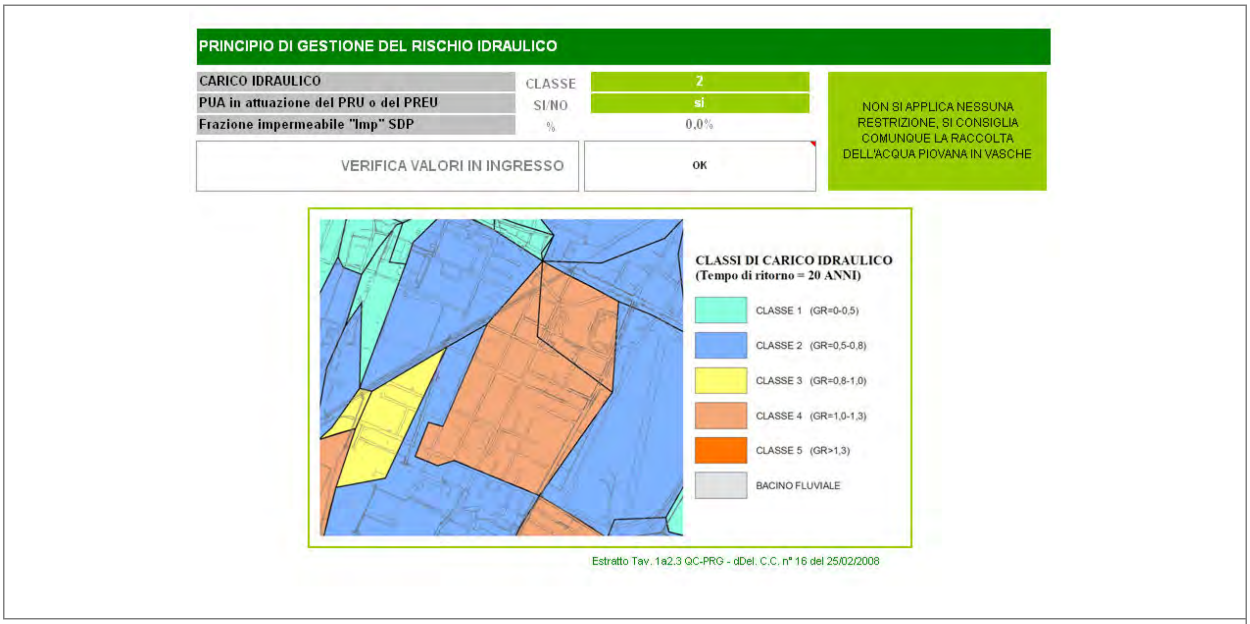
CARATTERISTICHE DEL LOTTO	UNITA' DI MISURA	STATO DI FATTO	STATO DI PROGETTO
SUPERFICIE FONDIARIA	mq	1000,0	1000,0
SUPERFICIE COPERTA	mq	300,0	300,0
ALTEZZA MEDIA	ml	15,0	15,0
LUNGHEZZA LATO a (parete 1)	ml	15,0	15,0
LUNGHEZZA LATO b	ml	20,0	20,0
INCLINAZIONE lato 1 (est-ovest) - 0° ≤α< 180°	°	60	60
VERIFICA VALORI IN INGRESSO		OK	OK



Software user's layout

In order to enable the spreadsheet to describe the hydraulic characteristics of the action area, the following information is also required:

- the hydraulic load class, as defined in the Knowledge Framework of the Municipal Structural Plan,
- the type of action (new building or restructuring).



Software user's layout

With this information, the building lot is analysed as a geometrically simplified one: in the actual state, just like in the planned state, the building volume is considered as a regular parallelepiped placed in the centre of an "equivalent" yard, in which the distance between the walls of the building volume and the limit of the property are constant on all four sides.

The inclination of the building volume makes it possible to acquire more information about the amount of solar radiation touching each wall (for this feature, see the following in-depth analyses).

The last two pieces of information (hydraulic load class and type of action) make it possible to define what principle to apply for managing the extents generated by the building lot.

Note: it is necessary to geometrically simplify the building lot lest the calculation of the index be overloaded with excessive input. By exaggerating in the definition of specific features, the index might be too articulated, thus losing its synthetic capacity. Indeed, it should be borne in mind that the aim of the index is not to create a simulation model, but to implement those already in existence.

However, subsequent implementations more specifically on the structure of the software than its logical setting cannot be excluded.

3.2
TYPES OF ACTIONS

The characteristics of the building lot are assessed on the basis of the various typologies of surfaces which characterise the actual state and the planned state. Twenty possible actions have been identified, in order to summarise the possible technical solutions used in the territory.

> *Note: If experts in this field tested the index, the envisaged typologies might be validated even further.*

YARDS

1	**gardens/meadows**	Meadows and areas to be turned into meadows, playgrounds, etc. They trigger photosynthesis and evapotranspiration processes capable of reducing the effects of the heat in the environment. They make it possible to preserve permeability of the ground. The planting of trees and bushes promotes the establishment of air movements and inhibits the discomfort which might be generated in large empty areas due to evapotranspiration processes.
2	**Trees/bushes**	They increase the surface of plants capable of producing photosynthesis or evapotranspiration processes. They enhance shading, resulting in the formation of areas protected from direct radiation. They can trigger air movements with local recirculation. Their positions must be considered depending on the position of buildings and main winds, in order to avoid the formation of "barriers" and interferences with the natural circulation of the air.
3	**self-blocking**	It makes it possible to make an area suitable for vehicles, while keeping part of the area permeable green.
4	**meadow suitable for vehicles**	It makes it possible make a yard suitable for vehicles without ruining the aesthetics of the garden and just partially reducing the permeability of the area. In these areas, however, planting trees or bushes is not allowed.
5	**with "cold" asphalt**	It is a light-colour asphalt used for city street infrastructures. It limits overheating due to solar radiation, but inhibits permeability of the ground.
6	**with normal asphalt**	It makes large areas suitable for vehicles, but inhibits permeability of the ground and causes overheating due to solar radiation.
7	**with gravel**	Ground with inert material which makes an area suitable for vehicles, limiting overheating due to solar radiation, while keeping a good part of permeability.

VERTICAL SURFACES

8	**green with a frame on the wall**	It is made by applying supports to vertical walls, adhering to them or at a certain distance, in order to facilitate air circulation. It is easy to make and takes advantage of the properties of certain rambling plants to grow upwards up to 20 metres of height, thus simplifying maintenance and creating an easily manageable aesthetic and protective effect. It enhances shading of the walls it covers and triggers photosynthesis and evapotranspiration processes capable of lowering the effects of heat in the environment. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.
9	**green integrated in the wall**	It is made by applying supports to the vertical walls, at a certain distance in order to facilitate air circulation. Inside the frame, some bags of earth are inserted, containing suitable plants. A watering system makes it possible to irrigate yearly and provides for the necessary fertilisation/watering to enrich the ground 3-4 times a year. It enhances shading of the walls it covers and triggers photosynthesis and evapotranspiration processes capable of lowering the effects of heat in the environment. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.
10	**ventilated with a frame on the wall**	It is a coating system laid dry on new buildings or existing constructions, which creates an air chamber between the wall and the coating. The energy benefits are mainly relative to the interior of the building rather than its outside; the ventilated wall lowers the energy load affecting the building in summer (thus lowering air conditioning expenses) and keeps the heat inside the building in winter (thus lowering heating expenses). The specific effect on the heat island can be compared, to a lesser extent, to that of wet surfaces in Japanese experimental buildings. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.
11	**plastered painted with a light colour**	This is a standard plastered surface, with a colour which partially reduces absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.
12	**plastered painted with a dark colour**	This is a standard plastered surface, with a colour which does not particularly reduce absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.
13	**visible bricks**	This is a standard surface, with a colour which does not particularly reduce absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the wall.

HORIZONTAL SURFACES		
14	**"extensive" green**	It is a garden, generally not accessible and particularly suitable for covering large areas, whose plants have the function of holding the ground. Maintenance is limited and the watering system is simple. Its thickness is approximately 5-12 cm, with a corresponding overload of about 60-250 kg/m_2. It triggers photosynthesis and evapotranspiration processes and can keep part of the rainfalls. In case of accessible green areas endowed with trees and bushes, the right term would be "intensive" green, but it is not taken into consideration by this study, due to its high costs. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
15	**“cold”**	It inhibits the amount of thermal energy going into buildings and its accumulation, with subsequent release into the environment. It is made by applying specific coatings (plasters, resins, paints, ceramics, etc.) and does not result in significant overloads. It is mainly applied to flat surfaces in buildings for productive activities. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
16	**"cold" tiles**	It inhibits the amount of thermal energy going into buildings and its accumulation, with subsequent release into the environment. It is made by using specific tiles and does not result in significant overloads. It makes it possible to also apply the "cold" roof technology to buildings covered with tiles. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
17	**photovoltaic (roof tile or else)**	It does not particularly inhibit the amount of thermal energy going into buildings and its accumulation, with subsequent release into the environment. Solar, photovoltaic or transparent roof tiles are an alternative to solar or photovoltaic panels, both in the construction of the roofs of new buildings and in their restructuring, since they make it possible to keep the house cover aesthetically pleasant, without giving up the possibility of using the solar energy for producing electric power or hot water. As an alternative, the use of photovoltaic panels applied to the cover makes it possible to optimise results, since they are placed according to the function of the specific latitude. The effect can be compared to that of a cold roof. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
18	**tile roof**	This is a standard surface typical of houses, made of materials which do not particularly reduce absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
19	**light colour flat roof**	This is a standard surface typical of production buildings, with a colour which partially reduces absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.
20	**dark colour flat roof**	This is a standard surface typical of production buildings, with a colour which does not particularly reduce absorption of thermal energy due to solar radiation. It is possible to write the year of construction on the wall, in order to keep track of the thermal resistance of the roof.

3.3 DATA ENTRY (ACTUAL STATE – PLANNED STATE)

Having identified the various types of actions characterising the Actual State (SDF) and the Planned State (SDP), the number of square metres relative to each surface typology is to be entered.

CORTILE

	INTERVENTO	UNITA' DI MISURA	STATO DI FATTO	STATO DI PROGETTO
1	giardini / aiuole	mq		700,0
2	alberi / arbusti	n°		
3	autobloccante	mq		
4	prato carrabile	mq		
5	con asfalto "freddo"	mq		
6	con asfalto normale	mq	700,0	
7	in ghiaia	mq		
	sommatoria valori inseriti [mq]		700,0	700,0
	totale da raggiungere [mq]		700,0	700,0
	VERIFICA VALORI IN INGRESSO		OK	OK
!	RACCOLTA ACQUE PIOVANE	mc	CALCOLA IL VOLUME	0

PARETI

	INTERVENTO	UNITA' DI MISURA	STATO DI FATTO N° PARETE 1	2	3	4	STATO DI PROGETTO N° PARETE 1	2	3	4
8	verde con telaio su parete	mq								
9	verde integrata nella parete	mq					225,0	300,0	225,0	300,0
10	ventilata con telaio su parete	mq								
11	intonacata tinteggiata chiara	mq								
12	intonacata tinteggiata scura	mq	225,0	300,0	225,0	300,0				
13	mattone a vista	mq								
	sommatoria valori inseriti [mq]		225,0	300,0	225,0	300,0	225,0	300,0	225,0	300,0
	totale da raggiungere [mq]		225,0	300,0	225,0	300,0	225,0	300,0	225,0	300,0
	VERIFICA VALORI IN INGRESSO		OK				OK			
!	ANNO DI COSTRUZIONE		dal 1960 al 1976	dal 1960 al 1976	dal 1960 al 1976	dal 1960 al 1976	per de trazioni	per de trazioni	per de trazioni	per de trazioni

TETTO

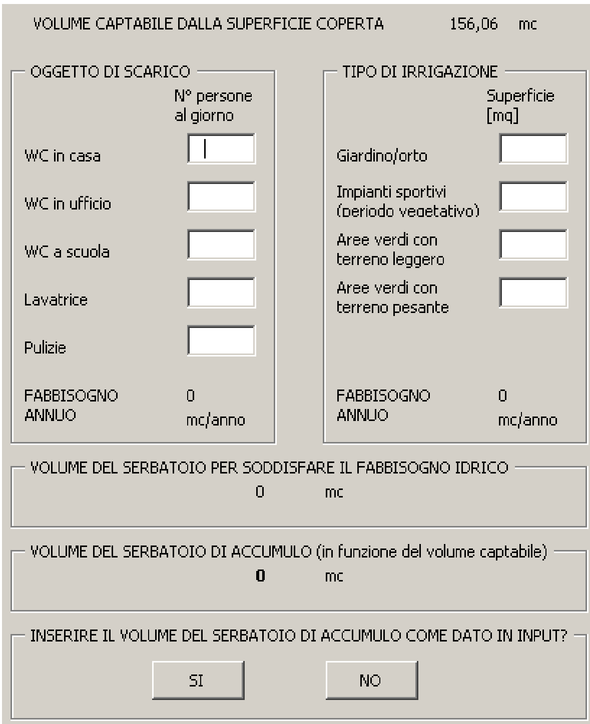
	INTERVENTO	UNITA' DI MISURA	STATO DI FATTO	STATO DI PROGETTO
14	verde estensivo	mq		300,0
15	"freddo"	mq		
16	tegole "fredde"	mq		
17	fotovoltaico (tegole o altro)	mq		
18	tetto a tegola	mq		
19	tetto piano chiaro	mq		
20	tetto piano scuro	mq	300,0	
	sommatoria valori inseriti [mq]		300,0	300,0
	totale da raggiungere [mq]		300,0	300,0
	VERIFICA VALORI IN INGRESSO		OK	OK
!	ANNO DI COSTRUZIONE		dal 1960 al 1976	per de trazioni

Software user's layout

For trees, it is necessary to enter the total number of those already present ("tree" means an element of approximately 3 metres of height, with a crown of approximately 8 m^2, which is deemed to be the equivalent of 4 bushes of about 1.5 metres of height and covering a surface of approximately 4 m^2).

For the specific calculation of thermal resistance of the walls and roof, it is necessary to enter the year when the walls and roof were built. For walls or a newly-built roof, by selecting the "ex lege" option, the minimum parameters required by law are set, whereas by selecting "per detrazioni", the legal parameters which may benefit from fiscal deductions are set.

In the data entry phase, it is also possible to specify if a rainwater collection tank is present, as defined by the voluntary requirement of the Building Town-Planning Regulations (RUE, No. XXVIII.3.2) of the Municipality of Modena. It is possible to specify the cubic metres of the tank or to calculate the cubic metres necessary in a specific context (by filling in a simple table, based on the provisions in the RUE).



Module implemented in the software for calculations relative to the rainwater collection tank, as defined in the RUE

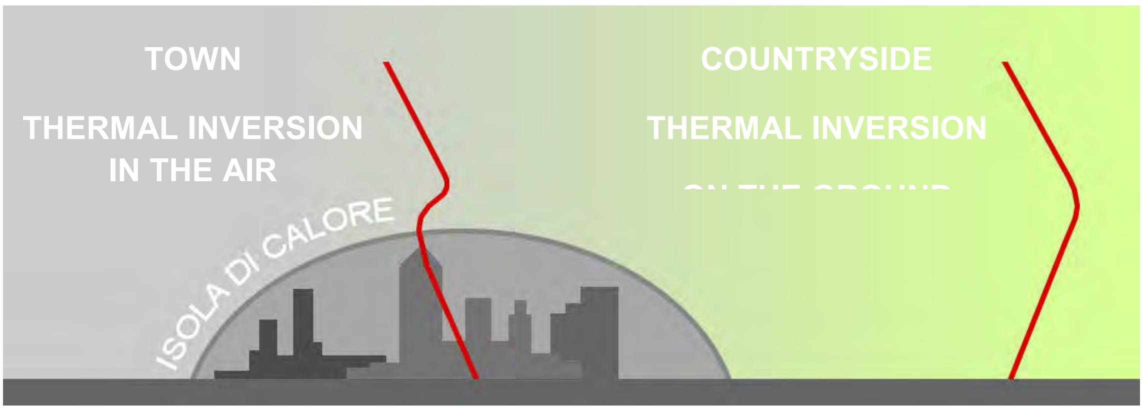
4

"RATE" INDEX (REDUCTION IN THE ABSORPTION OF THERMAL ENERGY)

In days characterised by anticyclonic conditions in the air and strong stability on the ground, a vertical temperature profile is established, with Thermal Inversion (thermal inversion on the ground, countryside). The heat produced by the buildings tends to contrast the vertical thermal inversion, without totally breaking it (thermal inversion in the air, town), creating an air dome whose maximum height corresponds to the zone with the highest concentration of buildings.

The inversion layer creates a barrier which prevents a redistribution of vertical air all over the atmosphere layer available. This creates a heat island, which therefore depends on the season, geographic position of the town and its characteristics.

This "blanket" withholds the heat, thus raising the temperature (for instance, minimum temperatures at night).



Graph showing the Urban Heat Island phenomenon

The presence of materials endowed with little capacity to reflect solar radiation (solar reflectivity), in conditions of strong solar irradiation, results in high thermal loads on the surface in general. If this surface has a scarce thermal isolation capacity (thermal resistance), it tends to warm up and, in its turn, if it does not have a good capacity to release this heat by irradiation (emissivity), it will take a certain period of time to return to ambient temperature. Continuing to release heat, even during the night, the material will affect the rising of the temperature within the heat island.

The capacity of materials to reflect solar radiation (solar reflectivity), to release the heat absorbed (emissivity) and to isolate thermally (thermal resistance) make it possible, at the same time, to reduce the heat entering buildings (in summer) and reduce thermal dispersion from the inside to the outside (both in summer and in winter), thus making it possible to reduce both summertime consumption due to air conditioning systems and winter consumption due to heating systems, improving energy saving.

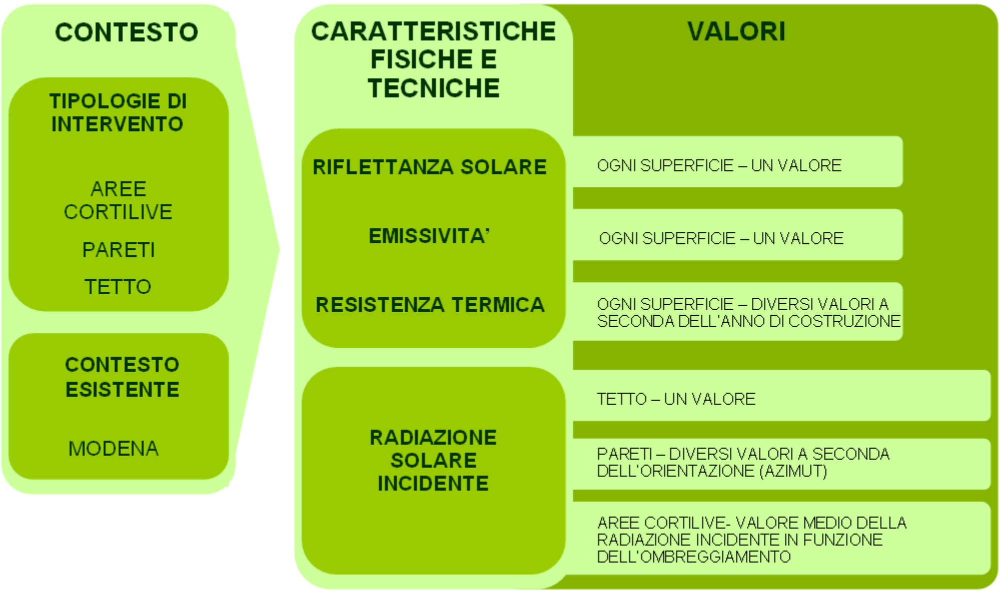
4.1
PHENOMENA ANALYSIS METHODOLOGY

The physical properties of the materials which make up the building lot (solar reflectivity, thermal resistance and emissivity) can be combined along with incident solar radiation in order to obtain a single value expressing the thermal energy absorbed [kWh/m^{2}y].

Summary of the methodological approach

For each type of floor, wall and roof (reported in the table above), the respective identification parameters were obtained (solar reflectivity, thermal resistance and emissivity).

In order to take into consideration the various irradiation conditions of the roofs and walls, energy values per unit of surface were used, obtained by applying norm UNI 10349 (for walls this value was attributed as a function of the azimuth angle). For assessing irradiation of yards, starting from the energy associated to the horizontal surface, the amount of energy lost due to the shading caused by the "equivalent" building lot was taken into consideration. For this calculation, a calculation file already in existence is used[6], based on the UNI norms in force.



Summary of the methodological approach

Note: deterioration of the technical characteristics of materials and degradation of plant elements are not taken into consideration. For instance, in case of building defects, ageing of surfaces, lack of watering of green areas or increased volume of trees, the typical parameters of each single surface and, as a consequence, their relative indexes might vary.

Note: the yards simulated by the "equivalent" lot do not take into consideration the real position of the various grounds; the average value of radiation on the yard is associated with them.

[6] "SOLE – Stima Ombreggiamento Locale Edifici" – Dott. Ing. Giulio de Simone – Dipartimento di Ingegneria Meccanica – Università degli studi di Roma "Tor Vergata" – Excel file.

4.2
SIMULATION OF PLANTS

For calculating the thermal energy absorbed by trees or bushes, by using parametric coefficients, the part of solar radiation used for the photosynthesis (about 5%) and which is released as latent heat in evapotranspiration processes (about 45%) were taken into consideration.

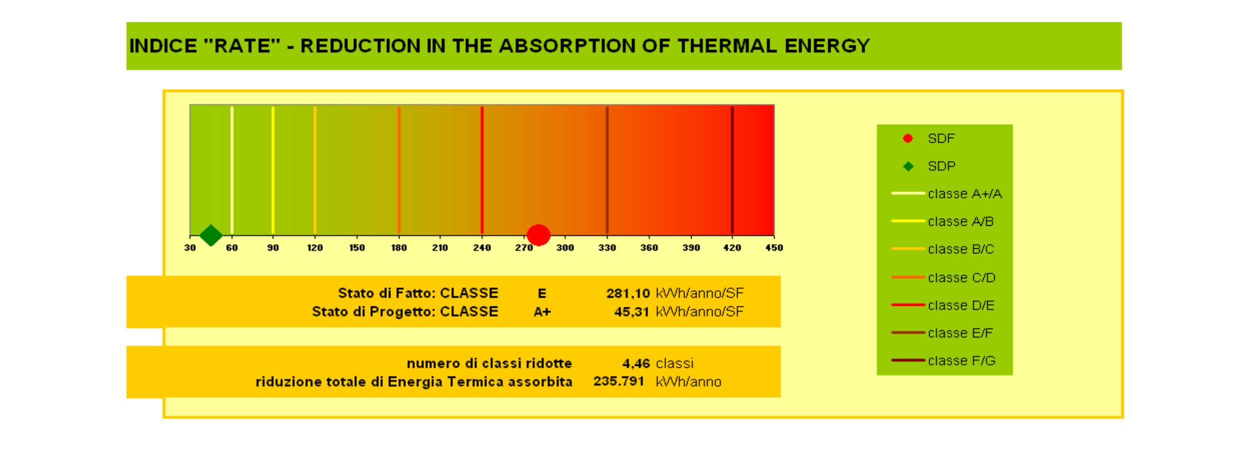
In order to assess the effects of trees, the shading in the yards due to the tree crowns (also with reference to the loss of shading due to proximity of trees with the property limits) is assessed, as well as the consequent loss of energy on the garden. In the calculation, the thermal energy absorbed by the tree crowns is also calculated, but the shades, if any, on the building walls is not assessed.

4.3
INDEX OUTPUT

Calculating the index, the total thermal energy absorbed by the surfaces making up the building lot (kWh/year) is calculated in the Actual State and in the Planned State. The ratio between these values and the Land Area (SF) is the index reference parameter (kWh/year per m_2 of SF). By associating the thermal energy absorbed by all the surfaces in the building lot with the Land Area only, we take into consideration the "weight" of the building volume (if the volume grows, the index grows, the SF being the same).

The output value is the measure of specific "performances" of the building lot and can be highlighted depending on various features.

- the class of the planned scenario (SDP) identifies the quality of the action;
- by processing the different classes of energy performance which output values are associated with, the number of reduced classes between the initial scenario (SDF) and the planned scenario (SDP) highlights the improvements achieved;
- the total reduction of thermal energy absorbed (kWh/year) in the planned scenario (SDP), in comparison with the initial scenario (SDF) highlights the extent of the improvements with reference to the building lot size.



Software output

Note: air circulation is not taken into consideration, therefore the natural movements of the air and the "barriers" which might be caused by the positions of buildings and trees are not assessed. For these issues, see the relevant guidelines.

Note: the canyon effect due to the presence of adjacent buildings is not taken into consideration, therefore it has to be dealt with, from a qualitative point of view, by referring to relevant guidelines.

Note: the energy performance classes used so far are approximate, they will have to be adjusted by analysing various study cases. From a merely qualitative point of view, the class typology used draws inspiration from the one used to classify energy performances of buildings (there is no relevance from a quantitative point of view).

Note: the assessments were made with reference to the yearly solar radiation, but the software is also set to calculate the summer solar radiation. In order to enhance improvements even more, in terms of energy consumption reduction (relative to the yearly solar radiation) or reduction of the heat island effect (more relative to the summer solar radiation), some further software implementations are being designed.

5

"HYPER" INDEX (HYDRAULIC'S PERMEABILITY AND ELEMENTS OF RETENTION)

A building lot capable of ensuring proper disposal of surface water and rainwater, avoiding their stagnation and promoting a controlled outflow, contributes to mitigation of floods in urban area and non-urban areas, thus helping to reduce the hydraulic risk. The technical characteristics of building lots, necessary to meet these conditions, are defined in the municipal Building Town-Planning Regulations (RUE, binding requirement No. XXVIII.3.14).

The RUE define various principles to manage the hydraulic risk in the territory. For defining these principles, several data are necessary: the size of the surface of the building lot analysed, the fraction of the total area deemed to be impermeable, the hydraulic load class (which makes it possible to differentiate the various basins as "critical" and "non-critical") and the type of action (new building or restoration of areas already urbanised).

The applicable principles require a maximum value to be applied for the outgoing extent from the building lot in the planned scenario; they may be the following:

- principle of controlled hydraulic increase: it allows a possible specific extent increase of up to 100%, 50% or 30% of the specific value of the outflow of the area in question, as it was before the start of the action;
- hydraulic invariance principle: it keeps the specific value of the outflow of the area in question unaltered, as it was before the start of the action;
- principle of hydraulic attenuation: it requires a specific outflow extent reduction of at least 30%, 40% or 50% of the specific value of the outflow of the area in question, as it was before the start of the action.

All the principles are based on the specific value of the outflow of the area in question unaltered, as it was before the start of the action. This value is usually calculated when the hydraulic sheet of the building lot in question is drafted and requires the number of square metres of the various yards and roofs to be specified. These surfaces, associated with specific outflow coefficients and the hydrological parameters defined in the RUE, make it possible to determine the size of the rainwater drainage network (with a return time of 20 years).

For calculating the index, a calculation algorithm was implemented which, on the basis of the principle of hydraulic risk management to be applied in the building lot, defines the maximum value allowed for the outflow extent due to the SDP (Qsdp,max). If the outflow extent generated by the input action typologies for characterising the SDP (Qsdp) exceeds this value, the index requires a check of this extent and imposes the Qsdp=Qsdp,max equation, envisaging the presence of a lamination tank in the line where exceeding extents flow, then it calculates the volume of the reservoir. The tank is calculated on the basis of a return time of 50 or 100 years (depending on what is envisaged by the RUE).

If the user has chosen to prepare a rainwater collection tank, and the index has calculated that it is necessary to also envisage a lamination tank, then the square metres of the rainwater tank are deducted from those of the tank.

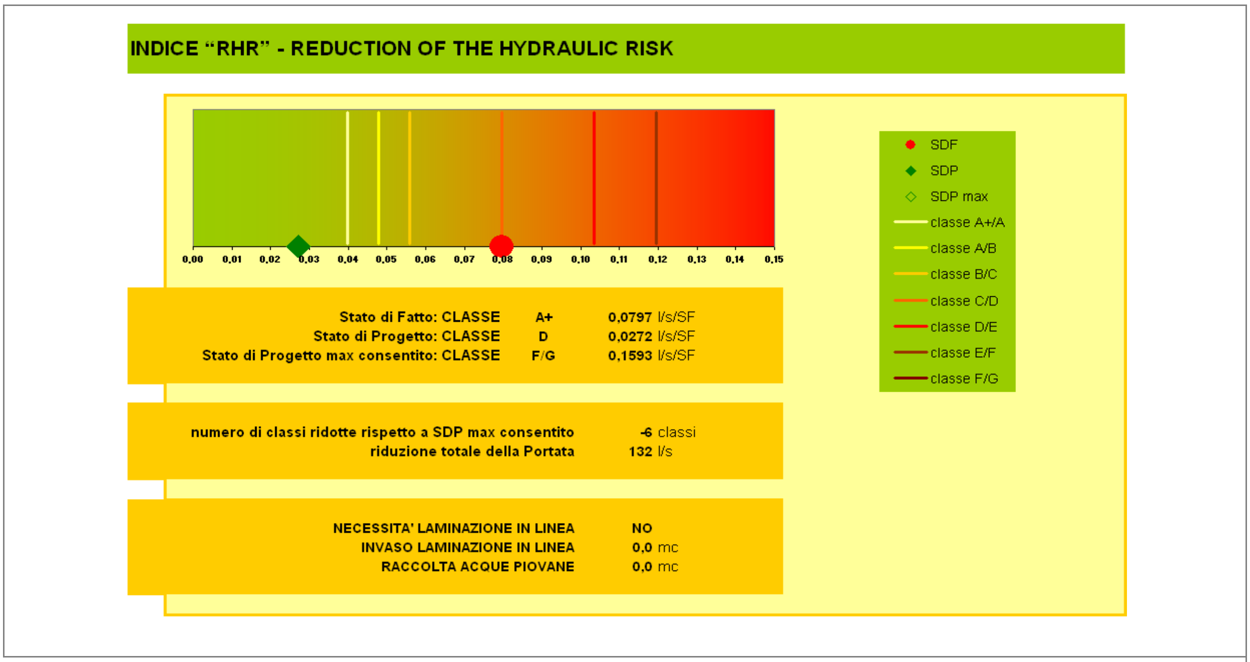
5.1 INDEX OUTPUT

In the calculation of the index, the extent (l/s) in the Actual State and in the Planned State is defined. The ratio between these values and the Land Area (SF) is the index reference parameter (l/s per m_2 of SF).

Since the hydraulic risk management principles "calibrate" the plan extent (Qsdp) on the basis of the extent in the actual state and the maximum plan extent acceptable (Qsdp,max), the classes defined for assessing the output have been associated to the Qsdp,max values required by the various principles. In this case, unlike what was done for the "RATE" index, the output produced by the Planned State was not compared with that of the Actual State, but with the maximum one in the Planned State (determined by the principle applied).

The output value is the measure of specific "performances" of the building lot and can be highlighted depending on various features.

- the planned scenario (SDP) class identifies the quality of the action with reference to what is already required by the principle applied (SDPmax);
- by processing different classes of energy performance output values are associated with, the number of reduced classes between the planned scenario (SDP) and the maximum planned scenario (SDPmax) highlights the improvements achieved;
- the total reduction of extent (l/s) in the planned scenario (SDP), in comparison with the maximum planned scenario (SDPmax) highlights the extent of the improvements with reference to the building lot size.



Software output

Note: energy performance classes defined in this way are variable, since they are associated with values depending on the extent of the Actual State in the specific building lot analysed. A different approach from the one applied for the "RATE" index is therefore used. For the validation of this approach, see further analyses.

6 INDEXES AS GUIDELINES FOR THE PLANNING PHASE

The analysis of the indexes already used by other administrations, the analysis of the possible solutions to implement in yards and to cover buildings, and the analysis of the respective physical and technical characteristics have made it possible to obtain a complete and rational list of types of action, to be included in the experimental indexes. This list is the starting point for the various technical criteria explained in the previous chapters for calculating the output of the indexes, and it has been designed in such a way as to guide the planning in the implementation of new buildings and in the upgrading of existing buildings. By defining the characteristics of the existing context and the possible planning solutions, planners receive output which enables them to check the overall improvements achieved (in terms of reduction of the RATE or HYPER index).

If planners intend to modify the overall improvements, they can change the combination of types of planned actions and obtain new outputs, to be compared with the previous ones, in order to refine the planning and increase its environmental value.

The types of actions included in the indexes represent, therefore, a reasonable and functional synthesis of planning guidelines, which can provide both support to the architectural planning and an assessment of the impacts generated immediately and with suitable precision.

6.1 *INDEXES AND ECONOMIC ASSESSMENT OF PLANNING SOLUTIONS*

As an integration to the planning support tools mentioned above, the indexes also implement an assessment of the parametric costs of the various types of action envisaged. By applying the same approach used for the assessment of impacts produced by the planning solution envisaged by the planner, a dynamic table has been designed, relative to the parametric costs of planning actions.

In this way, planners check the types of action chosen which might be applied in order to find the right balance between costs and resources. Moreover the planner is able to verify the quality/cost ratio of each type of action.

In order to promote such analyses, the software shows the synthesis of all the information relative to the two indicators and the parametric costs. By reading the information relative to each type of action, it is possible to easily check and compare the impacts caused and the relative costs.

7

FURTHER GUIDELINES SUPPORTING THE PLANNING PHASE

In order to design the indexes, the need to implement a greater number of potentials, for calculating the environmental value of the building lot while trying to keep its use suitably simple, was discussed for a long time. While designing the software, it was decided to make some simplifications and not to implement certain physical aspects. The indexes and calculation methods implemented could be improved even more, in order to remove the simplification applied and refine the processing, also including all the necessary physical issues; in this way, though, the immediate applicability of a town-planning index would be lost and you would have a calculation software programme with an enormous potential, but only to be used by suitably trained experienced users. Although at the moment it is not possible to exclude such a future development, for the time being the structure of the indexes has willingly been processed in such a way as to make it as simple and self-explanatory as possible. Although the indexes require much more complex processes than those developed for similar indexes already in existence, in the data entry phase the approach has not been altered. Like in the other indexes, observations are put forward about a building lot, the materials present in it and their specific sizes. This approach identifies the building lot as an independent item, without putting it into the existing urban context.

This approach is a non-banal simplification of the context analysed, which has two limits:

- since the context in which the lot lies is not known, it is hypothesized that the solar irradiation conditions in the lot are not affected by elements outside the lot itself, like buildings, rows of trees, etc. This simplification makes it possible to apply the same theoretical maximum irradiation to each lot and, as a consequence, provides output values comparable among the various lots. The negative side of this approach is not seeing a lot within its specific context; for instance, although the indexes can assess the positive effect due to photovoltaic panels, installing them on a building would make no sense if that building stood in the shade of a skyscraper in the hours of the day when sun exposure is maximum;
- although the context in which the building lot lies is not known, the indexes will merely be used for analysing the impacts caused by the lot "within the lot" and do not allow to check the relationship between impacts caused by the lot and the surrounding lots. Therefore, the indexes cannot simulate how proximity to other buildings, roads or other structural elements of the town may affect the indicators taken into consideration on the whole.

These issues show that the use of the indexes cannot ignore knowledge of the territory in which a general action takes place. The data produced by the indexes must be supported by further assessment elements, to be processed on the basis of a careful analysis of the urban context.

As for the Artisan Village, these elements are represented by the guidelines envisaged *ad hoc* within the framework of the EU "UHI Project", in which the Artisan Village Upgrade Plan is a pilot study case. These guidelines have revealed the urban and building characteristics, the main environmental issues, morphological, climatic and architectural aspects of the town structure already in existence and the possible planning features within the framework of the Artisan Village.

By processing this content even further, the experimental indexes design phase will be completed, and a list of guidelines will be drafted to support the planning. By taking into consideration the various territorial contexts within the Village (for instance: lot on the side of a street, lot inside other lots with buildings of the same height, etc.), these guidelines will be useful for the planning phase.

For example, in this way such phenomena as the Urban Canyon and the air circulation dynamics will be taken into consideration and, before deciding what planning actions to enter into the software programme to calculate the indexes, it will be possible to have a further tool for analyses, which can help planners to choose the best types of actions.

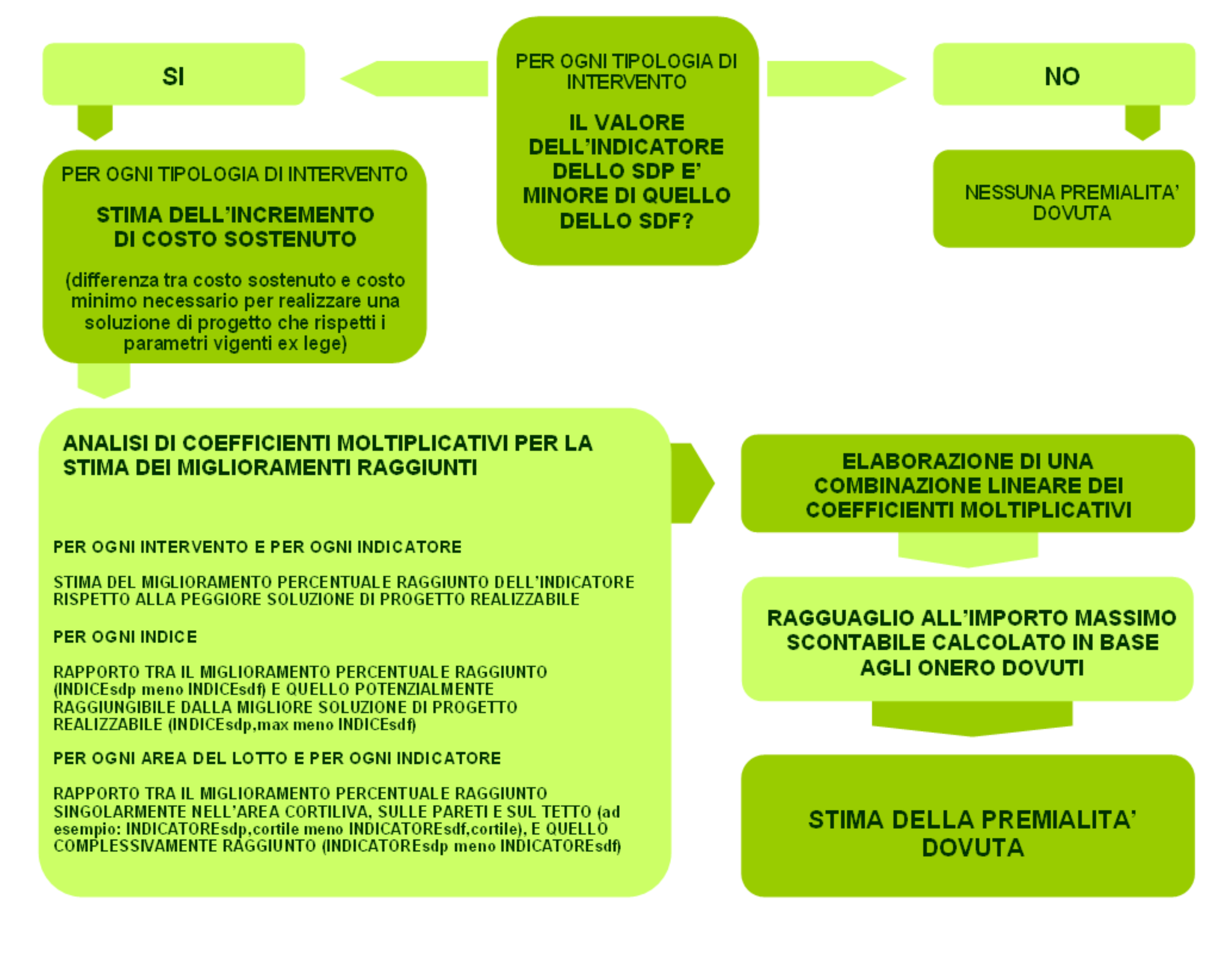
Later on, the main features which can affect the planning phase (presence of roads, presence of buildings, presence of green barriers, etc.) will be extracted from these guidelines, and a list of best practices will be drafted, to be applied in the planning of these features. In this way, by following and implementing the experience of the Green Points of Malmö, a list of actions will be drafted, which planners will have to respect in the planning of a building lot, having checked the surrounding context.

8
INCENTIVES, BONUSES AND AWARDS

The analysis of the urban indexes in existence, which has served as a basis for this study, initially aimed to define a measurement tool such as to quantify the improvements made by high-quality planning solutions, such as green walls or green roofs, and such as to provide a calculation method for assessing the awards to attribute to these types of actions, taking into consideration the environmental benefits brought about and the relative costs.

The improvement of the indexes, achieved by defining the two experimental indexes, also thanks to an assessment of the parametric costs of single actions, has resulted in a tool capable of describing the quality/price ratio of a planning solution.

Within the framework of the Artisan Village Upgrade Plan, the incentive procedure envisages the granting of discounts for upgrade expenses. These discounts will be calculated on the basis of the quality achieved by planning actions which, in its turn, will be assessed on the basis of bonuses and awards defined for each type of action.



Calculation of awards - methodological setting

For calculating awards, the methodological setting shown in the table above is used. Also for this calculation, the software programme has been designed in order to automatically calculate all the various passages (except for the calculation of charges, which might in any case be implemented).

For calculating any bonuses which might result in further proportional discounts or one-off discounts, issues connected with the architectural and town-planning value of the actions implemented will be taken into consideration. Through these bonuses, the administrations will be able to manage the planning phase, within the framework of the Plan, towards solutions which do not just enhance the value of a single lot, but also result in a benefit for the whole district. These bonuses, which are still being designed, will focus on issues relative to the improvement of the landscape publicly visible, as it is envisaged by the Green Factor in Seattle. Along certain streets and in some other specific contexts, also resulting from the best practices and the guidelines defined in chapter 7, some bonuses will be determined, such as to allow the administration to promote a coordinated and rational evolution of the urban landscape.

8.1

LIMITS TO THE GRANTING OF BONUSES AND AWARDS

For attributing the awards and bonuses, the subject promoting an upgrading action will have to concretely prove the will to implement the planning actions used for calculating the indexes.

General setting of procedures to attribute awards and bonuses

The check of the indexes and further guidelines enable planners to assess the actions which may ensure the best environmental value, the least costs and to assess the relative awards and bonuses. This phase precedes the planning phase and must be verified when the plan is approved. The municipal administration must require some suitable guarantees, in order to avoid the risk that certain actions envisaged by the project not be implemented or cease due to a lack of suitable ordinary maintenance works. In this respect, for each type of action, some necessary and sufficient binding characteristics will be defined in order to grant awards or bonuses. For instance, for the construction of yards, it will be necessary to make an automatic watering system, whereas for green walls or roofs, it will be necessary to prove that a maintenance contract of suitable duration has been signed, etc.

By means of a check system based on sample verifications, the administration will verify the upgraded areas, in order to ensure the preservation of the promoted features in the long run.

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5.3 The Urban Corridor of Venice And The Case Of Padua

Marco Noro, Renato Lazzarin, Filippo Busato

Department of Management and Engineering - University of Padua (ITALY)

Abstract Urban Heat Island effect was widely studied in large cities around the world, more rarely in medium size ones. The chapter reports on the study of the UHI phenomenon in Padua, a medium size city of the North-East of Italy, one of the most industrialized and developed parts of the country. Experimental measurements were carried out during 2012 summer, recording the main thermo-hygrometric variables (dry-bulb temperature, relative humidity, global solar radiation) by a mobile survey along an exact path crossing different zones of the city area: urban, sub-urban and rural. The analysis of the data highlights the presence of UHI effect with different magnitudes in function of the zone of the city. In the city centre, an historical zone, the effect was up to 7 °C. In the meantime, some measurements in situ were carried out in order to evaluate other thermal comfort indexes rather than air temperature and humidity only: wind velocity and mean radiant temperature (besides the other meteorological variables) in some characteristic sites of the city area like historic centre, high and low density populated residential zones, industrial zone, rural zone, were recorded. In particular, a very famous square of the city (Prato della Valle) was analysed: it can be considered representative of the phenomenon because of the size and the very different characteristics from the UHI effect point of view. RayMan simulation model was used to calculate some outdoor comfort indexes and Envimet model was further used to evaluate the effect of some mitigation strategies in characteristic sites of the city.

Keywords: Urban Heat Island, Padua, RayMan, ENVImet, outdoor thermal comfort

5.3.1 Urban and environmental framework

Veneto Region climate is characterized by different issues: the region is between 44.9° and 46.7° North latitude and it is between central Europe (where western and Atlantic currents are predominant) and southern Europe (where subtropical anticyclones and Mediterranean Sea influences are predominant). The presence of the Po Valley, the Adriatic Sea, the Alpi Mountains and the Garda Lake are further factors that affect the Veneto Region climate. In a simple way, the climate is characterized by two main regions: the alpine zone (central Europe mountain climate) and the Po Valley zone (continental climate), with two sub-regions with milder climate (Garda Lake and Adriatic Sea zones).

Padua stands on the Bacchiglione River, 40 km West of Venice and 29 km South-East of Vicenza, inside the eastern part of the Po Valley; it has a humid subtropical climate (Köppen climate classification Cfa) with cold winters and hot summers, frequently associated with air stagnation (respectively fog and sultriness). The city has an area of 93 km^2, a mean altitude of 12 m a.s.l. and a population of 214000 (as of 2011); the population density is quite high for Italy, 2300 inhabitants/km^2, the higher in Veneto Region and not far from that of Rome. The city is picturesque, with a dense network of arcaded streets opening into large municipal squares ("piazze"), and many bridges crossing the various branches of the Bacchiglione River, which once surrounded the ancient walls like a moat. The industrial area of Padua was created in 1946, in the eastern part of the city; now it is one of the biggest industrial zones in Europe, having an area of 11 million m^2. Here the main offices of 1300 industries employing 50000 people are located. It can be of some interest to give some feature (data of 2010 (ARPAV 2011)) concerning the situation of the energy consumption of the territory. In terms of subdivision in electricity, thermal and transport consumption, no data at Province level are available. On the regional level, the respective values are: 2724, 6042 and 3088 ktep. The Province of Padua consumes 5500 GWh of electricity (19% on the Veneto Region basis, 1.8% on Italy basis), a half is consumed by industry sector and 28% by tertiary sector. Concerning the residential sector only, Padua city per-capita consumption of electricity is 1300 kWh y^{-1} while the consumption of natural gas is around 700 m^3 y^{-1} (the averages of all Italian capitals of province are respectively 1200 kWh y^{-1} and 390 m^3 y^{-1}, data 2011 (ISTAT 2012)).

City of Padua is quite sensitive to initiatives concerning the protection of the environment, human health and energy saving. During the last decade, the Municipality has been involved in different European Projects (Life Siam - n. LIFE04 ENV/IT/000524, Life “South-EU Urban ENVIPLANS”, Belief - Building in Europe local intelligent energy forums, LIFE-PARFUM); initiatives like the arrangement of the Energy Plan and the Climate Plan have been adopted in order to give practical tools to reduce energy consumption and to introduce adaptation and mitigation strategies to climate change.

All these climatic and environmental characteristics of the territory can put forward the interest in the study of the heat island effect of the city of Padua.

5.3.2 Pilot areas identification methodology

The first phase of the study was carried out by choosing five areas of interest within the city of Padua, in which to make the analysis of urban planning and surveys on urban heat island. Such areas were selected on the basis of the location with respect to a transect north-west to south-east (
Fig. 5.3.1) and compared to urban characteristics: historic centre, urban mixed, high density residential, low-density residential, industrial. The selection of the pilot area, between the five hypothesis, were done considering useful to study the typical settlement of the central Veneto Region, with the aim to replicate in other areas the results and the mitigation techniques studied.

5.3.3 UHI phenomena in the pilot area

Mobile surveys

The goal of the field survey was a first characterization the UHI phenomenon in a medium size city like Padua (Noro et al. 2014). Within the framework of the “UHI” Project the Authors used mobile surveys with the measurement instrumentation installed on a vehicle running through the territory from the rural to the urban zone, in order to log data continuously (
Fig. 5.3.1).

Fig. 5.3.1 The path along which the mobile surveys were conducted, going from the NW to the SE of Padua and return (Google Earth)

Experimental data were logged by mobile surveys from 26 July 2012 to 9 August 2012, some of them in double sessions: day-time (during late afternoon) and night-time session (between 1 and 4 h after the sunset in order to investigate the phenomenon during its potentially maximum intensity). Dry-bulb air temperature, relative humidity and solar global radiation on the horizontal, with a time step of 5 s, were the main variables measured by the mobile station equipped on a vehicle. UHI intensity was determined by the difference between mobile measured air temperature and the value recorded at the same time by the reference ARPAV (Regional Agency for Environment Protection in Veneto) rural fixed meteorological station of Legnaro (rural zone, 8.5 km far from the city centre).

Details about the path, the instrumentation used and the measurement procedure are available in references (Noro et al. 2014). Here some very brief results are reported. Concerning air temperature, urban heat island intensity would be mostly present during night-time in the range of 3-6 °C, while the day-time would show a much less significant effect (1.2-2 °C,

Fig. 5.3.2). Only the "return" (SE to NW) path was considered for the UHI intensity measurement because this was the most precautionary path, both in spatial terms –moving from the countryside towards the city centre – and in temporal terms – as the air was cooling. Considering the night-time surveys, the minimum

UHI intensity was recorded in a lateral street (an unpaved dirt patch road in the countryside) of via Roma ("via" means street in Italian), crossed only during the NW to SE path. The maximum UHI intensity was recorded across the narrow streets (high H/W ratio) of the historic centre. As depicted in

Fig. 5.3.2, going along via Guizza (a long road that traverse the sub-urban to inside of the city) UHI intensity would always increase, mainly due to the increase of the H/W ratio and the increase of the vertical and horizontal impervious surfaces facing the road. The subsequent stretch of path (via Goito) was along San Gregorio Canal, so the evaporative cooling effect of water would lead to a decrease of the temperature.

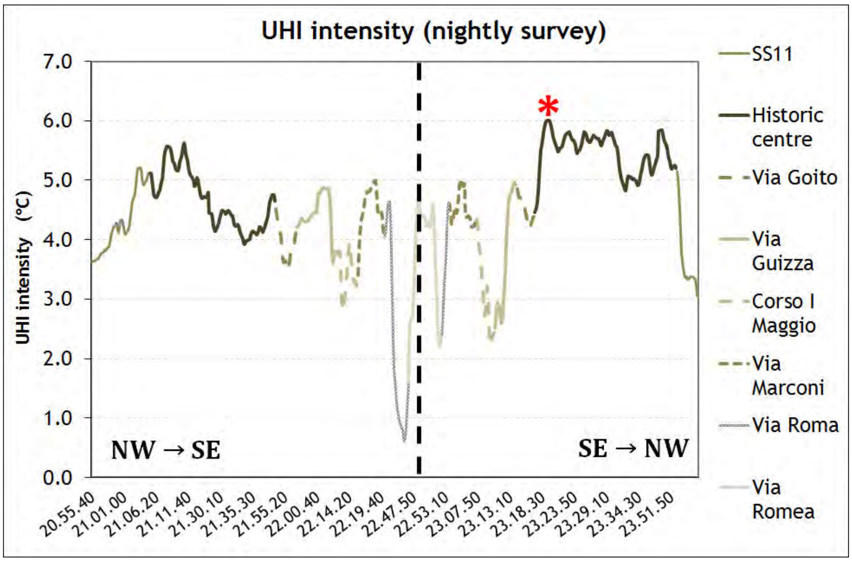

Fig. 5.3.2 UHI intensity during night-time mobile survey of the 30th July, 2012. The vertical broken line indicates the U-turn during the survey (the names of the streets refer to Fig. **5.3.1**). The red star represents Prato della Valle

The graphs concerning humidity ratio (more significant with respect to relative humidity because it is independent on air temperature) show some particular situation along the path, with a presence of water and/or green areas, but the presence of a gradient directed from the countryside to the city centre (from 12.8 to 12 g_v kg_a^{-1} in

Fig. 5.3.3) is apparent. Differences in humidity ratio between rural and urban zones are more noticeable during the daily runs because of the higher evapotranspiration effect due to the presence of the solar radiation.

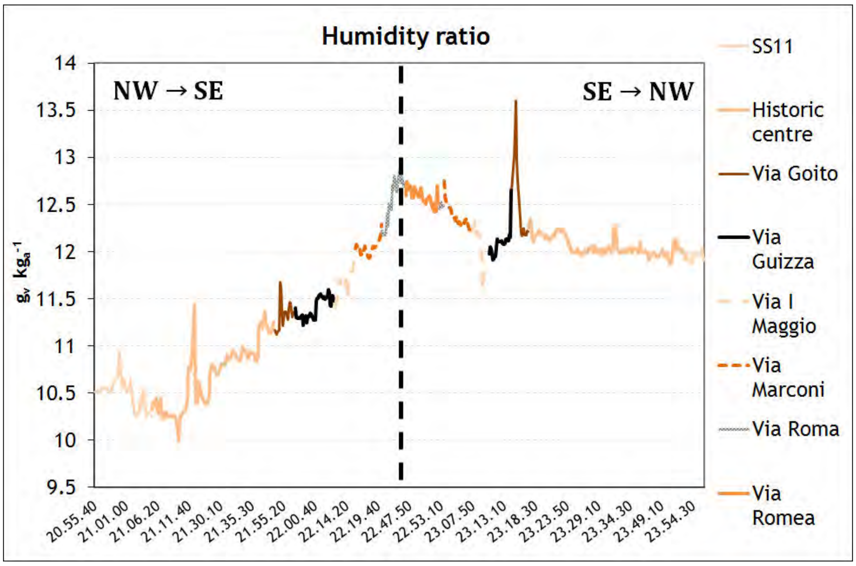

Fig. 5.3.3 Humidity ratio during the night-time mobile survey of the 30th July, 2012. The vertical broken line indicates the U-turn during the survey (the names of the streets refer to Fig. **5.3.1**)

Prato della Valle, in the centre of the city, is a very famous and picturesque circle and the second largest (about 90,000 m^2) urban square in Europe (the first being the Red Square of Moscow), with a lot of water flows and green zones, so a decrease in nightly temperature would be expected, while a maximum shown as the red star in the historic centre in

Fig. 5.3.2 was measured. As a matter of fact the path passes along the perimeter and not inside the circle: the spatial influence of the green would be limited and a deeper investigation within this zone will be presented in the next section.

In situ measurements

Besides the mobile surveys, in situ measurements were performed in some characteristic sites of the city area along the path, in order to measure air temperature and humidity, wind velocity and mean radiant temperature. Consequently these data were processed using the RayMan model (Matzarakis et al. 2007) (Matzarakis et al. 2010) in order to calculate some outdoor thermal comfort indexes: the Predicted Mean Vote (PMV), the Physiological Equivalent Temperature (PET) and the new Standard Effective Temperature (SET*). RayMan model is a simulation tool for the estimation of radiation fluxes and mean radiant temperature (T_{mr}) and other variables, compatible with Windows® that can analyse complex urban structures and other environments. The model requires only basic meteorological data (air temperature, air humidity and wind speed) for the simulation of radiation flux densities and common thermal indices for the thermal human-bioclimate.

Tab. 5.3.1 reports a comparison of the three thermal comfort index values. All these indexes were calculated by the mean radiant temperature T_{mr}, a physical quantity that accounts for the human-biometeorological influence of short - and long - wave radiation flux densities (Jendritzky et al. 1990). While PET and SET* have been specifically defined to assess outdoor thermal comfort (Matzarakis et al. 2007) (Matzarakis et al. 2010) (Mayer 1993) (Gagge et al. 1986) (Höppe 1999) (Mayer and Höppe 1987), the use of PMV is not universally recognized. Also the ISO 7730 standard focused on the use of PMV only as indoor thermal comfort index. Nevertheless some authors applied the use of PMV to outdoor environment (Matzarakis et al. 2007) (Matzarakis et al. 2010), (Berkovic et al. 2012) (Honjo 2009) (Jendritzky and Nubler 1981) (Thorsson et al. 2004). In this study the mean radiant temperature was measured using the globothermometer during night-time measurements only, when UHI intensity was higher. For this reason the use of PMV for outdoor thermal comfort assessment was judged to be suiTab. for this study.Via Rinaldi is an urban canyon in the historic centre of the city (Tab. 5.3.2). Street pavement was constructed by porphyry, buildings by brick walls and tiled roofs; no trees are present. It is characterized by a relative high H/W ratio (street width 5.5 m, buildings height between 8 and 12 m) and a small SVF (calculated by the RayMan model by position and height of buildings). The latter hampers the nightly cooling of surfaces causing the mean radiant temperatures to be higher or similar to air temperatures (respectively around 29 °C and between 28 and 29 °C). UHI intensity was always more than 4 °C during the measurement sessions. Such environmental conditions determines, for a person with summer clothing (0.5 clo) and slight level of activity (metabolic rate 80 W), slight thermal stress (PMV and PET) or thermal comfort (SET*). During day-time UHI intensity was small, about 0.4-0.8 °C. Lower values of UHI could be measured during the morning because direct solar radiation would reach the point of measurement only during central hours of the day (Tab. 5.3.2).

Two residential zones were studied: via Pindemonte (higher population density) (Tab. 5.3.3) and via San Basilio (lower population density) (Tab. 5.3.4). The first is a lateral street of via Guizza (
Fig. 5.3.1) with high apartment buildings (18 m) and wide street (15 m) so H/W is lower (1.2) than that of via Rinaldi. The pavement is covered with asphalt and there is the presence of trees (Tab. 5.3.3). The SVF measured was slightly higher than via Rinaldi but mean radiant temperature values were near to dry-bulb air temperatures, respectively 28 and 27.2-27.7 °C. The lower values of T_{mr} and the higher values of wind velocity in via Pindemonte with respect to via Rinaldi resulted in lower values of the thermal comfort indexes.

Via San Basilio (Tab. 5.3.4) is mainly characterized by detached houses with height of 6-8 m and streets width of 18 m, so the H/W ratio is quite small (0.4). The lack of trees is also the reason of high SVF value (0.75). This is why the mean radiant temperature measured was always 0.5-1 °C lower than air temperature, so PMV and PET indicate full thermal comfort situation; nevertheless UHI intensity measured during evening sessions was quite significant, about 3-5 °C. During the day no significant UHI effect measured.

PMV	PET (°C)	SET* (°C)	Sensation
>3 (3.5)	41	>37.5	Very hot, great discomfort
2 – 3 (2.5)	35	34.5 – 37.5	Hot, very unaccepTab.
1 – 2 (1.5)	29	30 – 34.5	Warm, uncomforTab., unaccepTab.
0.5 – 1 (0.5)	23	25.6 – 30	Slightly warm, slightly unaccepTab.
-0.5 – 0.5		22.2 – 25.6	ComforTab., accepTab.
-1 – -0.5 (-0.5)	18	17.5 – 22.2	Slightly cool, slightly unaccepTab.
-2 – -1 (-1.5)	13	14.5 – 17.5	Cool, unaccepTab.
-3 – -2 (-2.5)	8	10 – 14.5	Cold, very unaccepTab.
< -3 (-3.5)	4	<10	Very cold, great discomfort

Tab. 5.3.1 Comparison between the three outdoor comfort indexes. Values between brackets in PMV column refer to the correspondent values of the other indexes

Tab. 5.3.2 to Tab. 5.3.6 provide the description of the five sites selected for the in situ measurements, representative of very different zones of the fabric of the city. The pictures show the main uses of territory, all the data measured during experimental sessions were reported in the Tab.s; the sites differ for the decreasing

H/W ratio (height of buildings to width of street) and for the increasing SVF (sky view factor).

Via Rinaldi is an urban canyon in the historic centre of the city (Tab. 5.3.2). Street pavement was constructed by porphyry, buildings by brick walls and tiled roofs; no trees are present. It is characterized by a relative high H/W ratio (street width 5.5 m, buildings height between 8 and 12 m) and a small SVF (calculated by the RayMan model by position and height of buildings). The latter hampers the nightly cooling of surfaces causing the mean radiant temperatures to be higher or similar to air temperatures (respectively around 29 °C and between 28 and 29 °C). UHI intensity was always more than 4 °C during the measurement sessions. Such environmental conditions determines, for a person with summer clothing (0.5 clo) and slight level of activity (metabolic rate 80 W), slight thermal stress (PMV and PET) or thermal comfort (SET*). During day-time UHI intensity was small, about 0.4-0.8 °C. Lower values of UHI could be measured during the morning because direct solar radiation would reach the point of measurement only during central hours of the day (Tab. 5.3.2).

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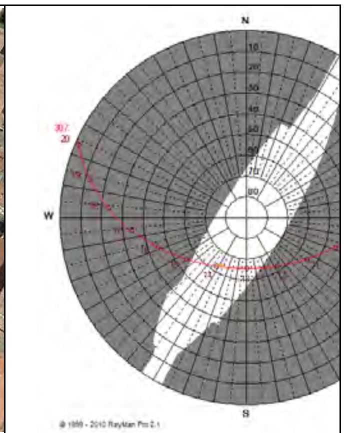
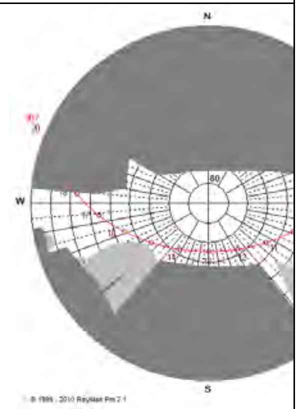
Via Rinaldi (H/W = 1.8 - SVF = 0.18)



Date	27-Jul	30-Jul	31-Jul	2-Aug	9-Aug
Hour	21:53	21:28	21:49	16:01	16:11
Temperature (°C)	29.1	27.9	28.0	34.5	31.7
UHI Intensity (°C)	4.2	4.5	5.5	0.8	0.4
Relative humidity (%)	57.1	45.6	41.9	33.4	33.1
Humidity ratio (g_v kg_a^{-1})	14.5	10.7	9.9	11.4	9.7
Wind velocity (m s^{-1})	0.3	0.2	0.2	0.9	0.5
T globe (°C)	28.9	28.5	28.4		
T radiant mean (°C)	28.7	29.0	28.9		
PMV	1.4	1.2	1.2		
PET (°C)	28.8	28.3	28.2		
SET* (°C)	23.1	23.1	23.0		
Global radiation (W m^{-2})				622	182

Tab. 5.3.2 Data obtained in measurement sessions in via Rinaldi (historic centre) (see also Fig. 5.3.1). The “X” refer to the point of measurement. Thermal comfort indexes refer to a person with summer clothing (0.5 clo) and slight activity level (80 W above the basal metabolism) (Google Earth-RayMan)

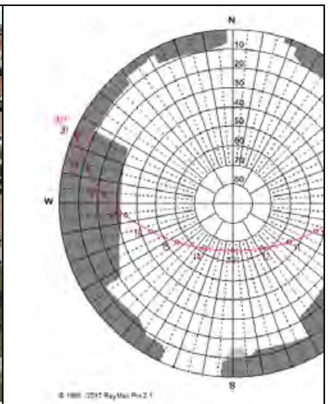
Via Pindemonte (H/W = 1.2 - SVF = 0.29)



Date	27-Jul	30-Jul	2-Aug
Hour	22:37	22:09	16:28
Temperature (°C)	27.7	27.2	34.2
UHI Intensity (°C)	4.2	4.8	0.8
Relative humidity (%)	56.6	50.6	33.0
Humidity ratio ($g_v\ kg_a^{-1}$)	13.2	11.4	11.2
Wind velocity ($m\ s^{-1}$)	0.6	0.3	2.1
T globe (°C)	27.9	27.5	
T radiant mean (°C)	28.2	27.9	
PMV	0.9	0.9	
PET (°C)	26.8	27.0	
SET* (°C)	21.1	21.7	
Global radiation ($W\ m^{-2}$)			548

Tab. 5.3.3 – Data obtained in measurement sessions in via Pindemonte (see also Fig. 5.3.1). The "X" refer to the point of measurement. Thermal comfort indexes refer to a person with summer clothing (0.5 clo) and slight activity level (80 W above the basal metabolism) (Google Earth-RayMan)

Via San Basilio (H/W = 0.4 - SVF = 0.75)



Date	27-Jul	30-Jul	9-Aug
Hour	22:59	23:06	16:57
Temperature (°C)	26.4	25.9	31.5
UHI Intensity (°C)	3.1	4.8	0.3
Relative humidity (%)	65.2	58.7	33.2
Humidity ratio (g_v kg_a^{-1})	14.1	12.3	9.6
Wind velocity (m s^{-1})	0.3	0.4	0.8
T globe (°C)	26.1	25.4	
T radiant mean (°C)	25.8	24.8	
PMV	0.6	0.3	
PET (°C)	25.7	24.4	
SET* (°C)	20.5	19.2	
Global radiation (W m^{-2})			432

Tab. 5.3.4 Data obtained in measurement sessions in via San Basilio (see also
Fig. 5.3.1). The “X” refer to the point of measurement. Thermal comfort indexes refer to a person with summer clothing (0.5 clo) and slight activity level (80 W above the basal metabolism) (Google Earth-RayMan)

In order to compare environmental conditions of urban and sub-urban sites with a rural site, measurements in a lateral unpaved road of via Roma were carried out (Tab. 5.3.5,
Fig. 5.3.1). The road winds through agricultural fields with no obstacles nearby (SVF = 1); mean radiant temperature was 2-3 °C lower than air temperature, due to the very high SVF and the lower temperature of the agricultural surface (char-

acterized by higher emissivity, lower thermal inertia and higher water storage capacity with respect to urban surfaces).

Finally, a deeper analysis of the thermal comfort in Prato della Valle was performed. This very popular circle is characterized by a central green island delineated by a channel decorated by statues and encircled by a wide asphalt circle road (Tab. 5.3.6). Because of the extension of the square, six different positions were fixed for the measurements.

The results indicate a difference of 0.5-1 °C in the air temperature between position 4 (on the green) and external positions near urban streets (1, 2, 3, 6); a quite larger difference in mean radiant temperature was measured, with a maximum of 7 °C, because of the different surface characteristics (emissivity, thermal inertia and water storage capacity) and SVF (higher) at the centre of the square with respect to outer positions.

The thermal comfort indexes calculation had reflected these considerations: PMV and PET had indicated a slightly warm environment at outer positions while on the green there was a neutral situation.

It is interesting to compare Pos. 4 and 5: the first was on the grass, the second was on a dirt patch near a fountain. Even so, same air temperature (27 °C) was measured at these locations. This was mainly due to the lower T_{mr} for Pos. 4 and to the evaporative cooling effect for Pos. 5.

Via Roma (SVF ≈ 1)

Date	30-Jul	31-Jul	2-Aug
Hour	22:46	22:52	16:53
Temperature (°C)	21.4	22.9	33.6
UHI Intensity (°C)	0.5	0.4	0.8
Relative humidity (%)	80.8	61.2	35.8
Humidity ratio (g_v kg_a^{-1})	13.0	10.7	11.6
Wind velocity (m s^{-1})	0.0	0.2	2.4
T globe (°C)	19.0	21.6	
T radiant mean (°C)	18.4	20.6	
PMV	-0.5	-0.4	
PET (°C)	21.6	21.4	
SET* (°C)	15.8	17	
Global radiation (W m^{-2})			502

Tab. 5.3.5 Data obtained in measurement sessions in a lateral dirt road of via Roma (see also Fig. 5.3.1). The "X" refer to the point of measurement. Thermal comfort indexes refer to a person with summer clothing (0.5 clo) and slight activity level (80 W above the basal metabolism) (Google Earth)

Prato della Valle

	Pos.1	Pos.2	Pos.3	Pos.4	Pos.5	Pos.6
Date	2-Aug	2-Aug	2-Aug	2-Aug	2-Aug	2-
Hour	21:53	22:03	22:14	22:25	22:35	22:44
Temperature (°C)	28.4	28.4	28.1	27.0	26.9	27.4
UHI Intensity (°C)	3.2	3.9	4.3	3.8	3.7	4.7
Relative humidity	48.0	48.2	49.1	52.9	53.5	51.5
Humidity ratio (g_v	11.6	11.7	11.7	11.8	11.8	11.7
Wind velocity (m	0.8	0.8	0.8	0.8	0.7	0.7
T globe (°C)	27.8	28.1	27.2	24.8	25.3	26.5
T radiant mean	26.5	27.4	25.2	20.1	22.2	24.8
PMV	0.8	0.8	0.6	0.0	0.1	0.5
PET (°C)	26.1	26.5	25.3	22.5	23.3	24.7
SET* (°C)	20.1	20.5	19.3	16.5	17.6	19.0

Tab. 5.3.6 – Data obtained in measurement sessions in Prato della Valle (dimension of ellipse are 180 x 230 m) (see also
Fig. 5.3.1). Thermal comfort indexes refer to a person with summer clothing (0.5 clo) and slight activity level (80 W above the basal metabolism) (Google Earth)

5.3.4 Feasibility study: UHI mitigation strategies by simulations

Many mitigation measures can be adopted and have been proposed by various researchers, which could be classified as measures that could only be implemented during the design and planning stage (e.g. sky view factor and building material etc.) and those that could also be implemented after the design and planning stages (e.g. green areas and roof spray cooling) (Rizwan et al. 2008). RayMan model was used in order to quantify possible increasing in thermal comfort as a consequence of some possible mitigating measures of both types. Main inputs of the model relate to the outdoor environment conditions: dry-bulb air temperature and RH, wind velocity, Bowen ratio (ratio of sensible over latent heat flux in evapotranspiration, fixed at 1.5) and cloud cover (fixed at 1 okta). Other inputs are the albedo and emissivity of surfaces, fixed respectively at 0.30 and 0.95, typical values of urban environment.

The following limitations in RayMan analysis must be highlighted:

- emissivity is considered the same for all the different kinds of surfaces;
- consequences of higher albedos cannot be correctly evaluated: the lower surfaces temperature would not be estimated as it is given by the air temperature (input of the software).

For these reasons next simulations concern topology modifications only (height and distance of buildings, presence of green); obviously these are mitigation strategies that can be implemented during the design and planning stage only.

As described by Noro et al. (2014) and Busato et al. (2013), a slightly warm PMV was obtained for via Rinaldi (Padua old town) and in via Pindemonte, the pilot area (high density population residential zone): for the latter the modification in thermal comfort with some characteristics of the site was evaluated. Tab. 5.3.7 reports the results considering different layout of buildings:

- considering the actual situation;
- increasing the street width from 15 to 25 m;
- limiting the maximum height of buildings to 12 and 6 m;
- having a garden in front of the point of measurements instead of an apartment building.

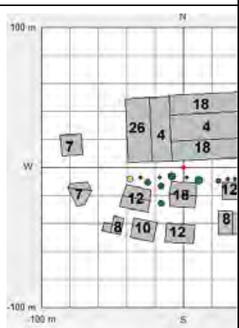
Every simulation was repeated using the same values of environmental variables (air temperature and RH, wind velocity) as measured during the experimental sessions. Results in Tab. 5.3.7 show that an increase in Sky View Factor (SVF) thus allowing a more effective nightly cooling of surfaces and a decrease of T_{mr}. In particular, limiting the maximum height of buildings to 6 m would be the action with the most relevant effect. The mean radiant temperature was shown to decrease by 2.6 °C and PMV by 0.2. Anyway, the night effects of an increased SVF were probably underestimated by RayMan, because the mean radiant temperature and so PMV and PET were calculated by knowledge of air temperature (input) that is actually expected to decrease when SVF increases. Also the effect of having the green (last solution of Tab. 5.3.7) was probably underestimated because the model does not consider the cooling effect due to evapotranspiration.

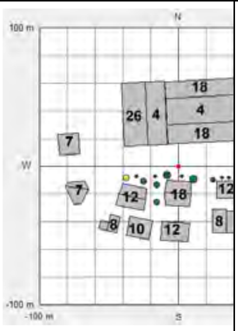
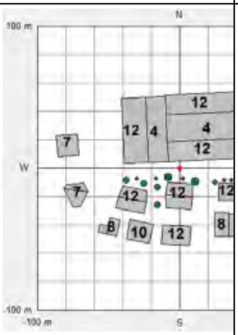
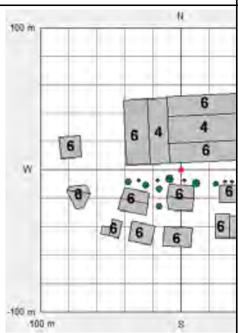
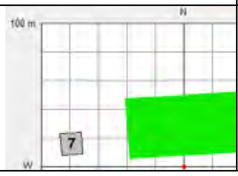
The measures just described can be suggested both in new and built areas, in case of a redevelopment of an existing urban area. Within the frame of the European Project “UHI”, the Authors conducted simulations using the ENVImet model (Bruse and Fleer 1998) in order to quantify the effect of selected mitigation actions (usable in already built areas) in the pilot are of via Pindemonte.

ENVI-met is a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environment with a typical resolution of 0.5 to 10 m in space and 10 s in time. The model area is described in Fig. 5.3.4 and Fig. 5.3.5. The main area is a 99x70x30 grid (in a x,y,z tridimensional reference system), with a 5x5x3 m grid dimension. An appropriate number of nesting grids (five) has been set in order to minimize boundary effects. Four specific points of interest have been identified in the zone to characterize the air temperature (at 2 m above ground) during 24 hours, from 6am to 6pm. Simulations lasted 72 hours, but only the last 24 hours have been considered for the results. The daily mean air temperature of the days before the start simulation ones (

Tab. **5.3.8**) have been used as initial air temperature at 6am of the first day. As requested by the Project, four characteristic days representative of the four seasons were considered. Simulations used the default values of ENVImet except for the ones reported in

Tab. **5.3.8**.

		SV F	Da te	T_{m} $_{r}$	P MV	P ET
Actual situation		0.2 9	27 -Jul	24. 9	0. 6	2 5.3
			30 -Jul	24. 3	0. 5	2 5.3

Street width enlarged by 10 m		0.38	27-Jul	24.2	0.5	25
			30-Jul	23.6	0.5	24.9
12 m buildings height max		0.45	27-Jul	23.6	0.5	24.7
			30-Jul	22.9	0.4	24.6
6 m buildings height max		0.6	27-Jul	22.3	0.4	24.2
			30-Jul	21.7	0.3	24.1
Green in front		0.56	27-Jul	22.7	0.4	24.4

			30-Jul	22.1	0.3	24.2

Tab. 5.3.7 Calculated T_{mr} and thermal comfort indexes in via Pindemonte (Bowen ratio = 1.5, cloud cover = 1 okta, clothing = 0.5 clo, activity level = 80 W above the basal metabolism) for different disposition of buildings

Fig. 5.3.4 The model area in ENVImet used for the simulations of the “AsIs”, “Cool pavements” and “Cool roofs” scenarios. The red numbers identify four characteristic points for which air temperature at 2 m above ground has been considered in the study

Fig. 5.3.5 The model area in ENVImet used for the simulations of the "Green ground" and "Green ground + Cool pavements" scenarios. The red numbers identify four characteristic points for which air temperature at 2 m above ground has been considered in the study

Simulation tool: ENVI-met 3.1
Start Simulation at Day (DD.MM.YYYY):
02.02.2012 Winter; 02.05.2012 Spring; 27.07.2012 Summer; 03.11.2012 Autumn
Start Simulation at Time (HH:MM:SS) = 06:00:00
Total Simulation Time in Hours = 72.00
Save Model State each ? min = 60
Wind Speed at 10 m ab. ground [m s^{-1}] = 3
Wind Direction (0:N.. 90:E.. 180:S.. 270:W..) = 90
Roughness Length z0 at Reference Point = 0.1
Initial Temperature Atmosphere [K] = 279 K Winter; 290.9 K Spring; 300 K Summer; 282.2 K Autumn
Specific Humidity at 2500 m [g_{water}/kg_{air}] = 7

Relative Humidity at 2 m [%] = 50
Output: air temperature at 2 m above ground

Building properties
Inside Temperature [K] = 298
Heat Transmission Walls [W m^{-2} K^{-1}] = 1
Heat Transmission Roofs [W m^{-2} K^{-1}] = 2
Albedo Walls = 0.2
Albedo Roofs = 0.3 (all scenarios except "Cool roofs"); 0.6 ("Cool roofs")
Albedo pavements = 0.4 (all scenarios except "Cool pavements"); 0.5 ("Cool pavements")
Albedo roads = 0.2 (all scenarios except "Cool pavements"); 0.5 ("Cool pavements")

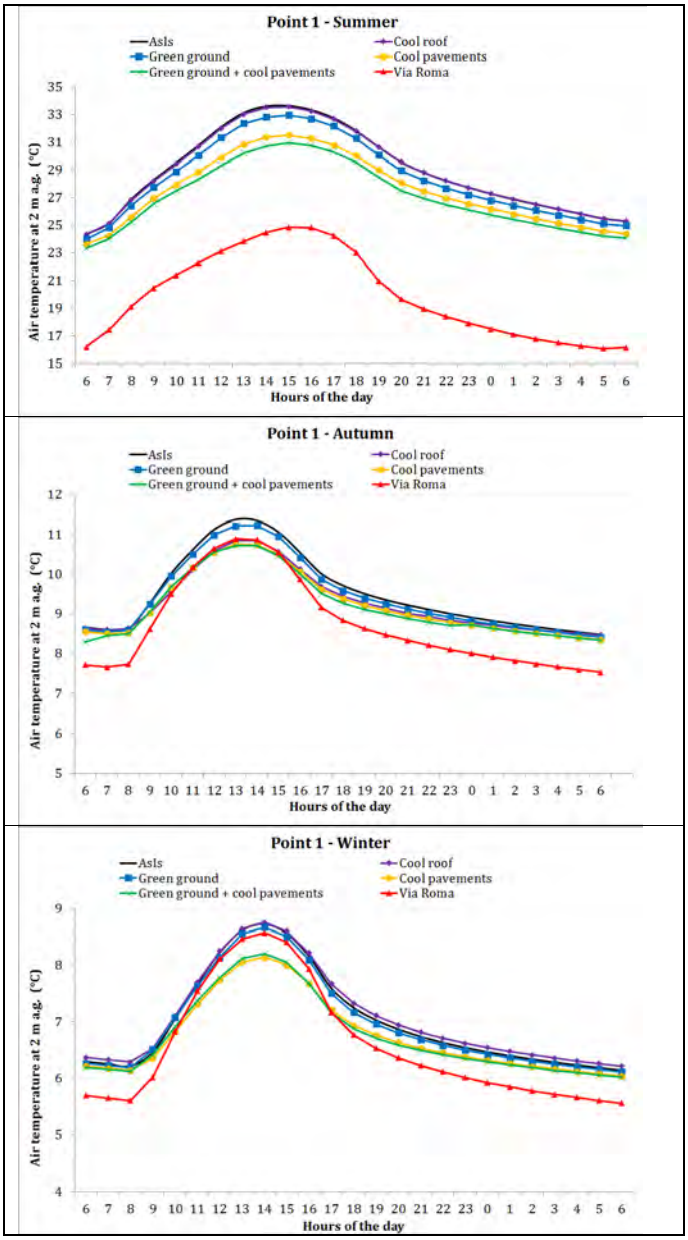
Tab. 5.3.8 Configuration values in ENVImet

To measure the UHI intensity, simulations have been extended in the rural zone just outside Padua (Via Roma), in the same point where the previously described experimental measurements have been conducted during 2012 summer. Four scenarios were supposed besides the actual one ("AsIs" scenario):

- "Green ground": increasing the pervious surfaces of the area from 18% to 23% by planting trees, 10 m height, within the urban canyon and the main road of the area, and converting an impervious zone - e.g. asphalt car park surface - to a pervious zone by planting grass. The main effects were: Sky View Factor decreases for the presence of trees along the streets; impervious surface fraction decreases (and pervious surface fraction increases) because green area increases; albedo slightly increases; other thermo-physical properties of the surfaces/materials remain quite the same;
- "Cool pavements": substituting all the traditional asphalt (albedo 0.2) and concrete (albedo 0.4) (roads and pavements) with "cool materials", that is materials with an higher albedo (0.5). The main effects were that albedo significantly increases while other properties remain the same;
- "Cool roofs": using of "cool materials" for the horizontal impervious surfaces of roof. In particular albedo has been increased from 0.3 to 0.6 for roofs;
- "Green ground + cool pavements": scenario with both the mitigation actions just described simultaneously.

Results, in terms of 24 hours of air temperature at 2 m above ground and UHI intensity with respect to Via Roma (rural zone) are reported in Fig. 5.3.6 for the point 1 of Fig. 5.3.4 (as representative of the area) and for the four characteristic days of the year. Summarizing, the main results were:

- The higher UHI intensity (difference between the "AsIs" and "Via Roma" curves per each hour of the day) is obviously obtained in summer. During the other seasons the UHI phenomenon is much lower and negligible in winter during the central hours of the day;
- Talking about the summer, the higher UHI intensity (9-10 °C) is noticed after the sunset (8pm) and till the first sunrise (4am);
- The same value of 9-10 °C for the UHI intensity during the day is noticed only for point 2 (1pm), that is a street canyon (characterized by low SVF and impervious surfaces); for the other points the maximum daily UHI intensity is always lower than 9 °C;
- The best UHI mitigation strategy is the "Green ground + cool pavements" (Scenario 4) that allows 2 °C decrease in UHI maximum intensity (but till nearly 3 °C decrease in Point 2);
- The "Cool pavements" mitigation strategy allows between 1 and 2 °C decrease in UHI maximum intensity in all the points;
- The "Green ground" mitigation strategy allows an appreciable UHI maximum intensity decrease only in point 2 (around 1 °C): in all other points the positive effect of the action is quite negligible;
- During the day (afternoon) the most effective mitigation actions are "Green ground" and "Green ground + cool pavements": they allow till 3 °C decrease in UHI intensity;
- During all the other seasons, but especially in winter, the most effective UHI mitigation strategies ("Cool pavements" and "Green ground + cool pavements") cause a negative effect during the central hours of the day: UHI intensity becomes negative, that is air temperature in urban zone id colder (about 0.5 °C) than in rural zone.


Point 1 - Summer
Asls
Cool roof
Green ground
Cool pavements
Green ground + cool pavements
Via Roma
Air temperature at 2 m a.g. (°C)
Hours of the day
Point 1 - Autumn
Asls
Cool roof
Green ground
Cool pavements
Green ground + cool pavements
Via Roma
Air temperature at 2 m a.g. (°C)
Hours of the day
Point 1 - Winter
Asls
Cool roof
Green ground
Cool pavements
Green ground + cool pavements
Via Roma
Air temperature at 2 m a.g. (°C)
Hours of the day

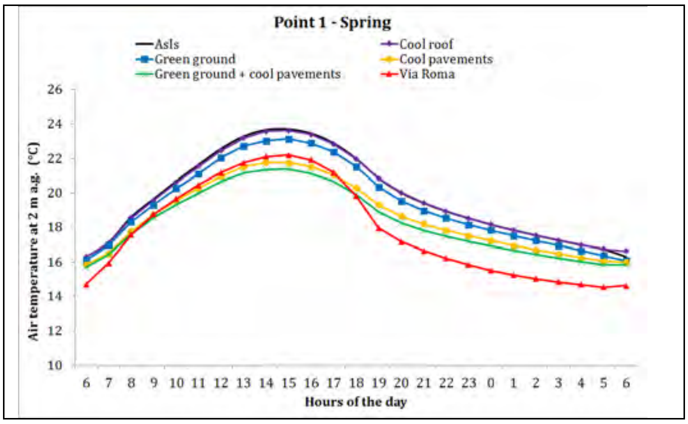


Fig. 5.3.6 Air temperature at 2 m above the ground during one typical day (from 6am to 6am of the day after) for each season at point 1 of the pilot area modelled by ENVImet (asphalt car park surface in front of a flat block). The differences between the upper curve (the actual scenario "AsIs") and the other ones depict the UHI intensity mitigation for the strategies described in the text

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5.3.5 Mitigation of and adaptation to UHI phenomena: the Padua case study

Francesco Musco, Laura Fregolent, Davide Ferro, Filippo Magni, Denis Maragno, Davide Martinucci, Giuliana Fornaciari

Department of Planning, University IUAV of Venice

Introduction

The test developed by the Veneto Region and by the working group of the IUAV University of Venice as part of the European project "UHI - *Development and application of mitigation and adaptation strategies and measures for counteracting the global Urban Heat Islands phenomenon*" is based on the territorial peculiarities of the Veneto region's lowlands, mostly characterized by small sized historical centers and the widespread settlements that have developed around them over the last forty years.

This urbanization occurred without strategies or rules as a summation of individual initiatives that amalgamated residential forms and functions with large thoroughfares, as well as production and commercial areas (Selicato, Rotondo, 2003).

In some ways, this process broke the environmental balance of the medieval towns (which were designed keeping in mind local microclimate regulation) often creating an artificial barrier around them, suffocating them, and contributing greatly to raise the amount of impermeable surfaces to the detriment of permeable ones. In recent years, the relationship between urban planning and architecture paid a price for the rigidity dictated by Local Strategic Plans conforming to homogeneous and repetitive rules rather than adapting to the peculiarities of the various land areas (Samonà, 1980). As a result, we are dealing with areas that are already rigid and intensely anthropized, with a paucity of characterizing settlements, whose development in the near future may be expected to involve mostly the transformation of the existing tissues. Our test focused on the connection between local climate, urban structure and the emergence of the urban heat island effect, with the purpose of providing land management guidelines for the near future (Musco *et. al.*, 2014). Within this framework, we singled out a section of Padua's metropolitan area for analysis and planning, with the intent of applying the results of our tests to the rest of Veneto's central area. Often, the cause for urban heat islands are specific factors (such as large paved areas), which are directly connected to widespread systemic factors (such as the nocturnal dispersion of the heat absorbed by peripheral urban tissues, or pollution from production areas, again located in the suburbs). Such a plurality of causes leads to studying heat islands from different points of view, which are both horizontal and vertical.

Oke's model (2006) approaches this phenomenon by analyzing different urban climate scales, where diverse climate events occur that influence each other:

- Horizontal scale: Microscale, Local scale and Mesoscale;
- Vertical scale (according to different UHI types): *Air* UHI (*Urban Canopy Layer* UCL, and *Urban Boundary Layer* UBL), *Surface* UHI, and *Subsurface* UHI.

The *Urban Boundary Layer* (UBL) encompasses the urban cover layer above the average height of buildings, whereas the *Urban Canopy Layer* (UCL), encompasses the urban cover layer below the average height of buildings. After considering the goals of our projects, namely to analyze the causes of this phenomenon at the microscale level with the intent of coming up with accurate mitigation measures, we proceeded by considering the heat island on the vertical scale encompassed between ground level and the average height of buildings, that is, in the *Urban Canopy Layer*.

This microscale level can help verify the relationship between urban form, roofing materials and UHI, with particular reference to the vegetative cover, soil permeability and albedo of materials. Within this context, the following factors influence microclimate at different urban scales in a significant way: orientation of buildings, surface covering, Sky View Factor (SVF), solar incidence, materials used, and shape of buildings. For example, where building facades are too close to each other, temperatures are affected by the SVF, i.e., they heat up more than other facades located on more open and ventilated roads (which are perhaps no more than thirty or forty yards away).

A recent study shows how urban microclimate affects the functions of buildings in terms of thermal performance, proving that urban form has an effect on the UHI phenomenon (Wong and Chen, 2009). Speaking specifically of Italian cities, heat islands are not caused by the anthropogenic heat produced by human activities, but rather by the heat stored by urban surfaces (buildings, roads, parking lots) during the day and then released gradually at night. This effect generates a nocturnal heat island, insofar as the heat released does not allow the city to cool down as much as the rural environments external to it.

The complexity of the UHI phenomenon is directly related to the relationship between city and atmosphere; urban climate and atmospheric climate affect and influence each other (Oke, 2006b).

Usually, the aspects that influence climate, generating an urban microclimate that is different from the climate of the atmosphere, (Shahmohamadi, 2012) are the following:

- amount of grass, permeable soil, trees, asphalt, and concrete;
- artificial heat released from buildings, air-conditioning systems, cars, and production areas;
- surface water storage and lamination in favor of underground canals and drains;
- air pollution;
- urban ventilation.

Urban heat islands arise from extensive anthropization, or rather, it could be said that the fewer the ecological properties of a city, the greater its heat island will be. It is no coincidence that this effect had already been observed by meteorologist Luke Howard for the first time in 1818, in London, at the height of that city's expansion. At the time, it was not identified as a heat island[1]; the term "island" was coined when isotherms were used to map the city. When air temperatures are mapped through isotherms, the city appears like an island compared to the surrounding rural areas, which are differentiated by lower temperatures. On these bases, we started our project by studying the different behaviors of the urban heat island of pilot experiment city Padua vis-à-vis its different urban contexts. We chose this area also taking into account our purpose of drafting an urban planning manual for the Veneto Region to be delivered to municipal administrations in order to support their future strategic choices in terms of mitigating the UHI phenomenon and adapting vulnerable urban areas to climate changes. Therefore, we picked this area for our study also because it conforms to the urban and spatial characteristics of other cities and areas of the Veneto region.

To conduct urban heat island effect analyses and surveys, we then went on to selecting five pilot areas in the municipality of Padua, based on their location with respect to a survey transect crossing the city along the north-west/ south-east axis and the intrinsic features of their settlement structure. These features are the following (Fig. 5.3.5.1):

Area 1, a dense urban area located inside the medieval historical center;
Area 2, a mixed-use area, ranging from a major river to a large parking lot;
Area 3, a “high density” residential area built in the 60/70s;
Area 4, a “low density” residential area, also built in the 60/70s, located in the first outer ring of the city and consisting of free-standing 1-2 storey buildings;
Area 5, a production area located outside the municipality of Padua.

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[1] The term “urban heat island” was coined in 1958 by Gordon Manley in an essay found in the *Quarterly Journal of the Royal Meteorology Society*

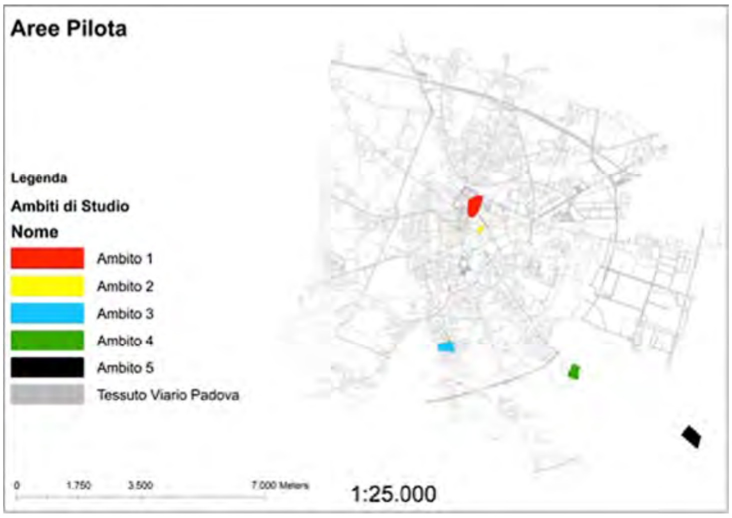

Fig. 5.3.5.1

Analysis methods: traditional surveys and remote sensing

The first part of our project concerned the implementation of an efficient urban heat island study method. We focused our attention right away on producing an urban planning manual that could be used by other municipal administrations. With this in mind, we sought to adopt simple but effective methods. An ideal process of analysis would require atmospheric temperature readings throughout the urban environment.

Temperature is an important descriptor of UHI behavior; unfortunately however, detectors often are not spread evenly through the urban environment. In Italian cities, the location of temperature and humidity detection devices is often organized around the monitoring of pollution rather than the microclimate. Due to this lack of information, it was not possible to build a homogenous framework capable of bringing out the causes of urban overheating for the various scales. In addition, some land management data usually available to public administrations do not consider the variables used to identify this phenomenon. As part of our project, the University of Padua research unit measured urban environment atmospheric heat, working to determine the heat island within the city by paying specific attention to the five selected areas described above (Fig. 5.3.5.2).

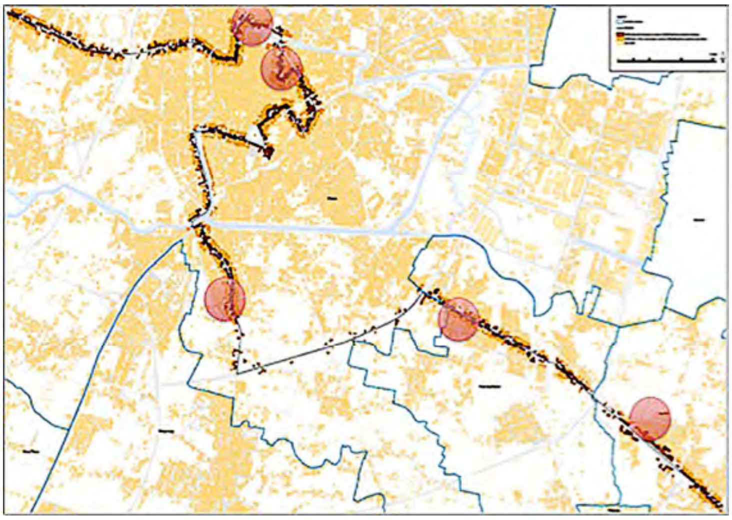

Fig. 5.3.5.2

The picture that emerged from our analysis revealed a significant difference in nocturnal temperature between the urban area and the rural area peripheral to the city. A nocturnal heat island that becomes more intense as dawn approaches is already a strong indicator of the causes of urban overheating, mainly due to its morphology and surface types.

Scientific literature (Oke 1982, Santamouris 2005) states that heat islands are caused by anthropogenic factors when developing gradually from late afternoon to night time (namely, resulting from human activities), whereas if they are detected during the night, their formation factors are dependent on the ratio between permeable and impermeable surfaces, materials used and urban ventilation (Papadopoulos, 2001).

It was therefore clear from the outset that our analyses and possible strategies should address built-up areas rather than the human activities in and around them.

Our analysis of the existing urban fabric followed the guidelines of the Technical University of Vienna, which has proposed a number of indicators for weighing and quantifying the various UHI production factors (Tab. 5.3.5.1).

Proposed variables for the specification of an urban unit of observation (U2O)

DOCUMENT WP5 UHI 01_112012

WP 5, authors A. Mahdavi, K. Kiesel, M. Vuckovic (November 5th, 2012)

Geometric properties	Symbol	Unit	Range	Definition
Sky View Factor	ψ_{sky}	-	0-1	Mean value of the fraction of sky hemisphere visible from ground level
Aspect ratio	H/W	-	0-3*	Mean height-to-width ratio of street canyons, consider length of streets as a weighting factor
Built area fraction	A_b/A_{tot} A_b : building plan area [m²] A_{tot} : total ground area [m²]	-	0-1	Ratio of building plan area to total ground area; fraction of ground surface with building cover
Unbuilt area fraction	$1 - A_b/A_{tot}$	-	0-1	Ratio of unbuilt plan area to total ground area; fraction of ground surface without building cover
Impervious surface fraction	A_i	-	0-1	Ratio of unbuilt impervious plan area (paved, sealed) to total ground area
Pervious surface fraction	$A_p = (A_e + A_g + A_{H2O})$	-	0-1	Ratio of unbuilt impervious plan area (bare soil, green, water) to total ground area
	A_e : earth	-	0-1	Bare soil area
	A_g : green	-	0-1	Green area
	A_{H2O} : water	-	0-1	Water bodies area
Mean building compactness	l_c $l_c = V_b / A_b$ [m³/m²] V_b : built volume [m³]	m	-	Ratio of built volume (above terrain) to total building plan area
Built surface fraction	A_s/A_b A_s : total built surface area [m²]	-	>1	Ratio of total built surface area (above terrain) of buildings (walls and roofs) to total built area
	A_W/A_b A_W : total wall area [m²]	-	>1	Walls
	A_R/A_b $A_R = (A_{R,i} + A_{R,p})$ A_R : total roof area [m²]	-	~1	Roofs
	$A_{R,i}/A_b$ $A_{R,i}$: total impervious roof area [m²]	-	~1	Impervious roofs
	$A_{R,p}/A_b$ $A_{R,p}$: total pervious roof area [m²]	-	~1	Pervious roofs
Mean sea level	h_U	m	-	Average height above sea level

Surface/material properties	Symbol	Unit	Range	Definition
Reflectance/albedo	ρ_{sw}	-	0-1	Mean value of albedo (shortwave)
Thermal conductivity	$\lambda = (\lambda_i + \lambda_p)$	$W \cdot m^{-1} \cdot K^{-1}$	>0	The property of a material's ability to conduct heat
	λ_i : impervious surface	$W \cdot m^{-1} \cdot K^{-1}$	>0	Thermal conductivity of impervious surfaces
	λ_p : pervious surface	$W \cdot m^{-1} \cdot K^{-1}$	>0	Thermal conductivity of pervious surfaces
Specific heat capacity	$c = (c_i + c_p)$	$J \cdot kg^{-1} \cdot K^{-1}$	>0	The amount of heat required to change a unit mass of a material by one degree in temperature
	c_i : impervious surface	$J \cdot kg^{-1} \cdot K^{-1}$	>0	Specific heat capacity of impervious surfaces
	c_p : pervious surface	$J \cdot kg^{-1} \cdot K^{-1}$	>0	Specific heat capacity of pervious surfaces
Density	$\rho = (\rho_i + \rho_p)$	$kg \cdot m^{-3}$	>0	The mass density of a material is its mass per unit volume
	ρ_i : impervious surface	$kg \cdot m^{-3}$	>0	The mass density of impervious surfaces
	ρ_p : pervious surface	$kg \cdot m^{-3}$	>0	The mass density of pervious surfaces
Anthropogenic heat output	Q_F	$W \cdot m^{-2}$	>0	Mean annual heat flux density from fuel combustion and human activity (traffic, industry, heating and cooling of buildings, etc.)

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Tab. 5.3.5.1

We quantified these indexes and compared them to our temperature readings to obtain cogent results that would approximate the real state of things. Thanks to this approach we were able to evaluate the various urban microclimates of the selected areas and single out incidence factors.

For example, the first area that we analyzed showed that heat island production factors are mostly ascribable to the low ratio between permeable - impermeable surfaces and the sky view factor, whereas the fourth area (which we later picked as final pilot area) showed that heat production is mostly ascribable to the type of materials used for buildings. Therefore, it seems obvious that mitigation strategies (and the urban planning tools for implementing project interventions) must be different for the two areas in question.

In order to ensure and maintain the high effectiveness of the proposed interventions and solutions, it is essential that the different overheating causes and issues of each area be carefully identified so as to come up with site-specific strategies. The necessary information for evaluating (and then monitoring) the resilience of an urban area to heat waves were the following:

Paved surface areas;
Permeable surface areas;
Built up surface;
Sky View Factor (SVF);
Urban compactness;
Solar incidence;
Reflectance/albedo of materials;
Thermal conductivity of materials;

Due to the great number of details provided by all this information, we had to come up with an appropriate data collection method for our analysis. Two alternative methods were used; one was a traditional analysis on the field that classified ground covering and building types as well as the height of buildings, the other used remote sensing and three-dimensional data processing from LiDAR[2] and very high resolution orthophotos.

The traditional method allowed us to map the urban tissue and determine the types of materials of all the surfaces, as well as their thermal properties. This activity required a lot of time, spent mainly on the field, but yielded a complete and current set of facts for the area.

The remote sensing method required less time to collect the data and yielded useful information to describe and map the phenomenon. Depending on the infor-

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2 Il LiDAR (Laser Imaging Detection and Ranging) performs remote sensing to determine the distance of an object or surface through the emission of high frequency laser pulses by a flying sensor (plane or drone). The distance of an object is given by the length of time elapsed between emission and reception. Very high frequency pulses bouncing from objects or the ground are converted into georeferenced and dimensioned points, thus giving rise to a "point cloud" from which the exact reconstruction of an area can be created in the form of three-dimensional digital models.

mation, computers and technology available to individual local administrations, this method could be applied easily and quickly to the whole of the Veneto region.

Remote sensing analyses require LiDAR data and high resolution orthophotos (0.2-0.5 m per pixel), preferably including the infrared band, for the entire administrative area.

For each selected area, this methodology allowed us to find out the sqm of vegetation (divided by height), the ratio between permeable and impermeable surface, the incident solar irradiation, and the sky view factor (P. Berdahl, Bretz., 1997). Technically, the analysis involved the creation of three-dimensional digital models of the terrain, DSM (Digital Surface Models) and DTM (Digital Terrain Models), which made it possible to identify and inventory the composition of urban surfaces. By adding the DEM (Digital Elevation Models) obtained by processing the LiDAR data with the multispectral orthophotos, we also got to an automatic breakdown of the horizontal surfaces of the city by type and height, resulting in an atlas of surfaces composed of green spaces, with their respective heights, and impermeable spaces (buildings, roads, parking lots).

Next, we used software like *LAStools*, *Saga Gis* and *eCognition* to produce sky view factor and solar irradiation maps, which most importantly provide essential information to determine the specific areas that require intervention, in addition to which interventions should be performed to mitigate the UHI phenomenon and adapt the urban environment to climate changes.

The key strength of these innovative analysis techniques is that they can be replicated over very extensive urban areas, whose level of detail would require months to obtain with traditional topographical detection methods. However, we must realize that not all areas are equipped with LiDAR or similar detection devices, which means this methodology is still used in limited areas despite the fact that it is innovative and efficient.

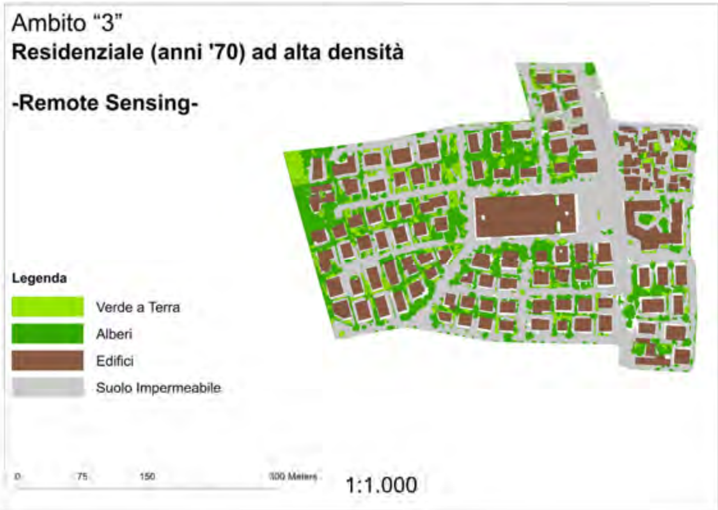

Fig. 5.3.5.3

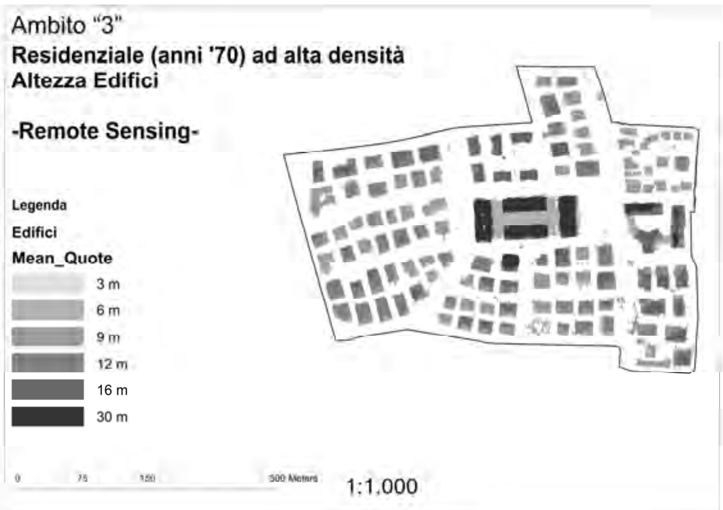

Fig. 5.3.5.4

Fig. 5.3.5.5

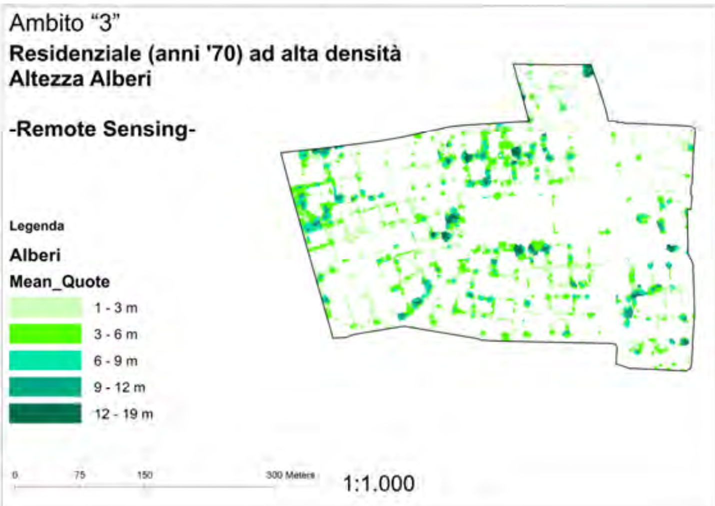

Fig. 5.3.5.6

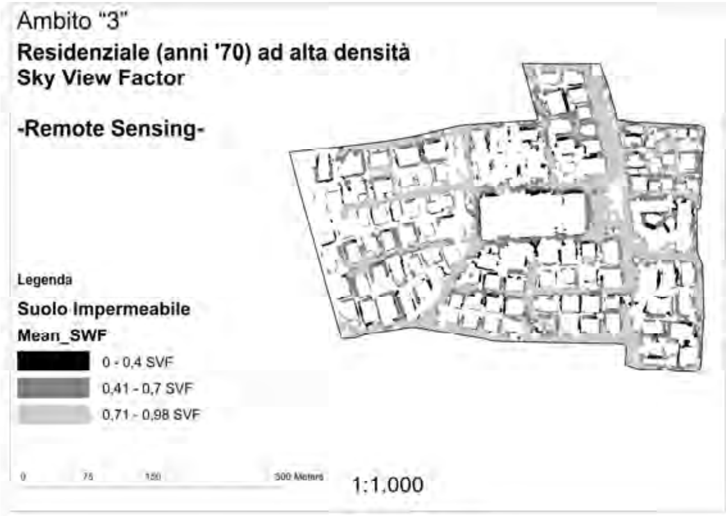

Fig. 5.3.5.7

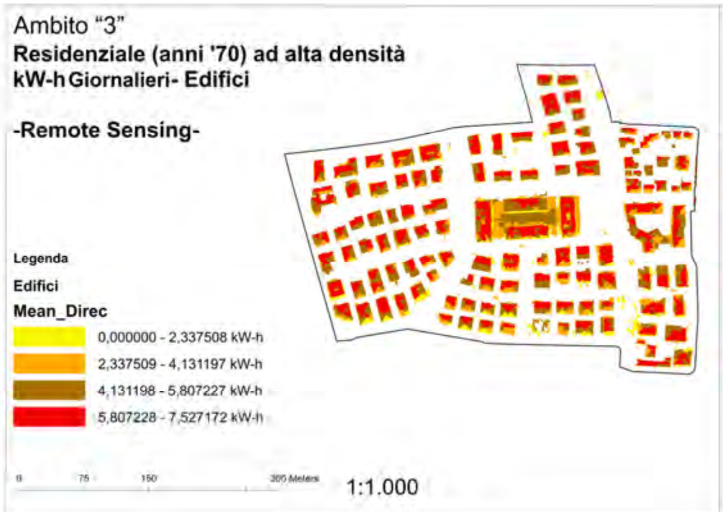

Fig. 5.3.5.8

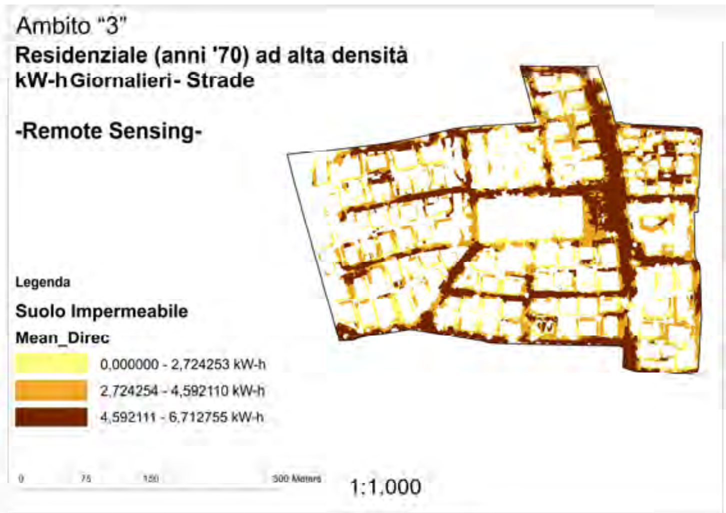

Fig. 5.3.5.9

The collected information, converted into vector format, can be queried using height and covering type data. Breaking down the city in all its three dimensions, we can identify the areas that are most vulnerable to heat waves, and also adapt portions of the city to the extreme weather phenomena, suggesting some possible strategies to achieve that goal. So as to test and evaluate the efficacy of the interventions, we then proceeded to build four different transformation scenarios of the area under study.

The four scenarios, and their specific interventions, which resulted from the integration of accurate temperature readings and the indicators research, were then processed using the *ENVI-met* software, which simulates air temperature changes based on the physical changes proposed within a selected area. It can therefore verify and indicate mitigation strategies for the UHI phenomenon by showing the results of the proposed interventions. For example, this simulator can show what benefits would be derived from adding trees to an actual area or modifying the albedo of some of its surfaces. *ENVI-met* can not only verify the effectiveness of an intervention but also the optimal location for its application.

Feasibility study

After processing the data pertaining to the areas inside the survey transept, it became necessary to understand what mitigation and adaptation interventions should be considered based on the morphological aspects of this specific neighborhood of the city of Padua, including buildings, outdoor public spaces, and private spaces.

The integration of these sets of interventions produced the "transformation scenarios" that were later tested for effectiveness with the *ENVI-met* software.

Through this process, we initiated an actual project for the pilot area, by adapting to it specific mitigation measures that until then had been generic proposals for other areas. As a result of the preliminary project test performed inside the pilot area, we came up with four different project scenarios as follows:

"green ground": **a scenario where the permeable surface of the area is increased (from 18% to 23%) by turning a paved parking lot into a grass surface and planting 10 m tall trees along the main roads of the area;**

"cool pavements": **substituting the traditional paving material (0.2 albedo) and concrete (0.4 albedo) used on streets and sidewalks with high albedo (0.5) "cool" materials;**

"cool roofs": **substituting the traditional tile or covered flat roofs with "cool" materials (0.3 to 0.6 albedo);**

"green ground + cool pavements": **a scenario that adopts both these mitigation interventions simultaneously.**

The precision of the digital terrain model, obtained through the use of *LiDAR* and orthophotos data, made it possible to increase the number of details with which to perform the effectiveness measuring simulations in terms of temperature reduction, using the various mitigation interventions considered for each of the four scenarios.

The subsequently performed simulations allowed us to close the working cycle through the virtual testing of the interventions under consideration, thereby assessing the best strategies for the pilot area.

The fourth scenario, *"green ground + cool pavements",* tested with the *ENVI-met* software, provided the best results from the point of view of temperature reduction. Based on this, we used this scenario for our project.

The pilot area as testing ground for the Veneto Region

The scenario we selected for the pilot area is aimed at increasing resilience to negative externalities caused by climate variability. This urban green infrastructure plan becomes a driving force for the adaptation of urban and regional systems to climate changes.

A network of natural and semi-natural areas has a good ability to make the land more resilient; if well designed, green infrastructure can mitigate the effects of floods and the increasing droughts, improve water and air quality, effectively promote soil protection, and oppose hydrogeological instability. In addition, it ensures air filtration, erosion protection, water flows regulation, coastal protection, soil structure maintenance, and carbon storage.

The multiple benefits of green infrastructure are also set forth in the European strategy for green infrastructure published last year (EU, 2013). For example, trees and green areas may prevent flooding in cities while reducing air pollution and noise levels. Furthermore, the use of natural systems can often be cheaper and more durable than a hard artificial structure.

However, we have yet to understand how to apply these changes to a real area. Veneto's central area, having been greatly transformed over the last 40 years, mostly through a series of small spread out interventions, requires a specific design approach. By the same talking, the pilot area transformation project produced by our feasibility study can be implemented through small interventions that will be made presumably over a period of about twenty years.

Our project and its graphical representations provide a potential scenario that can presumable be striven for. Its mitigation measures against the heat island effect can be effectively used in the first place through the adoption of appropriate land and urban management and planning tools that can implement the new adaptation priorities arising from climate changes.

Based on this, in order to make our mitigation measures as applicable as possible, our work group performed a survey of the existing land management and planning tools, linking each measure to a potentially modifiable planning tool (Tab. 5.3.5.2).

GROUND SURFACES	**Intervention**	**Main regulating body**	**Tool (for urban planning or managment)**	**Indication type**	**Notes**
Management of the Reflectance and Emissivity of impermeable surfaces for public and private spaces	1) Pigmentation type 2) Material type	Municipal Administrations	Municipal urban plan (the name will change according to the specific regional legislation)	Indications on the surfaces of each ordinary transformation area	The pigmentation of existing pavements should be modified gradually. New surfaces should employ materials that combine greater reflectance and a low impermeabilization rate.
			Ordinary and extraordinary maintenance plan	Reflectance parameters of existing surfaces	
			Infrastructure plan	Reflectance parameters of new infrastructure surfaces	
			Building regulation	Reflectance parameters of surfaces of new private and public buildings	

Tab. 5.3.5.2 Ordinary urban planning and management tools: possible UHI moderation interventions. Source: *IUAV data processing, 2014*

Possible transformations of the pilot area

The possible transformations/interventions proposed below refer to the previously analyzed *"green ground + cool pavements"* scenario. We took the basic pattern used for *ENVI-met* modeling and came up with a number of potential transformations for the pilot area.

These possible interventions are not part of a single urban planning project, but they are structured rather as small interventions to be implemented through the use of the urban planning tools analyzed above (see table 3).

It should be noted that the proposed interventions can be effective on their own in mitigating the heat island effect; however, more specifics are needed on the areas they are going to be applied to, so as to make effective and cost effective decisions. Maximum effectiveness can be reached when all of these interventions together become part of a general strategy of adaptation to climate changes combined with the more important urban and/or socio-economic concerns of a given area.

Intervention 0 actual conditions + summary of intervention 0 actual conditions

Outdoor public spaces

Fig. 5.3.5.10 Intervention 1 + summary of intervention 1.
Modify the albedo of streets. Modify the reflectance of the road surface

The first intervention posits an increase in the reflectance of the road surface. This can be done by means of several types of materials. Two technical options may be considered: the more immediate one would be acting on the pavement's coloration/pigmentation, the other would involve a more structured approach of asphalt type modification. This type of intervention can be planned on a municipal scale over a set period of time, for example, the years it would take to pave everything over and remanufacture some types of streets signs. For the sake of economic sustainability, it would make sense to prioritize such interventions by area with the aid of specific maps. For larger cities, the mapping process can be integrated with urban heat studies, using direct readings or indirect photogrammetric data processing. Municipalities that do not have access to complex analyses of urban heating phenomena can prioritize their most densely occupied areas, and also apply the indexes suggested by the University of Vienna for this specific project.

Fig. 5.3.5.11 Intervention 2 + summary of intervention 2.
Modify the albedo of sidewalks and parking lots. Modify the reflectance of sidewalks and parking lots

The second intervention also concerns the reflectance of impermeabilized urban surfaces; however, in this case, the spaces considered - sidewalks, parking lots, and city squares - do not involve car traffic. These surfaces, like the ones we just discussed, need to be approached according to a set of urban planning priorities. Modifications will necessitate the application of street furniture programs that will include reflectance limits to the repaving of city squares and sidewalks. For the application of this intervention inside the pilot area, we considered also parking lots and street side parking areas, which are normally paved, and which will have to be handled using a different approach, like more permeable materials for improved absorption of rainwater.

Fig. 5.3.5.12 Intervention 3 + summary of intervention 3.
Add green areas on the ground of public spaces in addition to public trees

Public green spaces: create new traffic islands and plant new trees.

The third intervention focuses on increasing public green spaces. Here too, we are not talking about great new parks or large green areas; these are micro interventions that can be applied in a city with a consolidated infrastructure. Practically speaking, it is about creating new traffic islands and planting new trees. These interventions necessitate an innovative approach based on a new public space management vision. At present, for most Italian cities to add new trees and traffic islands in urban areas where everything has already been built could involve an increase in maintenance costs and a loss of needed urban space (for car, bicycle, and pedestrian traffic, parking, etc.). This is why this new approach would have to be adopted as part of a strategic paradigm shift in the general management of city spaces. Creating new green spaces inside the context of a built up city entails changing one's perception of street space as just for transit, parking, and car maneuvering. A new paradigm for the use of public green spaces requires a strategic rethinking of urban greenery, insofar as what it can offer in terms of the urban ecosystem adapting to climate changes. Going down this road means understanding and valuing the gamut of services that green spaces can offer to mitigate the heat island effect in addition to other negative externalities due to weather phenomena: lamination for the containment of water during extended rainfall, reducing air pollution, helping to reduce the speed of urban traffic, and even a general improvement in the environmental and aesthetic quality of public spaces. New traffic islands were added inside the pilot area along the streets whose width could reasonably be reduced or that could be switched from two-way to one-way traffic. We also added a green area on a space used as a square along Via Guizza.

Private Outdoor Spaces

The management of private outdoor spaces is also a major factor in determining the occurrence and intensity of urban heat islands. Depending on the type of settlement, a significant portion of Veneto's cities that is not covered by buildings is private property; in the case of Padua's pilot area, private property covers more than 1\3 of the total surface.

It is obvious that the management of these surfaces is greatly relevant to the mitigation of the heat island effect. However, in this case, even a simple technical solution (increasing the green surface and the reflectance of impermeable surfaces) must be justified at the management and legislative level; a cogent response is necessarily based on a general strategic vision that can harmonize individual management needs with the understanding of the importance of adapting to climate changes. Private outdoor spaces can easily be handled when it comes to new buildings, where building codes can set new extension and surface type parameters, but they require a much more thorough consideration for consolidated urban areas, as is the case of the pilot area, since it is more difficult to find legislative levers or incentives to modify already built property.

In these cases, implementation can be achieved through the following:

- come up with education programs for the city's inhabitants, so that the more sensitive section of them may be stimulated into performing ordinary maintenance of their private spaces;
- coordinate with the water department to establish incentive policies where bill payments reflect how much of a property is impermeabilized.

Within the pilot area, we proposed to modify only the reflectivity of the private surfaces currently impermeabilized by asphalt, concrete or the like with intervention 4, whereas with intervention 5 we proposed to replace them with greenery.

Fig. 5.3.5.13 Intervention 4 + summary of intervention 4. Albedo on private paved surfaces. Modify the reflectance on private surfaces

Fig. 5.3.5.14 Intervention 5 + summary of intervention 5. Put greenery on private surfaces
Add green areas on private surfaces

Post-scenario intervention

The last project intervention on the pilot area takes a step beyond the interventions encompassed by the feasibility study, proposing a more incisive transformation that involves buildings as well.

This intervention pictures a gradual transformation of the roofs of private buildings, first by modifying the reflectance of flat surfaces and then by turning them into green roofs. A real expansion of green roofs can only occur if our cities will understand and assess their value in terms of the services that they can offer to the community: mitigation of the heat island effect, lamination of rainwater, improvement of air quality, and last but not least, recreational use.

This final scenario is not meant to offer a new utopian vision of what a city should be like, but it is rather an attempt to propose the application of solutions that would adapt the current state of affairs to a no longer so remote future of rapid climate changes.

To increase concretely the resilience of our urban system to climate changes, such as in the case of heat island mitigation demonstrated by this project, we must utilize several approaches: in-depth climate evolution studies on the regional and local scale, the use of climate modeling, the use of new technologies as a support for urban planning, the research of new building materials, the revision of the urban governance system, and above all the creation of a new strategy to review and harmonize all the aspects of the matter.

Fig. 5.3.5.15 Intervention 6 + summary of intervention 6. Green roofs: extra scenario intervention

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5.4 Pilot action City of Vienna – UHI Strat Vienna

Doris Damyanovic, Florian Reinwald, **Christiane Brandenburg, Brigitte Allex, Birgit Garntner**
Institute of Landscape Planning, Dept. of Landscape, Spatial and Infrastructure Sciences, Univ. of Natural Resources and Life Sciences, Vienna
Peter-Jordan-Straße 65, 1180 Vienna

Ulrich Morawetz
Institute for Sustainable Economic Development, Department of Economics and Social Sciences Univ. of Natural Resources and Life Sciences, Vienna
Feistmantelstraße 4
1180 Vienna

Jürgen Preiss
Vienna Environmental Protection Department, Municipal Department 22, Vienna City Administration
Dresdner Straße 45, 1220 Vienna

Abstract The article presents the results of the pilot action "Urban Heat Islands– Strategy Plan Vienna" (UHI-STRAT Vienna). It sets out by determining what potential consistent consideration of urban climate aspects at different levels of action and decision-making has and how to implement such consideration. In a second step it looks at today's and future development of UHI and the urban climate. The report goes on to explain the three fields of action identified, i.e. awareness building, information and public relations for UHI, as well as urban infrastructure and large-scale and more detailed technical and structural measures to support strong consideration of the issue. It shows up the levels of action in planning from the master plan to the actual project and the options available in the course. Two feasibility studies reveal how UHI-relevant measures can be implemented in designated areas of the city. They make a clear distinction between measures in the development of new city quarters and measures in adapting existing ones, and they also identify two different levels of planning, the strategic master plan on the one hand and the planning of legal provisions, i.e. the land-use and building development plans on the other hand. The "Master Plan for Nordbahnstraße – Innstraße" in Vienna's 20th municipal district is used as an example to show how measures can be introduced at different stages of the master plan process. Proposed measures can be embedded in land-use and building development plans, as demonstrated in the case of the quarter surrounding the Vienna University of Technology (Karlsplatz) in the 4th municipal district. The studies were assessed as to the feasibility of the measures proposed, which involved participation of different agencies of the Vienna City Administration. The summary points out the project's added value for the city, indicating that the journey Vienna has taken to protect the climate while at the same time adapting to the consequences of climate change is bound for success.

5.4.1 Introduction

The pilot action "Urban Heat Islands– Strategy Plan Vienna" (UHI-STRAT Vienna) is meant to trigger discussion processes, to make the problems entailed in UHI visible for political decision-makers and the city administration, as well as to offer assistance and clearly defined solutions. The results of the pilot action UHI-STRAT Vienna are helping to put the issue of Urban Heat Islands in the focus of future urban development. Increasing heat stress and a rising temperatures during the summer months as predicted for the City of Vienna can be mitigated by putting into place the strategic and technical measures proposed. Protecting and expanding the city's green infrastructure, for example, can effectively reduce the consequences of UHI while at the same time improving people's quality of life and boosting urban biodiversity. The pilot action UHI-STRAT Vienna helps the participating administrative agencies identify the measures relevant for their work, the measures they can implement in their own areas of competence, the steering tools and levels at their disposal, and the potential of the different measures. The pilot action UHI-STRAT Vienna was developed in close coordination with representatives from the Vienna City Administration and outside experts on the basis of autonomous yet interlinked discourses (Hubo and Krott 2012).

5.4.2 A consistent strategy for UHI in urban planning

The objective of the UHI-STRAT Vienna is to integrate consistent consideration of urban climate aspects at different levels of planning. There is a wide range of tools where the (urban) climate already features strongly, along with a number of strategies and rules on how to tackle the phenomenon of Urban Heat Islands. The subject matter includes contracts under international law, such as the UN Climate Change Convention, Austrian wide approaches, such as the Austrian Strategy on Adaptation to Climate Change, regional approaches, such as the Climate Protection Programme of the City of Vienna, as well as federal and provincial laws, guidelines, planning tools and planning assistance. Mitigating the effects of UHI combined with forward-looking urban planning for the prevention of Urban Heat Islands has become a very integrative task. Different fields of action, steering levels and planning processes are either influenced by the implementation of measures or influence the latter in turn. It is important in the context to bear in mind the hierarchy of the planning tools and the chronological order the different tools are used in in the course of planning.

This is why many aspects of adaptation to climate change have found their way into programmes and activities pursued by the City of Vienna, mostly in conjunction with objectives of environmental protection:

The Municipal Department for Environmental Protection has been promoting roof and façade greening for many years, measures to this end ranging from presentations, international congresses, publications and consultation with individual projects. It even has its own test area with several types of roof greening on the Department's office building. Numerous studies, expert meetings and public relations activities are dedicated to forward-looking use of rainwater (rainwater management), particularly with a view to raising the rate of evaporation. There is positive interaction with "ÖkoKauf " (EcoBuy Vienna) , a programme for sustainable procurement, and "Öko Businessplan" (EcoBusinessPlan Vienna), a cooperation initiative with the economic chamber to consult businesses on ecological measures.

The ecological criteria set out in UHI-STRAT are in line with the Environmental Department's wildlife conservation programme "Netzwerk Natur" (network nature), a topic which is also addressed in the project "Nachhaltiger Urbaner

Platz“ (sustainable urban space), a checklist for sustainable design of urban spaces.

“Microclimate” constitutes a separate assessment category along with other environmental goods incorporated into the “strategic preliminary assessment of environmental impacts caused by housing projects”. This tool is to make different locations and projects for the creation of housing more easily comparable and comprehensible with regard to their environmental impact at the urban development level already. It is to ensure that all environmental aspects are duly considered when choosing from different planning options.

All of the above programmes and projects are brought together in the city’s Smart City Strategy and the Climate Protection and Adaptation Programme (KliP II).

Implementation of UHI-STRAT Vienna must be addressed both in the different fields of action and at the various levels of planning. The UHI effect needs to be considered with measures relevant to the city as a whole, as well as with those that have a bearing on individual lots or buildings. It means acting strategically and setting specific measures within one’s own competence. Aside from large-scale urban planning approaches it is also important to build public awareness and make members of different Municipal Departments and agencies with the Vienna City Administration sensitive to today’s and tomorrow’s challenges in tackling the UHI phenomenon.

The city administration, builders and developers, private ones too, have the right to set measures of their own accord for the purpose of reducing the UHI effect.

Circumstances and concepts for reducing or preventing the UHI effect may vary depending on the location and occasion. Each development task (e.g. planning a new city quarter, adapting and enhancing existing buildings or project-related processes) has its own set of actions and measures. Political and legal settings, as well as planning instruments provide the basis for realising urban planning and development that is sensitive to UHI. Adjustment measures to reduce Urban Heat Islands are positioned at various political and legal levels and provide the frame for UHI-STRAT Vienna.

5.4.2.1 Consolidation at the European and the national level

The “EU Strategy on Adaptation to Climate Change“ (2013) is based on the premise that climate protection measures must be paired with adaptation measures if Europe is to master the challenges of climate change. From the point of view of the EU Commission “it is cheaper to take, early, planned adaptation action than to pay the price for not adapting“ (COM 2013, 2). The objective must be to raise climate resilience in Europe. The adaptation options are threefold: “gray“ and “green“ infrastructure approaches, as well as “flexible“ structural approaches (COM 2009). Promoting functions and services within ecosystems is considered imperative as these are considered more cost-effective and sometimes more viable than simply trusting grey infrastructure (COM 2009, 6). The “Austrian Strategy on Adaptation to Climate Change“ (2012) adopted by the Council of Ministers also makes it clear that along with measures to limit the global rise in temperature it also takes suiTab. and timely adaptation measures. This second pillar of climate policy constitutes a major complement to climate protection seeing as it reduces greenhouse gases. More specifically, the Austrian strategy emphasises the negative effects of heat waves on people’s health and the importance of measures to reduce these (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 5). The rise in hot days and the heat stress they create are considered tomorrow’s challenges which adaptation measures are required for. Land-use planning is addressed as one of 14 main fields of activity (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 16). “Prevention of overheating and heat islands and compensation of bioclimatic stress for people’s health“ is to be made possible by providing, in development plans, “green“ and “blue“ infrastructure for built-up areas, as well as “measures with an impact on bioclimate“ (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 117f). The strategy also calls for a ‘Climate Proofing‘ of spatial planning and tools“ to systematically consider the impact of climate change (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2012, 118f).

5.4.2.2 Strategic approach to UHI-relevant aspects in Vienna

The City of Vienna has taken a strategic approach to climate-sensitive action and measures to adapt to climate change.

The objectives and results of the individual aspects were combined to form the “**Smart City Vienna Framework Strategy**“ adopted by the Vienna City Council in 2014. It is an umbrella strategy for the period up to 2050 to be implemented step by step, individual objectives being subject to continuous monitoring. The overriding goal is to reduce CO_2 emissions from currently 3.1 tons per head to approximately one ton (minus 80 percent from 1990 2050). Unlike comparable strategies in other cities it encompasses environmental protection goals beyond that, such as reducing the share of motorised private transport from currently 28 to 15 percent by 2030, or maintaining the high share of green areas of 50 percent.

The current ***Climate Protection Programme of the City of Vienna (KliP II)*** encourages strong consideration of the UHI effect in tools of spatial planning, nature conservation plans, as well as informal tools. The "Climate Protection Programme of the City of Vienna (Klip II) – update 2010-2020" adopted by the Vienna City Council has coined as its key goal the reduction of greenhouse gases and proposes measures to adapt to and mitigate the impact of climate change. It contains a separate field of action dedicated to "mobility and urban structure". Again the focus is primarily on reducing energy consumption. The set of measures, however, clearly addresses urban planning measures that are to help reduce the UHI effect. Objectives for the field of action "urban structure and quality of life" include "pursuing integrated sets of measures to raise the quality of life in built-up urban areas (greening street space, courtyards and roofs, reducing soil sealing, upgrading green and open space,…)" (Vienna City Administration 2009, 93). Specific measures are "green paths, multiple use, activating green and open spaces already dedicated, roof greening, neighbourhood gardens and succession gardens " (Vienna City Administration 2009, 100). Regional cooperation must ensure "green and open space for the long term, linking green space (regionally) and strengthening awareness for agricultural products from the city region (Vienna City Administration 2009, 105et seq.). KliP II also for the first time stimulates Vienna's measures to adapt to global climate change.

The ***Urban Development Plan 2025*** (STEP 2025) in particular broaches the issues of urban climate and climate protection. Its aim is to make "climate protection and adaptation to climate change integral elements of planning, implementation and further development of city quarters and open spaces "(STEP 2025, 85). This involves, amongst others, creating open and green spaces that can contribute towards reducing the UHI effect. Specific measures include the greening of roofs and facades, as well as planting trees and avenues (STEP 2025). The chapter on open spaces in STEP 2025 has a separate focus on "adaptation to climate change ". Green and open spaces in this context are granted a major role in adapting to climate change while special emphasis is placed on their positive influence on the urban climate. A network of open space is to improve the microclimate in individual city quarters. The initiative "urban green instead of air conditioning" wants to identify the areas concerned and reduce UHI.

The ***Vienna Nature Conservation Act*** wants to protect and "take care of nature in all its forms across the city and to ensure urban ecology functions " (Nature Conservation Act §1). Protection of green and natural areas includes urban climate aspects considering that climate is part of the landscape balance (section 3, para. 2). "All measures must be planned and implemented in such a way as not to endanger or seriously impair 1. the balance of the landscape, 2. its structure or 3. its recreational effect on human beings" Vienna Nature Conservation Act §4 para 2). Site protection as provided for in the Nature Conservation Act essentially ensures that green spaces and their role for the climate in Vienna are maintained for the long term.

The ***Building Regulations for Vienna*** (Vienna Urban Development, Urban Planning and Building Code) set out the principles of urban planning, land use and construction engineering. The first part lists the objectives for determining or amending land-use and building development plans. These refer to climate-relevant aspects only indirectly, e.g. the objective " to (4.) preserve or create environmental conditions that will ensure a healthy environment, in particular with a view to housing, work and leisure time " (Building Code for Vienna, §1, para 2 Z4).

Protection of the urban climate has been embedded in the strategic and legal tools to enable targeted measures for reducing the UHI effect.

5.4.3 UHI and the urban climate in Vienna – status quo and future developments

Building up natural permeable surfaces is considered the main culprit in the development of Urban Heat Islands (Kuttler 2011). The UHI effect is further enhanced by both a steady decrease and fragmentation of urban green spaces and the waste heat produced by industrial processes, air conditioning and motor vehicles. Construction developments also increase the surface roughness, slowing down wind speed in the course. They prevent cold air flows generated in undeveloped "cold air production sites" from entering the densely built-up city. Building developments in many cases act as an additional blockade for cold air flows from undeveloped environs to agglomeration areas. Generally speaking temperatures are expected to rise from the periphery to the city centre (see Fig. 5.4.1).

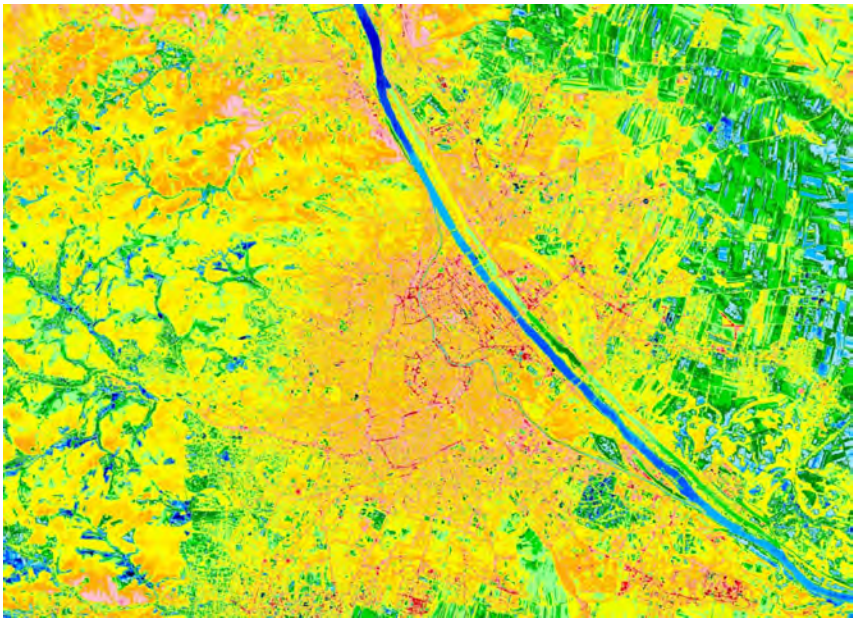

Fig. 5.4.1 *Thermal image of Vienna and surroundings by night. There is a noticeable difference between the urban agglomeration and the cooler rural areas (source: City of Vienna).*

The isothermal map highlights the Urban Heat Islands, the outlines of the built-up area, as well as the "hot spots", such as sealed car parks or industrial areas, and "cold spots", such as parks, agricultural areas and bodies of water in Vienna.

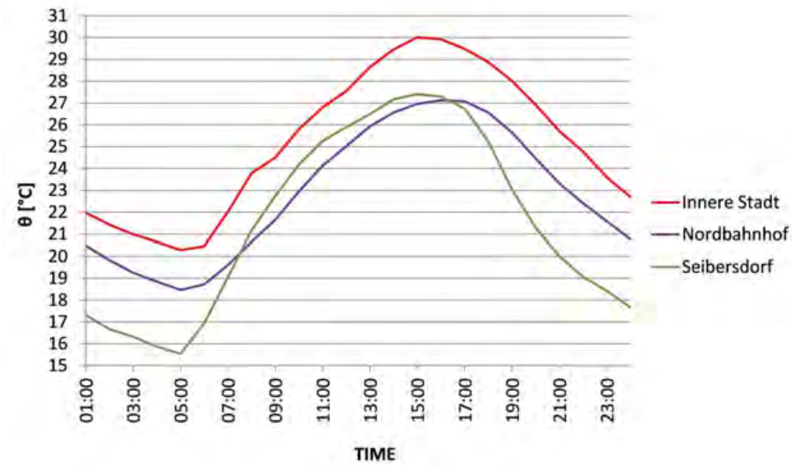

Fig. 5.4.2 *The Fig. shows the average hourly temperature distribution on a given day in the summer of 2012 – pictured here are two selected areas in Vienna (see chapter 4) compared to a*

rural area in Seibersdorf. Results clearly reveal significant differences in the microclimate of the areas studied, with conspicuously high temperatures in the city centre (source: Vienna University of Technology).

Forecasts for climate development are subject to a certain amount of uncertainty. From today's point of view temperatures in Vienna are reckoned to increase. "The 2040ies in the eastern parts of Austria will likely see an increase in temperatures of 1.3 to 1.8°C in winter, 1.8 to 2.5°C in spring, 2.0 to 2.5°C in summer and 2.5 to 3.0°C in autumn, compared to the 1980ies. Heat waves will be on the rise. Between 1961 and 1990 there were an average of 5.1 heat wave days per year (also known as "Kysely days"), between 1976 and 2005 there were as many as 9.1 already, and the current forecast for the period between 2010 and 2039 in the centre of Vienna is an average 17.7 Kysely days per year, the inner districts, because of the UHI effect, being more affected by the heat stress than the periphery" (Vienna City Administration 2009, 196).

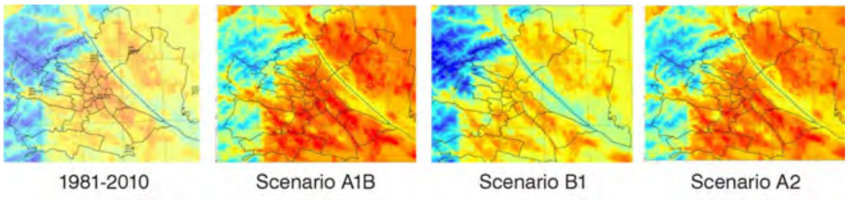

Fig. 5.4.3 *Average annual number of summer days 1981-2010 (far left) and possible climate scenarios 2071-2100 (source: ZAMG)*

The Central Institute for Meteorology and Geodynamics in Vienna (ZAMG), during the project "Focus I" (Zuvela-Aloise et al. 2013), calculated high-resolution, climate simulations of future heat stress in Vienna and examined the effectiveness of adaptation strategies in urban planning aimed at reducing heat stress in densely populated areas. The simulation showed how to improve buildings and open spaces by raising the amount of green and water surfaces, as well as the level of desealing, and by exploiting the Albedo (reflection coefficient) effect on surfaces and roofs. The aim was to create a scientific foundation for urban planning to build on. The MUKLIMO_3 experiments, for the purposes of urban development strategies, arrived at the conclusion that there is a great need for adaptation measures if heat stress in the city is to be reduced significantly. Targeted small-scale measures, when combined with each other, such as increasing the share of green space (+20%), reducing building density (-10%) and desealing (-20%), also have a decidedly positive effect (Zuvela-Aloise et al. 2013). All of the above can compensate the impact of climate change at least to some extent. Model results also revealed that because of the topography, the prevailing atmospheric circulation (NW and SE winds) and the different urban structures adaptation measures will not be felt the same throughout the city. Raising the share of green space (+30%), for example, has a higher cooling effect in the city centre than it does in districts on the outskirts.

5.4.4 Fields of action for STRAT-UHI Vienna - city-wide actions and actions for individual lots and buildings

UHI-STRAT Vienna identifies three fields of action to enhance consideration of the UHI effect, i.e. (1) awareness building, information and public relations for UHI, (2) urban infrastructure and large-scale strategic measures (3) and more detailed technical and structural measures.

Awareness building, information and public relations
This field of action covers measures aimed at making heat a major issue for future urban planning and development and at building awareness among people and planning experts in general.

It is primarily about providing information, whereby a distinction has to be made between information for residents and visitors to the city on the one hand and information relevant for planning purposes on the other hand. Information on (impending) heat stress for the city has been available since 2010. The Vienna Health Board in cooperation with the Central Institute for Meteorology and Geodynamics provides preventive information on expected heat waves on its website and via the local media (http://www.wien.gv.at/gesundheit/sandirektion/hitzebericht.html). This site, as well as that of the Public Health Services of the City of Vienna (MA 15) (www.gesundheitsdienst.wien.at), also explains about what to do in the event of a heat wave.

Implementing the UHI-STRAT also means building awareness and competences for the UHI issue and its impacts among the departments responsible for planning and projects at the City Administration. Spatial research and research projects on climate change are already generating information relevant for planning to some extent.

Urban structure, large-scale strategic measures
When implementing measures a distinction is made between long-term strategic measures and the more specific technical and structural ones, the difference being the scale – from the city as a whole down to individual buildings and open spaces – and the time horizon. Building an interconnected network of open spaces to gen-

erate and distribute cold air and expanding the tree population in the city are strategic measures with a long-term effect.

Specific technical and structural measures
This field of action describes different approaches for implementing the strategic goals of UHI-STRAT Vienna, as well as large-scale strategic measures for the planning and project stages. The 24 specific technical and structural measures are divided into five different areas, (1) green and open spaces (incl. streets), (2) water bodies in the city, (3) shading, (4) mobility and (5) buildings. The measures prepared take into account suiTab. courses of action with both existing and planned new structures.

5.4.5 Level of action – from master plan to project

Bearing in mind the overarching significance of Urban Heat Islands, the environmental and climate policy approaches for the protection of the (urban) climate and the rules and regulations associated with them the following main levels of action were identified for UHI-STRAT Vienna: (1) master plans and urban development guidelines; (2) strategic environmental assessment (SUP) and environmental impact assessment (UVP); (3) land use and building development plan; (4) planning and development of public green and open space; (5) developer competitions, housing initiatives and public housing construction; (6) planning and development of public utility buildings and (7) subsidising measures.

When implementing measures it is important to take into account the hierarchy of planning levels and the chronological order different tools are employed in during the planning process. Interfaces with the various tools call for integrated planning and harmonisation across departments and agencies if the measures employed against the UHI phenomenon are to be successful.

5.4.5.1 Master plans and urban planning mission statements

Urban development mission statements and master plans have a major bearing on subsequent steps of planning and development in city quarters (MA 21B, 2010). They harmonise public and private interests and create the foundation for further planning. Urban development structures, building density and distribution of open spaces are determined right here. While this planning level is not legally binding it is usually confirmed by a City Council decision to be used as a guiding principle for further development.

Urban development master plans, as a rule, are developed through a number of processes, e.g. citizen participation and competitions, and take into account the challenges planning entails, such as planning of new buildings, the development of former railway locations or branches of industry. Major subject matter and strategies are incorporated into this planning level to weigh up (partly) contradictory urban development objectives, such as densification vs. expansion of open space.

5.4.5.2 Strategic environmental assessment and environmental impact assessment

Major projects require various testing methods, more specifically the environmental impact assessment (UVP) and strategic environmental assessment (SUP). UVP is used for the approval of specific projects that have a major impact on the environment while SUP is implemented as early as the planning stage to set the course for decisions relevant to the environment. Both assessment methods investigate the impact of projects on the following protected goods: human beings, animals, plants and their habitat, soil, water, air and climate, landscape, material goods and cultural assets, as well as the interactions between them. Climate already ranges high with the assessment methods and projects are currently run to find our whether, how and to what extent climate change is considered in these methods.

5.4.5.3 Land use and building development planning

Land use and building development planning sets out legally binding conditions for all subsequent planning and development processes. Here is where building types, building heights and their orographic alignment are decided. Special Conditions also determine a number of UHI measures at this stage. Aside from building alignments and size, rules may be defined to determine the amount of green space on a given parcel of land, as well as the size and location if windows. Details on roof and façade greening may also be provided at this point.

5.4.5.4 Planning and development of public green and open space

Planning and development of public streets, squares, green and open spaces is vital for the implementation of UHI-reducing measures, because here is where qualities are determined for the long term. Major emphasis is placed on incorporating UHI-sensitive criteria into design competitions. Internal guidelines and checklists, some of which contain climate-sensitive aspects, facilitate implementation of measures at this level.

5.4.5.5 Developer competitions, housing initiatives and public housing construction

Approximately 60% of households in Vienna live in subsidised apartments (Kolbitsch & Stalf-Lenhardt 2008). This level of action is therefore relevant for many parts of the city. Developer competitions have proven successful in Vienna since 1995. The competitions help to promote quality in subsidised apartments. Four main criteria are used to assess the quality of drafts: architecture, economy, ecology and social sustainability. In addition there are "theme" competitions for low-energy and passive houses or car-free housing developments. Competitions to date have considered microclimate for the design of open spaces and have also included the vision of "climate neutral cities" (e.g. aspern Uban Lakeside).

The housing initiative launched in 2011 has contributed to ensuring quality based on a two-tier cooperative planning process. Both programmes have always emphasised climate protection but have not paid much attention to adaptations to climate change. Evaluation of these instruments (Liske 2008) shows that new and quite specific topics can be integrated into urban development at this level and turned into pilot projects for other projects to copy.

5.4.5.6 Planning and development of public utility buildings

Being a "model" in its own sphere of competence allows the City of Vienna to influence commercial developers and participants in competitions. This applies to all Viennese kindergartens, schools and campuses (Vienna Model where different school levels, from kindergarten to secondary schools, share the same building), as well as administrative buildings and other city-owned buildings. The “Space Book” (Municipal Department 34 – Building and Facility Management) and the “Criteria for Energy-conscious Building for Service Buildings in Vienna (Municipal Department 20 – Energy Planning) define quality standards for the purpose. These guidelines contain a number of UHI-relevant aspects and measures, such as effective sun protection, reducing the externally induced cooling energy provided for in the building code or avoiding large glass constructions to prevent overheating.

5.4.5.7 Subsidising measures

Subsidies are a way of influencing private persons and institutions. Municipal Department 42 (Parks and Gardens) has been subsidising roof greening, courtyard and vertical greening successfully since 2003. Subsidies for roof greening are calculated on the basis of the thickness of the rooting substrate. The example shows how subsidies can promote quality-assuring aspects and measures for the reduction of UHI.

Fig. 5.4.4 planning levels in the city relevant for the reduction of the UHI effect

5.4.6 Feasibility studies

The feasibility studies described below want to demonstrate how UHI-relevant measures can be put into practice using two selected areas in the city as examples. They make a clear distinction between measures in the development of new city districts and measures in adapting existing ones, and also identify two different levels of planning, the strategic master plan on the one hand and the planning of legal provisions, i.e. the land-use and building development plans on the other hand. The "Masterplan Nordbahnstraße – Innstraße" in Vienna's 20th municipal district is used as an example to show how measures can be introduced at different stages of the master plan process. Proposed measures can be embedded in land-use and building development plans, as demonstrated in the case of the quarter surrounding Vienna University of Technology (Karlsplatz) in the 4th municipal district. Workshops were held with different agencies at the Vienna City Administration to assess how the UHI catalogue of measures can feasibly be implemented at these planning levels. The Institute for Building Physics and Building Ecology at Vienna University of Technology simulated measures for both selected areas (e.g. tree planting, roof greening) to find out what impact these measures have on air temperature.

Fig. 5: location of the two pilot areas in the city (source: Vienna GIS)

The results of a survey carried out for the case study UHI STRAT Vienna are presented here to set the scene for the description of the feasibility studies. The survey reflects people's attitude towards heat in the city, their behaviour during heat waves, as well as their assessment of the measures employed to reduce the UHI effect.

5.4.6.1 People's attitude towards heat in the city

385 answers were collected during this postal survey among people in Vienna to assess their perception and attitudes towards heat in the city.

The survey was done in August 2013. Questionnaires were sent to 3792 households in Vienna, which approximately 10% of the addressees replied to. 27 blocks of flats were picked out randomly from different areas in Vienna, some more densely built-up than others, and the responses were weighted to arrive at as representative as possible a sample. Almost everyone in Vienna has witnessed at least one heat wave already. Three quarters consider this a negative experience. Heat is felt particularly strongly in the streets and in people's homes.

Fig. 5.4.6 *Rresponses to: how did the last heat period affect your wellbeing? (source: INWE)*

text for the Fig. :
...in the street,
...at home,
...at work
positive / fairly positive / neither nor / fairly negative / negative

People in their homes try to adjust to the heat and find ways to reduce its effect. Most frequently cited measures to fight heat are: open windows during the night (88%), make sure to take in more liquids (86%), keep blinds and curtains closed (80%). A negligible number of people considered leaving the city or working fewer hours an option during the last heat wave. Only 6% of the respondents used air-conditioning in their homes. Approximately half of the respondents used fans.

Most frequently perceived public measures against the heat are air-conditioning in public transport (64%), drinking fountains in the city (59%) and trees in the streets (51%). Respondents have hardly noticed measures, such as brightening of street surfaces, shading of pavements or greening of rail or tram tracks.

A vast majority (86%) believes that trees are a suiTab. measure for reducing heat stress in the city. An even greater number agrees that trees have a positive effect on the streetscape. Most respondents would like to see more trees in their neighbourhood (70%) and across the city (87%). A majority of 54% endorses the claim for "more trees and fewer parking spaces in my district". Only 24% are not in favour of this measure.

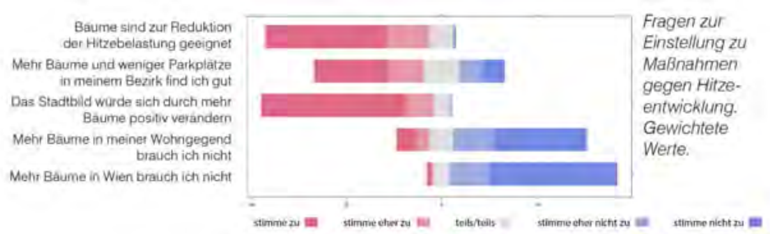

Fig. 5.4.7 Responses to: attitude towards measures against heat development, weighted values (source: INWE)

text for the Fig.:
trees reduce heat stress,
more trees and fewer parking spaces,
more trees would improve the cityscape,
I do not need more trees in my neighbourhood,
I do not need more trees
I agree / somewhat agree / partly agree / rather disagree / do not agree at all

5.4.6.2 Feasibility study for the urban development master plan

Planning and realisation of large-scale urban expansion and urban development projects can take years and even decades which is why it so important to find ways of reducing heat in city quarters at this strategic level. Urban development master plans and guidelines require intensive planning processes, usually in combination with participation processes. To implement UHI sensitive planning and development means to involve experts early on in the process, ideally when preparing the strategic objectives for the master plan.

5.4.6.2.1 UHI-relevant links in the master plan process

The following description of ways to incorporate UHI-relevant issues into the different stages of developing an urban development master plan or guideline is based on the study "planning as a process" commissioned by Municipal Department 21B – District Planning and Land Use – to collect experience with master plan processes in Vienna and internationally. Master plan development is characterised by the four stages of "opening, setting the programme, consolidating and implementing" (MA 21B 2010), during which UHI-relevant issues may be introduced and put into practice.

During the opening stage political and planning requirements, as well as the various expectations with regard to future development are identified. Process structures and participants are determined at this point so it is imperative to include persons knowledgeable in climate-sensitive urban planning. This stage also determines what basic information, plans, expert reports and studies will be required for the process. The master plan process has to specify what basic information on climate conditions in a city quarter must be obtained (e.g. main wind directions, significance of the area as a cold air production site, link with major cold air corridors etc.).

Setting the programme for actual planning usually means drawing a rough urban development guideline to give the project direction. The interests of politics, investors, landowners and representatives from the administration are translated into functional and structural specifications for the development of an area.

Structural and urban development criteria to prevent heating in future city quarters may be introduced at this stage. The objectives, challenges and general framework defined here provide the setting for further development. Analysing the planning area also reveals links that UHI-relevant aspects can be attached to. This means, amongst others, assessing the availability of green and open space in neighbouring quarters, wind corridors, air flows and water permeability of the soil.

The most important step towards incorporating UHI-relevant issues and measures (see below) at this stage is to define the requirements for preparing qualification processes and urban development competitions. The actual urban development qualification process rounds off this phase.

The "consolidation" phase in the planning and development process is about turning the competition results into specific guidelines, preparing feasible concepts and developing detailed implementation projects. By transferring the requirements to the land-use plan and preparing the environmental assessments and environmental impact assessments as needed UHI-relevant strategic objectives and clearly defined measures are introduced to the process. Issues, such as the effect of planned construction on the microclimate, must be dealt with in detail at this stage.

The phase is completed by an interface with the legally binding land-use and building development planning "Not every urban development aspect in the master plan requires binding regulations. By the same token it would be negligent to waive binding and reliable regulations in favour of informal agreements “ (MA 21B 2010, 51). Ways of embedding UHI-relevant measures in the land-use and building development plan are described extensively in the second example.

The implementation stage is about developing individual projects for the social and technical infrastructure provided by the public authorities, about implementing public space and building development. Technical and planning measures to reduce the UHI effect are put into practice at this stage.

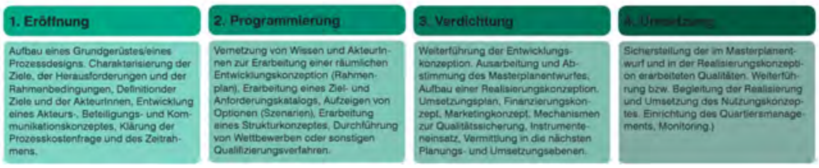

Fig. 5.4.8 *Stages of the master plan process and links to implementation of the measures (source: MA 21B 2010,)*

(Text:

1. Opening: setting up the basic structure /process design.

Determining objectives, challenges and prevailing conditions, defining objectives and players, developing a concept for players, participations and communication, identifying process costs and timeframe.

2. Setting the programme: linking knowledge with players to prepare a spatial development concept (framework). Preparing a catalogue of objectives and requirements, defining options (scenarios), preparing a structural concept, organising competitions and other qualifying procedures.

3. Consolidating: continuing the development concept. Elaborating and harmonising the master plan draft, drawing up a concept for realisation. Implementation plan, financing concept, marketing concept, mechanisms for quality assurance, use of tools, transfer to the next planning and implementation levels.

4. Implementing: ensuring the quality defined in the master plan draft and in the concept for realisation. Continuing and assistance with realisation of the utilisation concept. Establishing quarter management, monitoring.)

5.4.6.2.2 UHI measures in the master plan for “Nordbahnstraße - Innstraße“

“Nordbahnstraße – Innstraße“ is located on the premises of the former Nordbahnhof (a railway station in the 20th municipal district) developed gradually over the course of the past few years. Employees of the Vienna City Administration acted out a scenario to transfer competition results into an urban development mission statement that encompasses UHI-relevant measures.

Fig. 5.4.9 Feasibility Study "Nordbahnstraße - Innstraße" – section from an aerial view (left) and measures discussed (right) for the winner in the urban development competition

To spark the discussion objectives were defined for the "competition inviting urban development ideas for "Nordbahnstraße - Innstraße". Additional competition documentation defined quality objectives along with "hard" project requirements, such as gross floor area, the mix of residential areas/offices/retail/commerce in percent, as well as social infrastructure. Following spatial analyses and information campaigns for the public the "general conditions and objectives for the competition inviting urban development ideas" (MA 21A 2011) were drawn up. It was during this early planning stage that the first UHI-relevant goals and criteria were drafted. A number of solutions mentioned in the collection of measures were strategically positioned at this point already. The objectives for the urban development competition reveal modalities of how these measures may have a bearing on subsequent implementation stages. One of the requirements, for instance, was to create a system of green and open spaces with a high quality of use for everybody, another was to link the new city quarter with the surrounding main green and open spaces. Other requirements included minimising the degree of soil sealing, as well as considering and integrating urban climate aspects (sun/shade/wind/humidity) in competition submissions across the board (MA 21A 2011).

There was general agreement among staff from the relevant departments that most UHI-reducing measures at this planning level can be introduced during the phases of opening and setting the programme for the master plan process. It is important if not imperative to coin UHI-relevant propositions in the urban development guidelines already. Participatory development during the feasibility study and cross-agency discussions about chances and restrictions have proven successful. These negotiating processes can set the frame for addressing conflicting objectives and challenges and thus support the process of weighing up individual objectives. Attention also needs to be paid to bringing on board the "implementers", e.g. Vienna Public Transport for matters relating to designing and placing bus or tram stops, or coordinating green and open spaces across construction sites to minimise overheating in a quarter. Listed below are the points and issues that can and ought to be addressed and finalised during this early stage of urban planning and development: (1) What impact will the planned project have on climate? (2) Which measures for reducing the UHI effect can be implemented in the urban development scenario proposed? (3) Who is responsible for implementation? (4) Which tools will be employed and which planning processes applied to implement the measures? Which challenges does or may implementation pose?

5.4.6.2.3 Modelling measures and their impact with the example of "Nordbahnstraße - Innstraße"

The Department of Building Physics and Building Ecology at Vienna University of Technology (Mahdavi et al. 2014) was commissioned to simulate the impact of the master plan on microclimate based on the results of the winner in the competition inviting ideas for development of the former brownfield Nordbahnstraße – Innstraße.

As soon as the buildings were simulated the mean night air temperature in the area under investigation was seen to rise. This may be explained by a reduced sky view factor, an increase in thermal mass in the area and an increase in the long-wave radiation emitted as a result. In the daytime, however, a significant reduction in mean air temperature was noted (see Madhavi et al 2014).

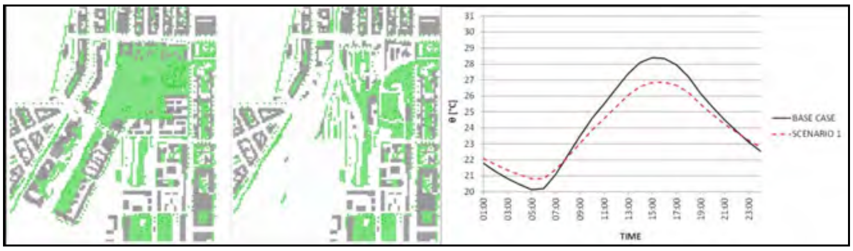

Fig. 5.4.10 *ENVI-met model before and after building development plus a comparison of average hourly temperatures in the course of a reference day before and after building development (source: TU Vienna)*

5.4.6.3 Feasibility study at the level of land-use and building development planning

Permissible utilisation and development on individual sites are made legally binding for owners and developers during land-use and building development planning. As a rule sites are zoned for building purposes, as green areas or as traffic areas. Aside from this classification the land-use and building development plan also defines the building categories, building methods and building regulations, height and cross-section of traffic areas (§5 Vienna Building Code), as well as additional definitions and "Special Conditions".

5.4.6.3.1 UHI-relevant links in the land-use and building development plan

In principle a distinction has to be made between new developments and structural improvements to existing buildings. Of course, there is more scope for implementing UHI-relevant measures with new developments. However, there is a wide range of regulations that can be implemented for future projects in existing buildings as well. Where major changes are made to existing buildings these must be adapted to the land-use and building development planning valid at the time. Again, this proves the long-term strategic significance of this planning level.

Essentially there are two areas where UHI-relevant topics and measures can be incorporated: in the drawn and in the written part. The drawn part sets out rules for escape routes, conditions for use or building classes, i.e. rules to do with the urban structure and the shape of buildings, as well as measures aimed specifically at reducing the UHI effect, such as various greening measures, or at mitigating the impact, such as requirements for shaded pathways and arcades. "Special Conditions" (BB) in the written part of the building development plan contain specifications for the defined area, offering additional suggestions for integrating measures to reduce the UHI effect. This includes, in particular, targets for garden design, roof greening, façade greening, desealing, greening of courtyards and tree planting.

Measures in the drawn part may range from directions of the streets to the geometry of a building. Streets heat up more in the course of a day than their environment. It is recommended that street layout and adjacent buildings with a shading effect on the streets are considered at this level. The width of streets is connected to the height of buildings with relevant regulations set out in the Vienna Building Code (§75 para. 4). These regulations are generally applicable with the exception of protected zones or areas designated "urban development hotspots". There is little point in narrowing the cross sections of streets as this would necessitate a reduction in building heights to avoid difficulties with lighting and exposure to light. Wider cross sections combined with green infrastructure can help to reduce the UHI effect. Depending on the direction of a street (E-W, N-S) measures, such as planting rows of trees or utilisation of surfaces may have more or less of an impact. Alignment of streets must take into account the main wind direction so as not to hinder the exchange of air. The height of buildings, their position in relation to each other and the shade they subsequently produce must be coordinated separately for each location. There is no rule of thumb here as the local wind situation, topography and supply of green space vary widely. For complex urban development situations or where climate challenges, such as strong winds, prevail microclimate simulation with different building scenarios is recommended. The drawn part can set the scene for "public pathways" and "arcades" for sun protection along major pedestrian axes. Measures may also be specified in the written part, i.e. the special conditions, as demonstrated in the second, inner-city example below.

5.4.6.3.2 UHI for the land-use and development plan for Karlsplatz and surroundings

The second example is located in the area surrounding Vienna University of Technology in the 4th municipal district of Vienna. An analysis was made as to how to incorporate requirements when revising the land-use plan to make sure that new constructions with and renovations of existing buildings take into account the phenomenon of UHI. Most of the area was developed during the Gründerzeit (in the late nineteenth century) with an utilisation mix of apartments, offices and commerce and is comparable to many quarters in the city centre of Vienna.

Special Conditions are particularly suiTab. for determining how UHI-relevant measures can be implemented in areas already developed. The Fig. shows the potentials staff from the Vienna City Administration gathered during an experimental game based on the requirements set out in the Special Conditions for land-use and building development planning. The Special Conditions proposed are concerned primarily with tree planting, roof and façade greening, landscape design of surfaces, as well as with requirements that have a bearing on the level of soil sealing, both in public and in private areas. Qualities, such as substrate thickness with roof greenings, or accessibility of roof gardens may also be defined in the Special Conditions. Other issues addressed may include taking the necessary steps to enable tree planting along streets and in public squares, determining the permissible percentage of sealing on a plot of land to reduce the level of soil sealing in park areas or specifying whether arcades are to be built in the area.

Fig. 5.4.11 *Feasibility Study "Karlsplatz" – section from an aerial view (left) and the measures discussed (right)*

5.4.6.3.3 Modelling measures and their impact with the example of Karlsplatz and surroundings

Three adaptation measures were modelled for assessment of the city centre. The scenarios include: (1) a basic scenario without measures, (2) tree planting, (3) roof greening and (4) a combination of tree planting and roof greening. The Fig.s below show the difference in climate conditions between the current building stock and the simulated implementation of individual measures on a reference day. The models were built by the Department of Building Physics and Building Ecology, Vienna University of Technology using ENVI-met 4.0 (Mahdavi et al. 2014). Clearly visible are the differences in air temperature between the current situation and after the simulated impact of the measures selected.

Results reveal that adaptation measures have the potential to reduce air temperature in the research areas on hot summer days. As expected different adaptation measures also have different levels of impact. Roof greening in the city centre has no noticeable effect on air temperature in the open spaces of streets (scenario 3), while trees do (scenario 2). The combination of the two selected measures proved particularly effective (scenario 4). Looking at the time patterns showed that differences in air temperature are more distinct in the evening and during the night (see Fig.5.4.12).

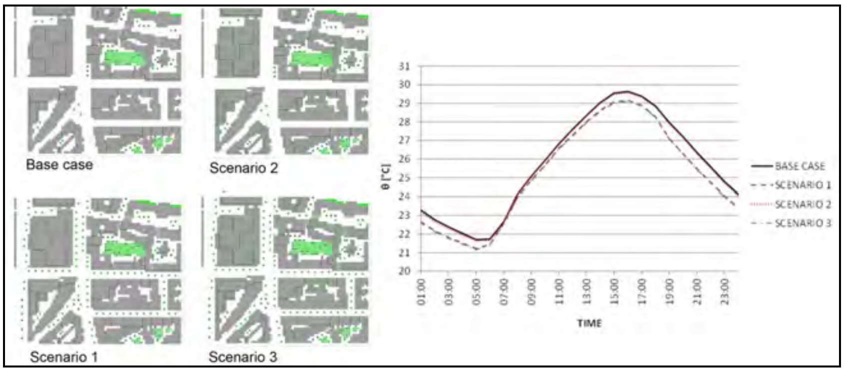

Fig. 5.4.12 *The research area in the ENVI-met model and after implementation of selected adaptation measures, as well as average hourly temperature on a reference day, shown for the current building stock and for the three adaptation scenarios (source: Vienna University of Technology)*

5.4.7 Conclusion

The pilot action UHI-STRAT Vienna shows how measures for reducing the UHI effect can be implemented in urban planning and urban development in Vienna. There is in fact a wide range of tools to trigger action at various levels of planning and to make urban planning climate-sensitive, from strategy planning to development and completion. Close cooperation with the administrative agencies relevant for planning confirmed that existing tools of urban planning, formal and informal, are quite capable of reducing the UHI effect. Many examples revealed during the project process are proof that urban climate is an issue already for many administrative agencies in their day-to-day business. The examples can help to make sure that Vienna will continue its successful venture of protecting the climate while at the same time adapting to the impact of climate change. This must be considered at an early stage at the strategic level and then broken down to the various levels of planning and finally development.

"Green" measures proved especially effective for Vienna. A growing city where densification of built-up areas is necessary to keep distances short can employ these measures to create green and recreational areas for residents, while at the same time reducing the UHI effect. There are strong synergies between measures to reduce the UHI effect and other strategies pursued by the City of Vienna, e.g. reducing (leisure time) traffic, promoting biodiversity, improving water retention and establishing a network of open space. UHI-STRAT Vienna provides the setting for the implementation of theses measures.

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5.5 Pilot actions in European cities - Stuttgart

Rayk Rinke[1], Rainer Kapp[1], Ulrich Reuter[1], Christine Ketterer[2], Joachim Fallmann[3], Andreas Matzarakis[2], Stefan Emeis[3]

[1] Section of Urban Climatology, Office for Environmental Protection, Municipality
Stuttgart, Gaisburgstrasse 4 D-70812 Stuttgart

[2] Meteorological Institute, University of Freiburg, Werthmannstrasse 10, D-79085 Freiburg
[3] Institut für Meteorologie und Klimaforschung, Atmosphärische Umweltforschung,
Karlsruhe Institute of Technology (KIT), Kreuzeckbahnstrasse 19 D-82467 Garmisch-Partenkirchen

Abstract The field of urban climatology has a long tradition in Stuttgart. It exists as discipline in Stuttgart since 1938. Stuttgart was the first city to establish its own Department of Climatology to research ways of improving the flow of fresh air into the city and to reduce thermal stress in most populated city districts. The specialist department of Urban Climatology, within the Environmental Protection Office, deals with tasks relating to environmental meteorology within the scope of air pollution control and also relating to urban and global climate protection. So in Stuttgart the urban heat island phenomenon (UHI) is studied for several decades, leading to a high level understanding of the UHI and the problems which it causes. The UHI causes an increase in air temperatures and thermal stress, that are identified as most negative impacts on human health and urban living. In the view of global climate change and the predicted temperature rise for the Stuttgart region of 1,5 to 2 K in this century, the negative impacts of UHI on human health and urban living will become more problematic in the future. According to the results of climate models the frequency of very hot days is expected to jump by nearly 30% at

the end of the century. The rising temperatures due to the global climate change in combination with the temperature shift as a result of the UHI will intensify the heat stress in urban areas, that leads to a significant increasing risk to human health, in particular to the very young and elderly. Not least due its importance for the human health and the quality of urban life in Stuttgart, the UHI is focussed by urban planners and is noticed by the future development of the city.

Within the pilot action study in Stuttgart several measure for reducing the UHI and the impacts on urban living and human health are analysed by the use of micro-scale and macro-scale simulations. With the help of these analysis realisable measure are selected. The most useful measures are implemented into a development outline plan for the redevelopment of the city district Stuttgart-West by the municipal urban planners.

Content

5.5.1 The city of Stuttgart

In the following chapter a short overview of the urban and climatic conditions in Stuttgart is given. Especially the basics of the complex topographic situation and the city structure, that influence strongly the urban climate in Stuttgart is described. Also the urban heat island phenomenon in Stuttgart is presented. More information can be found at the website: http://www.stadtklima-stuttgart.de

5.5.1.1 Urban and climatic situation in Stuttgart

Stuttgart is the capital of the state of Baden-Wuerttemberg located in south-western Germany. As the sixth-largest city in Germany, Stuttgart has a population of about 590.000 and is the centre of a densely populated area, the Greater Stuttgart Region, with a population of 2.6 million. Stuttgart covers an area of 207 km^2 thereof 49 percent are settlements. The population density is about 5410 person/km^2.

Stuttgart's area is characterised by a complex topographic situation with local distinctions (Fig. 5.5.1). It is one of the greenest cities in Germany. The land use distribution of Stuttgart is shown in Fig. 5.5.2. Greenery in the form of vineyards, forests, parks, etc. is prevalent throughout the city. In Stuttgart 39 percent o fthe surface area has been listed as protected green belt land or nature conservation area; a record in the whole of Germany. Despite this greenery populated, industrial and commercial areas are densely built-up. The city's location, building and topographical characteristics have a negative impact on urban climate and cause an intense urban heat island (City of Stuttgart, 2010).

The city is located in a river valley (the Stuttgart basin), nestling between vineyards and thick woodland. Stuttgart's centre is situated close by, but not on the River Neckar in a Keuper sink. The city area is spread across a variety of hills and valleys. Steep hill slopes surround the city centre on three sides. The elevation ranges from 207 m above sea level by the Neckar River to 549 m on Bernhartshöhe hill. The complex terrain has a significant influence on all climatic elements like radiation,air temperature and wind, resulting in large climatic distinctions within the city area. Stuttgart’s overall climate is mild with an average annual temperature of about 10 °C in the Stuttgart basin (city centre) and about 8 °C in the more elevated outskirts situated about 400 m asl. Fig. 3 shows the annual mean temperature distrubition in the city area). Besides the Upper Rhine Valley, Greater Stuttgart is one of the warmest regions in Germany. The month of July is the hottest month with an average temperature of 18.8 °C, while temperature in January averages 1.3 °C.

A major element of Stuttgart's climate is the light wind, that causes a lack of adequate air exchange. The light wind results not only of the city's position between two bights of the Keuper plains. The whole Neckar Valley is known for low wind speeds and very frequent lulls. This is the result of small air pressure differences common to Southern Germany and of Stuttgart's sheltered position between the Black Forest, the Swabian Alb, the Schurwald and the Swabian-Franconian Forest. Due to orographic conditions, it is impossible to indicate a consistent wind rose for the whole of Stuttgart. The sheltered position between the surrounding mountain ranges leads to a frequent development of local wind systems, especially at the slopes and in the valleys. In addition, over large green areas in the surrounding and the city area especially at the higher altitudes, in the nighttime cold air is produced, that generates cold air streams. Even if these winds have no high wind speeds, they play a significant role for the ventilation and local fresh or cold air supply in some city districts. Preserving these local winds and streams is an important objective in the urban planning process in Stuttgart with focus on environmental and urban climate protection since decades. It becomes apparent that primarily cold air flows effectively reduce UHI caused thermal stress in nighttime.

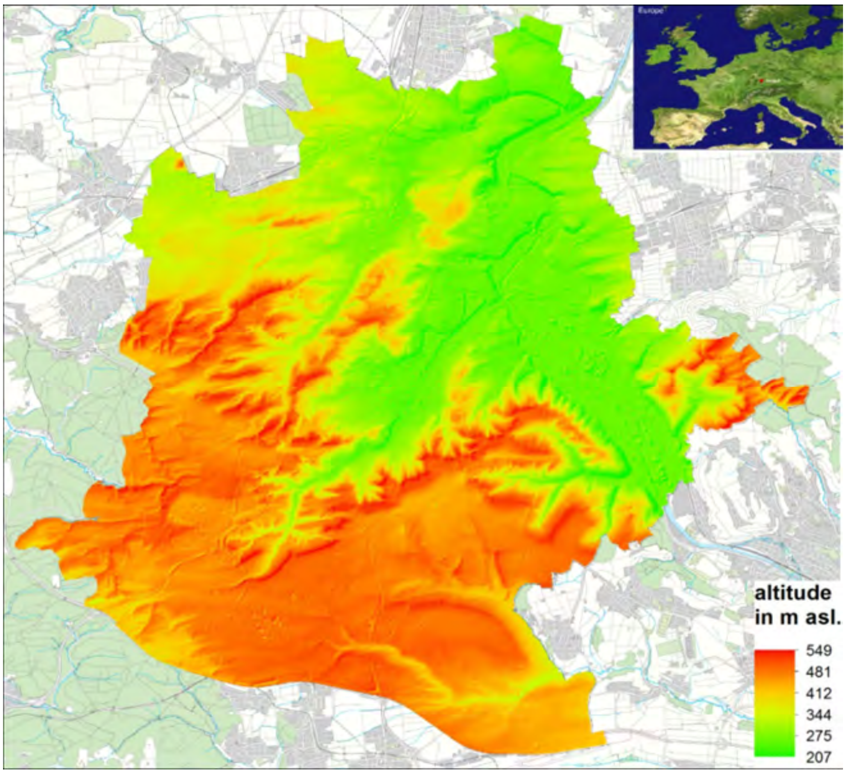

Fig. 5.5.1 Topographic map of Stuttgart's city area and Stuttgart's location within Europe.

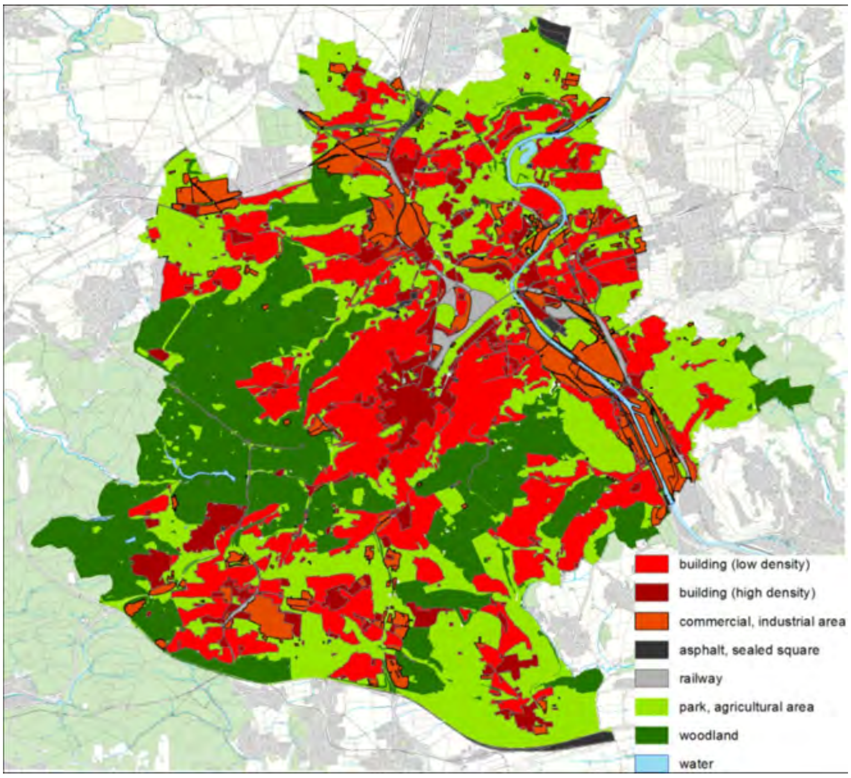

Fig. 5.5.2: Land use map of Stuttgart.

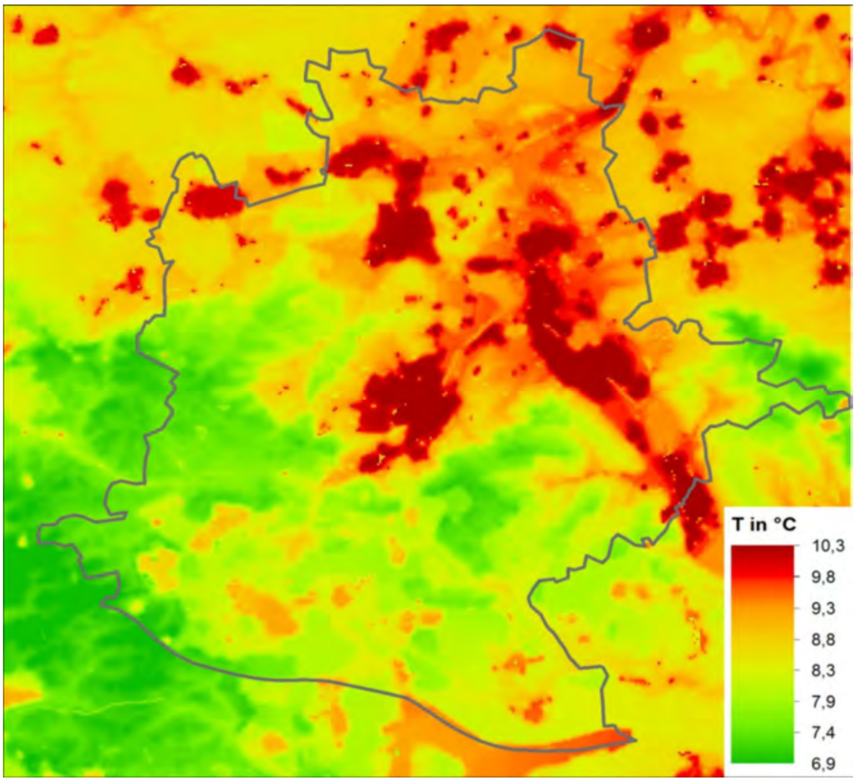

Fig. 5.5.3: Annual mean temperature in Stuttgart. The city area is marked with a grey line.

5.5.1.2 UHI in Stuttgart

The lack of adequate air exchange in combination with high building density and a huge amount of sealed surfaces, especially in most populated and industrial city districts, facilitate the development of an intensive UHI. Quantifying the intensity of UHI in Stuttgart is complicate, because of the differences in altitude, which influence the air temperature and overlay the temperture shift due to the UHI. However, the overall temperature raise due to the UHI phenomenon (UHI_{Ta}) in Stuttgart is identified within several studies by 1 to 2 K in annual mean, but locally the UHI_{Ta} intensity can reach more than 5 K. The UHI phenomenon modifies the climate in Stuttgart. For example in the surrounding of Stuttgart, the Filder region, there are 28 to 32 summer days (days with more than 25°C daily maximum temperature) as compared with 40 to 47 summer days in the Innercity region and the Stuttgart bight. The UHI turns Stuttgart's inner city into a region with high heat stress (about 32 days, Fig. 5.5.4) and only occasional cold stress.

For the longterm characterisation of UHI meteorological values such as temperature, solar radiation and humidity are measured continuously at about 10 sites in the city area, operated by German Weather Service (DWD), municipality Stuttgart (MS), University Hohenheim (UnH) and the environmental protection agency of Baden-Württemberg (LUBW). In this study the UHI is analysed using air temperature and also the thermal index Physiologically Equivalent Temperature PET (Mayer & Höppe 1987, Höppe 1993, 1999 Matzarakis et al. 1999) measured at the sites Schwabenzentrum (MS), Schnarrenberg (DWD), airport station Echterdingen (DWD) and at University Hohenheim (UnH) . Average annual UHI_{Ta} intensity (based on air temperature) at Schwabenzentrum is 2 K and at Schnarrenberg 1.6 K. In the Neckar valley, the mean UHI_{Ta} is 0.9 K. At the suburb Hohenheim, the UHI_{Ta} of 0.3 K is not pronounced as the suburb is surrounded by agricultural areas and has a higher elevation as the rural reference station Echterdingen. The urban-rural differences in PET are higher with 4.1 K (3.1 K) between Schnarrenberg (Schwabenzentrum) and Echterdingen.

During summer, the UHI_{PET} (UHI_{Ta}) is by 15.2 % (8.1 %) higher than 6 °C in the city center. However, a UHI between 0-6 °C is most frequent at the other measuring sites. The UHI effect is stronger and more frequent during summer than during winter, increasing the already existing heat load. The minimum UHI_{Ta} occurs in the late morning, whereupon the rural air temperature is often higher than the urban, especially during warm seasons. The UHI_{Ta} peaks at 6:00 pm in the winter and 9:00 pm during spring, summer and autumn at Schwabenzentrum. At Neckartal, the amplitude of the diurnal cycle is weaker and UHI_{Ta} is maximal in the early morning. The monthly maximum UHI_{Ta} occurs in winter in the city center due to anthropogenic heat production. However, considering hourly averages, the maximum UHI is experienced in summer. It can be observed that air temperature differences are largest at nighttime, but the PET differences are highest at daytime. The urban heat island intensity was compared to the air pressure as well as flow patterns. The UHI is more pronounced during periods with anticyclonic weather situation (Ketterer & Matzarakis 2014a).

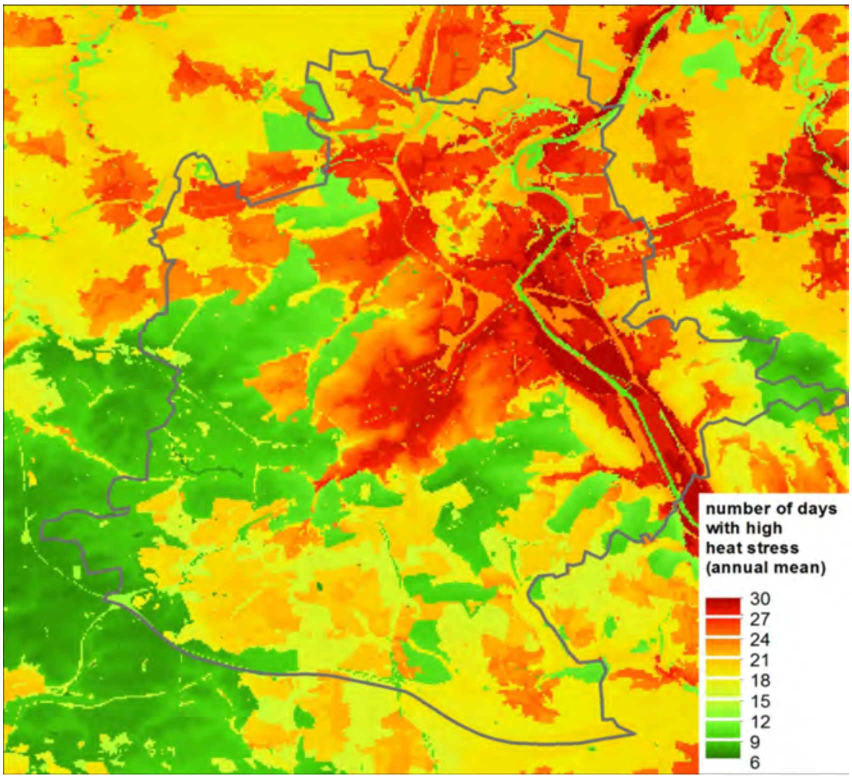

Fig. 5.5.4: Annual number of days with high heat stress in Stuttgart. The city area is marked with a grey line.

5.5.2 Pilot action study Stuttgart

In this chapter the pilot action study in Stuttgart is presented. For the pilot action area the city district Stuttgart-West is chosen. The area was selected in view of a problematic climatic situation with high thermal stress caused by the structure of building. An important point for the selection of the area is an initiative launched by the municipal urban planners for restructuring the district in the next decades. Expected changes in urban living, the predicted increase in urban population, within the district existing brownfields and also the poor climatic situation are facts for a necessary restructuring of the district. The objective of the pilot action study is to find out realisable options for improving the local climatic situation in the district mainly due to better the air ventilation and the reduction of thermal stress. The results of these study should be integrated into a development outline plan of the district, which is under development by the municipal urban planners. In Stuttgart development outline plans are an established pathbreaking helpful urban planning tool for the sustainable future development and restructuring of single city districts weighting residental, economical, public, natural, environmental and climatical aspects. Reducing the negative impacts of the UHI on urban living will be a topic of the development outline plan. For the implementation into the development outline plan, first the UHI intensity and hotspots of high thermal stress in the district have to be known. As a second the effectivity of measures must be analysed to set up the most valuable ones. Within the pilot action study, the UHI intensity and its impacts on urban living is analysed using meteorological measurements and micro- and macro-scale simulation tools. Micro-scale simulation tools are also used to verify the local effectivity of thermal stress reducing measures. To estimate the potential of measures for a city wide reduction of the UHI intensity, macro-scale simulation tools are used.

5.5.2.1 Pilot action area

The pilot action area Stuttgart-West (valley floor) is located in a small valley close to the city centre in the western inner-city region (Fig. 5.5.5). The area is surrounded by steep hills at three sites (South, West and North). Stuttgart-West is the most densely populated district in Stuttgart and has a population of about 33.000 and a population density of 18370 person/km^2. About 10 % of the inhabitants are younger than 15 years and about 15 % are older than 65 years, that means 25 % of the inhabitants are in early danger by thermal stress. The area is characterised by a high building density with predominant residental buildings. A high number of historical buildings, that have to be preserved, limit the redeployment of the district. Green areas and places for the recreation of the inhabitants are sparse available. The typical building structure in the district are blocks with additional buildings in the inner areas of the blocks (Fig. 5.5.6). These characteristics causes poor ventilation of the district and a high UHI intensity with increased thermal stress (Fig. 5.5.7). In addition the air pollution is on a high level. Due to these atmospheric conditions the pilot action area is less attractive for living with potential risks for human health.

The average UHI_{Ta} intensity is about 2 K, but can be many times higher on local hotspots depending on daytime and season. On hotspots an UHI_{Ta} intensity of more than 6 K is measured frequently. At the surrounding hill slopes local wind systems arise and at nighttime cold air flows are induced at the hill slopes. Because of the high building density in the valley floor, these local streams are blocked and mostly don't reach the inner district area. The pilot action area is the most thermally stressed area in Stuttgart. Based on case studies an optimized building structure for the pilot action area to reduce the thermal stress is developed.

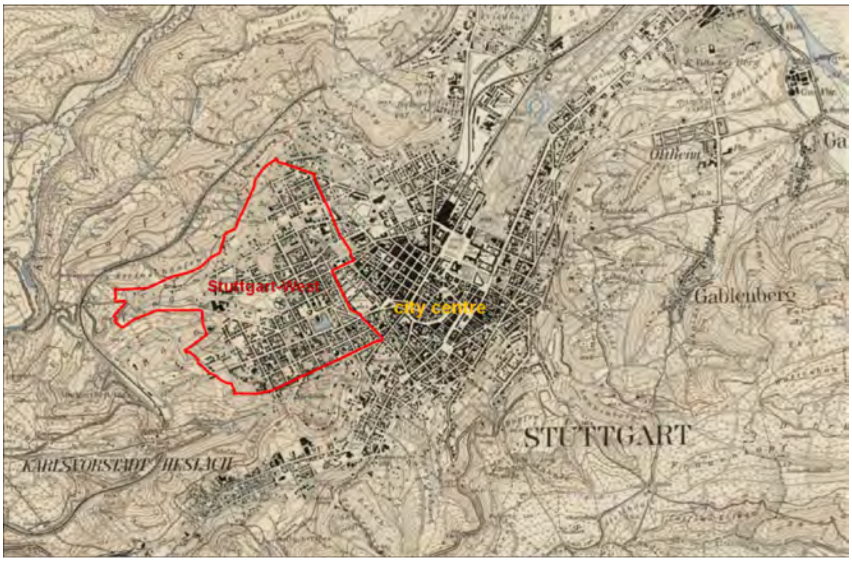

Fig. 5.5.5 City map of Stuttgart with the location of the pilot action area Stuttgart West (red marked arera).

Fig. 5.5.6 Airviews of Stuttgart-West, which illustrate the typical building structure.

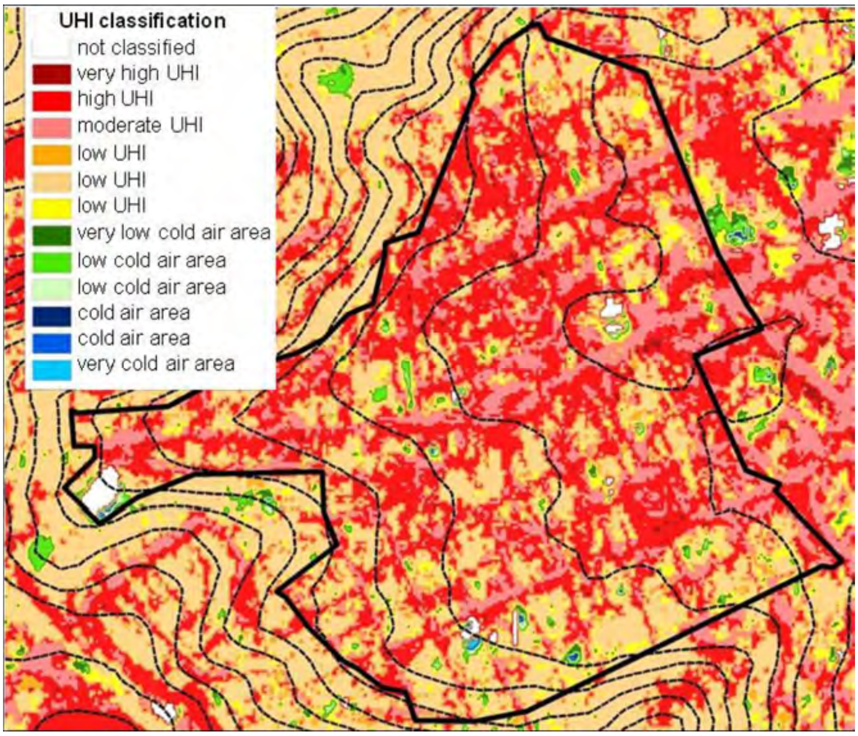

Fig. 5.5.7 UHI classification in Stuttgart-West (left) and number of days with high thermal stress in Stuttgart-West (annual mean, right).

5.5.2.2 Case study Olga Hospital (Stuttgart-West)

5.5.2.2.1 Quantification of mitigation and adaptation possibilities

For the case study the area of the Olga Hospital in Stuttgart-West is chosen. The Olga Hospital is a hospital, that is not longer in use and should be redisgned into a residental area in the next years. The human thermal comfort conditions of the case study area and different scenarios (Fig. 5.5.8, 5.5.9) were analyzed using micro-scale models RayMan (Matzarakis et al. 2007, 2010) and ENVI-met 3.5 (Bruse and Fleer 1998, Huttner 2012). The input parameters for the ENVI-met simulations are based on the measurements of the 24th July 2010 (wind speed 2.6 ms^{-1}, wind direction: 250 °, no clouds, shortwave radiation adjustment factor 0.83, relative humidity and potential temperature were forced). So, these case studies are representative for hot summer days with a high amount of solar radiation. The average mean radiant temperature in the whole area is 57 °C; ranging from 23.8 °C to 75.6 °C. The lowest mean radiant temperature was calculated in the shadow of trees in green areas. The mean radiant temperature is at least 3 K higher in the shadow of buildings and 45 K higher in sealed courtyards. The mean radiant temperature has the greatest influence on PET in the daytime on a sunny summer day. PET rises up to 58 °C above sealed surfaces with low albedo, high solar irradiation and low wind speed. In green areas, PET ranges between 18 and 28 °C in shaded, but does not exceed 35 °C in unshaded areas. Streets which are parallel to the wind direction (e. g. Bebel and Bismarck Street), featured lower PET (ΔPET ≤ 10 K) than other streets (Senefelder Street). The difference in PET between sealed and non-sealed areas is at least 10 K (Ketterer et al. 2013).

5.5.2.2.2 Micro-scale simulations

5.5.2.2.2.1 Surface types

Thermal conditions over green areas, paved and water surfaces are quantified using ENVI-met simulations. PET rises up to 58 °C above paved, unshaded surfaces with low albedo. Above green areas, PET does not exceed 35 °C in unshaded areas and 25 °C in shaded areas. The difference between paved and green areas is at least 10 K. Considering the assessment scale of Matzarakis and Mayer (1996), the thermal stress can be reduced from strong heat stress above paved surfaces to light heat stress above green surfaces (Fig. 5.5.9).

The installation of a small pond has no significant impact on the spatial average of the studied Olga Hospital area, but a local impact on the air temperature. Air temperature is decreased due to the smaller Bowen ratio and enhanced latent heat flux. Additionally, water has a very high specific heat capacity. However, small and shallow water surfaces heat up relatively fast, so that they can have a warming effect during evenings and nights in mid-summer as well as in early autumn.

ENVI-met simulations of the current scenario with the Olga Hospital and for a scenario with a park were done for a calm, hot summer day and compared for 14 LST. The specially averaged PET value decreases by 2.6 K in the park scenario. The wind speed increases due to lower roughness in the lee (east) side of the park and decreases PET, too. The PET value was decreased by maximum 7.0 K an on average by 1.7 K in the street east of the park. On the streets in the north and south of the park, PET is 0.4 and 0.8 K lower than in the current state. A park with a continuous green area is 1 to 20 K PET colder then green areas on the built-up area. The more trees in a park, the cooler PET on a hot summer day and the smaller the diurnal amplitude of the temperature. However, the air temperature differences between different scenarios are below 2 °C (Ketterer et al. 2013, Ketterer and Matzarakis 2014b).

5.5.2.2.2.2 Trees

PET in 1.5 m height was found to be around 10 K lower under trees compared to green areas and 25 K lower than over asphalt (Fig. 5.5.9). Therefore, shading by trees could reduce the frequency of daytime heat stress significantly (Fig. 5.5.10).

The increasing number of trees in the Olga Hospital area has no significant impact on the averaged air temperature during moderate warm conditions. However, during hot summer days it could reduce the air temperature in this area by 3.0 K (spatial average).

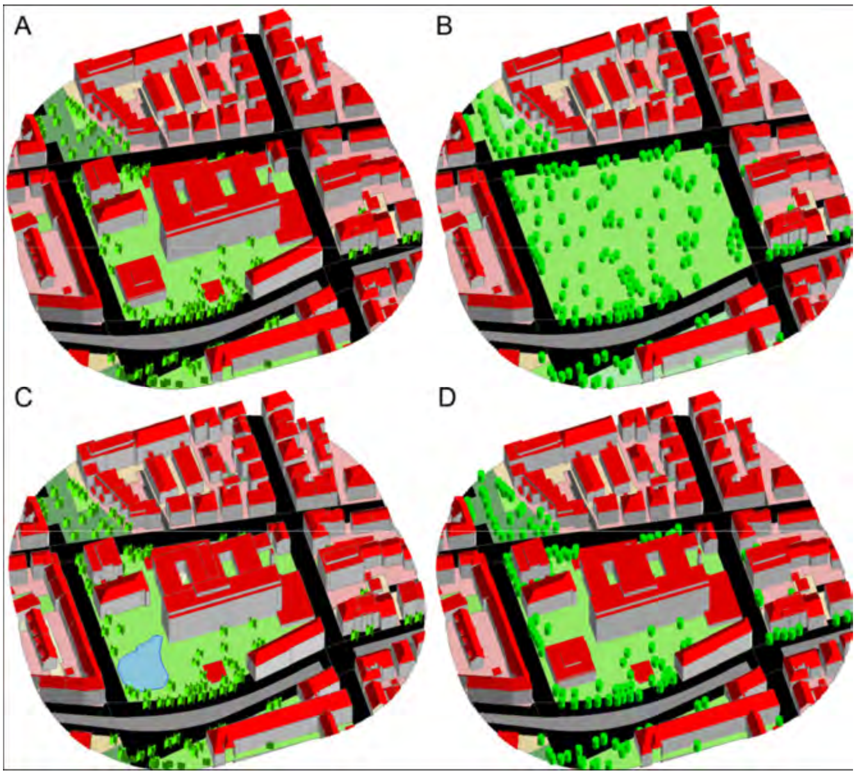

Fig. 5.5.8 Different scenarios for the Olga Hospital site as input for the micro-climate simulations. Panel A depicts the current state of the Olga Hospital (also with green roofs for every building with flat roofs), Panel B the park scenario, in Panel C one building is replaced by a small pond (shallow water) and in Panel C the number of trees along the streets was increased.

5.5.2.2.2.3 Green roofs

The effect of green roofs was quantified using ENVI-met and by changing all roofs of the hospital scenario into green roofs. The effect of green roofs on the local thermal conditions experienced by humans on street level are on a very low level (ΔPET < 0.06 K). The local air temperature differences on street level are even lower. However, green roofs significantly reduce the warming of urban roof surfaces in daytime. Inside green roofs the accumulation of heat is decreased, resulting in a lesser heat emission in nighttime. A large-scale revegetate of roofs is an effectively measure for the mitigation of UHI intensity especially in nightime.

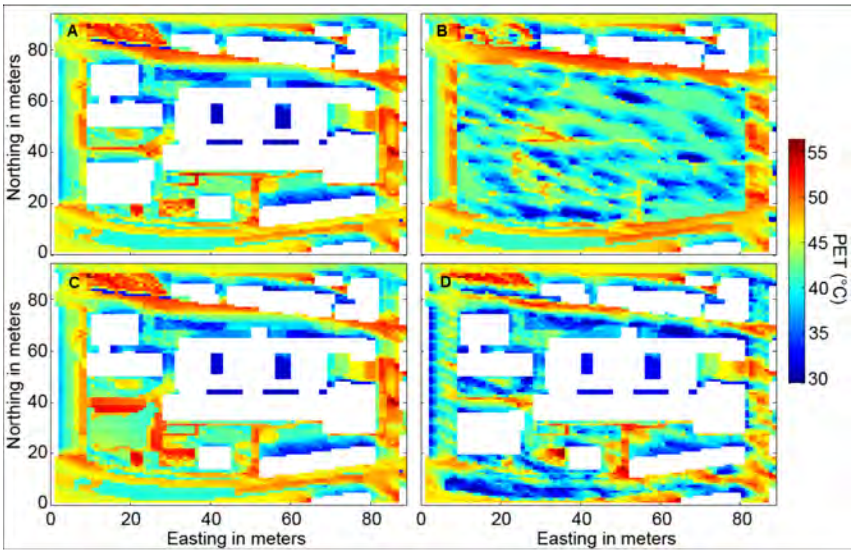

Fig. 5.5.9: Physiologically Equivalent Temperature (PET) of different scenarios (see Fig. 5.5.8) of the Olga Hospital area. The basic meteorological variables were simulated by ENVI-met 3.5 and PET was calculated by TIC-ENVI-met (Ketterer and Matzarakis 2014b). Finally, the data were averaged from 10 am to 4 pm for the height of 1.5 m above ground.

5.5.2.2.2.4 Urban morphology

The urban morphology is analyzed using RayMan Pro (Matzarakis et al. 2007, 2010). The morphology of street canyons influences solar access and radiation and therefore thermal comfort. The importance of solar access for city dwellers depends on the climate zone. While south of the Alps sun is considered as harmful, solar access is favored in northern cities such as Stuttgart. East-west oriented street canyons do not have solar access during winter months due to the low zenith angle of the sun. But during summer, the street canyon and especially the northern façade is illuminated during the whole day. Accordingly high is the frequency of heat stress in this E-W oriented street canyon. A N-S oriented street canyon is accessed by sunshine during the midday hours throughout the year (Ketterer & Matzarakis 2014b).

The daily maximum value of PET could be reduced by 10 K due to a changing H/W ratio from 0.5 to 3.5 and an orientation of 120 ° on a hot summer day. Throughout the year, the frequency of heat stress can be reduced by 477 h (4.3 %). Additionally, the occurrence of thermal comfort conditions could be increased by

10 %. However, a change in H/W ratio from 0.5 to 1 (2.5) could already reduce the frequency of heat stress by 192 (333) hours per year (Fig. 5.5.10).

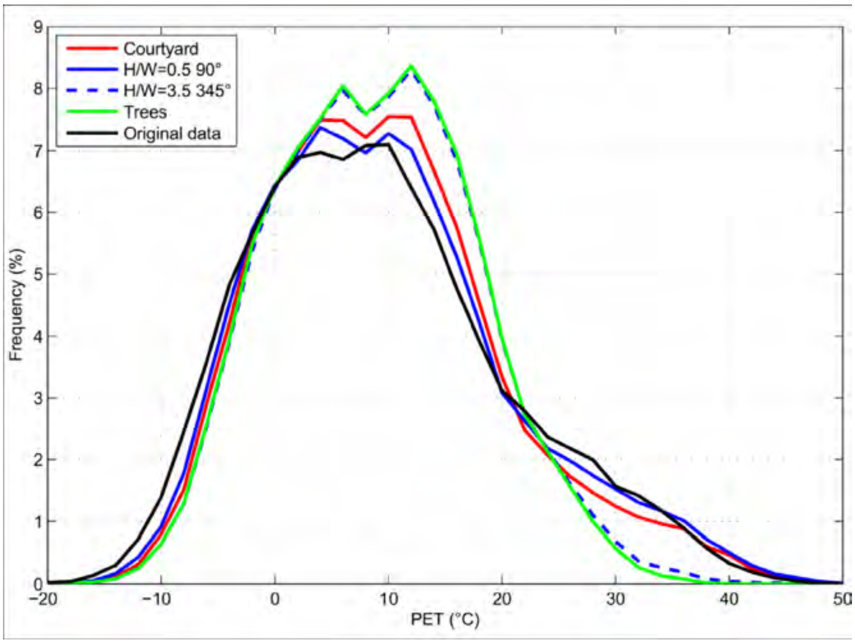

Fig. 5.5.10: Frequency distribution of the Physiologically Equivalent Temperature (PET) for following different urban morphology: courtyards, street canyon with aspect (H/W) ratio of 0.5 and 3.5 and rotation of 90° (E-W) and 345 ° (NNE-SSW), under a group of trees and the original data of the measuring station Schwabenzentrum (city center) for the period 2000- 2010.

5.5.2.2.2.5 Courtyards

The micro-climate of courtyards was studied using the micro-climatic models RayMan and ENVI-met. The human thermal comfort conditions in two courtyards (Schlossstrasse and Senefelderstrasse) in the Olga Hospital area were compared to the conditions in street canyons (Breitscheidstrasse, Senefelderstrasse) and on a green area (Elisabethenstrasse – Hasenberstraße) over 11 years. Therefore, the micro-scale RayMan model employing fish-eye photos was used to describe long term conditions. In the courtyards, the frequency of heat stress (PET > 29.1 °C) and thermal comfort is between 45.5 % and 51.6 % from May to September. Whereas the frequency of thermal comfort is between 3.6 % and 13.8 % higher in east-west and NNW - SSE oriented street canyons. Additionally, PET is also higher at nighttime than during daytime due to the smaller sky view factor in courtyards. Multiple reflections can also increase PET in courtyards. Another factor is the low wind speed in these sheltered locations, triggering a further increase in PET. ENVI-met simulations for a hot summer day show that PET is up to 25 K higher over a paved courtyard compared to a park area covered with plants and grass.

5.5.2.3 Macro-scale simulations

Specific urban planning strategies, like green roofs or facades and highly reflective materials are able to reduce the UHI. Taha (1997) demonstrated that increasing the albedo by 0.15 can reduce peak summertime temperatures for the urban area of Los Angeles by up to 1.5 °C. During the DESIREX Campaign 2008, Salamanca et al. (2012) stated that a higher albedo leads to about 5% reduction in energy consumption through air conditioning during summertime periods for the area of Madrid. The regional energy saving effect of high-albedo roofs can also be found in Akbari et al. (1997) and on a more global perspective in Akbari et al. (2009).

In the course of the project UHI - Development and application of mitigation and adaptation strategies and measures for counteracting the global UHI phenomenon" (3CE292P3) – CENTRAL Europe. (2011-2014), these kinds of scenarios are conducted for the urban area of Stuttgart. Due to its geographical location in a valley, the weak mountain – valley circulation leads to increasing potential for natural heat trapping in the urban region. Modelling work of the environmental agency of Stuttgart shows, that the area with more than 30 days/year heat stress is anticipated to increase from 6% (1971-2000) up to 57% (2071-2100). This reflects the calculations of the Intergovernmental Panel on Climate Change (IPCC) on global climate change.

The Karlsruhe Institute of Technology (KIT) conducts simulations using the numerical mesoscale Weather Research and Forecasting Model WRF Skamarock et al. (2005) on regional scale, coupled to urban parameterization schemes (Kusaka et al. 2001, Martilli et al. 2002). The results reflect the effects of certain urban planning strategies on near surface air temperature and on UHI intensity.

Four case studies were applied representing different mitigation measures.

1. Increase of the reflectivity of roof and wall surfaces in the urban area ('Albedo')

2. Decreasing the building density by 20% by increasing the Sky View Factor ('Density')
3. Replacing urban surface by natural vegetation in the city center ('Central Park')
4. Replacement of single urban areas scattered around the city area ('Many Parks')

The difference in 2m temperature between scenario- and base case ('reality') run reflects the efficiency of the mitigation procedure (Fig. 5.5.11). To refer to an extreme case scenario, a period during the European Heat Wave 2003 (August 11th-18th 2003) was chosen, where summertime temperatures exceeded the annual average.

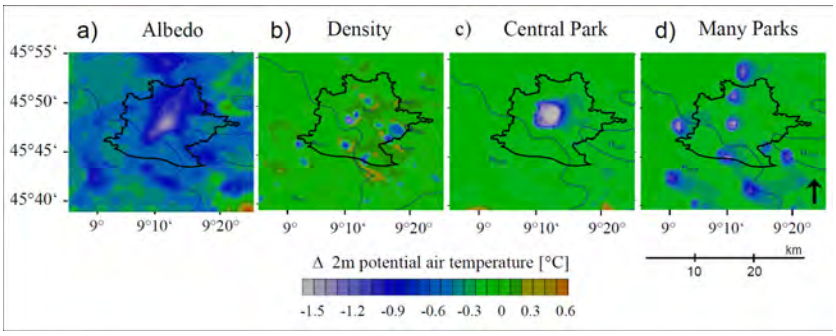

Fig. 5.5.11 Difference in potential 2m air temperature for the four scenarios: a) changed albedo for roofs and walls , b) modified proportion street width/building height and the two urban greening scenarios with one big park (c) and a number of smaller parks (d); projected time is August 13 2003 8:00 pm.

Tab. 5.5.1 presents the mean and maximum urban temperature as well as the UHI, calculated from mean urban and mean rural temperature with regard to Aug 13 2003 8:00 pm. The difference between Control run and Scenario is calculated for both temperature and UHI.

Scenario	Control	Albedo	Many Parks	Big Park	Density	delta [°C] Albedo	delta [°C] Many Parks	delta [°C] Big Park	delta [°C] Density
T mean urban [°C]	33.1	31.5	32.5	32.3	32.4	-1.60	-0.60	-0.80	-0.70
T max [°C]	34.3	31.9	33.5	33.3	33	-2.40	-0.80	-1.00	-1.30
UHI; delta Θ	**2.52**	**0.84**	**1.47**	**1.19**	**1.32**	**-1.68**	**-1.05**	**-1.33**	**-1.2**

Tab. 5.5.1: Impact on UHI formation expressed as the difference between mean urban and mean rural temperature, August 13 2003 8 pm. The control run indicates 'real' conditions.

Referring to Tab. 5.5.1, a changing of the albedo of wall and roof surfaces has the strongest effect on temperature, causing a decrease of the UHI intensity by nearly 2 °C.

Both vegetation scenarios show a decrease of about 1-1.3 °C. With 1.2 temperature reduction, the effect is similar for the 'Density' case.

Because of insufficient observation data in the rural surrounding, it is difficult to retrieve the UHI intensity from measurements. The difference between air temperatures observed at 'Stuttgart Schwabenzentrum' (37.4 °C) and at Stuttgart Hohenheim in the near surrounding (33.1 °C) accounts for 4.3 °C, for August 13 18:00 UTC. Assuming a height dependent temperature decrease of 1°C per 100 m between urban (250m NN) and rural (400m NN) location, the adapted observed UHI amounts to 3 °C. The second parameter in Tab. 1 describes the mean temperature for the whole modelling period for one single urban grid cell in the centre of the city, whereas all other parameters treat aerial statistics for one temporal snapshot.

The above findings describe the climatological and meteorological background for the forthcoming mitigation and adaptation actions to reduce the urban heat islands and its impacts. Besides the modeling results it is now of great importance to find the best urban planning strategy for the specific urban area of interest, considering a mixture of different mitigation strategies. However, due to the coarse resolution it is difficult to directly apply the measures proposed by that study. Rather, these kinds of modelling studies can be used as a decision support and provide meteorological boundary conditions for high resolution street scale models.

5.5.3 Transfering the findings of the pilot action study to urban planning process in Stuttgart

The findings of the studies within the pilot action Stuttgart, have shown, that several measure can be effectively reduce the UHI intensity and the impacts on urban living and human health. However, reducing UHI intensity in a city, which is growing over the centuries, requires deep changes in the city and building structure. Changing a city to improve the urban climate is a hard and challenging transaction, which needs a sustaniable future-oriented urban planning. Most of the measures for reducing UHI in a city are only effective by large-scale implementation, but changing a city due to urban planning are mostly concentrated on single buildings or small areas like existing brownfields. Additional difficulties are a low awareness for the problems caused by UHI by the public and political boards, existing national and internation strategies for the future development of urban areas, which potential forces the UHI intensity (for example the European sustainable development strategy, which supports the development of more compact and more densed cities), a low number of free available areas to set up measures like parks, contrary intrests of public, industry and economy and the ownership structure. Also, in Germany a legal basis for the consideration of UHI related aspects in the urban planning process is currently not available.

5.5.3.1 Legal basis for the consideration of UHI related aspects within the urban planning

To date in Germany no independent "Urban Climate Protection Act" exists in its own right. Also planning measures for Urban Heat Island specific requirements are not directly regulated. Instead, these concerns have been integrated into the structure of existing environmental legislation. This is due to the circumstance that many of the classical disciplines of environmental protection or rather ecology simultaneously exercises positive repercussions for climate change and that a firm foothold can be provided for climate protection within the framework of existing legislation. Examples of this include the Federal Building Code (BauGB), the Federal Nature Conservation Act (BNatSchG) and a variety of regulations issued by the Federal Immission Control Act (BImSchG).Also rulings given by a series of laws and regulations such as the Energy Saving Act (EEG) and the Energy Saving Ordinance make a specific contribution to global climate protection, as well as the "Greenhouse Gas Emissions Trading Act" (TEHG).

The German Building Code is the most powerful act in Germany for the municipal administration to arrange measures for urban planning in respect to environmental, nature, urban and global climate protection. The code offers differentiated possibilities for urban development that is urban and global climatically just.

5.5.3.2 Development outline plan

The development outline plan (DOP) constitutes a non-formalized level of spatial planning. It is not codified by the Federal Building Code and non-obligatory. In practice, however, the DOP proved to be a valuable and flexible tool to steer urban development within built up areas. It is an essential function of the DOP to define the municipality's development and planning goals for those parts of the city that show tendencies of urban change. In practice, the planning intentions for public spaces and streets can be described more precisely than those for private building sites. This is why the DOP often also functions similarly to a local design plan. The DOP is not subject to legal regulations.

In Stuttgart development outline plans are used to set up the urban planning strategy for the sustainable future development and restructuring of single city districts weighting all aspects of urban living, economy and nature, environment and climate protection.

For the pilot action area Stuttgart-West a development outline plan is under progress by the municipal urban planning department. Within the development outline plan Stuttgart-West the strategy for the future development of the city district is ascertained. One aspect of this strategy is to improve the climatic situation and to reduce the negative impacts of the UHI inside the district. Based on the analysis simulation results, done within the pilot action study, hotspots of high thermal stressed areas in the district are indentified. Also effective and realisable measure for reducing the thermal stress on the hotspots are choosen for the implementation into the development strategy and the development outline plan for the district.

Hotspots, which are high thermal stressed are located mostly in the inner region of the district (Fig. 5.5.12). These areas are characterised by a high building density with additional buildings inside the blocks, a high degree of sealing and a lack of greening. The high building density prevents a ventilation of the block inner area, which forces the accumulation of heat. For these blocks an optimised building structure (Fig. 5.5.13) for the potential reconstruction is developed based on the micro-scale simulation done in the pilot action study (Olga Hospital, see chapter 2.2). These optimised building structure supports a better ventilation of the block and the thermal stress is reduced compared to the existing building structure due the greening of the block in form of greened courtyards, green roofs and green facades or the use of cool materials for roofs and facades. However, the optimised building structure is not obligatory for the redevelopment of a block, but gives a reference to improve the climatic situation. If the suggested building structure is absolutly the optimum has to be checked from case to case under consideration of the ambient conditions. But setting up green roofs on new buildings can only be prevented for a comprehensible reason. Green roofs on new buildings are a standard in Stuttgart.

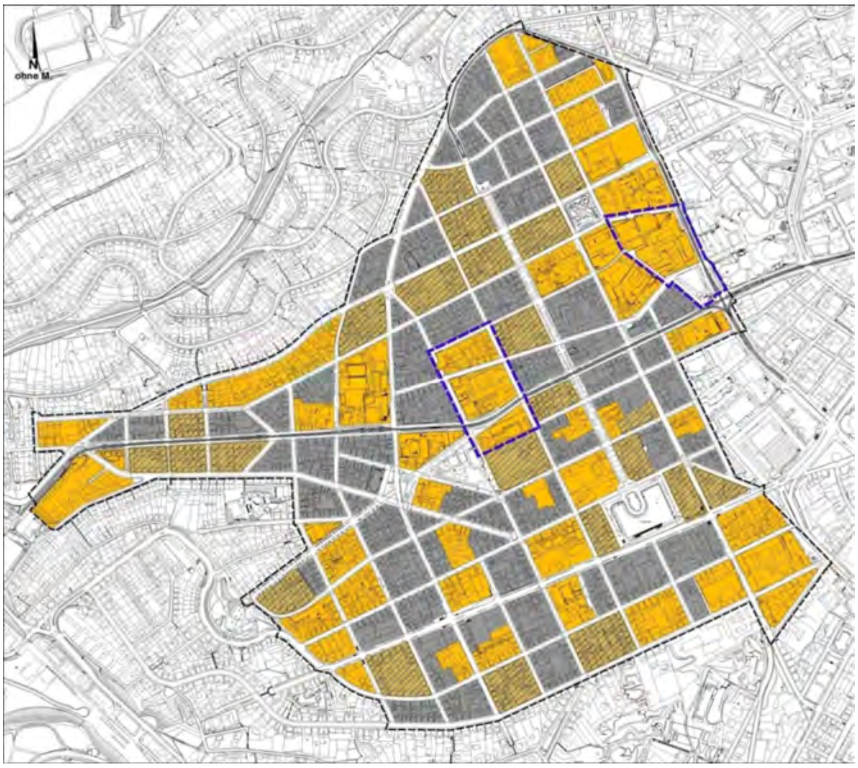

Fig. 5.5.12 Map based on the analysis of areas with high thermal stress. The grey shaded blocks are characterised by high thermal stress mainly due to a prevented ventilation of the inner area and due to high building density and unavailable greening. The grey blocks should be redesigned according the development outline plan. The purple surrounded blocks are currently under reconstruction.

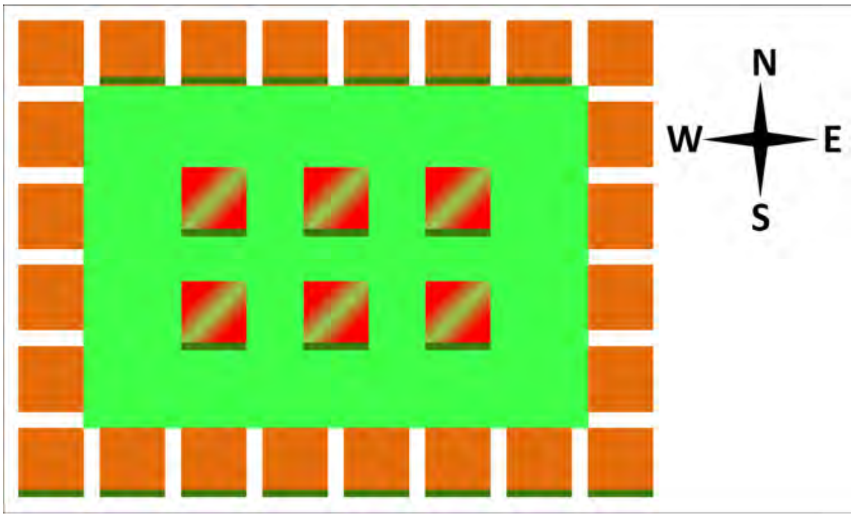

Fig. 5.5.13 Optimised building structure, which is offered to reduce the thermal stress inside the block. These building structure is part of the development outline plan is not obligatory for potential reconstruction of existing blocks, but gives a reference to improve the local climatic situation. Gaps between the buildings facilitate the ventilation of the inner area. The courtyard of the block (green marked area) is greened. Buildings inside the blocks (red-green marked) must be equipped with green roofs and the height of these buildings is limited. Buildings around the block (orange marked) should be equipped with green roofs, but it is not compulsory. Facades which are orientated to the south (dark green marked) have to be greened or designed with cool materials.

Beside the optimised building structure also suggestions for the design of public spaces are offered (Fig. 5.5.14, 5.5.15). The design of public spaces to reduce the thermal stress is relatively easy realisable, there no ownership structure must be respected. The measures offered for the design of public spaces mainly strive the improvement of the sojourn quality, due the reduction of thermal stress in street canyons, squares and parks. To reduce the thermal stress in street canyons, especially possible tree postions inside street canyons, which are orientated from east to west are identified and implemented into the development outline plan. Also for building facades along east to west orientated street canyons a design with cool materials and/or a facade greening is offered. The greening of existing brownfields mainly due to parks are also part of the development strategy of the district. The creation of connections between existing green areas (Fig. 5.5.14) are an utmost concern, which is considered within the strategy for the improvment of the climatic situation inside the district.

Fig. 5.5.14 Optimised design of street canyons in Stuttgart-West. Green lines marking street canyons, where the thermal stress is reduced due to facade greening of the use of cool materials for facades. Green circles marking possible positions for trees.

Fig. 5.5.15 Possible creation of green connections (green lines) in Stuttgart-West.

Also the ventilation of the district due to local wind systems and cold air streams is analysed (Fig. 5.5.16). To improve the ventilation of the district, reducing the obstruction of existing streams, due to the enlargement of the major stream axes (mostly street canyons) is implemented into to development outline plan for Stuttgart-West. For the enlargement of the stream axes in the concerned areas, a maximum building hight, an optimal building axes orientation and the reinstatement of buildings are offered.

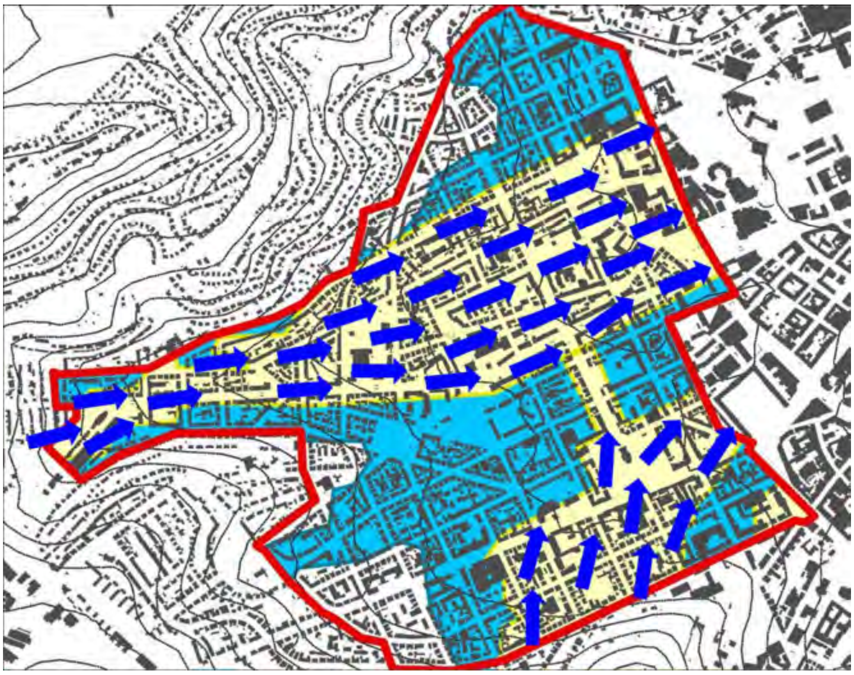

Fig. 5.5.16 Major cold air streams in Stuttgart-West. The yellow shaded areas mark areas with restriction to buildings to reduce the obstruction of existing streams.

5.5.4 Stuttgart's heat warning system HITWIS

The increase in the number of days exposed to high temperatures and high humidity will result in heat stress for the population. This can pose a danger, particularly for the elderly and those in poor health. In the summer of 2003, the extreme conditions accounted for an estimated 2000 additional deaths. So it is necessary to inform and to warn respectively. Additionally a customized behaviour must be advised different target groups.

To improve the more or less existing heat warning system in Stuttgart HITWIS was constituted a working group „Heat waves/heat stress“ including some parts of the municipality (health care, urban climate, social welfare office etc.). This working group is well connected to external institutions like ambulance services, housing societies, social services etc..

The following measures are recommended and have been partly realised:

- Supply of a leaflet including recommendations for a more adapted behaviour in a heat case.
- Development of a special heat app(lication) (f.e. inclusive a drink reminder) for mobile devices running on different platforms.
- Distribution of the web-based heatwarning of the german weather service for Stuttgart.
- Publication of special thematic website within the Internet presence of the Municipality of Stuttgart.
- Organisation and operation of a heat phone to warn and inform elder and lone people.
- Composing of a heat city map including „Cooling Zones“, water posts etc..
- Public relations in different media (sensibilisation, reminding), high visibility events with small gifts, promotional articles f.e. folding fans
- Instructions for different target groups f.e. families, sportsmanlike people etc.
- using of electronic advertising panels displaying prepared warnings and hints before and during heat waves.

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5.6 Urban Heat Island and bioclimatic comfort in Warsaw

Krzysztof Błażejczyk[1], Magdalena Kuchcik[1], Wojciech Dudek[2], Beata Kręcisz[2], Anna Błażejczyk[3], Paweł Milewski[1], Jakub Szmyd[1] and Cezary Pałczyński[2]

[1] Institute of Geography and Spatial Organization, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland,
[2] Nofer Institute of Occupational Medicine, św. Teresy od Dzieciątka Jezus 8, 91-348 Łódź, Poland,
[3] Bioklimatologia. Laboratory of Bioclimatology and Environmental Ergonomics, Łukowska 17/55, 04-133 Warszawa, Poland

5.6.1 Introduction - UHI as an effect of spatial organization of the city

Warsaw is the largest city in Poland. Its area of almost 515 km^2 has significant differentiation of land use. Currently about 248 km^2 is built-up area (48%). Within this the greatest part (about 57 km^2) is covered by industry, trade units and transport systems. Forests make up about 15% of the city. Urban parks and other recreational green areas cover 10%. 12% of the city territory is used as arable land, for crops and pasture. The category "heterogeneous agricultural areas" includes sparsely built areas and allotment gardens – 11.3% (Tab. 5.6.1). With 1.7 million residents and over 3.2 million residents of the greater agglomeration area, it has become the 10th most populous city in the European Union (Eurostat, 2013). After the Second World War, the area of Warsaw increased gradually; small villages and rural areas as well as natural forests were included into the city.

During the last 20 years, many fields, pastures and meadows were adapted for residential districts.

Land use	Area [km^2]	Area [%]
Urban fabric	**191.0**	**37.1**
Industrial. commercial and transport units	**56.9**	**11.1**
Construction sites	**3.3**	**0.6**
Artificial. non-agricultural vegetated areas	**53.4**	**10.4**
Arable land	**40.0**	**7.8**
Permanent crops	**0.5**	**0.1**
Pastures	**21.2**	**4.1**
Heterogeneous agricultural areas	**58.3**	**11.3**
Forests	**77.8**	**15.1**
Scrub and/or herbaceous vegetation	**0.6**	**0.1**
Open spaces with little or no vegetation	**1.6**	**0.3**
Inland wetlands	**0.2**	**0.0**
Inland waters	**9.9**	**1.9**
Total	**514.6**	**100.0**

Tab. 5.6.1 The land use types in Warsaw, according to Corine Land Cover 2006 (EEA 2007)

The recent tendency in city development is to build dense settled residential districts (both, small single family buildings and 4-6 floor blocks) as well as to insert new buildings into free spaces in the city centre (which was dramatically destroyed during the II World War). At the administration level of Warsaw there is not one single vision for city development. For the whole city there is only a general overview of investment intentions (Studium… 2010).

The shape of UHI in Warsaw resembles a diamond and reflects the distribution of the densest built area. The mean yearly intensity of the UHI-index (difference of the minimum daily temperature for the considered site to the value of the minimum daily temperature for Warszawa-Okęcie station) reaches over 2°C in the city centre. On the outskirts and in the forest area in south-east Warsaw, the UHI-index is from 0.5 to 1.0°C lower than at the airport station. During spring and summer, the intensity of UHI is comparable to the average. The most intensive UHI is to be observed in autumn. The very centre of the city is warmer in the night by 2.5°C comparing to Okęcie station. The lowest UHI-index occurs in winter – only 1.5°C, but then the spatial extent of UHI is greater than in other seasons. This situation is associated with the usage of house heating stoves in places not connected to central heating plants (Fig. 5.6.1).

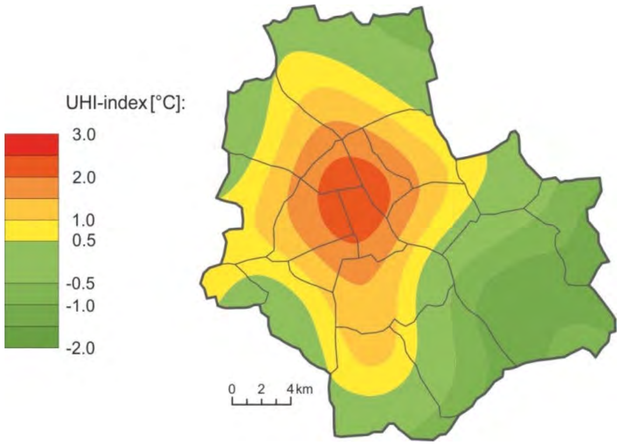

Fig. 5.6.1 Spatial distribution of UHI-index in Warsaw, mean values for the years 2011-2012

Thus, the general idea of pilot studies in Warsaw was: 1) to verify how the varying structures of space organization and land cover of selected residential districts influence UHI intensity and perceptible thermal conditions, and 2) how architectural solutions (e.g. planting additional lawns and trees, organizing green roofs) can minimise UHI and affect perceptible thermal conditions.

An additional aspect of the pilot studies was to assess the allergenic potential of plant cover (trees and bushes) growing inside the studied residential districts. It allows the validation of the health impact of vegetation and consequently, to give recommendations regarding plant composition which would be more friendly for the local population.

5.6.2 Pilot areas methodology

5.6.2.1 Presentation of pilot areas

The pilot studies were designed on the basis of a network of microclimatic measurements in Warsaw and its surroundings, working since 2006 as part of climate research carried out in IGSO PAS (Kuchcik et al. 2008, Błażejczyk, Kuchcik et al. 2013).

To cope with the aims of research, three small areas in Warsaw were chosen: Twarda (in the centre of the city) as well as Koło and Włodarzewska housing estates (in the western part of the city). As a reference site, representing outside rural conditions, the station situated in the Botanical Garden in Powsin was chosen (Fig. 5.6.2). For each area a detailed inventory of the greenery, type of surfaces, heights of buildings and horizon limitations was made.

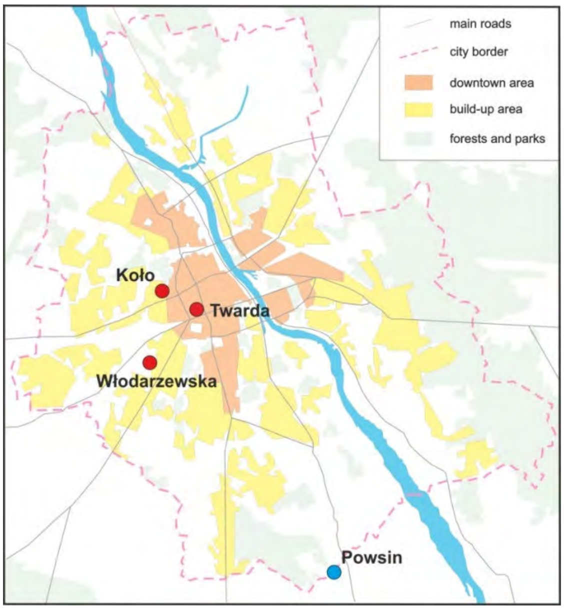

Fig. 5.6.2 Location of the pilot study areas (Twarda, Koło, Włodarzewska) and peripheral reference station (Powsin)

The Koło estate was established about 50 years ago (in the 1960s). The 4-5 floor buildings are built in low density and the majority are built from clay bricks. Few parking places are located inside the estate. Wide spaces between buildings are covered by lawns and tall, mature, deciduous trees. The RBVA (Ratio of Biologically Vital Areas), i.e. the ratio of areas covered by vegetation or open water (not sealed areas) in the plot size (according to Szulczewska et al. 2014) is 54.3% and FAR (Floor Area Ratio)[1] is 0.8 (Fig. 5.6.3a).

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[1] Floor Area Ratio, is calculated as the area of all building contours (Barea) multiplied by the number of floors (fn) and divided by the total area of the plot (Tarea), FAR = Barea·fn/Tarea

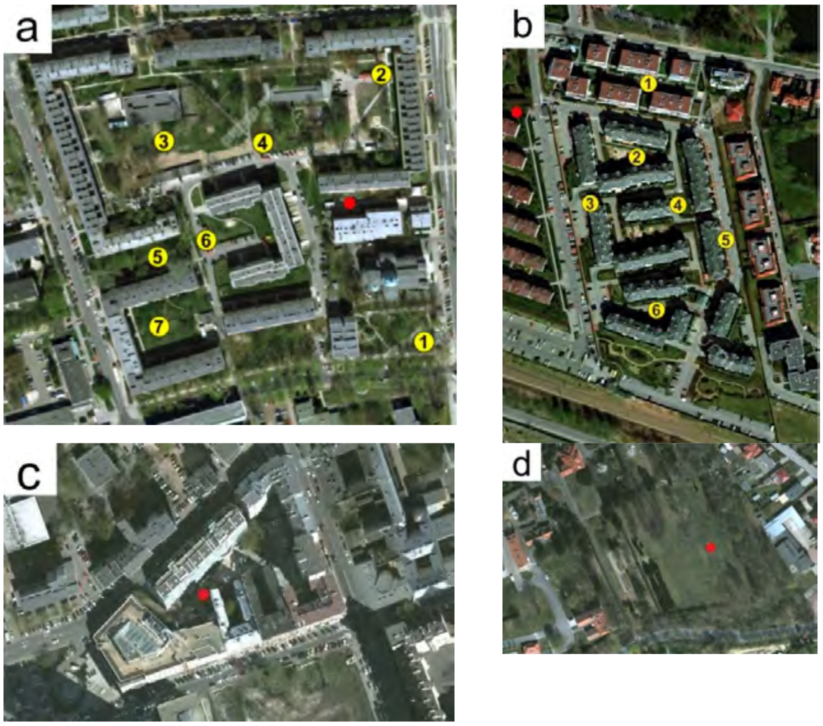

Fig. 5.6.3 Aerial view of pilot areas: Koło housing estate (A), Włodarzewska housing estate (B), Twarda district (C) and Powsin reference station (D); yellow points indicate sites of microclimatic measurements, the red points indicate sites of permanent microclimatic measurements

The Włodarzewska estate was built about 15 years ago (1995-2000) and is surrounded by many open spaces and a park, but arranged in a way which effectively precludes the entrance of air from the outside. It is characterized by compact development. The 4-5 floor blocks are very densely built up. They are constructed mostly from concrete and include underground car parks. Parking places are also organized along communication roads inside the estate. Many small flowerbeds and lawns with coniferous shrubs grow between the buildings. Only a few young deciduous trees grow there. RBVA is 40.7% and FAR is 1.25 (Fig. 5.6.3b).

The Twarda district is located in the city centre. It consists of a mixture of 80-year old buildings (from clay bricks), which were not destroyed during II World War as well as of newly constructed compartments (from concrete). 6-7 floor buildings predominate. Vegetation cover is very poor and only few trees and lawns can be found at the bottom of deep courtyards. Almost all the space between buildings is used as parking places. The area is surrounded by streets without any vegetation. The RBVA for this area is only 4% and the FAR index is 2.74 (Fig. 5.6.3c).

The characteristics of UHI and perceptible thermal conditions in each of the selected studied areas were compared with air temperature (Ta) and Universal Thermal Climate Index (UTCI) values observed at the peripheral reference station in Powsin. The station is situated in the Botanical Garden and represents open area conditions with ground covered by grass. Horizon shading is about 10% and the station is exposed to sunbeams almost the whole day (Fig. 5.6.3d).

5.6.3 Methods

The pilot studies in Warsaw have been composed of two steps. In the first step, experimental microclimatic measurements were made in two housing estates, Koło and Włodarzewska. They are located a similar distance from the city centre and from the city limits. However, they differ in type, density and age of buildings as well as in composition of green areas and the percentage of biologically vital area. The aim of the microclimatic measurements was to assess influence of local space organization on differences of UHI and perceptible thermal conditions. The results of the measurements were compared both with the Powsin reference station and with the city centre represented by Twarda district.

During the microclimatic research on 21 and 22 May 2013, the air temperature and humidity, wind speed and global solar radiation were measured in two periods of the day: early morning (5-7 a.m.) and at midday (12 p.m.-2 p.m.). The posts were situated in various micro structures of the housing estates (Fig. 3a-b). The perceptible thermal conditions were assessed with the use of the Universal Thermal Climate Index UTCI (Błażejczyk 2011, Bröde et al. 2012, Błażejczyk and Jendritzky et al. 2013). The index assesses heat stress in man caused by a complex outdoor environment (air temperature and humidity, solar radiation and wind speed). The spatial variability (in early morning and midday hours) of air temperature and UTCI and differences between microclimatic posts and the reference peripheral station were analysed.

As a result of the greenery inventory, all plant species have been divided into four classes according their allergenic potential. The classification was evaluated according to the Polish Society of Allergology guidelines for diagnosis and management of allergic diseases supported additionally by local allergists' experience.

Class 3 – great allergenicity, frequently sensitizing species (Alder, Birch, Hazel)

Class 2 – moderate allergenicity, rare sensitizing species (Poplar, Elm, Willow, Beech, Oak, Plane, Ash, Linden)

Class 1 – slight allergenicity, very rare sensitizing species or isolated case reports only (Acacia, Hornbeam, Maple, Elder, Spruce, Pine, Jasmine, Ambrosia, Olive)

Class 0 – no allergenicity, species with no or unknown allergenic potential (female cultivars of dioeciously plants from higher classes were also included in this class due to no pollen production).

If a plant species was not mentioned in any guidelines or local allergists' statement, the EBSCO scientific journal database was used to determine the potential allergenicity of the plant. If, during the last 15 years, there had been three or more cases or scientific reports published on the possibility of respiratory tract allergy induction, the plant was classified as Class 1; otherwise it was classified as Class 0.

Microclimatic measurements became the basis for the second, simulation step of the pilot studies. In this step a few scenarios of possible changes in land cover in Włodarzewska and Twarda, which could reduce UHI, were considered. The simulations of air temperature for 4 days a year representing spring, summer, autumn and winter were made with the use of ENVI-Met software in the Vienna University of Technology, Department of Building Physics and Building Ecology, Institute of Architectural Sciences.

5.6.4 The role of urban vegetation in reduction of UHI – the results of microclimatic research

The variation of air temperature (Ta) and heat stress (UTCI) inside residential districts was examined on two sunny days, 21-22 May 2013, in two housing estates, Koło and Włodarzewska, which differ in the provision of green areas as well as in the arrangement of buildings (Fig. 5.6.3a-b). On the measuring days, the wind was weak (<2 $m{\cdot}s^{-1}$), the mornings had clear sky, *Cumulus* clouds were created during the day and a short 10-minute shower occurred on 22 May. Global solar radiation in Koło was more differentiated inside the estate than in Włodarzewska, which significantly influenced the calculated UTCI values. The air temperatures in the housing estates and in the reference station (Powsin) fluctuated between 8-15ºC in the mornings and 20-23ºC during the middle of the day.

The differences in air temperature in various micro structures inside both housing estates ranged from 2.5-2.8ºC in the early morning to 3.3-3.5ºC at noon, reaching higher values in Włodarzewska. At midday, the spatial differences in air temperature increased due to an increase in solar radiation (up to about 600-800 $W{\cdot}m^{-2}$). The warmest air was above artificial surfaces (asphalt, concrete), at well insulated sites and the coldest air was found over natural, shaded surfaces (lawns under trees). The wind tunnel effect was clearly seen at post 2 (close to the tunnel under the block of flats) and 5 (between two buildings) in Koło, and at post 5 (on a street along a long block of flats) in Włodarzewska.

The spread of UTCI values inside the analysed estates was 3 times greater than that of air temperature, though they mostly fall within one heat stress category, named "no thermal stress". In the Koło estate, the differences in UTCI values between posts at individual points in time reached 10.5ºC in the morning. The coldest was recorded on a vast lawn in the centre of the estate, surrounded by high trees and buildings (post 3), and the UTCI values indicated "slight cold stress" there. The warmest was a calm site under a canopy of high trees (post 1), where, at midday, the differences in UTCI reached 10.4ºC. The coldest was a shaded site under a tree canopy (post 1) and the warmest – an asphalt surfaced parking area (post 6), where moderate heat stress was noted.

In the Włodarzewska estate, the differences in UTCI values were much smaller and they reached only 6.7ºC in the morning. The coldest were pavements next to a block of flats, the windiest in the estate (post 5), and the warmest – a calm and sunny square between buildings (post 6). At midday, the spread of UTCI values was up to 6.8ºC. The warmest was a small lawn with young trees, squeezed between blocks of flats (post 4).

Concluding, green areas, including both lawns, bushes and trees, play an important role in creating urban heat stress. The results of experimental research revealed a bigger variation of Ta and UTCI inside a housing estate with higher RBVA and lower FAR (Fig. 5.6.4). Significant differences were found when Ta and UTCI values observed inside pilot areas were compared with the peripheral part of Warsaw (Powsin). In early morning (which represents the classical definition of UHI), the greatest Ta differences were observed in the city center and the smallest – in the Koło area. Similar relations of Ta were found for the midday hours, though Koło was characterized by the same temperature as the peripheral station and Włodarzewska was little warmer. The differences between the studied areas in comparison to the peripheral reference station (Powsin) were even greater when considering the perceptible thermal conditions represented by UTCI. The Koło estate has UTCI values that are, on average, 4-5ºC higher than at the periphery station, though in the Twarda district (city center), UTCI is 7.5-8ºC higher. The reason for such good thermal conditions in Koło is the presence of well-developed vegetation with predominantly high, leafy trees which cause many places in the Koło estate to be as cool as is observed in the botanical garden (Fig. 5). The UTCI is very sensitive to even small changes in the meteorological variables induced by different urban structures on a very detailed scale. The comparison of two housing estates with different structures shows that low density settlements with a great portion of biologically vital surfaces and trees can create relatively mild biothermal conditions.

Fig. 4 The Ratio of Biologically Vital Areas (RBVA) and the Floor Area Ratio (FAR) of the pilot areas

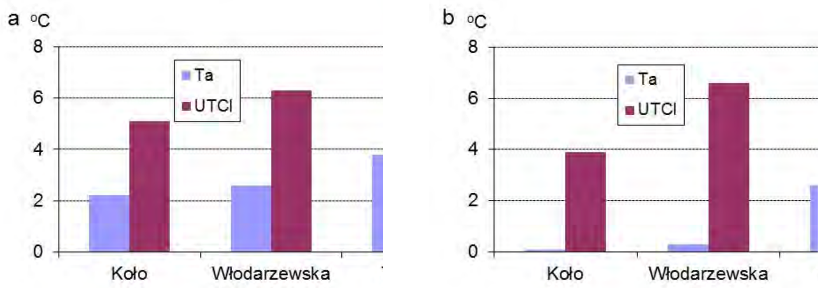

Fig. 5.6.5 The difference of the air temperature (Ta) and heat stress index (UTCI) between pilot areas and the Powsin reference point (a – morning hours, b – midday hours)

5.6.4.1 Allergenic potential of vegetation

In the ecophysiographic description of three pilot study areas (in this case vegetation was also analysed for the southern part of the Włodarzewska estate where microclimatic conditions were not considered), a total of 97 different plant species have been described (see Tab. 5.6.2). Tab. 5.6.3 contains the general evidence of allergenicity in classes of plants in the studied pilot areas.

Abies concolor *Abies koreana* *Acer campestre* *Acer negundo* *Acer platanoides* *Acer platanoides* *Acer pseudpolatanus* *Acer saccharinum* *Aesculus hippocastanum* *Alnus glutinosa* *Berberis thunbergii* *Betula pendula* *Buxus sempervirens* *Caragana arborescens* *Carpinus betulus* *Catapla bignonioides* *Cercidiphyllum japonicum* *Chaenomeles japonica* *Chamaecyparis pisifera* *Chamaecyparis sp.* *Cornus alba* *Corylus colurna* *Cotinus coggygria*	*Cotoneaster horizontalis* *Cotoneaster lucidus* *Crataegus monogyna* *Crataegus xmedia* *Daphne mezereum* *Deutzia scabra* *Elaeagnus angustifolia* *Euonymus fortunei* *Fagus sylvatica* *Forsythia xintermedia* *Fraxinus excelsior* *Hedera helix* *Hydrangea sp.* *Ilex aquifolium* *Juglans nigra* *Juniperus 'Blue Carpet* *Juniperus sabina* *Juniperus sp.* *Juniperus virginiana* *Juniperus xmedia* *Larix decidua* *Ligustrum*	*Mahonia aquifolium* *Malus purpurea* *Malus spMorus alba* *Parthenocissus quinquefolia* *Philadelphus sp.* *Physocarpus opulifolius* *Picea abies* *Picea pungens* *Pinus mugo* *Pinus sylvestris* *Platanus xhispanica* *Populus alba* *Populus nigra* *Populus simonii* *Potentilla fruticosa* *Prunus avium* *Prunus cerasifera* *Prunus domestica subsp. syriaca* *Pyracantha coccinea* *Pyrus pyraster* *Quercus robur* *Quercus rubra* *Reynoutria sachalinensis*	*Rhus typhina* *Ribes alpinum* *Robinia pseudoacacia* *Rosa sp.* *Salix alba* *Salix babylonica* *Salix caprea* *Salix caprea 'Klimanrock'* *Salix fragilis* *Sambucus nigra* *Sorbus aria* *Sorbus aucuparia* *Spiraea 'Grefsheim* *Spiraea japonica* *Spiraea xvanhouttei* *Symphoricarpos albus"* *Syringa vulgaris* *Tamarix sp.* *Taxus baccata* *Thuja occidentalis* *Tilia cordata* *Tilia platyphyllos* *Viburnum opulus* *Weigela florida* *Wisteria sp.*

Cotoneaster dammeri	*vulgare* *Lonicera maackii* *Lonicera xylosteum* *Magnolia sp.*		

Tab. 5.6.2 Plant species recognised in three pilot study areas (Latin names in alphabetical order)

Pilot area	Allergenicity			
	No (class 0)	Slight (class 1)	Moderate (class 3)	Great (class 4)
Koło (469)	134 (28.6%)	273 (58.2%)	54 (11.5%)	8 (1.7%)
Class 2&3 together			62 (13.2%)	
Włodarzewska (619)	302 (48.8%)	276 (44.6%)	15 (2.4%)	26 (4 2%)
Class 2&3 together			41 (6.6%)	
Włodarzewska-south (101)	49 (48.5%)	39 (38.6%)	9 (8.9%)	4 (4%)
Class 2&3 together			13 (12.9%)	

Tab. 5.6.3 Numbers of tree and shrub specimens with different allergenicity in compared housing estates

It is generally recognised that the Urban Heat Island (UHI) phenomenon has a detrimental impact on the health of populations that live under its influence. This phenomenon can act as an amplifier to heat wave events, mainly due to a lack of night-time thermal body regeneration. It can cause thermal stress through heat accumulation during consecutive days. Such conditions affect a certain population of city dwellers known to be at risk of developing heat-related illnesses. This population comprises subjects with chronic pulmonary and cardio- or cerebrovascular disorders, elderly people, young children and the disabled (Basu 2009). It is indispuTab. that phenomenon such as UHI need to be counteracted by launching various mitigation and adaptation strategies. One must remember that some of those strategies involve introduction of a new plant species into an urban area. It can mitigate the UHI phenomenon quite efficiently, but simultaneously can give rise to another major health problem. Improper plant choice may cause people who are susceptible to seasonal airborne allergens to develop symptoms of asthma, rhino conjunctivitis or urticaria/dermatitis. It is essential for mitigation and adaptation strategies to select appropriate plant species that do not aggravate the symptoms of airborne allergies. Although the definite impact of the UHI phenomenon on the allergenic activity of plants has never been described or proven before, there is some evidence supporting the hypothesis that such phenomena can alter plant physiology, causing them to be more allergy-aggressive. It has been proved in many studies, that in warmer climate plants can produce larger amounts of pollens when compared to those in cooler regions. An increase in carbon dioxide level has a similar impact (Cecchi et al. 2010). Factors typical for urbanized UHI areas such as: elevated ambient temperature, elevated carbon dioxide levels, increase in concentration of anthropic pollutants, i.e. sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone and airborne particulate matter (PM) affect plant physiology causing an increase in allergen production. Pollen grains released in such an environment contain more allergen proteins on their external surfaces than they do in cooler settings (Todea et al. 2013, Beck et al. 2013). Typical pollen grain diameters range from 15 to 40 μm. Such a diameter allows pollen grains to reach only the upper region of the respiratory tract to trigger rhinoconjunctival symptoms. Only particles smaller than 10 μm can penetrate the respiratory tract down to its deeper structures to provoke asthma seizures. Pollen grains are extremely resistant to fragmentation, however, allergens can easily be transferred from pollen onto smaller particles (PM_{10}, $PM_{2,5}$) and, in this way, easily reach every compartment of the respiratory tract. Therefore, increased plant allergenic activity and air pollutants can act synergistically and thus dramatically reduce the quality of life of subjects susceptible to airborne allergens. It is also hypothesized that combinations of those factors, in addition to triggering respiratory tract allergy symptoms, can also promote allergisation in the portion of the population so far unaffected by allergies, by facilitation of allergen penetration into the respiratory tract (Lovasi et al. 2013). The deeper the allergen can reach into the respiratory tract, the greater area of mucosa is affected and the longer the allergen stays inside the organism, the more severe allergy symptoms can be triggered as well as easier allergisation. Air pollution itself also facilitates allergisation. It can irritate respiratory tract mucosa, thus causing it to be more easily penetrated by allergen proteins. Another factor that can affect people susceptible to seasonal airborne allergens is the elongation of the pollen season (Bielory et al. 2012). In a warmer climate, plants start to pollinate earlier and continue to release pollens for longer periods. It causes the anti-allergic pharmacology therapy schedule and specific immunotherapy calendar to require additional modification (early implementation, prolonged administration). All facts described above indicate that suiTab. plant selection is essential for successful implementation of various greenery-related UHI adaptation and mitigation strategies. It is also important to remember that all plant allergenicity assessment is local-specific. The set of allergy patterns is different for various geographic regions. The best example is the allergy to olive trees, which is known to be a frequent allergy in the Mediterranean region but not in north of Europe. Therefore, for performing such an assessment, the cooperation of local urbanists, botanists and allergists is needed to develop a suiTab. model of plant cover for UHI mitigation and adaptation strategies.

The prevalence of plant species considered to be a recognizable hazard to people with seasonal airborne allergies (Class 2 and 3) ranged from 6.6 to 13.3%. The prevalence of Class 3 plants alone, known to cause the greatest allergological risk, range from 1.7% (Koło area) up to 4.2% (Włodarzewska area). Although Class 2 and Class 3 plants are almost evenly scattered throughout the pilot areas, there are two spots of Class 3 plant compaction close together. First, the spot at the south east corner of the Koło area contains six Class 3 plants. The second spot, at the north east corner of the Włodarzewska area, contains seven Class 3 plants. These spots are recommended for immediate remodeling. This limited intervention will allow the reduction of Class 3 prevalence to 0.4% in Koło and 3.4% in the Włodarzewska area.

5.6.5 Possibility of reducing UHI intensity

For the calculations of the scenarios of the possible UHI reduction, two areas were chosen – Włodarzewska and Twarda (very city centre). Koło was eliminated because there was nothing to change and the existing thermal conditions were friendly for humans.

Looking for the benefits from trees and the non-dense locations of buildings, a reduction in the number of buildings (pulling down 2 of them) and an increase in the number of lawns and trees (in the places of 2 new empty parcels) (Fig. 5.6.6) was proposed for the Włodarzewska estate.. For the Twarda district, the possible effects of two scenarios were verified. In the 1st scenario, planting an additional lawn area and deciduous trees inside court yards and along streets was proposed. In the 2nd scenario all roofs were additionally covered by vegetation (Fig. 5.6.7).

Four characteristics of the urban heat island for four days of the year were analysed: maximum UHI, i.e. the highest daily urban to rural air temperature difference (dTa), minimum UHI, i.e. minimum daily dTa value, average dTa value for night hours (9 p.m. – 7 a.m.) and average dTa value for day-time hours (10 a.m. – 4 p.m.).

Simulations of air temperature for the Włodarzewska housing estate showed that the replacement of some buildings by lawns and trees could lead to a significant reduction of UHI (Fig. 5.6.8). Maximum and minimum UHI values in spring, summer and autumn could be lowered by about 0.5°C, and in winter up to 1°C. The proposed land use changes would also cause a reduction of average UHI values, greater at night than during day-time hours.

Fig. 5.6.6 Land cover of Włodarzewska housing estate: left panel – the present state, right panel – changes in land cover proposed in scenario 1 (replacing 2 buildings by lawns and trees)

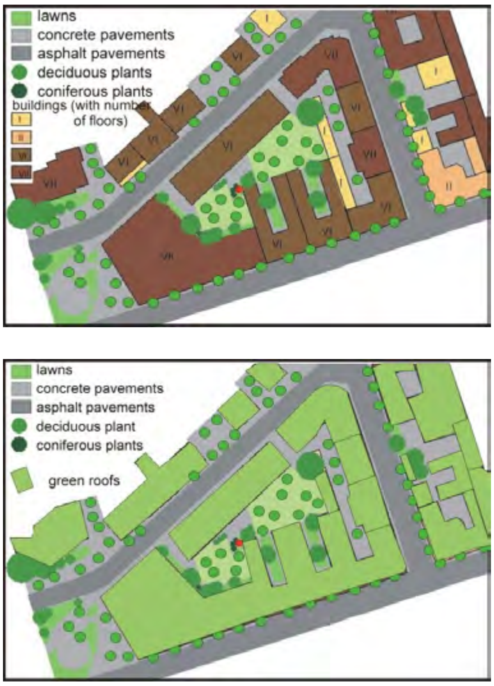

Fig. 5.6.7 Land cover of the Twarda district; upper left panel – present state, upper right panel – changes in land cover proposed in scenario 1 (additional trees and permeable surfaces), lower panel – changes in land use proposed in scenario 2 (additional trees, permeable surfaces and green roofs)

For the Twarda district, simulations have verified that the 1st scenario of land cover changes (additional lawns and trees) would result in no significant changes of UHI intensity. Some lower values could occur, especially in summer, but in autumn, values of minimum UHI and midday hours UHI can be higher than in the present state. A more positive effect was obtained when the 2nd scenario (additional green roofs) was applied. Lower values of UHI occurred in spring and summer but in autumn and winter no changes were observed.

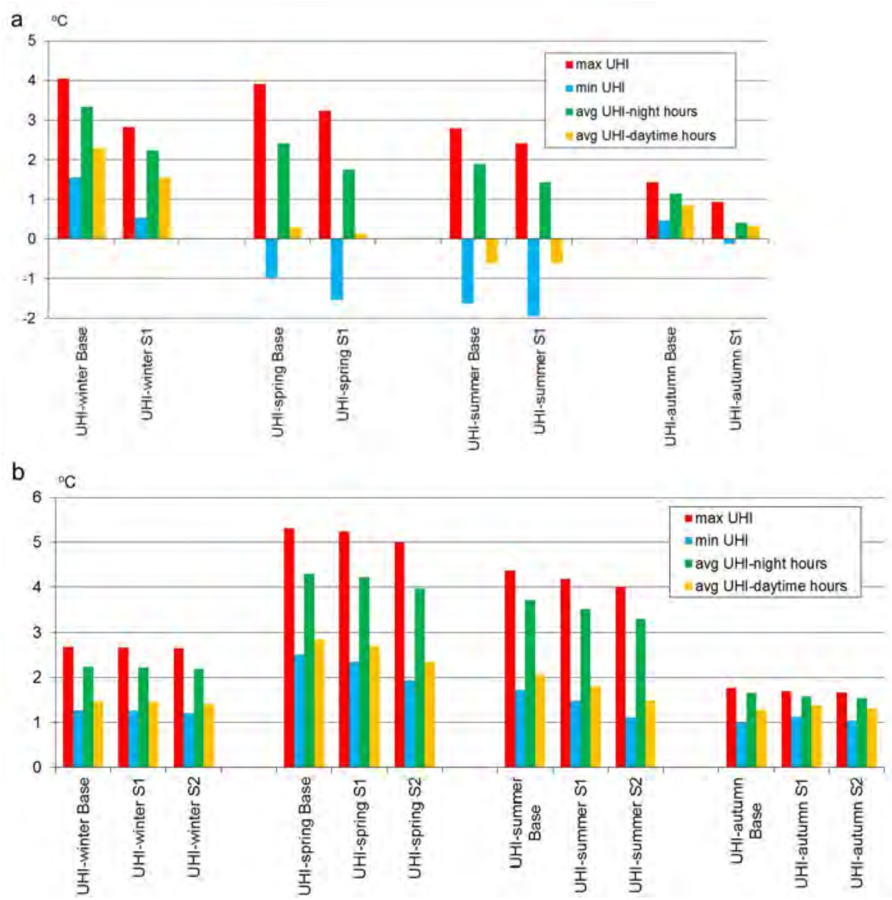

Fig. 5.6.8 Simulations of UHI-index (°C) made by ENVI-Met software for 4 days of a year representing winter, spring, summer and autumn for Włodarzewska housing estate (a) and Twarda district (b)

5.6.6Assessment of mitigation measures

Simulations showed that increasing the number of lawns and trees as well as implementing green roofs in Warsaw city centre cause only small changes in the intensity of the urban heat island. To make a significant improvement, some radical action is needed, involving the reorganization of the existing built-up area. In places where it is possible some buildings should be pulled down and replaced by lawns and trees. It is also advisable to forbid compaction of downtown and to take special care of present green areas.

There are many indications when designing new housing estates which could clearly mitigate UHI effects: applying a building layout which does not close the interiors of the housing estates but open them to the neighbouring green areas, using openwork metallic fencing was much more conducive to ventilation than high brick walls, which did not allow infiltration of the air from the outside.

Mitigation of the urban heat island in areas located at a greater distance from the city centre is easier. Small measures, e.g. planting deciduous trees, planting flowerbeds or reducing artificial surfaces can clearly mitigate UHI. Summarising, the following mitigation actions should be undertaken on all planning levels: 1) protection within the city structure of open spaces which can intensify air movement and remove heat, 2) protection of all existing green areas inside the city which can reduce air temperature and heat stress as well as allow to the human organism to recuperate during hot episodes, 3) when planning new estates and compartments the urbanists and decision makers must remember about green areas and sufficient open space between buildings, 4) planting tree belts along streets to reduce surface heating, 5) planting trees on squares and play areas for children and the elderly, 6) increase the number of green roofs, terraces, balconies and facades, especially in the city centre.

However, when planning new plants, the appropriate composition of species must be considered. All plants of great allergernicity (Class 3) should be removed as soon as possible and plants of moderate allergenicity (Class 2) are recommended to be removed during the soonest area greenery remodelling and replaced with low- or non-allergenic species (Class 0 or Class 1).

Examples of plant species suiTab. for greenery related UHI mitigation and adaptation strategies in Warsaw:

Trees: Maple, Hornbeam, Elder, Horse chestnut, Rowan, Acacia, Cherry plum, Mountain pine, Spruce, Fir, European larch, female cultivars of Poplar, Ash and Willow

Shrubs and bushes: Hedge cotoneaster, Boxwood, White dogwood, English dogwood, Border forsythia, Old-fashioned weigela, Staghorn sumac, Japanese quince, Red barberry, Common hawthorn.

Climbing plants (suiTab. for green facades): Common ivy, Five-leaved ivy, Russian vine.

5.6.7 Adaptation strategies

It is not possible to abolish the Urban Heat Island, and society must adapt to its occurrence. In 2013, the Polish Ministry of Environment published a strategic adaptation agenda for climate change in Poland to the year 2020 (Ministerstwo Środowiska, 2013). There are several links to Urban Heat Island phenomenon when considering adaptation of cities to climate change. Several adaptation actions were also defined in the area of human health. Some of them refer to increased air temperature as well as to the increasing risk of allergies.

Taking into consideration action proposed in the adaptation agenda and the results obtained within UHI project, the following adaptation activities are recommended in Warsaw and should be implemented by city authorities: 1) education of all groups of society (city officers and decision makers, planners, architects, teachers and general population) about UHI phenomenon, its influence on quality of life and mitigation possibilities, 2) incorporation of UHI monitoring and information systems about UHI intensity and extension, 3) installing air conditioning in public buildings, 4) supporting air conditioning in private buildings and apartments, 5) incorporating a warning system of cardiovascular disorders, asthma and allergenic risks, 6) incorporating a system supporting elderly and disable people during episodes of extreme heat waves and intensive Urban Heat Island.

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5.7 Urban Heat Island In The Ljubljana City

dr. Blaž Komac, Anton Melik, dr. Rok Ciglič, mag. Miha Pavšek, Anton Melik

Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

Alenka Loose,
Energy manager of the City of Ljubljana,

Adamič-Lundrovo nabrežje 2, 1000 Ljubljana,

Svetlana Čermelj, Mestna uprava,
Oddelek za varstvo okolja, Zarnikova 3, 1000 Ljubljana

Ljubljana, May 2014

dr. Blaž Komac, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana,

5.7.1 Introduction

Urban heat island is an urban area where temperatures are higher than in the surrounding area. This is mainly due to the accumulation of heat in buildings and on concrete and asphalt land during the day. This leads to a greater night long wave radiation from the surface and thus to a smaller cooling than the surroundings. The city is also lower albedo, the greater the diffuse solar radiation due to pollution, reduced evapotranspiration and lower relative humidity.

In Ljubljana, urban heat island was first detected when creating The climate map in 2000 (Fig. 1). Area with above-average temperatures was between the city centre and the Rožnik and Golovec hills. In the context of climate map guidelines for spatial planning were also prepared, which preserved the green wedges and fresh air corridors for the city centre.

During the UHI project we found that with the development of the city and in particular the construction of many shopping centres with large parking places a range of small areas where we perceive the phenomenon of heat island phenomenon. The project was designed primarily for mitigating as well as adapting to this phenomenon and thus climate change.

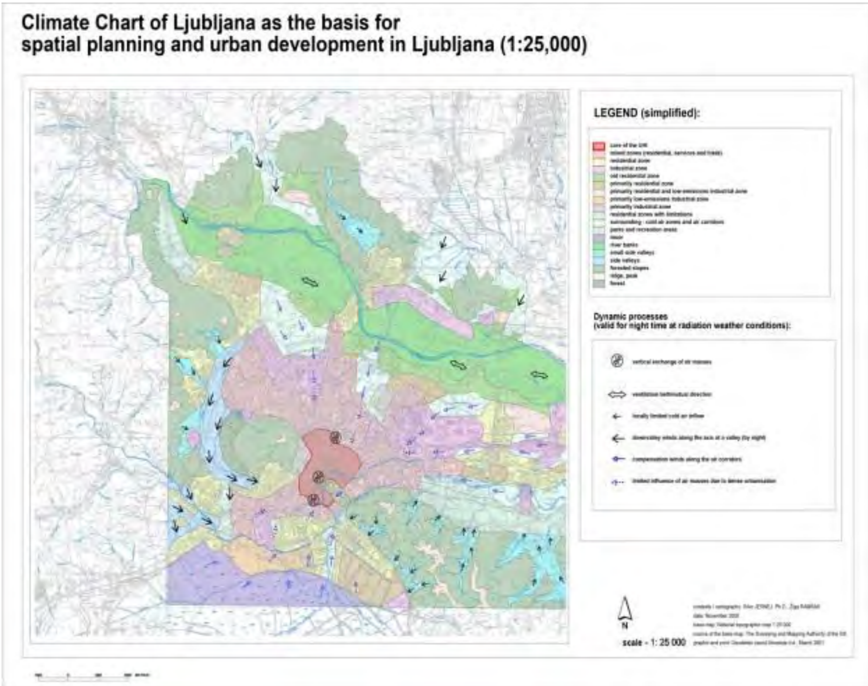


Fig. 5.7.1 Climate chart of Ljubljana showing the urban heat island area.

5.7.2.1 Meteorological measurements

During the project the urban heat island index was calculated for the Ljubljana Bežigrad (46 °07' N, 14°52' E, 299 m a.s.l.) and Brnik (46 °22' N, 14°22' E, 364 m a.s.l.) meteorological stations. The Ljubljana Bežigrad weather station is within the inner circle of the city. The area is representative for a typical urban Ljubljana setting, 1,5 km away from the city centre. The weather station is a synoptic one and thus equipped with many for the UHI-recognition meteorological devices (Internet 1). The Brnik weather station is in a complete rural area and stands on the SE edge of the Jože Pučnik Airport runway, over 100 m NW from it and more than 1 km away from the nearest bigger building. First larger forest area is over the airport's runway more than 500 m away. The surrounding terrain is in general flat, open and grassy. Weather station is a climate one and the measurements are taken automatically. The air distance between both weather stations is something more than 17 km; the difference in altitude is 65 m.

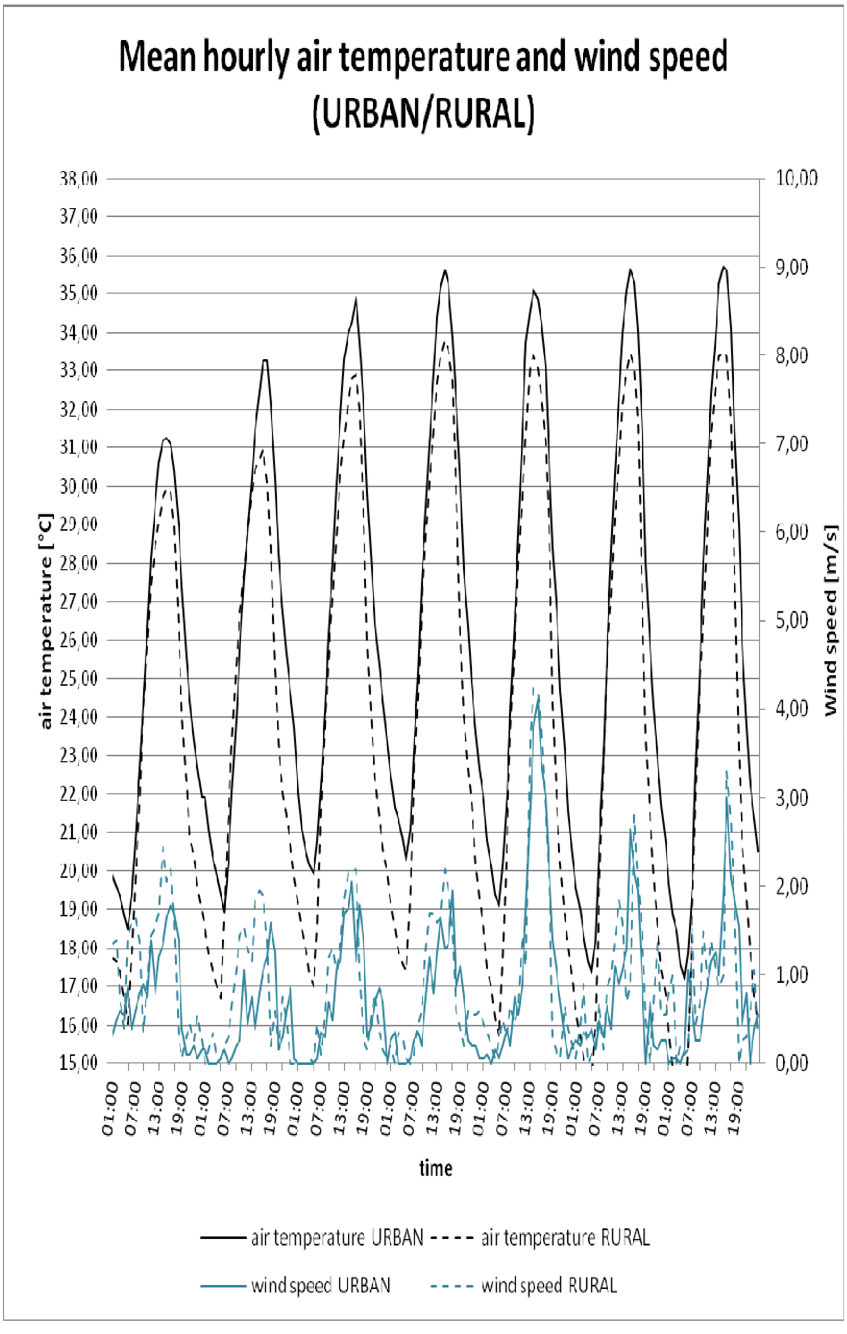


Fig. 5.7.2 Mean hourly air temperature and wind speed data in urban and rural station.

The UHI intensity-cycle was calculated for the period July 20. to 26. 2011. Its intensity was quite similar every day. The lowest intensity was present in the morning of the second day, when the heating at the rural station has started earlier than at the urban station and it was significantly more rapid. Before a midday the urban station became warmer, but in the evening rural station was cooling significantly faster. That caused that UHI intensity has reached the third highest value in the selected period (4.95K). A little higher air humidity compared to following days in the period was probably a cause for thin-fog formation near the middle of the night, which has decreased cooling rate at the urban site. In the whole period wind was varying from calm in the night/early morning time to the top speed around 2-3 m/s in the afternoon on the both stations. In the beginning of selected period the prevailing wind was weak mid-atmosphere NE winds, which usually doesn't reach the valley`s bottom. That is why none of the stations shows a signal of constant NE winds. The measured wind variations were thus thermally driven by a daily heating and nocturnal cooling, because in the selected period the sky was clear all the time. The biggest anomaly of the wind in the selected period occurred during the day on the 24th of August, when the wind direction in the middle altitudes has changed to SW, which descends over the Dinaric Mountains to Ljubljana basin and has some characteristics of the foehn wind. Also the air humidity was the lowest in that time at the both stations. A weak SW wind was blowing till the end of a selected period and very low humidity has caused the lowest night-time temperatures especially at the rural station and thus the UHI intensity has raised for 0.5–2 K.

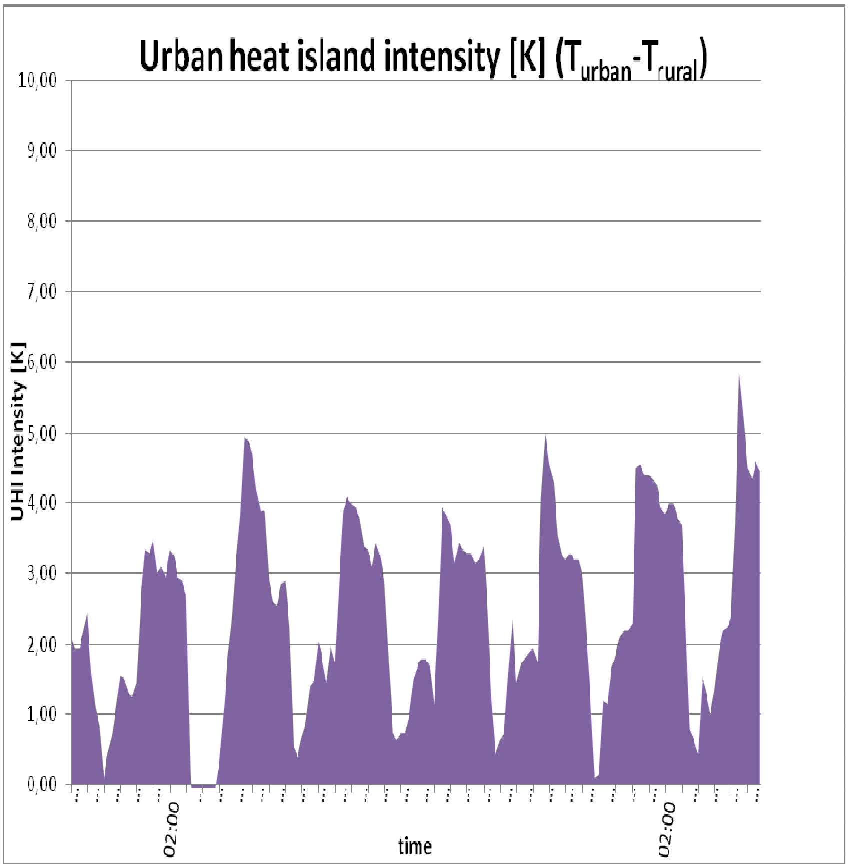


Fig. 5.7.3 Mean urban heat island intensity data.

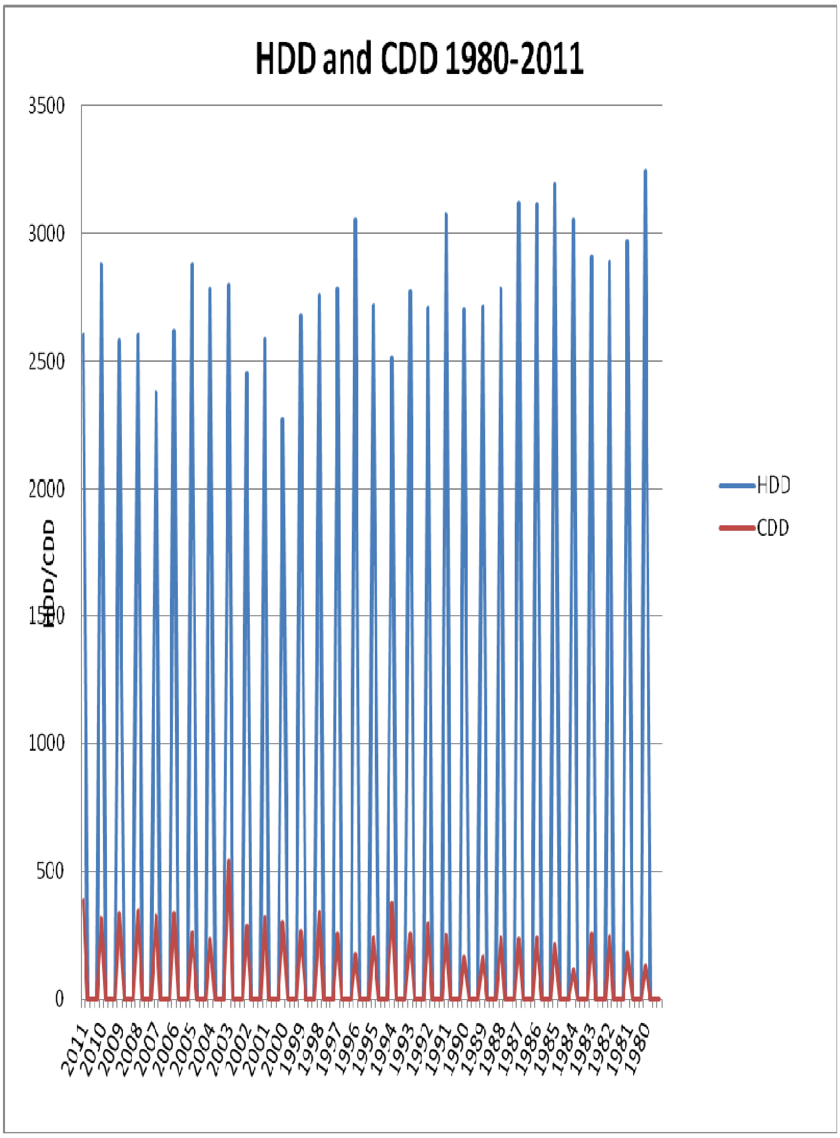


Fig. 5.7.4 Mean heat degree days and cold degree days in the period 1980–2011 for Ljubljana.

5.7.2.2 Satellite thermography measurements

dr. Krištof Oštir

Research centre of the Slovenian academy of sciences and arts, Novi trg 2, SI-1000 Ljubljana; Centre of Excellence for Space Sciences and Technologies, Aškerčeva 12, SI-1000 Ljubljana, Novi trg 2, 1000 Ljubljana, kristof@zrc-sazu.si,

dr. Žiga Kokalj

Research centre of the Slovenian academy of sciences and arts, Novi trg 2, SI-1000 Ljubljana; Centre of Excellence for Space Sciences and Technologies, Aškerčeva 12, SI-1000 Ljubljana, Novi trg 2, 1000 Ljubljana, ziga.kokalj@zrc-sazu.si

Efficient planning of city infrastructure and its activities has to take into account increasing average temperatures in a city, and therefore consider and monitor the effect of its urban heat island.

Land surface temperature can be monitored with satellite systems. To assess the extent and state of urban heat island of Ljubljana we used Landsat 8 imagery that has adequate spatial resolution for a detailed analysis of temperature variations. Images of Ljubljana and its vicinity are acquired twice every 16 days. Land surface temperatures were calculated from two cloudless images per season in the period between April 15th 2013 and March 8th 2014.

The area of interest was divided into three zones, with the first being inside the city ring road, the second a 3 km band from the first, and the third a 2.5 km band from the second. The zones have been further divided according to land use; we have grouped the classes into: build up, water, agricultural land, and forest. Build up and water areas smaller than the resolution of the thermal band (1 ha) were excluded from the analysis. The first zone was further partitioned to city districts, and the second and third zones to areas of settlements.

Comparison of temperatures included build up areas of smaller cities close to Ljubljana (Kranj, Domžale, Kamnik, Grosuplje, and Vrhnika) and some of the city's more interesting regions (the centre, industrial areas, business-shopping centres, areas of individual housing, and parks). The impact of water and trees on the surrounding surface temperature was assessed with profiling – across the whole city and through specific areas of interest.

We have found that Ljubljana exhibits a distinct urban heat island. Furthermore, some of its districts are constantly warmer than others, and specific areas are definitive hot spots.

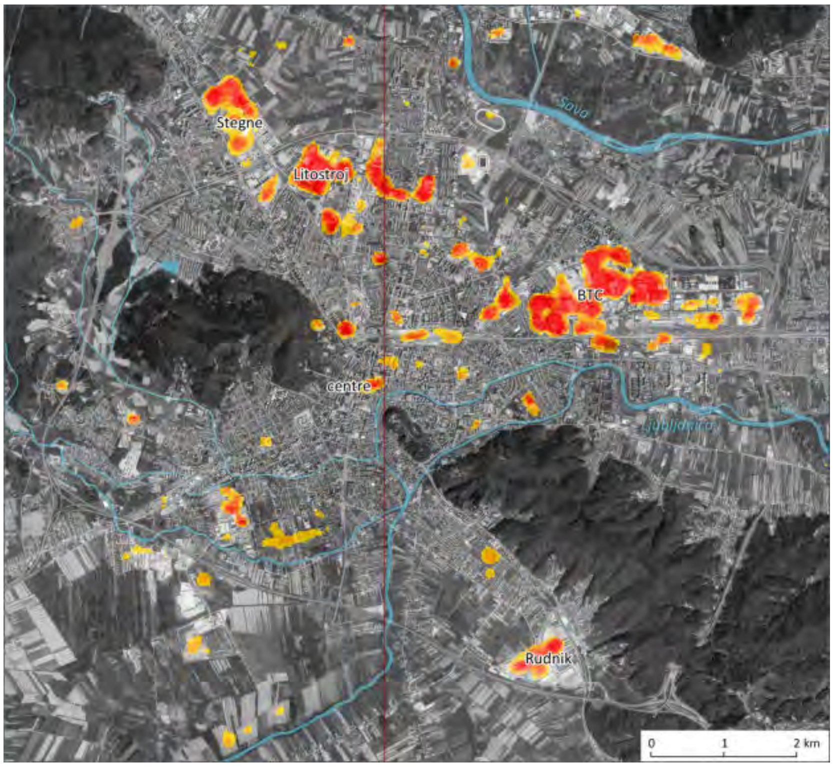


Fig. 5.7.5 The frequency of occurrence of the top two percent of the highest temperatures on build-up areas.

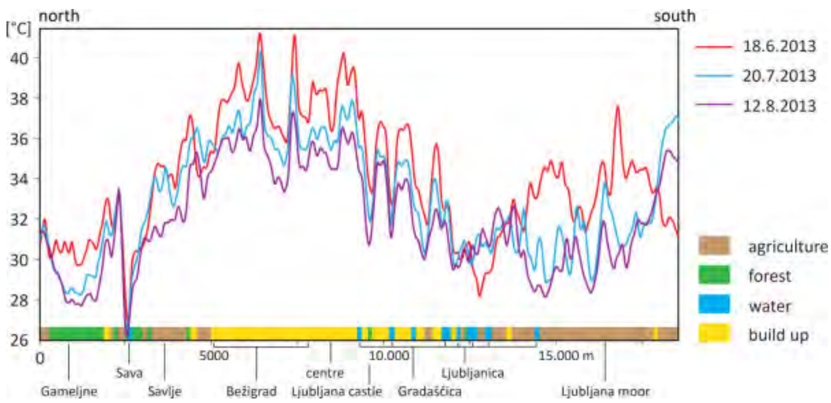


Fig. 5.7.6 Profiles of summer land surface temperatures across Ljubljana, with indicated land use and prominent orientation points. The location of the profile is marked as a red line on Fig. 1, but it extends beyond the boundaries of the Fig..

5.7.2.3 UHI Atlas

dr. Rok Ciglič, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljanadr.

Blaž Komac, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

The Urban heat island atlas is an internet application for visualization of spatial data, related to urban heat island in the area of Central European countries. The database was elaborated in GIS environment using Arcgis Desktop and published online using Arcgis Server. This project result is intended to support decision-makers in the field of spatial planning and is therefore free-accessible to everyone at **http://giam.zrc-sazu.si/uhi_atlas**.

The atlas presents urban heat island influencing factors including elevation, normalized difference vegetation index, land use (Corine land cover and Urban atlas data), human activity shown by night scene image (detected by VIIRS sensor data), air temperature at 2 m and land surface temperatures.

Viewer can analyse the data by making profiles across the temperature layers for April and August (at 2 pm). In this way, temperatures in the city and the surroundings can be compared (see the example of Ljubljana in Fig. 5.7.6).

Various local and regional datasets provided by the project partners are also presented in the atlas.

The atlas was prepared by the Anton Melik geographical institute ZRC SAZU and Hungarian meteorological service.

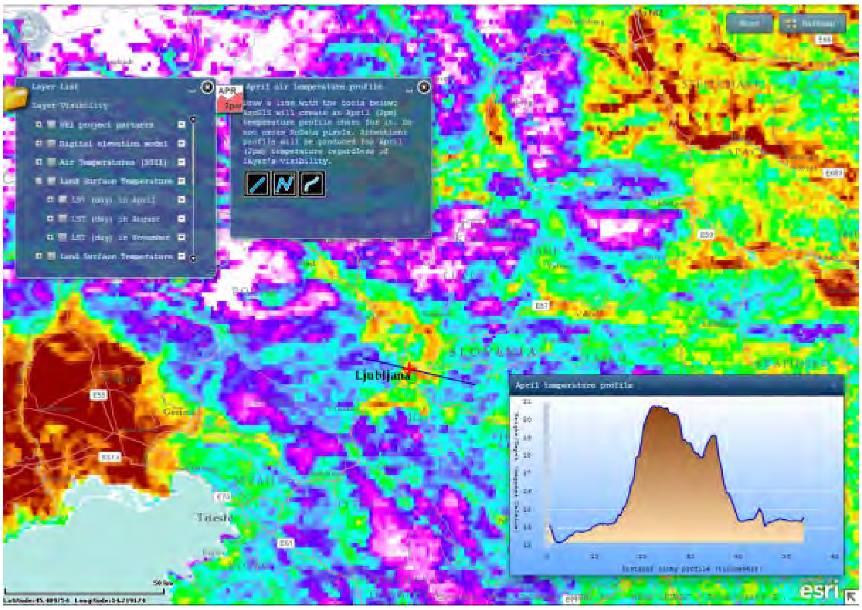


Fig. 5.7.6 Print screen of the Urban heat island atlas. Its user friendly interface enables users to select between different layers, make profiles across April (as below) and August temperatures in Central Europe and zoom to UHI partner data.

5.7.3 Mitigation of the urban heat island in the Ljubljana city area

Alenka Loose, Energy manager of the City of Ljubljana, Adamič-Lundrovo nabrežje 2, 1000 Ljubljana

Svetlana Čermelj, , City of Ljubljana, City Administration, Department for Environmental Protection,, Zarnikova 3, 1000 Ljubljana

dr. Blaž Komac, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

mag. Miha Pavšek, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

dr. Maja Topole, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana,

The purpose of the project was to establish the existence of a heat island, which was confirmed by data from meteorological stations and satellite thermography, and then use this knowledge to mitigate the effects of heat islands.

As urban island is affected by several factors such as green areas in the city, location and design of the land use, types of building and roofing materials, layout of buildings, and their energy efficiency, including spatial development of the city, we examined some of the characteristics of the city of Ljubljana. We carried out some pilot actions to draw attention to the importance of taking into account the effects of the urban heat island in the planning of land use and activities in the city. In 2010 the Municipal spatial plan was adopted defining the planned land use with special focus on urban land uses and future development of green areas.

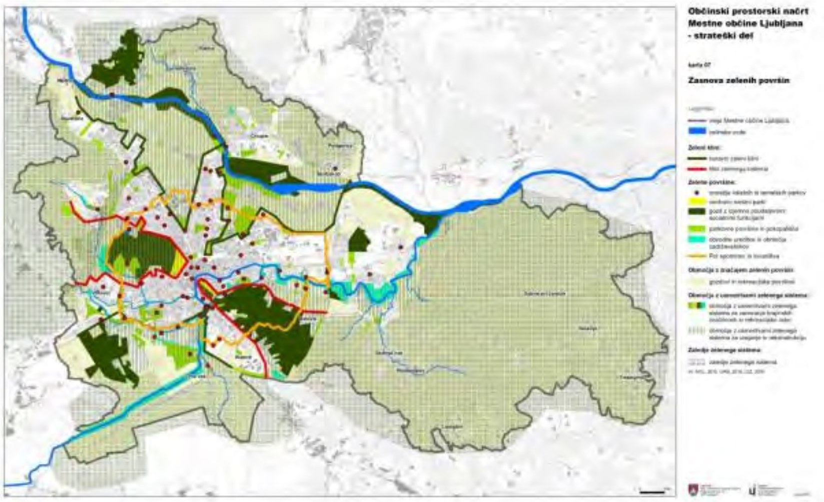


Fig. 5.7.7 Future development of green areas in the City of Ljubljana (Internet 3).

In order to minimize the effects of the urban heat island the basic strategic objective of the Ljubljana city is to create an interconnected and transparent network of open public spaces of high quality. During several last decades an action called »Ljubljana – My Town« has been under way. It stimulates the facades' renovation all over the important public areas or representative areas.

One of the most important measures is preserving the city green areas and protecting the city forests as a part of green wedges. A specific feature of the city is its green ring, a way along barbed wire, which encircled the city during the WW2 being a popular recreational area. The focus area is the axis along the river of

Ljubljanica and green areas along the Sava river, the Gruber's canal, the Špica bank, and the Gradaščica and Glinščica brooks.

Related to green areas a special attention is given to open public areas network that connect the surrounding of the city with its squares, streets, riverbanks and walkways, and also serve as an air-corridor network. They create micro-climatic and mesoclimatic conditions, enable ventilation of the city. The stretches of waterways also constitute a system of open public spaces. Adequate directions for protection and management are defined for such areas.

The extent of pedestrian areas increased lately due to the traffic limitation and complete stop in inner city centre. Still, poor airing is presented in the Ajdovščina area. The city planning measures regain pedestrian areas that would make various social interactions possible. Urban ventilation is therefore an important factor of urban heat island mitigation, and connecting natural areas in landscape parks with the city.

In Ljubljana garden-plot areas were spontaneously developed and distributed across the entire flat area of Ljubljana. Due to a urban lifestyle and a policy change by the city authorities, the area of garden plots fell considerably at the end of the twentieth and the beginning of the twenty-first centuries. Until recently garden plots were spread on 200 locations and covered 1,3 km^2 (Jamnik et al. 2009) Due to pesticide residues and heavy metals in the soil and produce, as well as groundwater contamination, plot gardening poses a threat to public health and the environment, and the 2008 Ljubljana Zoning Implementation Plan reduced the total area of plot-gardening areas by nearly half.

Another way of minimizing the effects of urban heat island is related to building and roofing materials. The majority of old buildings in the centre of the Ljubljana city are built of bricks and stone. In the broader city area concrete buildings were built in the 1970' and 1980', while iron was used to build some new high buildings. Most of the stone and brick buildings in the old city are plastered, while stone was used primarily for portals, window frames and in some cases, pet mats. Mitigation is difficult due to the fact that the Ljubljana centre was declared a cultural and historical monument, which requires full protection of the cultural, aesthetic, historical and natural values (Decree ... 1986). Common roofing material in Ljubljana is tiles. Tiles cover the majority of older buildings in the centre of the city. Some atriums of the buildings have been covered by glass and only few buildings and winter gardens have been equipped by green roofs until now, built mostly by incentives of individuals (Črnuče, Lek pharmaceutical company, Maros company) or by public funds (Stožice sport park a green roof with size 8000 m^2).

5.7.4 Pilot actions

Alenka Loose, Energy manager of the City of Ljubljana,
Adamič-Lundrovo nabrežje 2, 1000 Ljubljana

Svetlana Čermelj,
City of Ljubljana, City Administration, Department for Environmental Protection,, Zarnikova 3, 1000 Ljubljana

dr. Blaž Komac, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

mag. Miha Pavšek, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

The notion of spatial organisation as a method of urban management has been adopted in three typical areas of the City of Ljubljana: the compact city, the suburbia and the hilly hinterland. This division is merely schematic as it would be difficult to demark these areas where the contents are intertwined.

In Ljubljana 21 streets in the centre of the city have been closed to traffic since 2006. The public cycling system Bicikelj has been established in 2011. In some areas in the city centre the allowed speed of traffic was reduced to 30 km/h, allowing safer cycling and pedestrian transport.

The 2010 Municipal spatial plan defines land use activities from urban land use, green areas, cycling routes and green areas points of view.

A number of drinking fountains were established in the city centre next to several fountains. In 2010 two new parks measuring 15 ha have been established: the Northern park and the park at the Šmartinska street. The city of Ljubljana is taking care of more than 72,000 trees in the city and its surroundings. More than one hundred trees were planted in the streets of the city centre in 2009 and more than 250 trees were planted in 2010 as a part of a project the Labyrnth of Art. About 1409 ha of forests on the nearby hills (Rožnik, Šišenski hrib, Grajski grič, Šmarna gora and Grmada) were given a status of forest of special importance, although almost 90% of the forests are a property of private subjects. Next to a new stadium and sport hall about 90.000 m2 of green areas (parks and sport areas including cycling and running tracks) next to 5000 m2 of play grounds will be built. Also, the Ljubljanica river banks were reconstructed in order to allow public access to water in the city. Large areas of the city dump in the Ljubljansko barje area were transformed to golf links (http://www.ljubljanapametnomesto.si/). A list of buildings which are accessible for disabled people has been made public (http://www.disabledgo.com/sl/org/ljubljana).

The determination of pilot UHI installations locations was a subject of numerous consultations and debates within the City administration and public. Some of them were realized in 2013, the others were prepared and installed this year.

5.7.4.1 Ambient urban intervention »Boats in the fountain” on the plateau in front of Slovenian ethnographic museum (SEM), June, 2013

The architectural concept of the plateau in front of the SEM in the very city centre is a part of a collage of various surfaces and objects. Some of the surfaces are less used that expected, as is the case of the 260 m2 plateau, that was planned as a water surface, but was not realized for years. In the summer period, water is one of the most important elements of public space – it cools the ambient and represents an ideal playground for children. Water also reminds us on holidays, sea, boats, … , and is especially attractive for children. For those reasons we have decided to restore the project and to realize the long-time ago planned water surface in an innovative way that will be attractive for public.

In June 2013, the ambient intervention “Boats in the fountain” was realized, by:

- re-establishment of water surface,
- establishment of spaces where it is possible to play, work or rest,
- rearranging the area to bring it closer to the children and adults.

For the installation old boats were used, after the detailed renewal, each of them had its own name and own story. It became an ideal meeting place for all generations. Throughout the whole summer period numerous visitors enjoyed the vicinity of water surface, especially children. The project was concluded by the end of September.

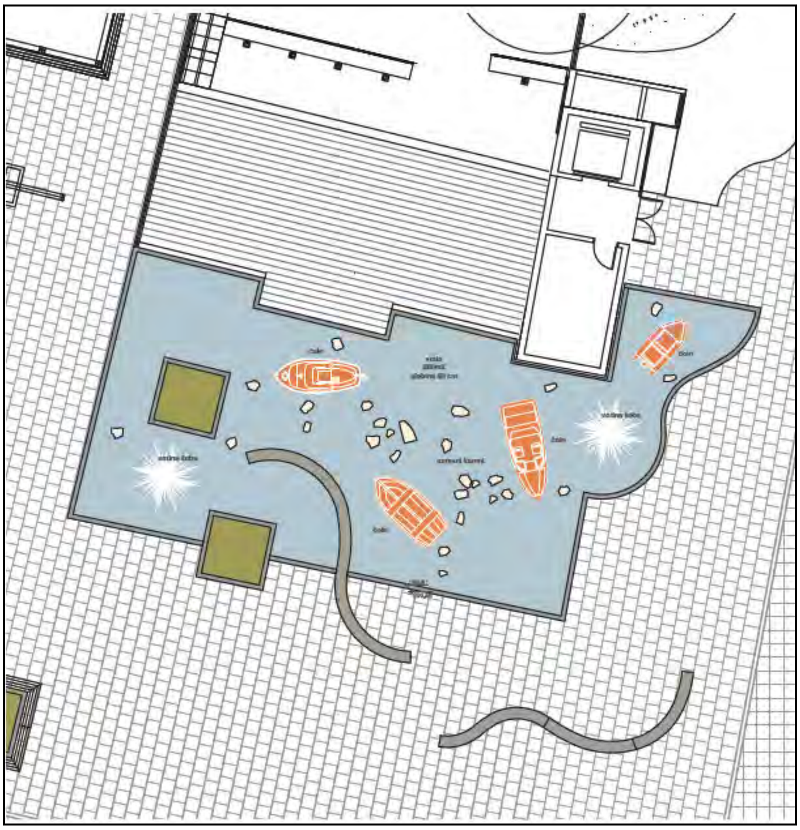


Fig. 5.7.8 Project baseline – Slovenian ethnographic museum (SEM).

Fig. 5.7.9 SEM – realized water surface

5.7.4.2 Temporary installation on the central section of the Slovenska street after its closure for the traffic (September 2013)

Since September, 22 2014, the central part of Slovenska street, passing through the very city centre was closed for motorized traffic, with the exception of public transport. With this measure the transit of motorized vehicles is being reduced in the city centre and the priority of using it is given to pedestrians, cyclists and public transport. On the occasion of closing the street a temporary arrangement was designed and realized to show the citizens and tourists what they can gain from the street closure. The project of temporary arrangement was planned in a sustainable way according to the principle “Less is more” (or “More with less”). All elements may be moved from one location to another, whenever needed. Besides street markings no element will be used for the Slovenska street only. Temporary arrangement comprised of:

- information point (Info point) about new arrangement of the Slovenska street – citizens were invited to give additional proposals for additional installations or improvement of the existing,
- potted groups of trees (wooden pots),
- smaller permanent green plants in pots – pocket parks,
- Tab.s and chairs,

An info point – container in which the exhibition of the projects concerning the new look of the street was prepared together with the exhibition showing the history of the main street. Numerous citizens and other visitors gave their proposals for improvements and compliments. It is important that the citizens were satisfied with new arrangements, using the newly gained space daily. With additional plants (green areas) an effort was taken to improve local environmental conditions and to establish more attractive street ambient. The black-carbon and nitrogen dioxide measurements were performed on-site as well.

Fig. 5.7.10 Temporary installation on the main street (Slovenska ulica) soon after its closure for personal motorized traffic

5.7.4.3 Green gym – gymnastic house with green roof (April 2014)

The prototype of small green gymnastic house with green roof was designed and built. It was designed for adults, to be placed on public playground for children to serve for parents and other adults while their children are playing. The time, usually spent waiting for children on the bench, has changed into the active/healthy recreation and can serve as an example of a good practice for children, as well. The gym-house is placed on recently renewed playing ground in the city centre.

The gym-house was named “Always young” has a base of 6m2 and is about 3m high. It consists of the metal construction that serves as well as a gymnastic object, solid roof planted with extensive growing grass on wooden base reinforced by metal sub-construction. As the installation is placed outside, the rain will be enough for the watering of the roof. In the house a simple construction consisting of three basic gym equipment suiTab. for both genders and ages are available. The gym house is funded on concrete foundation. Within the area of 1,8 m around house, material that buffers falls is spread. On the walls there is a Tab. with instructions how to exercise. As the gym-house is a part of the playground for children it was planned and built in such a way that it meets the standards (the gym-house is certified).


Vabilo
Ob Dnevu zemlje vas vljudno vabimo
na otvoritev prenovljenega otroškega igrišča
na Prulah, na Prijateljevi ulici,
v torek, 22. aprila 2014, ob 16.00 uri.
Tam nas bo pričakalo presenečenje - telovadna hiška z zeleno streho
za telovadbo staršev, babic in dedkov, pa še koga, ki se bo
najmlajšim pridružil pri igri. Pridružite se nam!
Z veseljem bomo delili dobro voljo z vami in z najmlajšimi iz Vrtca Pod Gradom.
VEDNOMLAD
V Ljubljani se vsak dan znova zavedamo pomembnosti varovanja našega planeta, kar z drobnimi in večjimi dejanji tudi uresničujemo. Telovadna hiška z zeleno streho je nastala v okviru evropskega projekta UHI, katerega namen je priprava in uporaba orodja za modeliranje pojava toplotnega otoka v mestu, ki bo služil predvsem načrtovalcem kot izhodišče za umeščanje dodatnih zelenih in vodnih površin v mesto, s ciljem zmanjševanja pregrevanja mestnega središča.
Mestna občina Ljubljana
CENTRAL EUROPE
UHI
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

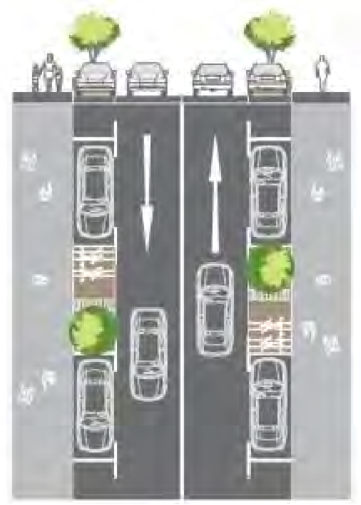
Fig. 5.7.11 Children and parents playground – the gym-installation for parents with the green roof was added to the classical playground for children, with the invitation letter (right)

5.7.4.4 Pocket-parks in the streets with parking places on both sides (April 2014)

Pocket parks are representing the long-term cultivation of public-spaces. With these installations we are trying to develop a method for revitalization and remediation of degraded spaces in the built part of the city centre. The interventions are not only artistic installations but also a serious search of new urban possibiliries for better use of urban spaces. The main objective is to pay special attention and to reveal selected city areas.

Pocket-parks are a kind of containers with the dimensions of a single parking place (car) that can play a certain role, with its planted part, to mitigate the UHI phenomenon on the micro-scale within the densely built area in the city centre.

Since May this year on four streets and one square it is possible to enjoy on one of the pocket-parks, called PARKplac (PARKplace). They are equipped according to the reuse concept. Local inhabitants and local merchants will take care about them. With these installations we are addressing the citizens to the new approach to the public space and spreading the 3R idea (Reduce, Reuse, Recycle). According to the 3R approach all materials that are used were taken from past installations.



5.7.4.5 Planting trees (April 2014)

By planting trees we are trying to increase the quantity of green areas in the city. Trees have been planted on three locations according to the standard SIST DIN 18916.

Near the Nove Fužine block-settlement the new park "Art Labyrinth" was planted. The Art labyrinth is bringing together the park as a green public area with the labyrinth art tradition, artistic approach and literature (book reading). The park is a kind of growing and development feature as it grows with its visitors. The more care that it is being given and the more trees that are planted, the bigger is the place where we can rest in peace and read a good book.

5.7.4.6 Promotion of the project

On different occasions the UHI project was promoted (opening the pilot installations). One of them was also the project "For the cleaner city" that was taking place through the whole city area from 22. March to 22. April, 2014.

The project was promoted by the lectures about UHI phenomenon, public polls considering the pilot actions and general opinion on climate change, delivering the UHI gadgets and leaflets, see Fig.s below.

5.7.5. Conclusions

Alenka Loose,
Energy manager of the City of Ljubljana, Adamič-Lundrovo nabrežje 2, 1000 Ljubljana

dr. Blaž Komac, Anton Melik
Geographical institute ZRC SAZU, Novi trg 2, 1000 Ljubljana

The urban heat island project gave us a comprehensive scientific insight in the phenomenon, useful tools and instructions for adaptation and mitigation of urban heat island effects. At the same time it was proved that our efforts in the past were successful preserving the important green areas (wedges) and fresh air corridors.

We are satisfied with a big success of the project that can be recognized by the number of people that were involved and mobilized by its activities.

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5.8 Pilot Action In Budapest

Baranka, Gy.[1], Ongjerth, R[2]., Szkordikisz, F[2] and Kocsis, O[2]

[1]Hungarian Meteorological Service
[2]Hungarian Urban Knowledge Centre Non-Profit Ltd

Abstract Pilot area chosen for evaluation is one of the biggest green investments of the latest 30 years: the area of this public park is 3.5 ha cost 500 million HUF. 2000 m^2 water surface is 1.2 m deep. Rehabilitation of Millenáris Park including reconstructions of main building and establishment of a public park costs 15 billions HUF. This is one of the intervention areas of local government (District II) in Budapest. Municipality has determined boarders of pilot area. Pilot area contains brownfield area, street canyon, public park, which were rehabilitated in the past and there is a big building, which will be destroyed in the future. Surface of the area is 0.48 km^2. Local meteorological measurements are continuously available to characterize changing in microclimate of pilot action. Urban planners, experts of green roof planning were involved in choosing pilot area for the UHI assessment.

Keywords Pilot action, ENVI-MET simulation, human comfort, mitigation and adaptation strategies, green roofs, green facades, single row of street trees, double row of street trees, planters, heat waves alert system

5.8.1 Planning Framework

Legal foundations of urban planning

In urban planning even the smallest municipalities (local government) have wide discretionary powers. Their planning decisions may be annulled only in cases of breaking the law (central state act or a government statute). Legal control of local plans is performed by the State Government Offices in each of the 19 Counties. The control in specific professional fields is exercised by 9 State Chief Architects with regional competencies. In cases of disputes the final authority is the Constitutional Court. Therefore, Hungarian urban planning is deeply embedded in codified law. The base of urban planning law (Act on the Formation and Protection of the Built Environment) was adopted by the Hungarian Parliament in 1997, after a seven year period of preparatory work. It was modelled on the German law (Baugesetzbuch). The Act was supplemented in the same year by a central government statute, the National Building Code (OTÉK). Besides the National Building Code some other governmental edicts give orders regarding the detailed contents of the particular plans. The Code is binding on all local planning decisions, but municipalities are permitted to render its maximum/minimum standards more "rigorous". The 1997 Act introduced four planning tools, namely:

- Urban-planning development strategy
- Urban Development Concept
- Structure Plan (preparatory land use plan)
- Regulatory Plan (binding land use plan)
- Local Building Code.
- the Action plan is though not part of the edict, but it is used quite often, if needed. (The action plan is a mide-term operational plan concerning to a particular part of a given territory.

The first two tools are adopted by the local authorities through a local government decision (e.g. they are "only" binding on the local government and it's organisations), the other two are adopted through a local government statute (i.e. they are binding for all concerned – e.g. property owners and developers).

Planning decisions are enforced by the Building Authorities functioning as departments of local government offices in cities and bigger villages. For some building affairs (i.e. heritage buildings, heritage areas, Natura 2000 districts) other state agencies function as first level building authorities and their full consent is needed for the issuing a building permit. As in the case of planning legislation, none of these authorities and agencies has discretionary powers, but operate in terms of the platform of law administered and enforced by them. The second level building authority – the place for appeals against decisions – operates within the State Government Offices in each County.

Growing environmental complexity of urban planning in Hungary

While the permitted regulatory content of urban physical building plans in Hungary is rather limited, another important trend facilitates their complexity. Most state agencies, representing specific professional fields look at local physical plans as "omnipotent" tools for the assertion of their interests. That is why a great – and growing – number of so called "supporting studies" should be worked out as part of a local plan.

These include:

- the protection of local historic and architectural heritage (including archaeology),
- environmental protection and control
- landscape and nature protection (including Natura 2000 areas)
- generation and management of local traffic
- development of public utilities
- rain water management.

These studies should be part of the non-binding Structure Plan, thus enhancing the complexity, specifically the environmental foundations of local planning. However, the 27 State agencies find it rather problematic to formulate clear-cut and legally sound regulations in these fields in Regulatory plans and in local building codes. It is also noteworthy that no social or housing studies are prescribed by law as "supporting studies". Social planning has never been strong in Hungary while environmentalists are gaining ground here as everywhere in the world.

5.8.2 The UHI Project and the Planning of the Pilot Area

Climate-conscious urban planning, especially that of public spaces, has little history in Hungary. Although Hungary's Environmental Law requires that each settlement prepare a program for the protection of the environment, these documents tend to be either overly theoretical studies or summaries of the initiatives of local non-governmental organisations. In urban planning documents, climate consciousness manifests itself mostly in the parroting of well-known slogans, without any concrete practical suggestions.

This situation – found not only in Hungary – is what the UHI Project wished to remedy: Relying on several years' worth of research identifying and evaluating factors that influence climate, and inviting the contribution of external partners, we tested the effects that climate-related factors of urban development had on a pilot area. Background support for the experiment was provided by a computer program called ENVI-MET, which, based on knowledge of the existing situation, is able to use several dozen climatic variables to calculate changes that would occur if the plans were realised.

5.8.3 Description of the Pilot Area

The Budapest pilot area lies on the Buda side of the city: an area of approximately 50 ha, bordered by Margit körút – Retek utca – Fillér utca – Garas utca – Alvinci út – Kapor utca – Felvinci út – Ribáry utca – Bimbó út – Keleti Károly utca. The pilot area fits the nature of the experiment rather well, from several points of view, since it is a rather multifaceted area. In terms of neighbourhood character, it is located at the meeting point of traditional high-density urban cores characteristic of the end of the 19th century; rather dense, quasi-urban areas along Margit körút, built in the 1930s and 1940s, with larger, green yards; and a high-prestige green belt with villas. The area is centred around a brownfield regeneration project, which used to be the site of an earlier turbine factory but which in the early 2000s gave way, with a complete change of its functions, to a recreational and cultural centre, retaining and utilising some of the earlier industrial structures and incorporating them into a public park. Another characteristic example of green space in the area is a park called Mechwart liget, which was renewed during the last few years, keeping intact its proportion of green space. The area also comprises several streets, such as Retek utca and Kis Rókus utca, which, along with Keleti Károly utca, provide typical examples of city canyons, with practically no trees.

Thus climate-conscious replanning of the area will offer, on the one hand, an opportunity for computer modelling that can project climatic conditions for a relatively diverse set of spaces, and, on the other hand, a potential starting point for the examination and analysis of many other modelling regions.

In addition, both the method of analysing data from the modelling regions and the content of the action plan can help to provide a framework for elected representatives in the local government of the targeted Budapest district to conduct informed discussions on the subject. The material may also provide ideas for the climate-conscious construction of projects for the new EU planning period.

5.8.4 Methodology – the Tools

The methods applied within the UHI Project are not new to public space planning: it is well known both in and outside professional circles that vegetation, for example, cools the environment through evapotranspiration; and these methods represent the primary tools employed in the redevelopment of outdoor public spaces in general. The novelty of the project – which is hopefully of revolutionary significance – lies in its ability to predict and calculate reliably the climatic effects of the tools employed, as well as the possibility to distribute these tools widely. Unfortunately, in Hungary – as in several other European countries – with the increase of solid paved surfaces, the currently fashionable trends in planning open public spaces often not only fail to improve but actually contribute to the deterioration of climatic conditions in the redeveloped areas, yet this effect is difficult to estimate in practice without reliable quantifiable methods. The methods tested within the UHI Project, designed to be made readily available for wide circulation, are expected to help specialists in organisations responsible for the regeneration of public spaces in accepting only commissioned plans that improve, rather than deteriorate, climatic conditions; otherwise visitors using public spaces will have a less comforTab. experience in the summer, and even though there might be temporary stop-gap measures taken, such as the installation of mist cooling gates, the new public spaces will be used less often than the old ones were.

Within the pilot area, the planners of the Budapest modelling regions used the following tools provided by the climate specialists of UHI:

- Single Row of Street Trees
- Double Row of Street Trees
- Planters
- Green Spaces
- Permeable Pavement
- Green Walls - Vertical Gardens
- Green Roofs

5.8.5 Suggestions for Application of the Tools

Open Space Characteristics of the Pilot Area

Rows of street trees appear only sporadically within the area (for example, in Lövőház utca, Bimbó út, Marczibányi tér, Fillér utca, Felvinci út, Kapor utca, Kitaibel Pál utca, Tizedes utca, Ribáry utca), and public green spaces or vegetation are present only to a minimal extent (Fillér utca).

The rows often have trees missing; there are single and double rows of street trees in the area (featuring Fraxinus, Koelreuteria, Acer, Robinia ssp.); and there are two areas of significant dimensions which also include water surfaces: Millenáris Park (3.5 ha) and Mechwart liget (1.8 ha).

Examples of permeable surfaces in the area are negligible; apart from isolated examples (such as Lövőház utca, Káplár utca, or Keleti Károly utca), the dominant surface is asphalt, on both the roads and the sidewalks.

Action Plan and the Tools Employed

Rows of Street Trees in Public Spaces

Main effects: shading; reducing the air and surface temperature; evapotranspiration; windbreaks; protection from UV rays; and reducing air pollution and greenhouse gas emission.

Street trees may be planted depending on the types of buildings, the forms of facades and streets, and the cross-section of the street; in many cases the dimensions of the sidewalk and parking lane will not allow for any green spaces other than rows of trees. Single or double rows may be planned (Fig.1 and Fig. 2).

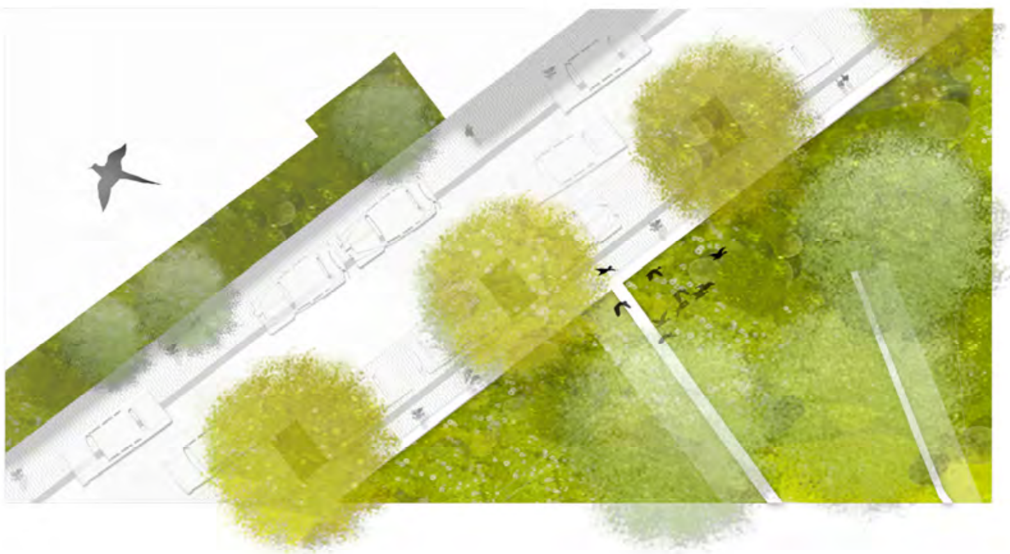


Fig. 5.8.1 Single row of trees ont he pilot area

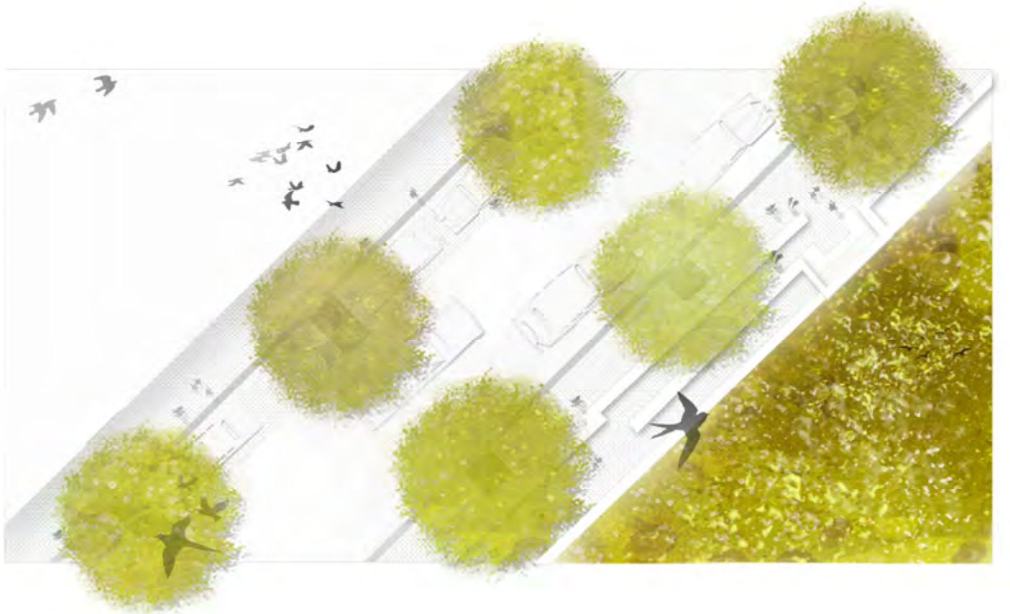


Fig. 5.8.2 Double row of trees

Street trees recommended for the area: a single row of Tilia x euchlora (15-20 m) in Keleti Károly utca; a single row of Fraxinus excelsior 'Jaspidea' (10-15 m, yellow-leaf variety) in Mechwart tér and Fillér utca and a double row in Fény utca (Fig. 5.8.3); a single row of Gleditsia triacanthos 'Sunburst' (10-15 m, yellow-leaf variety) in Buday László utca; a single row of Fraxinus excelsior 'Westhof's Glorie' (20-25 m) in Garas utca; a single row of Koelreuteria paniculata (5-8 m) in Ezredes utca and Pengő utca (Fig. 4); and a single row of Acer platanoides 'Emerald Queen' (10-15 m, yellow-leaf variety) in Retek utca.

Fig. 5.8.3 Double row of trees in Fény utca

Fig. 5.8.4 Single row of trees in Pengő utca with permeable pavement and tree protection

On occasion, rows of street trees will be planted in combination with parking, at an appropriate distance from the building facades, taking into account the relatively narrow cross-section of the street – 10-11 m between facades – and the expected growth of the canopy. Based on these considerations, we recommend planting individual trees every 11.5 m, replacing every other parking space.

To protect each individual tree, a Corten Steel tree hole is provided, with a base of at least 1.5 m x 1.5 m (when combined with parking, the base will be of 1.5 m x 2.3 m) and with a fully accessible finished surface. The species and types recommended are drought-tolerant, pollution-tolerant and at least relatively quick-growth. For planting in streets with more shade, the high-tolerance species of Koelreuteria paniculata is recommended.

Planters

Planters may bring green spaces to streets that cannot accommodate trees.

In combination with rows of street trees, planters produce multi-zone vegetation (Fig. 5.8.5), but this solution is recommended only if the width of the sidewalk is at least 1.5-2 m – green surfaces that are too narrow can cause maintenance problems – and if parking allows enough space (that is, the parking lane is at least 2.5 m wide).

Fig. 5.8.5 Planters combined with rows of street trees

It is necessary to raise the level of the planters 50-60 cm from the surface of the sidewalk, because of their use within the city – litter, snow shovelling in the winter, salt, pedestrian traffic, dog walking, etc. - in order to ensure a longer lifetime for the vegetation.

Recommended locations: in the middle section of Fény utca, on both sides, with widths of 2.3 m and 2 m, respectively; in the southern section of Fillér utca, on one side, with a width of 1 m; and in the middle section of Bimbó út, on one side, with a width of 1.5 m (Fig. 5.8.6).

Fig. 5.8.6 Planters in Bimbó street

In terms of species and types to plant, low shrubs, perennials and grasses are preferable.

Species and types recommended for planting in full/partial sun: Helictotrichon ssp., Panicum ssp., Carex ssp., Calemagrostis ssp., Yucca ssp., Lavandula ssp., Rosmarinus ssp. For containers interspersed with rows of street trees, shade tolerant species and types are recommended: Carex ssp. (C. morrowii, C. sylvatica, C. oshimensis etc.), Deschampsia ssp., Hakonechloa ssp., Phalaris ssp., Vinca ssp.

Green Spaces

Contiguous green spaces greatly contribute to decreased storm water runoff within inner city areas, and, due to the significant presence of ligneous plants, have advantages similar to those of planting rows of street trees. The plan recommends the installation of new green spaces: a public park in the area bordered by Margit-körút - Kis Rókus utca - Fény utca, adjacent to Millenáris, which is to be called "Széllkapu Park" - a pun on the neighbouring public transport hub called Széll Kálmán tér and the Hungarian words szél (’wind’) and kapu (‘gate’); at the corner of Fillér utca and Garas utca (see Fig. 7); and in the inside courtyards of buildings Fillér utca 9-11 and Lövőház utca 24, 22, 20 and 16b.

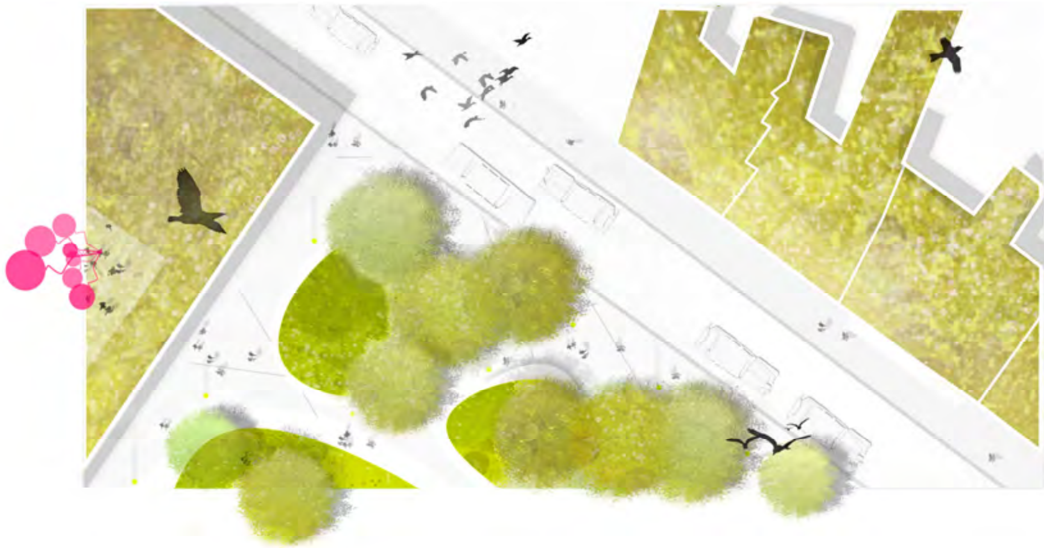


Fig. 5.8.7 Green spaces in Széllkapu Park

These planned green spaces are characterised by multi-zone vegetation; the species and types recommended for planting in the Széllkapu area are similar to those planted in Millenáris (Fig. 5.8.8). Within green spaces, permeable pavement may be applied in areas paved for foot and service traffic: gravel, concrete tiles and light natural stone, such as limestone.

Fi

Fig. 5.8.8 View of Széllkapu Park

Permeable Pavement

Permeable pavement is applied to decrease storm water runoff and desiccated soil in the city, thereby increasing evaporation even on paved surfaces.

Recommended locations: replacing older pavement on sidewalks (except for Lövőház utca, Káplár utca and Keleti Károly utca), and in parking lanes. As for the choice of materials, an important consideration is the use of light colours for a higher albedo, instead of dark, waterproof asphalt. For sidewalks, mostly used for foot traffic, the use of concrete tiles is recommended, while for areas of heavy use (surfaces in new green spaces) natural stone – limestone – is suggested.

For the installation, permeable pointing and foundation work must be applied.

Green Walls – Vertical Gardens

The use of green walls or vertical gardens contributes to the shading of walls, thereby lowering the surface temperature of wall facades, reducing heat gain and lowering energy use inside buildings, as well as cooling through evapotranspiration.

Green walls or vertical gardens are best used in locations where the width of the street does not allow for the placement of any other vegetation. Recommended locations: Kis Rókus utca 35, 18 (Fig. 9); Fény utca 21 (on the facade of the Melegpörgető building). Species and types of plants recommended: Parthenocissus ssp., Vitis ssp., Hedera ssp., Reynourtia ssp.

Fig. 5.8.9 Green wall in Kis Rókus utca

Green Roofs

Using green roofs (Fig. 5.8.10) helps in retaining water and shading roofs; via evaporation, in reducing the surface temperature of roofs; in reducing air temperatures and cooling the city; in reducing heat gain and lowering energy use inside buildings; and in storing storm water within the substrate as well as evaporating it to the atmosphere.

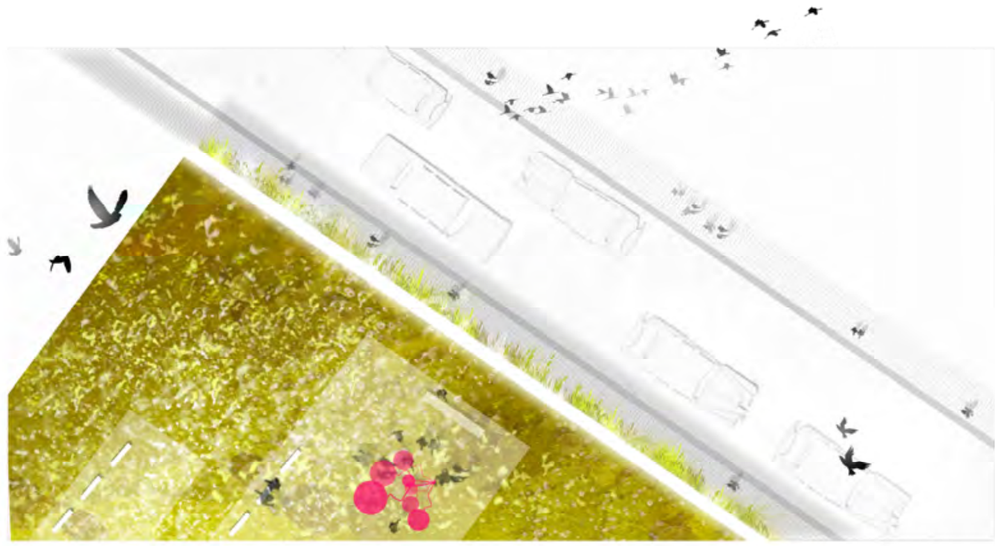


Fig. 5.8.10 Green roof within the pilot area

Extensive green roofs – with a 5-10 cm soil bed – do not require watering and are low maintenance in general.

In the effort to encourage the installation of extensive green roofs, local authorities have a range of possibilities to intervene, depending on the ownership of the property: for buildings belonging to the local government, the local authorities themselves have full control over modifications, while in the case of buildings owned by other legal entities – such as the state government or private companies – the local authorities may initiate the process or, in the case of buildings owned by private citizens (condominiums, for example), may offer financial support as part of the preferred solution. Recommended locations:

Green roofs on buildings owned by local government: Marczibányi tér 5a, 13, etc.;

Green roofs on buildings owned by other legal entities: Tulipán utca 24, Marczibányi tér 3, Kis Rókus utca 18, 16, 14, 12, 2, 4, 6, Lövőház utca 1-6, 12, 14, Fényes Elek utca 7-13, 14-18, etc.;

Green roofs on buildings with multiple private owners: Kis Rókus utca 33-31 (Fig. 10), 1-1a-3-5-7, etc.

Species and types of plants recommended: Sedum ssp., Euphorbia ssp., Delosperma ssp., Thymus ssp.

5.8.6 Effects of Interventions on the Local Climate

Characteristics of the Local Climate

The microclimate of the pilot area is influenced by several factors. On the one hand, the prevailing north by north-westerly winds arrive from the direction of Hűvösvölgy, while on the other hand the terrain plays a significant role in the formation of the microclimate of the area, which lies on the south-western slopes of Rózsadomb, reaching down to Margit körút. In addition, larger buildings have a significant impact, especially in narrow streets with high facades, such as Lövőház utca, which, moreover, runs parallel to the prevailing winds, making it the most significant city canyon of the area. It is also important to mention that, as is true for District II as a whole, the pilot area is also quite well endowed with urban trees. Yet the state of the trees and, on occasion, run-down conditions in general offer sufficient justification for the regeneration of the area.

Description of the ENVI-MET model

In order to examine the effects on the microclimate created by the most important interventions planned in the area, a microclimate-modelling project was undertaken using ENVI-MET modelling software. Since the entire area would have been too extensive to model, three representative regions were selected, as shown by the map in Fig. 5.8.11.

Fig. 5.8.11 Layout of modelling regions within the pilot area

For modelling microclimates, 4 m x 4 m cells were used throughout. The direction of the wind was defined as north-westerly; wind speed at the elevation of 10 m was defined as 3 m/s. Simulations were started on a typical summer day at 9 p.m.; the period of simulation was 24 hours. Initial air temperature was set to 23°C; relative humidity at the elevation of 2 m was set to 70%. For each selected region the model was projected in two versions: the first one represented the original situation, while the second one represented the planned situation.

Evaluation of the Simulation Results

Below, the effects of the intervention tools described in the previous section will be summarised briefly.

Rows of Street Trees: Planting single and double rows of street trees results in decreases local to each tree, both in terms of mean radiant temperature (MRT) and in terms of predicted mean vote (PMV). With expansion of the canopy of the trees, or by planting trees closer together, the distribution of these decreases tends to become more linear.

As is shown by Fig.s 5.8.12-5.8.15, rows of street trees typically reduce predicted mean vote (PMV) value by 2, occasionally by 3. In our case this means that while in the initial situation 80% of pedestrians on the sidewalk feel uncomforTab., after trees are planted this ratio is reduced to 10-30%.

Planters: In isolation, planters have little effect on the microclimate; however, they exercise an undeniably positive effect on the streetscape and on the psychological well-being of the population. In Bimbó út, planters appear in combination with rows of street trees; here their effects cannot be clearly distinguished from the microclimatic effects of the trees, and, therefore, far-reaching conclusions cannot be drawn concerning their effectiveness.

Permeable Pavement: Permeable pavement cannot be modelled using the ENVI-MET program, thus its effects can only be estimated based on descriptive studies. It is well known, however, that, depending on the base layer, permeable pavement is typically able to retain 35-60% of the water. This has several advantages. Due to its porosity and absorbance, it warms more slowly and cools more quickly than traditional pavement surfaces and, therefore, has a positive effect on the microclimate. It decreases storm water runoff, thus allowing water to reach the trees along the street, and helps replenish the water Tab.. Using permeable pavement therefore addresses two important problems of urban heat islands: it improves the radiation and water balances.

Green Walls – Vertical Gardens: For the scale of the modelling regions, the planned green walls and vertical gardens could not be modelled; earlier research shows, however, that green walls – vertical gardens that are nearly parallel to the direction of the prevailing winds significantly decrease mean radiant temperature (MRT) and predicted mean vote (PMV) values in their immediate surroundings.

Green Roofs: The effects of the planned green roofs are rather complex, and, therefore, difficult to model. Green roofs not only decrease the intensity of urban heat islands but also decrease storm water runoff, thus also reducing the amount of greywater to be treated. They also play a significant role in improving the quality of life for people working or living in the buildings by offering a natural area for relaxation and recreation.

Green Spaces: Within the pilot area, there are two significant public green spaces, Millenáris Park and Mechwart liget, where no changes were recommended. The model did, however, examine the effect of a new green space: the new park, to be created at the site of a soon-to-be-demolished ministry building, which will significantly increase the green spaces of Millenáris Park. The disappearance of the ministry block and the creation of the new green space will decrease air temperatures by 1.5-2.5°C, according to the microclimate modelling results (Fig. 5.8.16-5.8.17).

In summary, it can be stated that within the modelled regions the microclimate – following the localised nature of the intervention – improves in discrete areas due to the proportionate increase of green spaces: cross-ventilation improves, relative humidity increases, mean radiant temperature (MRT) significantly decreases and, in cases of drastic intervention, air temperatures also show significant decreases.

ENVI-MET Simulation Results

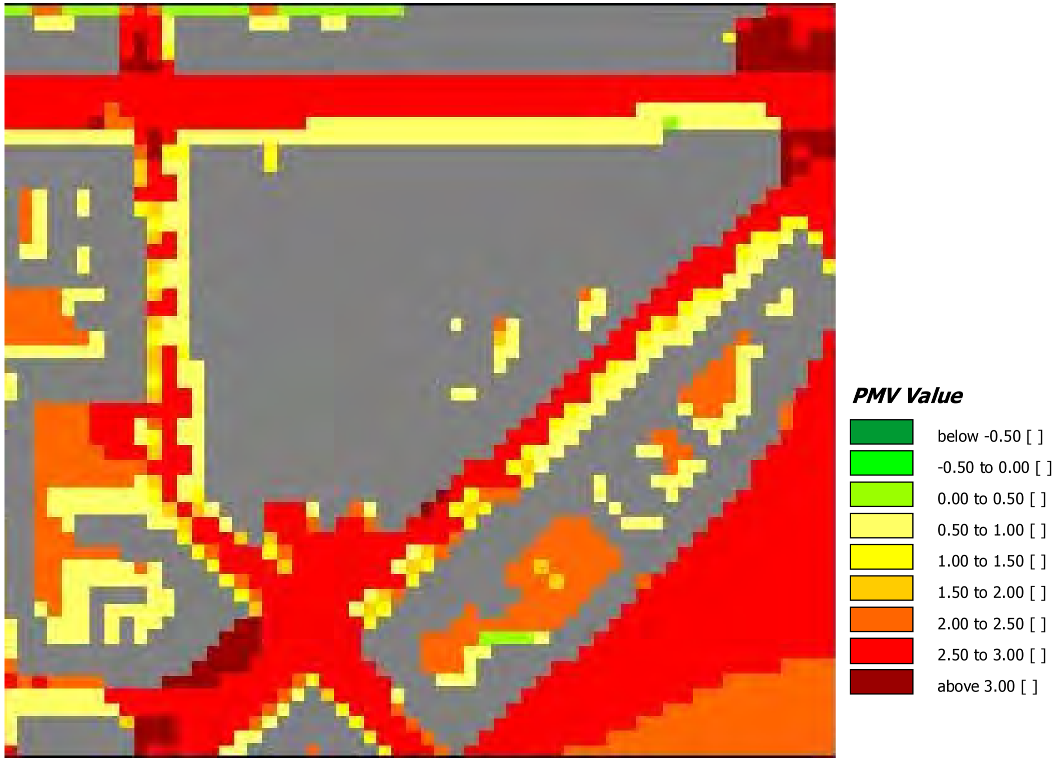


Fig.s 5.8.12-5.8.13 Effects of single and double rows of street trees on predicted mean vote (PMV) in Fény utca and Retek utca (summer status, 12:00 p.m., 1.6 m)

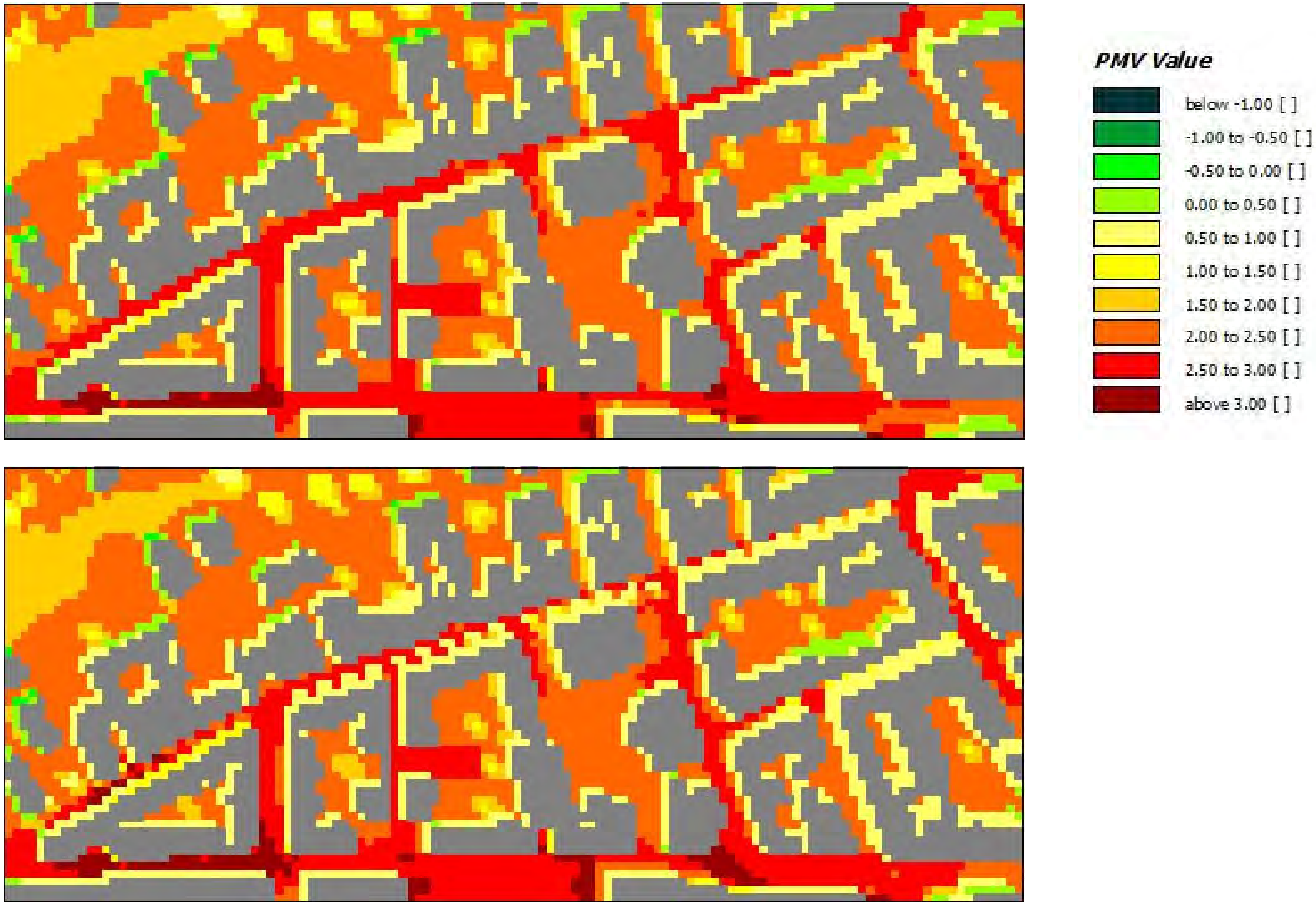


Fig.s 5.8.14-5.8.15 Effects of rows of street trees on predicted mean vote (PMV) in Keleti Károly utca (summer status, 12:00 p.m., 1.6 m)

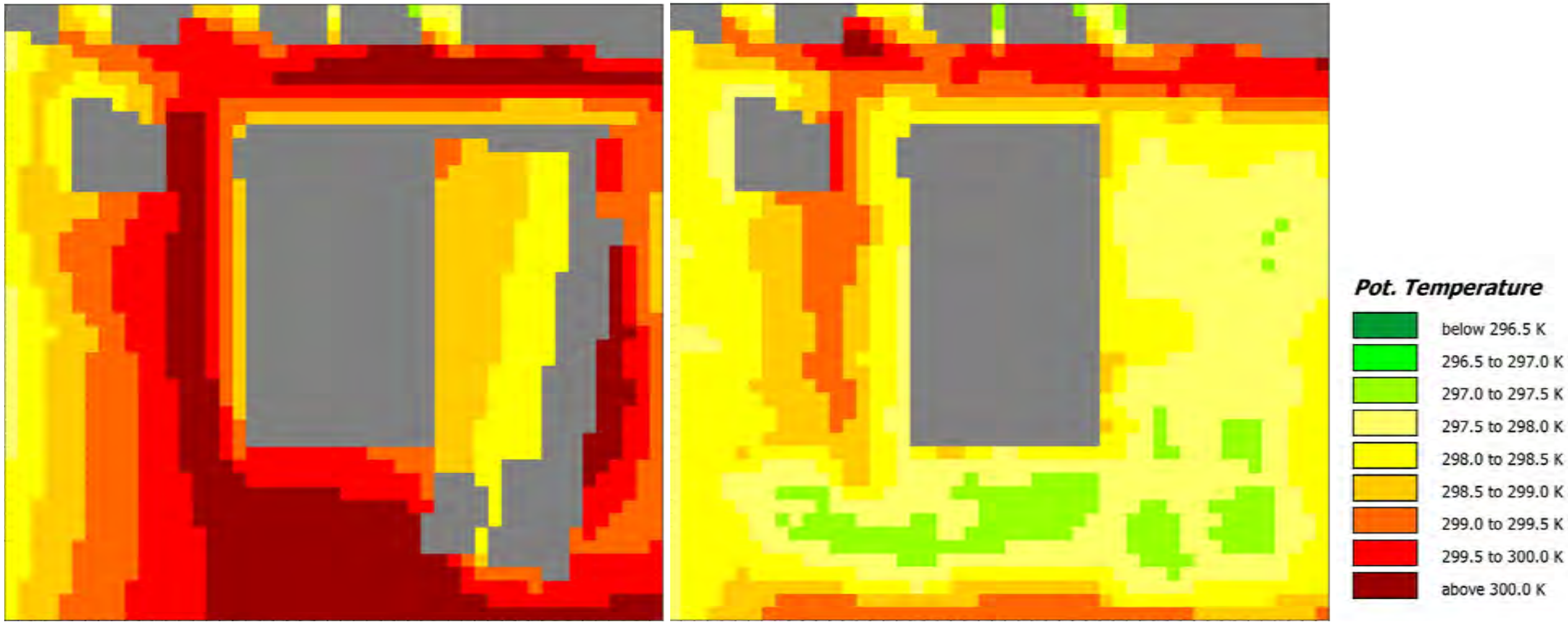


Fig.s 5.8.16-5.8. 17 Area of Széllkapu Park: status before (left) and after (right) the demolition of the ministry building and the installation of the planned park (air temperature, summer status, 12:00 p.m., 1.6 m)

Suggestions Concerning Organisation and Logistics

For the realisation of climate-conscious development of the area, the suggested solutions are similar to traditional solutions, undertaken in such a way that the role of the local government is in harmony with existing tools on the one hand and with the ownership relations of the properties to be developed or regenerated on the other, with special attention to properties owned by the local government.

Due to the diversity in ownership, interests and abilities, it cannot be hoped that the suggested plans could be realised in their entirety in one, well organised initiative, in a short period of time - yet most elements of the plan could indeed be carried out in such fashion, while a smaller proportion of the plans could be realised as – preferably coordinated – individual actions carried out by the other parties but initiated, and on occasion supported, by the local authorities.

For the preparation and organisation of tasks, especially those to be carried out by the local authorities, the relevant local government body responsible for urban development and planning should be appointed as coordinator – who will, then, invite the contributions of other parties, such as planners and constructors, as necessary.

As for the timing of individual tasks, priority should be given to properties owned by the local authorities, to tasks that can be carried out within the jurisdiction of the local authorities, primarily to public spaces that could serve as direct examples, such as green roofs on buildings of institutions controlled by the local authorities. An equally important recommendation is the simultaneous commencement of negotiations with the property managers of national institutions, to invite them to participate in the program and to help realise climate-conscious redevelopment for elements of their buildings. The installation of a green wall or vertical garden on the Kis Rókus utca facade of the buildings in Millenáris Park may have a special position in this respect, as the soil in which the vegetation is planted is in a public space owned by the local authorities, while the vegetation climbs on the walls of a building under national ownership. Here a special agreement will be necessary between parties concerning maintenance, the recommended solution being that the local government take responsibility for planting and watering the plants.

The inclusion of local businesses and condominiums in the program requires yet another set of solutions. In both cases the recommended procedure would be for the local government to invite owners to participate in the program, and to explain in the course of preparatory negotiations how advantages and savings will accrue as a result. In addition, for businesses, PR-based incentives might be introduced (such as the establishment of the title 'Climate-Conscious Business of the Year'), while for condominiums a system of financial support might be successful.

Cost Estimate and Suggestions for Financing

Costs and sources of funds for realising the climate-conscious urban development action plan are estimated below. The sums presented are to be viewed as an order-of-magnitude estimate and relate primarily to the establishment of cost ratios, intended to help make decisions about subsequent steps and actions.

Rows of Street Trees
Individual trees

Keleti Károly utca: Tilia x euchlora (15-20 m) single row
45 @ 50,000 HUF, total: 2,250,000 HUF
Mechwart tér: Fraxinus excelsior 'Jaspidea' (10-15 m, yellow-leaf variety) single row
22 @ 25,000 HUF, total: 550,000 HUF
Fillér utca: Fraxinus excelsior 'Jaspidea' (10-15 m, yellow-leaf variety) single row
38 @ 25,000 HUF, total: 950,000 HUF
Fény utca: Fraxinus excelsior 'Jaspidea' (10-15 m, yellow-leaf variety) double row
28 @ 25,000 HUF, total: 700,000 HUF
Buday László utca: Gleditsia triacanthos 'Sunburst' (10-15 m, yellow-leaf variety) single row
10 @ 20,000 HUF, total: 200,000 HUF
Garas utca: Fraxinus excelsior 'Westhof's Glorie' (20-25 m) single row
17 @ 50,000 HUF, total: 850,000 HUF
Ezredes utca: Koelreuteria paniculata (5-8 m) single row
14 @ 20,000 HUF, total: 280,000 HUF
Pengő utca: Koelreuteria paniculata (5-8 m) single row
14 @ 20,000 HUF, total: 280,000 HUF
Retek utca: Acer platanoides 'Emerald Queen' (10-15 m, yellow-leaf variety) single row
14 @ 20,000 HUF, total: 280,000 HUF

Trees total: 6,340,000 HUF + 27 % VAT = 8,000,000 HUF

Tree hole grilles
202 @ 200,000 HUF, total: 40,400,000 HUF

Rows of street trees, total: 48,400,000 HUF

Planters
Fény utca: 2 m wide, on both sides
200 m^2 @ 20,000 HUF, total: 4,000,000 HUF
Fillér utca: 1 m wide, on one side
70 m^2 @ 20,000 HUF, total: 1,400,000 HUF
Bimbó út, 1.5 m wide, on one side
270 m^2 @ 20,000 HUF, total: 5,400,000 HUF
Plants, planters, total: 10,800,000 HUF
Green Spaces

SzéllKapu area
12,000 m^2 @ 20,000 HUF, total: 240,000,000 HUF
Green spaces, total: 240,000,000 HUF
Permeable Pavement
Total of 5 km pavement, on average 3.5 m wide
5,000 lm @ 50,000 HUF, total: 250,000,000 HUF
Permeable pavement, total: 250,000,000 HUF
Green Walls – Vertical Gardens
Trellises
1100 m^2 @ 5,000,000 HUF, total: 5,500,000 HUF
Plants
110 lm @ 5,000 HUF, total: 550,000 HUF
Green walls – vertical gardens, total: 6,050,000 HUF
Green Roofs
On buildings owned by local government
3,900 m^2 @ 15,000 HUF, total: 58,500,000 HUF
On buildings owned by other legal entities
26,000 m^2 @ 15,000 HUF, total: 390,000,000 HUF
On buildings with multiple private owners
21,000 m^2 @ 15,000 HUF, total: 315,000,000 HUF
Green roofs, total: 763,500,000 HUF
Reconstruction of Public Utilities
In streets with rows of trees, organised in tandem with the introduction of district heating, in cooperation with FŐTÁV, the Budapest district heating agency
5 km @ 400,000,000 HUF, total: 2,000,000,000 HUF
Complete reconstruction of public utilities in affected streets, total: 2,000,000,000 HUF

Climate-conscious regeneration of complete area, sum total: 3,318,750,000 HUF

Costs to be paid directly by local government: 613,750,000 HUF

Costs to be paid by local government without the relatively low-benefit yet high-cost permeable pavement: 363,750,000 HUF

Costs of climatically most efficient and also most spectacular investment (street trees and planters), which are within the jurisdiction of local authorities: 59,200,000 HUF

A fundamental prerequisite for planting rows of street trees, however, is coming to a satisfactory arrangement with public utilities. Planting may be coordinated with complete upgrades carried out by the utility companies, or with the installation of a significant new type of utility – such as district heating – which necessitates the relocation of underground utility installations. It is therefore recommended that preliminary negotiations be conducted with utility companies, primarily with the representatives of FŐTÁV Zrt, the Budapest district heating agency, concerning the submission of an EU pilot project, such as Horizont 2020.

5.8.7 Action Plan for Local Governments in Heatwave Alert Situations

The following legal regulations apply, and should be considered, before raising a heat alert:

Act LXXII of 2012 on the Amendment of Act CXXVIII of 2011 Concerning Disaster Management and Amending Certain Related Acts;

Decree of the Minister of the Interior No. 61/2012. (XII. 11.) on the Disaster Management Categorisation of Municipalities, and on the Amendment of the Decree of the Minister of the Interior No. 62/2011. (XII. 29.) on Certain Rules of Disaster Management.

Act LXXXII of 1995 on the Promulgation of the UN Framework Convention on Climate Change;

Act CXXIX of 2000 on the Amendment of Act LIII of 1995 on the General Rules of Environmental Protection;

Act XV of 2005 on Greenhouse Gas Emission Allowance Trading; and 213/2006 (X. 27.) Governmental Decree Implementing Act XV of 2005 on Greenhouse Gas Emission Allowance Trading;

Act LX of 2007 on the implementation framework of the UN Framework Convention on Climate Change and the Kyoto Protocol thereof; and The National Climate Change Strategy (NCCS), which was based on the act on the implementation framework of the Kyoto Protocol;

"Adapting to Climate Change in Europe" European Commission Green Paper, June 2007;

Act XXXVII of 1996 on Civil Protection;

Act LXXIV of 1999 on Disaster Management (direction and structure of protection against disasters and the protection against major accidents involving hazardous materials);

Within the system of civil protection planning, the 'Decree of the Minister of the Interior No. 20/1998. (IV. 10.) on the System and Requirements of Civil Protection Planning' classifies the types of hazards that necessitate planning;

The Fundamental Law of Hungary (25 April 2011).

Due to climate change caused by global warming, extreme weather incidents have occurred in Hungary with increasing frequency; summer heatwaves, lasting for several weeks, are particularly stressful for the population. In Hungary, disaster management is conducted within a strict legal framework; the tasks of local authorities are specified in Act CXXVIII of 2011 on Disaster Management and Amending Certain Related Acts.

The steps for preparing for longer heatwaves, along with special points for consideration, will be detailed below. The European Commission Green Paper, June 2007, draws attention to, among other things, the dangers posed by heat to human health; thus, it is extremely important to prepare an action plan to protect the population during heat alerts.

There are several groups within the population of Hungary that are especially at risk. The age distribution of the population categorizes Hungary as an ageing society. A significant proportion of people performing manual labour are outdoors in the summer during heatwaves, for extended periods of time or all of the time. Summer is also the period for open air events, with cultural and sports events attracting large numbers of participants. Special attention must be paid to minimizing health risks for participants in these programs. Employers must seek to protect the health of employees working outdoors; during heatwaves, they must provide for their employees ample drinking water, periods of rest in shady areas, appropriate working clothes and protective gear.

From the point of view of the environment and of environmental health, special consideration must be given to those utilities and public services that influence positively or negatively the quality of life of the population, as well as the quality of the environment, during heatwaves.

Special protection must be provided for the drinking water infrastructure, particularly strategic reservoirs and water mains, which are maintained by water utilities to provide high-quality drinking water for the population.

In the event of disruptions to electricity service during heatwaves, all customers can be provided with electricity with blackouts averaging 2-3 hours. During longer heatwaves, energy demands may increase, which might require the imposition of limitations on consumption.

Since Hungary is a country along major transit routes, dangers affecting branches of transportation during heatwaves must also be taken into account. A relatively minor disruption in railway services might cause serious delays. In extensive heat, rail lines can be deformed; overhead wires and pylons can be damaged. During a temporary suspension of railway services, railway stations must offer shelter for railway passengers until such time as they can continue their journeys. While these passengers remain stranded, their basic needs must be addressed.

Settlements are often situated near motorways and major transit routes. During periods of continuously high daily average temperatures, the number of accidents may increase in the affected stretches. When congestion builds up following an accident, people sitting in cars will need to be supplied with liquids.

Transit lines run by public transportation companies work continuously on days of high average temperatures as well. Newer vehicles have been equipped with air conditioning, which must be used. On older vehicles, cross ventilation and the use of ventilators must be applied continuously to offer heat protection for the passengers.

During periods of high daily average temperatures, communal waste must be collected more frequently in order to prevent epidemics.

Communicating with the Public

Heatwaves are usually possible to predict, and, therefore, the public must be informed about preventive measures they can take to protect their health. If the local authorities are to issue a warning, attention must be paid to the following considerations: Communication may be effected in writing or as a personal announcement. It may take the form of a press release, a public announcement, a briefing or interactive communication, during which attention must be called to the negative effects of heatwaves on health; the necessity of remaining hydrated; the need to seek shelter in shady places; and the dangers of leaving one's place of residence.

The public must be informed that they should take along some drinking water if they leave their homes. Warnings must be issued about the need to be extra careful and circumspect in traffic. The information issued must always be authenticated; creating a sense of panic must be avoided.

The tasks of the preparatory phase are as follows:

The forecasts and news bulletins of the Hungarian Meteorological Service and the National Public Health and Medical Officer Service (NPHMOS) must be followed.

The public must be informed.

People with severe medical conditions and others at special risk must be identfied.

Reserves of drinking water must be prepared.

Vehicles delivering drinking water must be arranged.

Any available street watering trucks must be pressed into service.

Local institutions with air conditioned buildings that may accommodate large numbers of people must be identified.

The tasks of the protection phase are as follows:

Local authorities must remain in contact with the local offices of NPHMOS and with disaster management authorities.

Communication with the public must be continuous.

Access to public buildings with air conditioning must be arranged.

Shelters must be opened, if necessary.

Drinking water distribution in the busiest centres of the community must be organised.

Major routes and public spaces must be watered down several times a day.

Logistical support, with special attention to the availability of equipment and manpower, must be established and operated continuously.

Stages of heatwave alerts, action items, and the raising of alerts

Level One (Heatwave Advisory)

Criteria: according to forecasts, the daily median temperatures exceed 25°C for at least 1 day

Actions required: Within its own internal system, NPHMOS provides information to its regional and micro-regional institutions. Local authorities will decide whether to inform the public through local media.

Level Two (Stage 1 Alert)

Criteria: according to forecasts, the daily median temperatures exceed 25°C for at least 3 days

Actions required: The Chief Medical Officer will use the institutional network of NPHMOS to inform public health institutions, emergency services, doctors' offices and nurses' stations within the primary healthcare network and local authorities concerning the duration and degree of the heat alert. The task of the local authorities is to inform their own institutions (primarily those providing social services) to warn members of the public to take preparatory measures to protect their health.

Level 3 (Stage 2 Alert)

Criteria: according to forecasts, the daily median temperatures exceed 27°C for at least 3 days

Actions required: The responsible authorities must verify that actions taken at Level 2 for the Stage 1 Alert are maintained. The public must be informed of the Stage 2 Alert through the media and via the local authorities. Protective measures must be initiated by health care institutions, nursing homes, chariTab. institutions, crèches, nursery schools, day care centres, and summer camps.

Rapid alert system for heatwave alerts

The first step is to set up a list of officials authorised to raise, and call off, a heatwave or UV alert. The appropriate level of heatwave or UV alert will be raised, and called off, by the Mayor, based on the alert issued by NPHMOS, the UV index values published by the Red Cross, or both. Based on the weather forecasts made by the Hungarian Meteorological Service, the Chief Medical Officer and NPHMOS will issue a warning. They will send a letter to inform the doctors' offices and nurses' stations of the primary healthcare network and the micro-regional local authorities concerning the duration and stage of the heatwave alert, asking for their cooperation in abiding with the orders issued. The Mayor's Office will issue a warning to the institutions of the rapid alert system, as well as the general public, to take preventive action to protect their health. The Mayor's Office must notify without delay the following institutions concerning the situation that has developed:

Civil Protection Office

Municipal Police Headquarters, Department of Public Order and Safety

Hospitals

National Ambulance Service

Social care institutions and sanatoriums
Local water works
Local energy providers
The Hungarian Labour Inspectorate
Local crèches
Preschools in operation at the time
Day camps and summer camps
The affected population, institutions and organisations, through the local media

Suggestions and important messages for the general public in the event of heatwave alerts	
How to avoid heat	Important comments
Cool your home.	Monitor room temperatures.
Keep the windows closed during the day; use curtains, shutters, or other means of keeping the room dark. Open the windows to air the room at night, if possible. Switch off non-essential electric appliances (even including lights). If you have air conditioning, keep windows and doors closed.	During heatwaves, when external temperatures reach 35-39°C, the ideal indoor temperature is about 28°C. Very cold settings for the air conditioner should be avoided. Electric fans should be used only for short periods of time.
If these measures cannot be taken, spend at least 2-3 hours in air conditioned places.	People can be directed to the list of air conditioned places open to the public, as arranged during the protection phase.
Avoid heavy physical work and stay in the shade during the hottest hours.	
For the next summer, consider cooling your home (“cool” paint, humidifier, green plants).	
Keep your body temperature low and drink plenty of liquids to prevent dehydration.	
Take frequent showers or baths in lukewarm water.	Showers may increase the risk of falling for the elderly.
Use wet bandages and cool your feet in lukewarm water.	
Wear loose garments of light colour and natural materials. If you go out in the sun, wear a large-brimmed hat and sunglasses.	
Drink liquids regularly. Do not drink beverages with alcohol or high sugar content.	During hydration, it is important to replenish lost salt and to avoid water intoxication. Caffeine acts as a diuretic.
If you take medications regularly, ask your doctor about the effect of your medications on your internal fluid balance.	People with elevated body temperatures require special attention.
Monitor your body temperature.	It is important to realise that body temperatures above 38°C are detrimental to one’s health. Heat strokes can occur at body temperatures exceeding

	39°C. Body temperatures above 40°C present a life-threatening situation.
Keep your medications at the appropriate temperature.	If room temperature exceeds 25°C, medications should be kept refrigerated, even if their boxes do not say so.
Contact your doctor if you suffer from a chronic illness or if you take several different medications. If you experience unusual symptoms, contact your doctor immediately.	
Inform yourself about the forms of assistance available.	

Tab. 1. Advice for the general public

Advice for various age demographic groups in the event of heatwave alerts is presented below in Tab.s 2-4 in an easily understandable form, which can be converted to flyers. The colourful, printed flyers with illustrations can help draw attention to the information and reinforce the message.

Tab. 5.8.2 Brief, easily understandable advice for the elderly

Useful advice during heatwaves for the prevention and treatment of heat strokes for the elderly

Those above 68, the disabled, or, especially, those with heart problems or high blood pressure should seek medical help immediately if their symptoms become worse in the heat.	If you have an electric fan, use it in hot weather. During heatwaves, stay home in a darkened room, in a relatively cool place, for the hottest hours of the day, especially around noon or in the early afternoon.
In very hot weather, take frequent showers or baths in lukewarm water.	In hot summer days, do not go to the market during the hottest hours.
WHAT TO DRINK Water, mineral water, tea	WHAT NOT TO DRINK Coffee, alcoholic beverages
Non-carbonated soft drinks	

Tomato juice, curd, kefir, yoghurt	Carbonated beverages with high caffeine and sugar content
Soups	
If you are taking medication for a heart condition, consume sufficient amounts of liquid while taking diuretics, that is, 1 litre per day more on hot days than the usual amount.	

Tab. 5.8.3 Brief, easily understandable advice for young mothers and small children

Useful advice during heatwaves for the prevention and treatment of heat strokes for young mothers and small children

Babies and small children should be taken out for air only in shady places. Do not take babies for walks in extreme	If you have an electric fan, use it in hot weather. If possible, leave windows open at night for ventilation.

heat.	
Never leave children or animals (dogs) in locked, unventilated, parked cars.	Protect yourself and your child by wearing wide-brimmed hats and sunglasses.
WHAT TO DRINK Water, mineral water, tea	WHAT NOT TO DRINK Coffee, alcoholic beverages
Non-carbonated soft drinks	
Tomato juice, curd, kefir, yoghurt	Carbonated beverages with high caffeine and sugar content
Soups	
Babies in particular need a lot more liquid, even in addition to breast milk. Always offer them water or some tea with lemon and a little salt after breastfeeding.	

Tab. 5.8.4 Brief, easily understandable advice for the young

Useful advice during heatwaves for the young

Protect yourself from the heat of the sun by wearing wide-brimmed hats and sunglasses. Wear light, loose cotton garments of light colour on hot days.	Apply sun protection lotion appropriate for your skin type several times a day. If you have very light skin and blue eyes, use sun lotion with a sun

	protection factor (SPF) above 10.
In very hot weather, take frequent showers or baths in lukewarm or cold water. Spend 1-2 hours in air conditioned spaces.	If you are doing sports outdoors during heatwaves, cool yourself frequently and drink at least 4 litres of liquids. It is also important to replenish lost salt.
WHAT TO DRINK Water, mineral water, tea	WHAT NOT TO DRINK Coffee, alcoholic beverages
Non-carbonated soft drinks	
Tomato juice, curd, kefir, yoghurt	Carbonated beverages with high caffeine and sugar content
Soups	

The latest tools for communicating with the public

Along with the public media (television, radio), web applications can also help in communicating with the public. In 2013, the National Directorate General for Disaster Management (NDGDM) developed and launched a disaster alert information application that can be downloaded on smart phones and Tab.ts free of charge. The mobile application makes it possible for people to be notified immediately about local weather anomalies or other dangers relevant to their homes or current locations. Through these devices, users with an Internet connection can conFig. the application to receive alert information relevant to the whole country or to a specific county, depending on their personal preferences. If the device has a GPS, that is, a unit able to define their position using a space-based satellite system, users can receive information for actual locations, for a planned route, or even for great distances.

In conjunction with its weather forecast and alert system, the Hungarian Meteorological Service (OMSZ) developed an application called Meteora, which can be downloaded from http://meteora.met.hu/meteora.html. The Meteora application is a clock that runs on mobile devices and also provides weather information. The program uses the positioning and Internet data access capabilities of the mobile device. Based on cell information, Meteora defines the position of the user and, using the data connection, automatically downloads local alerts and forecasts from the computers of the Hungarian Meteorological Service. Meteora is a widget developed for Android devices; after downloading, the version designed for the device screen size must be installed (Fig. 5.8.18). Installing the clock automatically activates the alert function.

Fig. 5.8.18 Alert system application developed by the Hungarian Meteorological Service, displaying a clock on the mobile device

Updates calling off alerts are passed on via the same rapid alert system.

The tasks for resuming normal life are as follows:

Establish responsibility.

Draw conclusions.

Evaluate efficacy and efficiency.

Provide relief as long as needed.

Resume the operation of institutions.

Reconcile costs incurred during disaster management.

Earlier experience indicates that the negative effects of extreme heat can affect extended areas and large segments of the population. It is therefore of paramount importance to be prepared for extended heatwaves and to utilize the protective powers of local governments to their full extent. Special attention must always be given to the protection of human life and property, as well as to the execution of any reconstruction work immediately required. Local authorities have a significant role in disaster management; they must devote special attention to the careful preparation of protective measures against the detrimental effects of extreme weather phenomena, because these preparations are crucial for developing an effective adaptation strategy.

5.9 Pilot actions in European cities - Prague

Michal Žák, Pavel Zahradníček, Petr Skalak, Tomas Halenka

5.9.1 Urban and environmental framework

5.9.1.1 General remarks on Prague

Prague is the capital of the Czech Republic. As the largest city in the country by its area (496 km^2) and by population (1.2 million inhabitans) faces the same environmental challenges, as the other large cities in the world. The city strives for the substantial reduction of the environmental burden as to become clean, healthy, and harmonic place for living.

Prague is situated on the banks of the Vltava river and its tributaries. The complicated morphology creates limitation for a good ventilation of the area. The lowest point is in 149 m and the surrounding hills at the southwestern part of Prague are almost 400 m above sea level.

5.9.1.2 Prague urban heat island analysis

Michal Žák, Pavel Zaradníček, Petr Skalak, Tomas Halenka

Prague and especially its city centre belongs to the warmest regions of the Czech Republic with annual average air temperature around 10 °C in the city centre (see Fig. 5.9.1). This is partly caused by the urban heat island (UHI) of Prague.

The intensity of UHI is about 1.6 °C when we use the average daily temperatures. The highest intensity occurs during June, while the lowest intensity in September. It has to be noted, that the UHI intensity of Prague is considerably higher when looking at minimum temperatures (annual average is approximately 3 °C) but smaller for maximum temperatures (annual average approx. 1 °C). The intensity of Prague's UHI has increased during the last 50 years. This increasing is caused due to the city enlargement and transport intensification.

The magnitude of this intensification is 0.15°C/10 years for minimum temperatures, 0.07°C/10 years for average daily temperatures and 0.02°C/10 years for maximum temperatures. This intensification of UHI is documented on Fig. 2 where differences of daily air minimum temperatures between period 2001–2010 and 1961–1970 are demonstrated. While the temperature in the whole Prague area increases (due to the climate change in the Central Europe), the largest increment of the temperature can be seen in city centre, close to the Vltava river, in the densely built up part of the city.

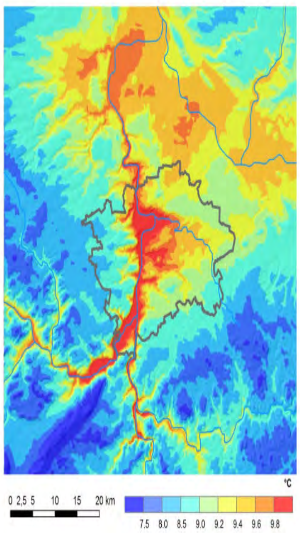


Fig. 4.9. 1 Annual average air temperature for Prague and surrounding, period 1961–2010.

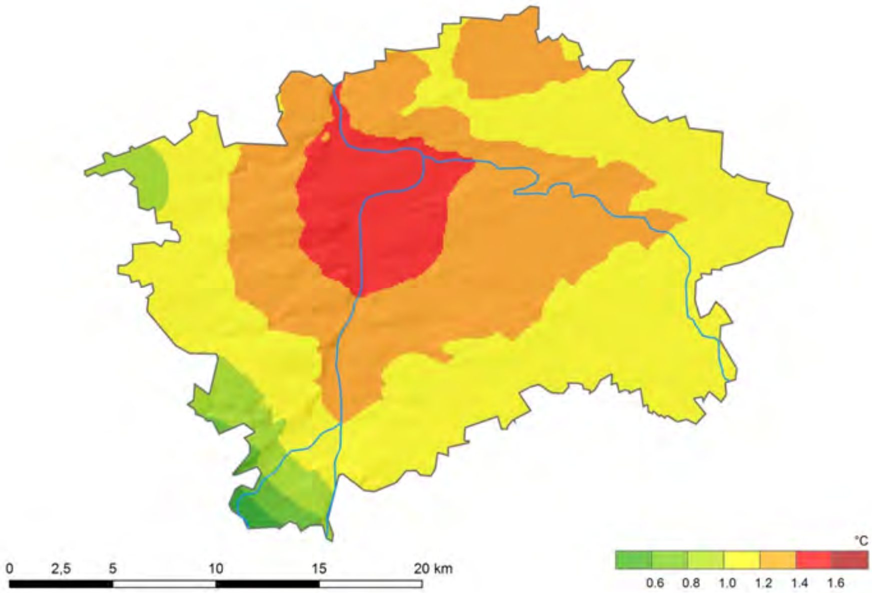


Fig. 5.9.2 Difference of daily air minimum temperature between period 2001–2010 and 1961–1970.

Another point of view of the intensity of UHI can be obtained by using physiological equivalent temperature PET (Matzarakis, A., Rutz, F., Mayer, H., 2010: Modelling Radiation fluxes in simple and complex environments – Basics of the RayMan model. International Journal of Biometeorology 54, 131-139). This temperature describes the temperature really felt by the human being standing outside and includes not only influence of air temperature and wind, but also humidity and radiation including the radiation coming from buildings in the streets. The average annual and daily course of PET for the Praha–Karlov stations is given in Fig. 5.9.3. It can be seen, that the highest values occur during summer months, July and the first half of August.

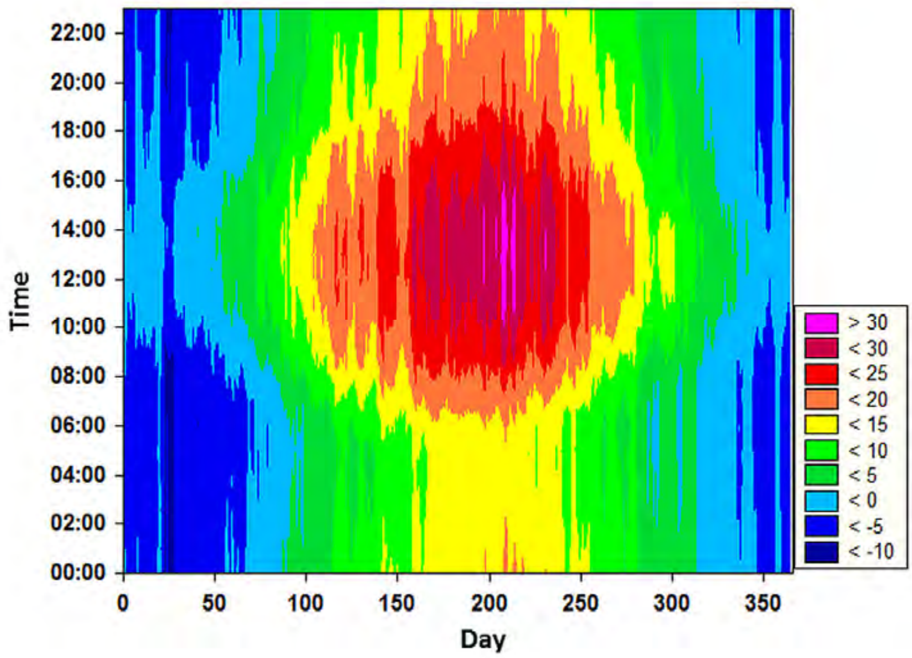


Fig. 5.9.3 Annual course of PET for Praha-Karlov station, period 2005-2013.

The differences of PET values between Praha–Karlov station located in the city centre and Praha–Ruzyně station situated on the periphery of the city (Fig. 5.9.4) show the highest values in the summer half of the year starting after the sunset and vanishing during the morning hours. Few hours after the sunrise this differences can be even negative indicating lower PET values in the city centre. Regarding long term changes, there is positive trend in PET values in Prague during spring and summer indicating greater human stress during the warm summer half-year. It should be noted that PET was computed for the location with ideal horizon without obstacles – this is also the case of the following case study of a hot day.

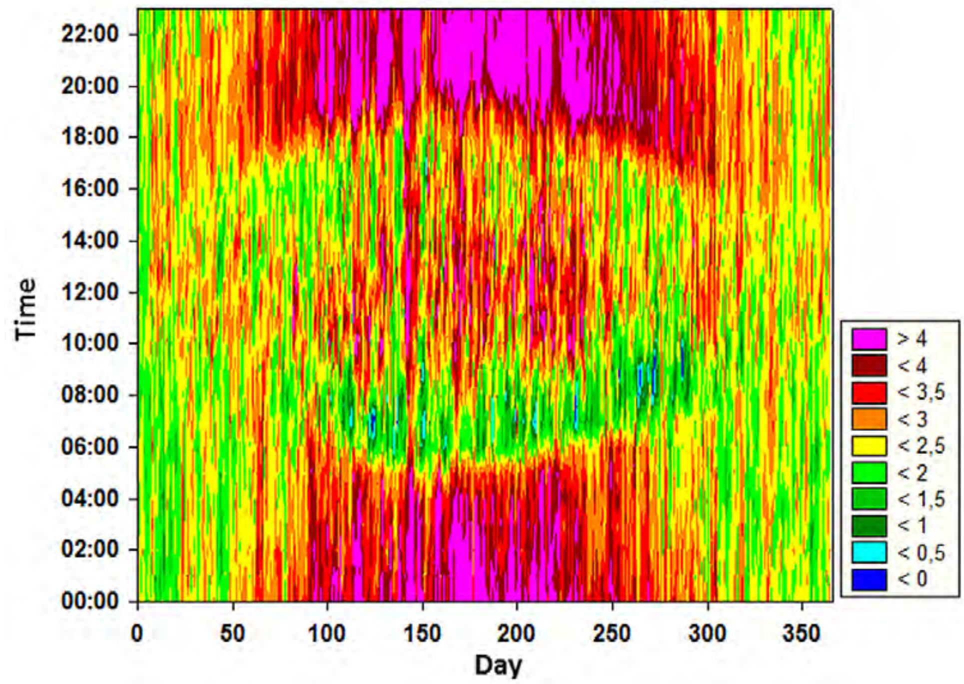


Fig. 5.9.4 Annual course of PET of differences between stations Praha-Karlov and Praha-Ruzyně, period 2005-2013 (positive values mean Karlov is warmer than Ruzyne).

The largest UHI negative effects (in the sense of bioclimatic discomfort) usually occur during the summer months. For demonstration, case study of hot day, the day of 28th July 2013 has been chosen. Maximum air temperature on that day reached values around 37 °C (Fig. 5.9.5), with differences among different parts of the city being maximal about 2 °C. PET values (Fig. 5.9.6) on that day reached over 46 °C in the city centre, with difference through the city being a bit higher compared to the differences in the air temperatures. Values of PET over 40 °C started already around 9 in the morning and continued to 5 in the afternoon. Especially in the evening, the differences between city centre and periphery exceeded 8 °C.

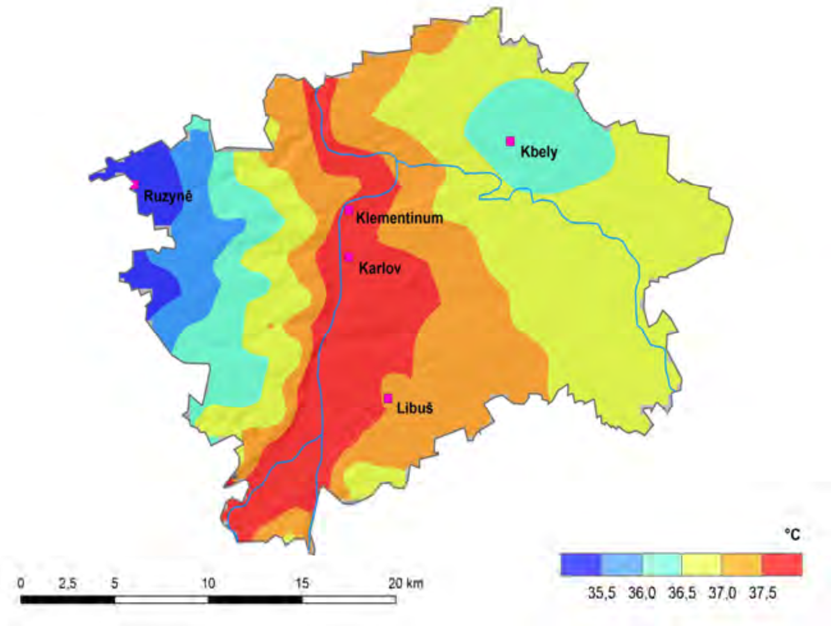


Fig. 5.9.5 Maximum air temperature in Prague on 28th July 2013

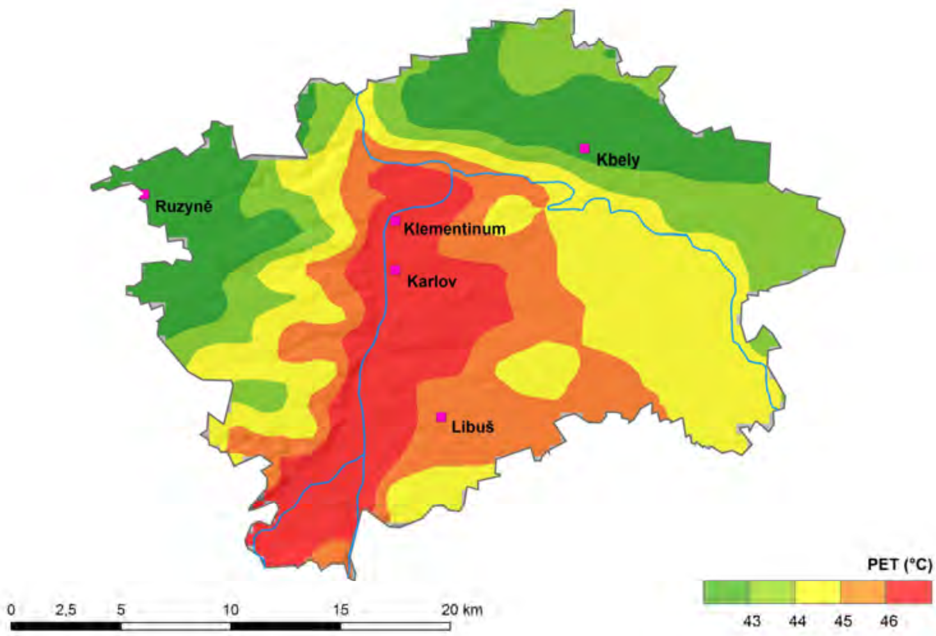


Fig. 5.9.6 Maximum PET in Prague on 28th July 2013

5.9.1.3 Air-quality issues (Mária Kazmuková, Peter Huszár, Tomáš Halenka)

Despite the substantial reduction of the emissions from industrial sources in the past years, air quality is still influenced by the emissions from automotive traffic, as a main source of air pollution. In the suburban residential areas air quality is influenced by the emissions from local heating burning solid fuels.

In the agglomeration of Prague the limits for air quality are exceeded, especially for particular matter PM10, NO2, O3 and benzo(a)pyren. The majority of exceedances is connected with the high traffic loads in Prague, but also with the domestic heating in family houses in the residential areas in Prague.

The share of mobile sources on the total of PM emissions is more than 85 %, on the total of NO_x ca 75 %. The contribution of the household heating to PM emissions is almost of 16 %.

In the last years the ambient air quality has been improved. The annual limit concentration NO_2 (40 µg.m^{-3}) has been exceeded only on 2 traffic monitoring stations in Prague, however it can be supposed that the exceeding could occur in other areas with a similar traffic volume.

Also the PM_{10} concentrations dropped significantly, nevertheless the average 24 hours PM_{10} concentrations are exceeding the limit at the 13 monitoring stations.

The concentrations of benzo(a)pyren measured at 2 monitoring stations in Prague were exceeded only at 1 of theme, the results of monitoring fluctuates around the limit of 1 ng.m^{-3}.

The concentrations of O_3 are regularly exceeded only at the 1 background station in the suburb over years.

The rest of the air quality limits are usually met in the area of Prague.

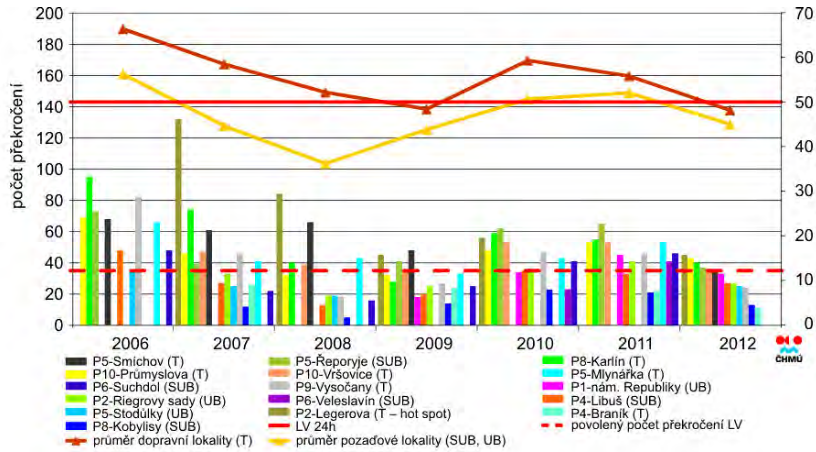


Fig. 5.9.7 Trends in yearly characteristics of the fraction PM_{10} and the 36th highest 24-hour PM_{10} concentration in selected monitoring stations in Prague

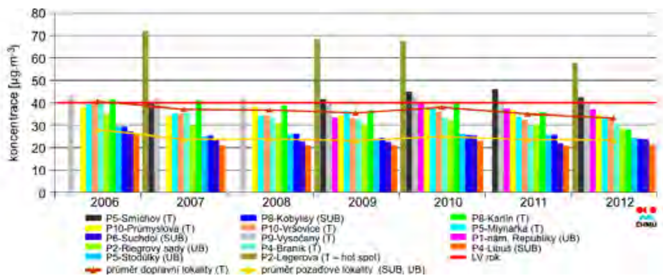


Fig. 5.9.8: Trends in yearly characteristics of NO2 in selected monitoring stations in Prague

5.9.2 Pilot areas identification methodology.

The pilot areas in Prague were selected with the aim to enable the simulation of UHI mitigation strategies in different scales.

For the scale of a street canyon the Legerova street was selected, representing one of the streets with a very high traffic volume crossing the residential area.

For the Pilot Area 2 was chosen the brownfield Bubny – Holešovice, an abandoned railway area, which aspires to be a new city quarter. Microclimatic simulations were performed for the central part measuring 500 meters by 500 meters.

The Pilot Area 3 as the whole territory of Prague has been chosen to enable simulations of the mitigation effects as a green belt around Prague or traffic emission reduction in all Prague agglomeration.

5.9.3 UHI phenomena in the pilot area and connection with specific aspects of urban form and built environment

Main output description

5.9.3.1 Pilot Area 1

Legerova street

Dominik Aleš, Vladimír Fuka, Michal Žák, Pavel Zahradnicek, Mária Kazmuková

Legerova Street represents a corridor with the width of 25 m, surrounded by 21 m high buildings. The traffic density is approximately 45 000 cars per day in 4 lines.

The street leads through a residential area in north-south direction. During summer months it is fully open to sunshine and the incoming solar energy is largely absorbed by asphalt and concrete as well as by facades of the buildings. There are only a few sparse parts of grass beds and no availability for shade.

Fig. 5.9.9 Prague

Fig. 5.9.10

Implementation of tree alleys was assessed as a mitigation measure. Three different scenarios varying the form and position of the alleys were tested in cooperation of Prague Institute of Planning and Development, Czech Hydrometeorological Institute, and the Department of Meteorology and Environment at Faculty of Mathematics and Physics, Charles University in Prague.

Besides the thermal comfort, also the air pollution concentrations were taken in mind. The initial NO_x concentrations in Legerova Street could reach ca. 33 $\mu g/m^3$ on the east windward sidewalk and even around 160 $\mu g/m^3$ on the west leeward sidewalk due to the prevailing west wind direction which causes this unbalanced air pollution dispersion.

The thermal comfort was simulated by using of the microclimate model RayMan [Matzarakis, A., Rutz, F., Mayer, H., 2010: Modelling Radiation fluxes in simple and complex environments – Basics of the RayMan model. International Journal of Biometeorology 54, 131-139]. The ventilation conditions for air pollution were simulated by a model developed at the Department of Meteorology and Environment, CUNI Prague.

A mild summer day of 21^{st} June 2013 was chosen for the simulation of all proposed scenarios. Temperature effect was also modelled on a tropical day of 18^{th} June.

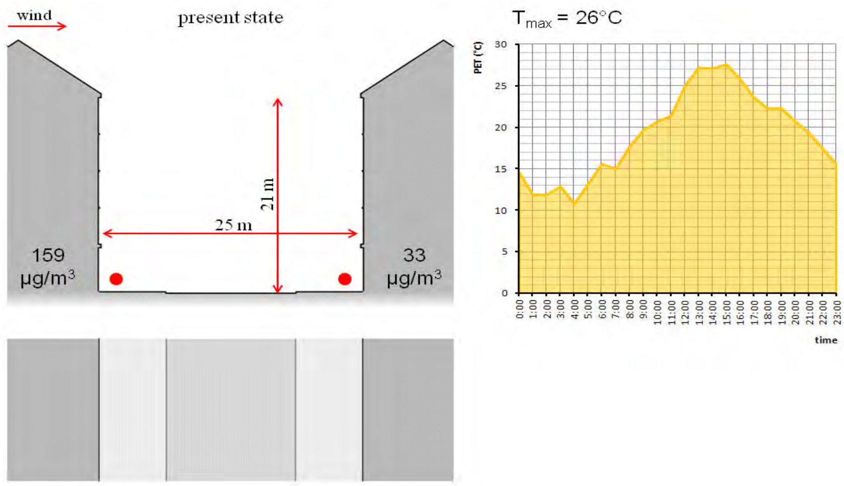


Fig. 5.9.11 mild summer day scenario

The simulation results for all scenarios in the mild summer day ($T_{A,max}$ = 26°C) show a possible effect of PET reduction of 2.3 degrees in shade. During the tropical day ($T_{A,max}$ = 37°C) the reduction can reach 3.5 degrees. However, all scenarios show also more or less negative impact on the ventilation conditions for air pollutants.

In the scenario with small trees positioned densely along the sidewalks, there is quite short time period of shade provided to one assessed point. On the other hand, the street canyon ventilation in not worsened noticeably.

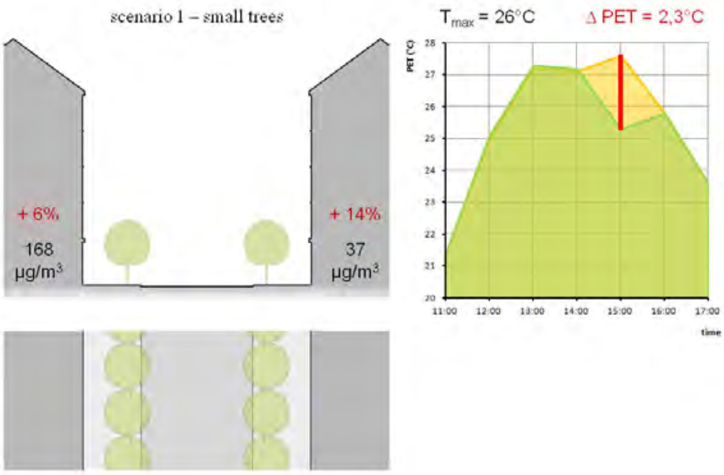


Fig. 5.9.12 effect of PET reduction

The effect of PET reduction in the scenario with large trees along the sidewalks lasts for a longer afternoon period due to a larger shade. However, the large crowns significantly impact the air flow and cause a serious concentrations increase on the windward sidewalk.

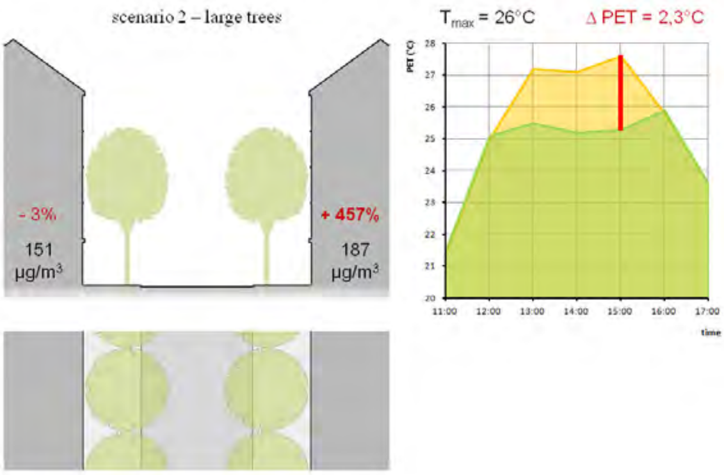


Fig. 5.9.13 Scenario 2

The simulation of the scenario with an axial position of small trees in one row in the centre of the street shows no impact on PET, providing no shade on the sidewalks. At the same time, this arrangement constitutes an obstacle to the vortex and thus causes additional increase of already worse high concentrations on the leeward sidewalk.

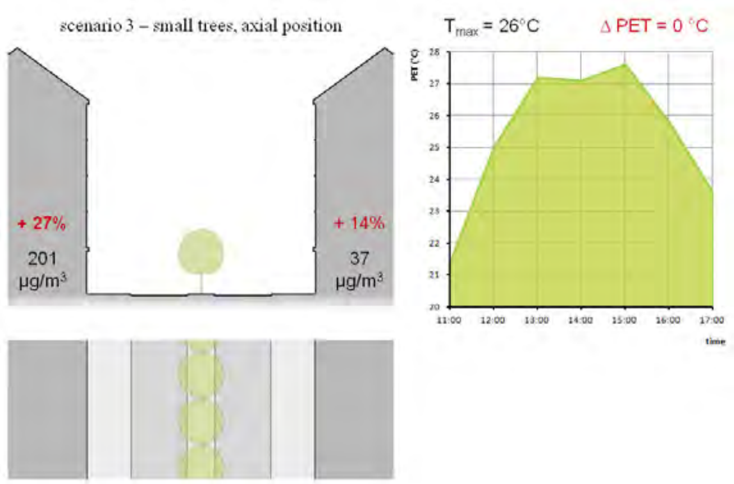


Fig. 5.9.14 scenario with the small trees planted densely along the sidewalks

High trees in the street bring more shade with a positive effect on PET, but also create less favourable ventilation conditions. The scenario with the small trees planted densely along the sidewalks seems to be the optimal solution for UHI mitigation for Legerova Street. This scenario does not have such a negative effect on ventilation conditions and provides shade and a positive effect on PET.

5.9.3.2 Pilot Area 2 Holešovice - Bubny

Mária Kazmukova, Ondrej Zemanek, Jan Flegl, Kristina Kiesel, Radek Jareš et al., ATEM, Michal Žák, Pavel Z.

Lokalita Holešovice – Bubny

Holešovice – Bubny was chosen to be one of the Prague's pilot areas due to its strong development potential and proximity to the city centre. Once used as a freight station the site is nowadays a brownfield that aspires becoming a living city quarter. A significant part of the area is occupied by the transport infrastructure, the rest is scattered with isolated buildings and fragments of block structure. Existing greenery is not properly maintained. In the east and west the site is adjoining various urban structures and the Vltava River in the north and south. The selected pilot area is about 82.5 hectares large.

Fig. 5.9.15 future residential and commercial district

The site is considered to be the future residential and commercial district. According to the current urban study the area shall be converted into a block structure, accompanied by small-scale parks and alley-like streets. Mean building height (between 25 and 26 meters) shall be pierced with several landmarks (height from 50 up to 70 meters). These adjoin to park areas as well as to the northern river bank. Existing railway tracks shall be reduced and elevated to enable streets to pass beneath.

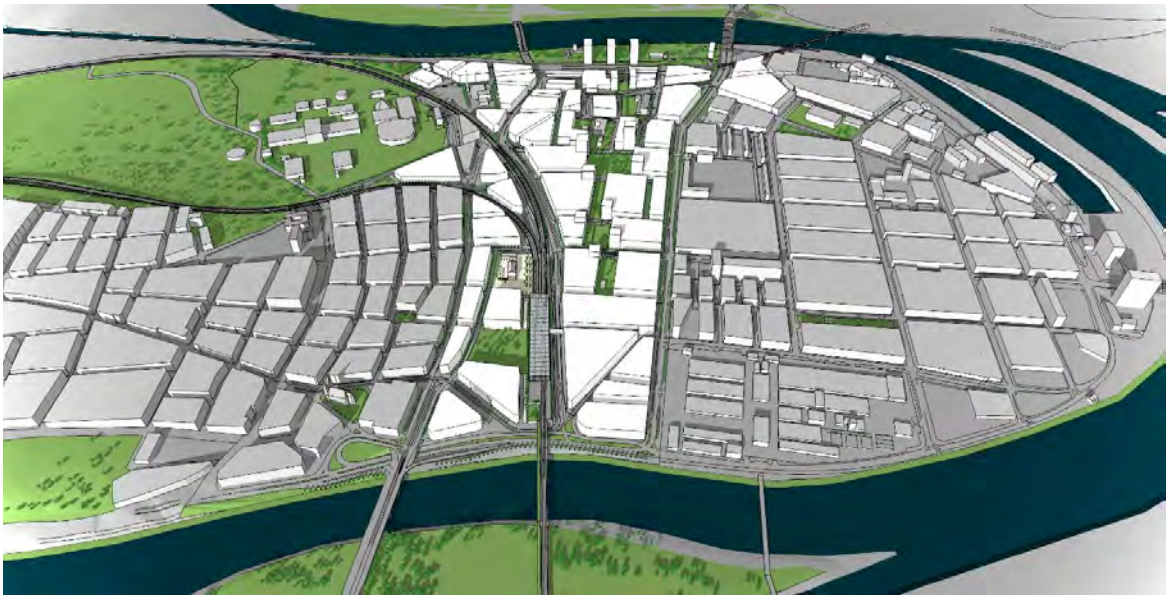


Fig. 5.9.16 Series of small-scale parks shall by hooked up through alley-like streets:

Fig. 5.9.17 Inside yards of housing blocks shall be used for greenery and be walkthrough:

Fig. 5.9.18 Scenario 1

The aim of the research was to examine the benefits of the current study (scenario 1) and to compare it with alternative urban studies proposing different urban structures and larger park areas (scenarios 3 to 6).

Fig. 5.9.19 Scenario 2

In terms of land use, greenery types and building characteristics the following GIS models were performed:

Fig. 5.9.20 e 5.9.21 (Scenario 3 and Scenario 4)

Scenarios 3 and 4 propose a massive east-west oriented park strip located in the middle of the pilot area. A loose urban structure with high buildings of small footprints adjoin to the park in the north.

Fig. 5.9.22 better ventilation scenario

This arrangement should leave more space for greenery and enable better ventilation of the area.

Similarly to the current study scenarios 5 and 6 propose a block structure combining it with another arrangement of the central park:

Fig. 5.9.23 and 54.9.24 Scenario 5 and 6

In collaboration with the Meteorological Institute of the University of Freiburg and ATEM Prague following microclimate models were carried out with use of the ENVI-met software. The models simulate life conditions 1.5 metres above the ground level during the day with the strongest insolation on June 20th at 3.00 PM.

We are conscious that the following conclusions are badly one-sided. For acquiring more realistic climatic conditions it would be necessary to perform a higher number of simulations.

Street canyons shaded by buildings have cooling effect (depending on the aspect ratio):

Fig. 5.9.25 e 26 Scenari

Wide streets not surrounded by buildings and not shaded by trees have a desiccating effect:

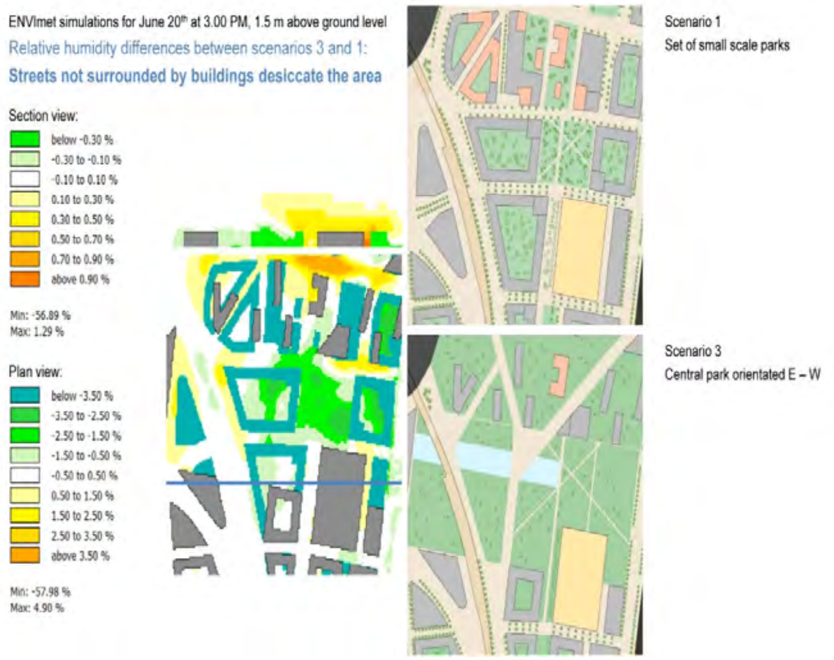


Fig. 5.9.27 Scenari 1 / 3

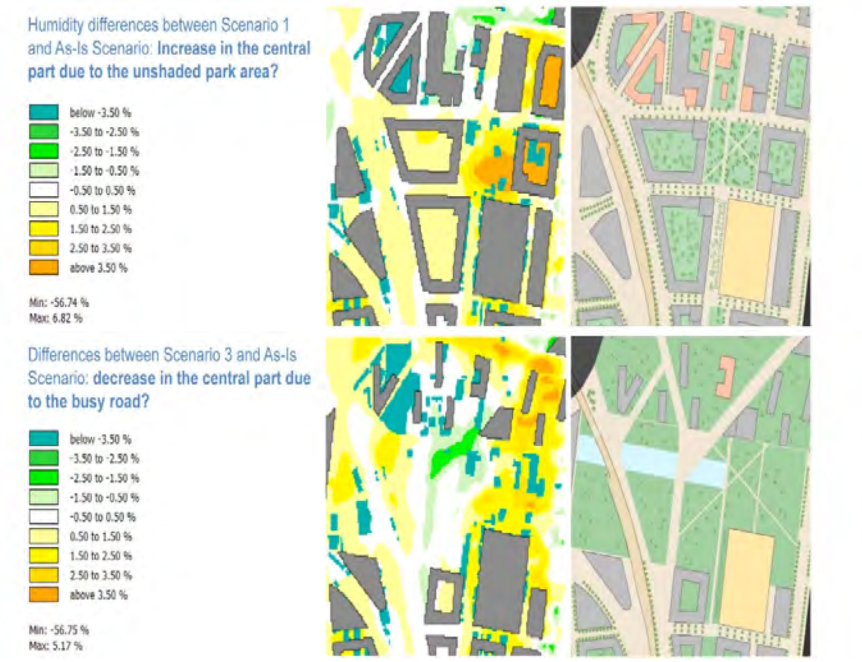


Fig. 5.9.27 and 28 Humidity differencies

Busy streets have a warming effect due to the heat output from motor transport (see the bottom Fig.). Still water basins have no cooling effect:

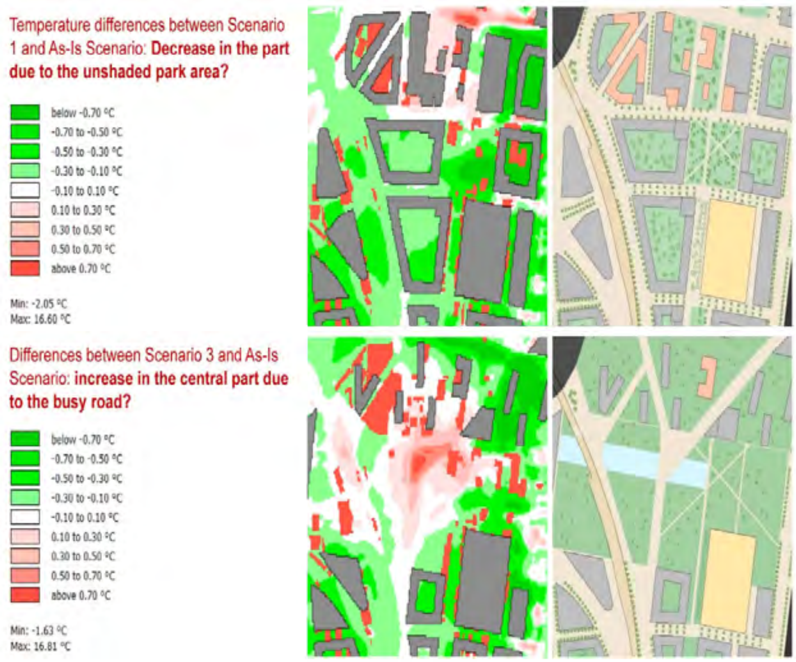


Fig. 5.9.29 The cooling effect of green roofs is negligible:

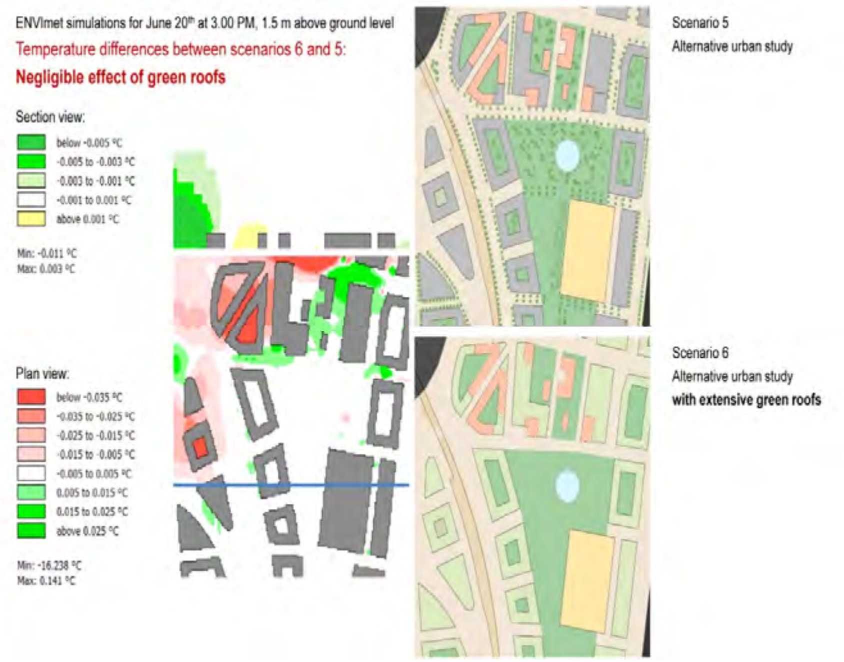


Fig. 5.9.30 the block structure offers better day time conditions

As mentioned above the block structure offers better day time conditions than the loose urban structure. However further research should explore the cooling effect of the parks during the night time.

5.9.3.3 Green Belt

Mária Kazmukova, Tomas Halenka, Jaroslav Ressler, Radek Jares, et al. ATEM

The assessment was focused on the issue of modelling of meteorological fields and air quality in conditions of conurbation with regard to presence of urban heat island phenomenon. Within the project framework, modelling tools for air quality evaluation were tested while meteorological parameters and chemistry of the atmosphere were taken into account. Based on the acquired findings from the base state, the horizon of fulfilment of land use plan in its present form and the variants of urban and traffic concept were assessed.

The project assessed the following scenarios: baseline state, fulfilment of the land use plan, low-emission zone and implementation of a green belt. In addition, sensitivity to the expected climate change was studied.

In terms of UHI, the most important was evaluation of green belt scenario, i.e. state when the transport concept and vehicle fleet composition corresponds to the year 2020 and fulfilment of the land use plan is presumed with the exception of areas defined as green belt whose land use is assumed to be changed into forest area or forest park.

The method used for modelling of transport of chemical substances required to include a large territory in which boundary conditions were modelled, influencing meteorological quantities and concentrations of pollutants within the area of interest. The entire modelled area covered Europe, i.e. area measuring 4 644 × 3 294 km with its centre being located in Prague. Assessment with the finest resolution was carried out for Prague and its surroundings where grids of 1 km and 333 m were used.

Input data for the project were prepared in such detail that has not yet been realized. For this purpose, data from regularly updated study Evaluation of Air Quality in the Territory of the Capital City of Prague Based on Mathematical Modelling as well as data about the area of interest provided by the IPR institute and available databases from other sources were utilized.

The project involved both modelling of meteorological fields using the WRF model and modelling of air pollutant dispersion using the CMAQ model. The meteorological model was conFig.d with an urban surface impact model; the emission flux model contained an anthropogenic emission model, a biogenic emission model, a chemical transport model and modules of data post processing and statistical processing of the outputs. For long term experiments, urbanized RegCM was used with 10 km resolution, allowing SUBBATS (Pal, J. S., F. Giorgi, X. Bi, N. Elguindi, F. Solomon, X. Gao, R. Francisco, A. Zakey, J. Winter, M. Ashfaq, F. Syed, J. L. Bell, N. S. Diffenbaugh, J. Karmacharya, A. Konare, D. Martinez, R. P. da Rocha, L. C. Sloan and A. Steiner, 2007: The ICTP RegCM3 and RegCNET: Regional Climate Modeling for the Developing World, B. Am. Meterol. Soc., 88, 1395–1409) in 2 km.

Both meteorological parameters (temperature, humidity, wind speed) and concentration of pollutants were modelled.

Outcomes of the assessment allow evaluating not only long-term indicators (annual average) but also characteristics that have not yet been assessed sufficiently accurately, such as exceedance period of an air pollution limit and n^{th} highest values of short-term average values in accordance with legislation. Also ozone concentrations can be evaluated. The results are available both for current state, for future scenario of land use plan and other scenarios being assessed.

The evaluation points out the following:

By 2020 or by the horizon of land use plan fulfilment, respectively, reduction of concentrations of pollutants in Prague can be expected with the exception of vicinity of large transport structures where the impact of newly introduced car traffic outweighs.

Improvement in vehicle fleet composition has a positive effect on NO_2 and suspended particulate matter concentrations and also on benzene (but less). In the case of ozone, the peak concentrations (which are limited in terms of health) decrease and average annual concentrations increase (higher concentrations at night time).

The evaluation showed that secondary aerosols have a relatively high contribution to air pollution load by suspended particulate matter. This issue requires further specification because higher concentrations of PM_{10} are one of the major problems of air quality protection in the capital city of Prague.

The influence of the green belt is rather small; it affects only few sites by small decrease in temperature and consequent change in concentrations of pollutants caused by a change in biogenic emissions production and by a change in chemical reactions in the atmosphere. Certain changes can be seen in long term simulation, with small temperature decrease, especially in summer night. Remote effects are rather climatic noise. Changes in the future go with the overall temperature change, but they are again rather small.

The presented project practically verified the potential use of chemical transport models for air quality and UHI assessment in a small scale. The fine resolution that reaches up to 333 m for the innermost domain allows assessing air quality and UHI effect in cities in detail.

Proposed green belt around Prague

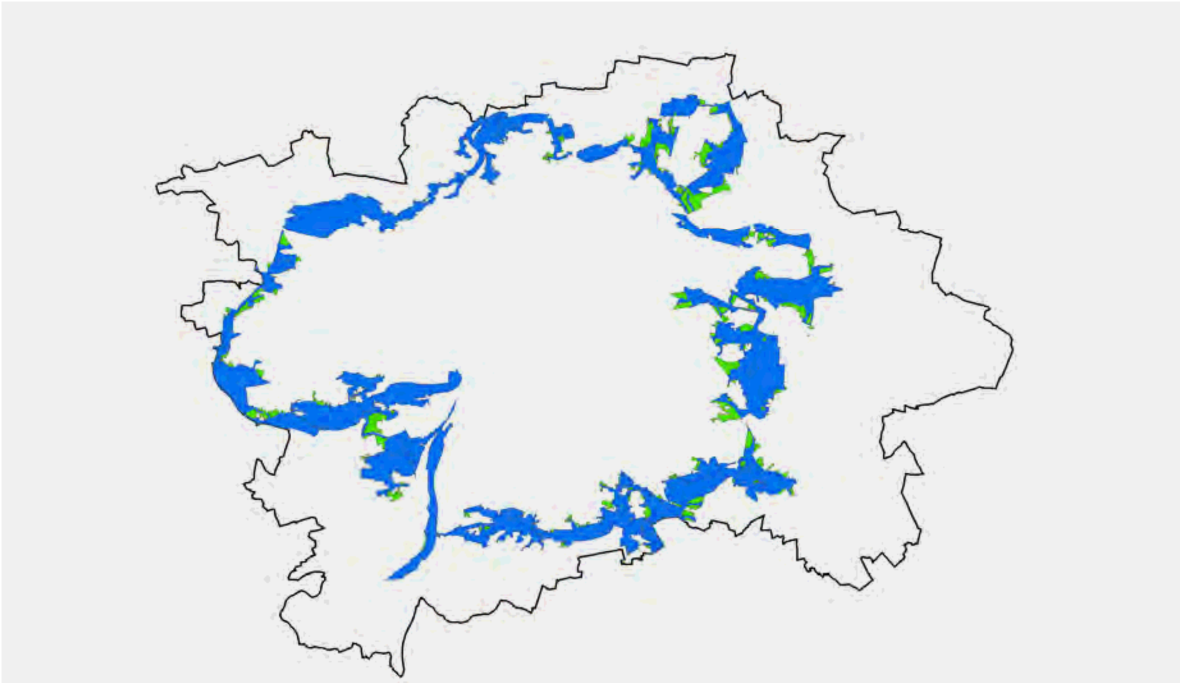


Fig. 5.9. 31 Temperature shift caused by green belt in a hot July day

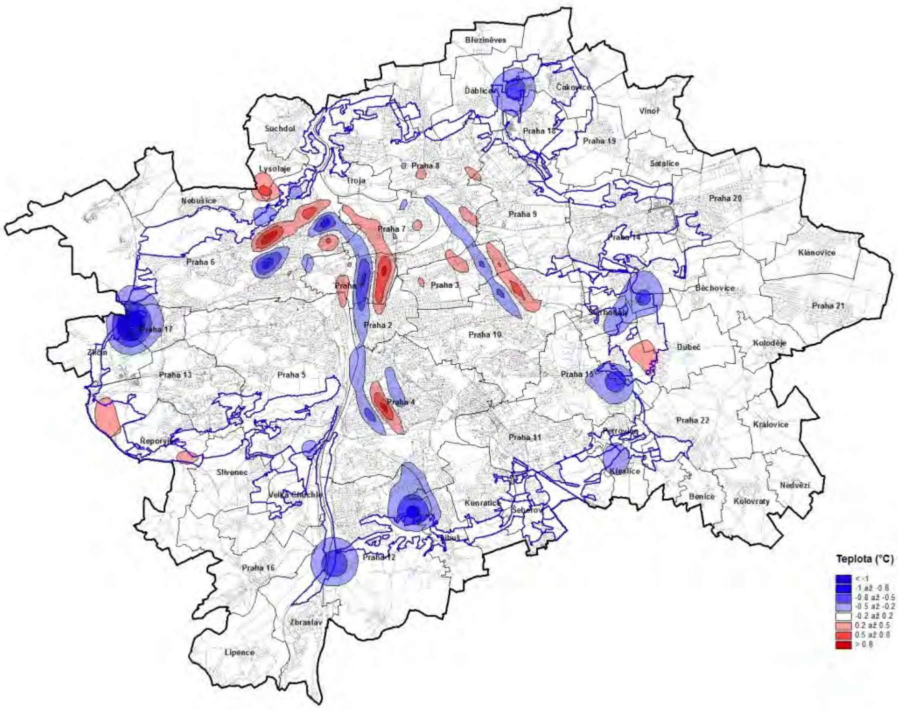
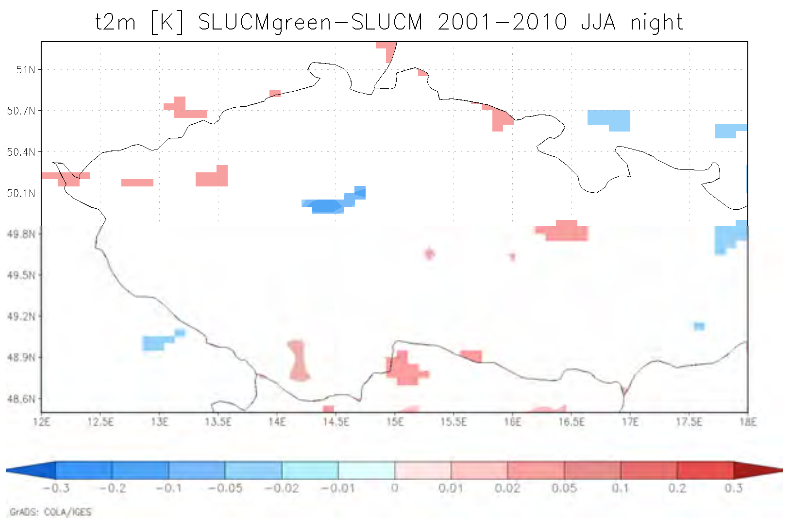


Fig. 5.9.32 and 33 Temperature changes in long term simulation of 2001-2010 (JJA, night) caused by green belt



Differences in 24-hour-averaged PM_{10} concentrations between years 2010 and 2020

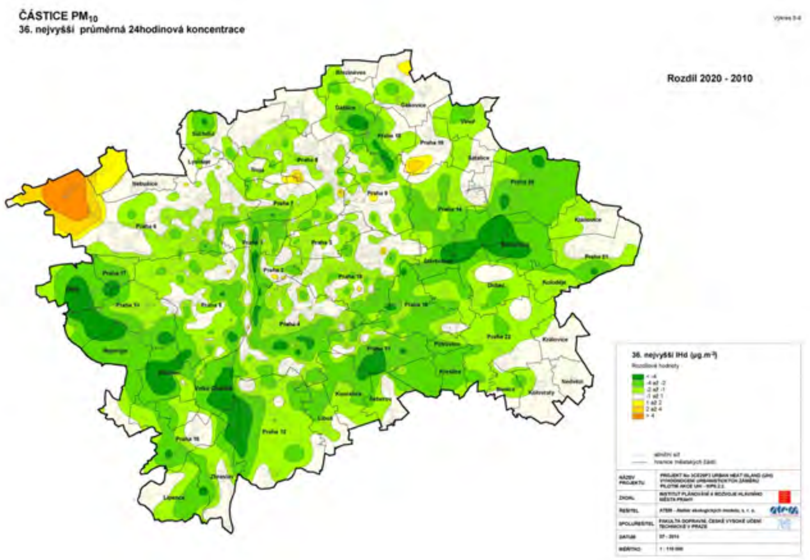


Fig. 5.9.34 Differences in 24-hour-averaged PM_{10} concentrations

5.9.4. General strategic vision to mitigate UHI effects- *Counteracting measures*

5.9.4.1 Street canyons

As a result of the simulations, the scenario with the small trees planted densely along the sidewalks seems to be the optimal solution for UHI mitigation for Legerova Street and other similar street canyons with a heavy traffic volume. This scenario does not have such a negative effect on ventilation conditions and provides shade and a positive effect on PET.

5.9.4.2 Development areas:

The aim of the research was to examine the benefits of the different scenarios compared with alternative urban studies proposing different urban structures and larger park areas.

The simulations have shown that the block structure offers better day time conditions than the loose urban structure. However further research should explore the cooling effect of the parks during the night time.

5.9.4.3 Green Belt

The assessment of the effect of a proposed green belt as a scenario for UHI mitigation in Prague was focused on the issue of modelling of meteorological fields and air quality in conditions of conurbation with regard to presence of urban heat island phenomenon.

Within the project framework, modelling tools for air quality evaluation were tested while meteorological parameters and chemistry of the atmosphere were taken into account.

In terms of UHI, the most important was evaluation of green belt scenario, i.e. state when the transport concept and vehicle fleet composition corresponds to the year 2020 and areas defined as green belt are assumed to be changed into forest area or forest park.

The method used for modelling of transport of chemical substances required to include a large territory in which boundary conditions were modelled, influencing meteorological quantities and concentrations of pollutants within the area of interest

The project assessed the following scenarios: baseline state, fulfilment of the land use plan, low-emission zone and implementation of a green belt.

The presented project practically verified the potential use of chemical transport models for air quality and UHI assessment in a small scale. The fine resolution that reaches up to 333 m for the innermost domain allows assessing air quality and UHI effect in cities in detail.

As a result of the recent modelling, the influence of the green belt showed to be rather small; it affects only few sites by small decrease in temperature and consequent change in concentrations of pollutants caused by a change in biogenic emissions production and by a change in chemical reactions in the atmosphere. Further simulations with traffic modifications are needed. It should be pointed out, that the effect of climate change for the year 2020 is negligible compared to the effects by changes in land-use and transport concepts with vehicle fleet changes.

Adaptation strategies to contrast bioclimatic emergencies were included in a proposition for the Prevention plan in cooperation with the State Institute of Health. The proposition of the Prevention Plan includes the instructions for people, especially for sensitive groups how to react and what measures to take in extreme hot periods in cities.

The proposed HEAT Warning System will help to coordinate adaptative strategies and the reaction of City Authoritities to the extreme weather phenomena as to protect citizens against the harmful effects of heat and the UHI.

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Glossary and Abbrevations

This glossary has been compiled using definitions found on European Commission, Intergovernmental Panel on climate Change and other relevant sources, with brief descriptions provided on main topics.

Rectal temperature - Tre (°C).

Tskm - mean skin temperature (°C).

Tskfc - face skin temperature (°C).

Mskdot - sweat production (g/min).

Shiv - heat generated by shivering (W).

wettA - skin wittedness (%) of body area.

VblSk - skin blood flow (%) of basal value.

DTS Dynamic Thermal Sensation

Physiologically Equivalent Temperature The Physiologically Equivalent Temperature (PET) is the equivalent temperature at a given place (outdoors or indoors) to the air temperature in a typical indoor setting with core and skin temperatures equal to those under the conditions being assessed. Thereby, the heat balance of the human body with a work metabolism 80 W (light activity, added to basic metabolism) and a heat resistance of clothing 0.9 clo) is maintained (Höppe 1999).
The Universal Thermal Climate Index UTCI (Jendritzky et al., 2012) is defined as the air temperature (Ta) of the reference condition causing the same model response as the actual condition. Thus, UTCI represents the air temperature, which would produce, under reference conditions, the same thermal strain as in the actual thermal environment.

Both meteorological and non-meteorological (metabolic rate and thermal resistance of clothing) reference conditions were defined:

- wind speed (v) of 0.5 m/s at 10 m height (approximately 0.3 m/s in 1.1 m),
- mean radiant temperature (Tmrt) equal to air temperature,

- vapor pressure (VP) that represent relative humidity of 50%, at high air temperatures (>29 ºC) the reference air humidity is defined as 20 hPa.

representative activity to be that of a person walking with a speed of 4 km/h (1.1 m/s). This provides a metabolic rate of 2.3 MET (135 W/m^2).

CE: Central Europe

DSS: Decision Support System

LP: Lead Partner

WP: Work Package

AF: Application Form

UHI: Urban Heat Island

ACT: Action

DBMS: Database Management Software

MBMS: Model Base Management Software

DGMS: Dialogue Generation Management Software

SMS: Short Message Service

TN: Transnational Network

M&A: Mitigation and Adaptation

Combined heat and power (CHP) – Also known as cogeneration, this is an efficient, clean and reliable approach to generate electricity (power) and thermal energy from a single fuel source. CHP can greatly increase the facility's operational efficiency and decrease energy costs. At the same time, CHP reduces the emission of greenhouse gases, which contribute to global climate change.

Conference of the Parties (COP) – All countries that have ratified the United Nations Framework Convention on Climate Change (UNFCCC) are referred to as the Parties. The COP is responsible for implementing the objectives of the Convention and there have been regular meetings since 1995, these are often referred to as the United Nations Climate Conferences.

Covenant of Mayors – A movement of mayors of Europe's most pioneering cities joining a permanent network to exchange and apply good practices to improve their energy efficiency and promote low-carbon business and economic development. The development of the Covenant of Mayors was supported by the Directorate Transport and Energy (DG TREN) of the European Commission (EC).

Degression rate – The degression mechanism was chosen in part as a means for gradually eliminating the premium paid to renewables relative to the so-called market price. It was believed at the time this measure was necessary to circumvent the European Union's prohibition against state aid. This "degression" rate varies with technology.

District heating – A system for distributing heat generated in a centralised location for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, although heat-only boiler stations, geothermal heating and central solar heating are also used, as well as nuclear power. District heating plants can provide higher efficiencies and better pollution control than localized boilers.

Electricity from renewable energy sources (RES-E) – Electricity produced from renewable energy sources shall mean electricity produced by plants using only renewable energy sources, as well as the proportion of electricity produced from renewable energy sources in hybrid plants also using conventional energy sources and including renewable electricity used for filling storage systems, and excluding electricity produced as a result of storage systems.

Emissions inventory – An itemised list of emission estimates for sources of air pollution in a given area for a specified time period. It can also include infomation on activities that cause emissions and removals, as well as background on the methods used to make the calculations. Policy makers use greenhouse gas inventories to track emission trends, develop strategies and policies and assess progress. Scientists use greenhouse gas inventories as inputs to atmospheric and economic models.

Energy efficiency – Measures undertaken as part of Demand-Side Management to reduce the consumption of electricity for a specific task or function.

Energy Performance Contracting (EPC) – An innovative financing technique that uses cost savings from reduced energy consumption to repay the cost of installing energy conservation measures.

European Union (EU) – Originally a regional economic integration organisation, known as the EEC (European Economic Community), the European Union has grown into a geographical political and economic entity. Also see Member States.

feed-in tariff system – Renewable energy payment as an incentive structure to encourage the adoption of renewable energy through government legislation, with the government regulating the tariff rate. The price per unit of electricity that a utility or supplier has to pay for renewable electricity from private generators is fixed.

Fischer–Tropsch (FT) process – A method for the synthesis of hydrocarbons and other aliphatic compounds. Synthesis gas, a mixture of hydrogen and carbon monoxide, is reacted in the presence of an iron or cobalt catalyst; much heat is evolved, and such products as methane, synthetic gasoline and waxes, and alcohols are made, with water or carbon dioxide produced as a by-product. Combination of biomass gasification and Fischer-Tropsch (FT) synthesis is a possible route to produce renewable transportation fuels.

Fossil fuels – Also called mineral fuels, these are finite fuels from fossil carbon deposits such as oil, natural gas and coal. When burned to gain energy, greenhouse gases are released during the combustion processes.

Gasification – A thermochemical conversion of a solid fuel to a gaseous fuel.

Gigawatt (GW) – A unit of power equal to 1 billion watts; 1 million kilowatts, or 1,000 megawatts

Global warming – An increase in the average temperature of the Earth's surface. Global warming is one of the consequences of the enhanced greenhouse effect and will cause worldwide changes to climate patterns.

Global warming potential (GWP) – The index used to translate the level of emissions of various gases into a common measure in order to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. The International Panel on Climate Change (IPCC) has presented these GWPs and regularly updates them in new assessments (see http://unfccc.int/ghg_data/items/3825.php)

Greenhouse effect – The trapping and build-up of heat in the lower atmosphere near a planet's surface. Some of the heat flowing back towards space from the Earth's surface is absorbed by water vapour, carbon dioxide, methane and other gases in the atmosphere. If the atmospheric concentration of these gases rises, then theory predicts that the average temperature of the lower atmosphere will gradually increase.

Greenhouse gases (GHGs) – The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent – but very powerful – greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Gross domestic product (GDP) – Defined as the measure of the total output of goods and services for final use occurring within the domestic territory of a given country, regardless of the allocation to domestic and foreign claims.

Heat pumps – Heat pumps offer the most energy-efficient way to provide heating and cooling in many applications, as they can use renewable heat sources in our surroundings. A typical electrical heat pump will just need 100 kWh of power to turn 200 kWh of freely available environmental or waste heat into 300 kWh of useful heat.

Intergovernmental Panel on Climate Change (IPCC) – A scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP) to provide the decisionmakers and others interested in climate change with an objective source of information about climate change. In accordance with its mandate and as reaffirmed in various decisions by the Panel, the IPCC prepares at regular intervals comprehensive Assessment Reports of scientific, technical and socio-economic information relevant for the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation.

IPCC Fourth Assessment Report (AR4), "Climate Change 2007" – The most recent IPCC report, as a consensus report on the state of knowledge on climate change, with scientific, technical and socio-economic information presented to decision-makers. It is comprised of four volumes, with contributions by working groups composed of experts. The fourth volume is the Synthesis Report, which was published in November 2007.

Kilowatt hour (kWh) is a unit of energy: is the product of power in kilowatts multiplied by time in hours. Energy delivered by electric utilities is usually expressed and charged for in kWh.

Light-emitting diodes [LED] lighting – This is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device, as in the simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow- spectrum light is emitted.

Local Agenda 21 (LA21) – Local Agenda 21 is a local-government-led, community-wide, and participatory effort to establish a comprehensive action strategy for environmental protection, economic prosperity and community well-being in the local jurisdiction or area.

Megawatt hours (MW) is a unit of energy equal to 1 million watt hours.
Member states – The EU-27 countries are split into New Member States (NMS) and Old Member States (OMS), based on their date of their accession into the European Union (EU). The OMS are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. The NMS include the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Malta and Cyprus, with the most recent expansion including Bulgaria and Romania in 2007.

Methane – A hydrocarbon that is a greenhouse gas with a high global warming potential (estimated GWP is 24,5). Methane (CH_4) is produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and oil, coal production and incomplete fossil fuel combustion.

Metric tonne carbon dioxide equivalent (Mt CO_2 e) – A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as 'million metric tonnes of carbon dioxide equivalents (MMTCDE)'. The carbon dioxide equivalent for a gas is derived by multiplying the tonnes of the gas by the associated GWP.

Public private partnership (PPP) – A mechanism to use the private sector to deliver outcomes for the public sector, usually on the basis of a long term funding agreement, in a win-win scenario.

Renewable energy sources (RES) – Renewable energy is energy generated from natural resources naturally replenished in a short period of time. The renewable sources used most often are: wind, solar, geothermal heat, wave motion, tidal, hydraulic, biomass, landfill gas, treatment process gas and biogas.

Renewable heating and cooling (RES-H) – Heating and cooling are necessary elements of any comprehensive strategy to develop renewables and to achieve sustainability in the energy sector. Renewable heating and cooling can significantly contribute to security of energy supply in the EU and reducing CO 2 emissions.

Stern Review (SR) – The Stern Review on the Economics of Climate Change, the most comprehensive review ever carried out on the economics of climate change, was published on October 30, 2006 and was lead by Lord Stern. The Review set out to provide the report assessing the nature of the economic challenges of climate change and how they can be met, both in the UK and globally.

Third party financing (TPF) – This is an appropriate tool for funding of optimization strategies without financial charge to the final user. This is due to budget savings from increased energy efficiency and more appropriate allocation of financial resources made available.

Terawatt hours (TWh) is a unit of energy equal to 1 billion kilowatt-hours
parts per million (ppm) – Commonly used as a measure of small levels of pollutants in air, water, body fluids, etc. This is a way of expressing very dilute concentration of substances. One ppm is equivalent to 1 milligram of something per liter of water (mg/l) or 1 milligram of something per kilogram soil (mg/kg).

United Nations Framework Convention on Climate Change (UNFCCC) – An international treaty signed at the Rio Earth Summit in 1992 in which 150 countries promised stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
The UNFCCC supports all institutions involved in the climate change process.

Urban planning – Design and regulation of the uses of space that focus on the physical form, economic functions, and social impacts of the urban environment and on the location of different activities within it. Urban planning concerns itself with both the development of open land and the revitalization of existing parts of the city, thereby involving goal setting, data collection and analysis, forecasting, design, strategic thinking, and public consultation. The holistic approach of landscape and urban research was stimulated by the introduction of aerial photography.
This proved to be a valuable instrument, not only to make thematic inventories and monitor changes, but also to describe holistic aspects of complex landscapes.

urban sprawl – The expansive growth of an uncontrolled or unplanned extension of urban areas into the countryside. Urban sprawl is commonly used to describe physically expanding urban areas. The European Environment Agency (EEA) has described sprawl as the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas. Sprawl is the leading edge of urban growth and implies little planning control of land subdivision. Development is patchy, scattered and strung out, with a tendency for discontinuity. It leap-frogs over areas, leaving agricultural enclaves.
Sprawling cities are the opposite of compact cities – full of empty spaces that indicate the inefficiencies in development and highlight the consequences of uncontrolled growth (EU 2008).

Francesco Musco *Editor*

Counteracting Urban Heat Island Effects in a Global Climate Change Scenario

Urban Heat Islands (UHIs) are a microclimatic phenomenon which manifests as a significant increase in the temperature of cities compared to their surrounding areas. Recently the phenomenon has been enforced by the tendency to climate change and in particular by extreme climate events. This book presents and analyzes the results of a project to develop and apply mitigation and adaptation strategies and measures for counteracting the global urban heat islands phenomenon, supported by the EU's Central Europe Regional Development Fund. Pilot studies were carried out in eight metropolitan areas: Bologna/Modena, Budapest, Ljubljana, Lodz, Prague, Stuttgart, Venice/Padua, and Vienna. The project involved feasibility studies and strategies for appropriately altering planning rules and governance to tackle the problem of UHIs, and focused on the specific morphology of EU urban areas, which are often characterized by the presence of historical old towns.

The first part of the book is devoted to evidence, measures and tools, including tools to facilitate UHI analysis and decision support systems. The second part explores measures for counteracting urban heat islands, including specific analysis of the case studies and offering solutions for European cities. The volume includes supplemental materials such as references, glossaries and keyword lists.

The UHI management plans developed here can be integrated into national and regional sustainable development approaches for urban and land planning. They can also contribute to the application of innovative urban planning techniques that foster a new "climate proof" planning approach in European cities.

UHI project has been implemented through the CENTRAL EUROPE Programme co-financed by the ERDF

Environment

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