Subgroup: Cities & Infrastructure

Case study: Jena (Germany)

(UFZ)

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Project:

FP7/ Project BASE [2012-2016]

Date of release:

26.10.2015

Purpose of this document:

"The Case Studies Living Document (CSLD) will be the document that each case study leader will use to share the information that (i) characterize and give context to its case study, (ii) the goals within BASE, (iii) the methods used and mainly (iv) a synthesis of the results that that case study is providing to BASE project. This will allow the CS leader to understand how its own case is going (having a good overview), but also (v) will allow the sub-group to which the case study belong to know what is happening and what can be done (mainly on synergies and so on) as well as to (vi) WP4 & 5 coordinators to use that information to report (including each WP task leaders). These living documents will also (vii) allow WP6 & 7 partner to know the information."

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1 General Case Study Description

GPS: 50°55'34,9" N, 11°35'3,3" E, height 155 m above sea level
Widest points: north-south: 14.7 km, east-west: 12.2 km;
Total area on the land register: 11,447.6 ha
Area: 114.5 km^2

1.1 Location

Figure 1: Panoramic view, Jena city centre facing East
Source: Gebhardt 2013

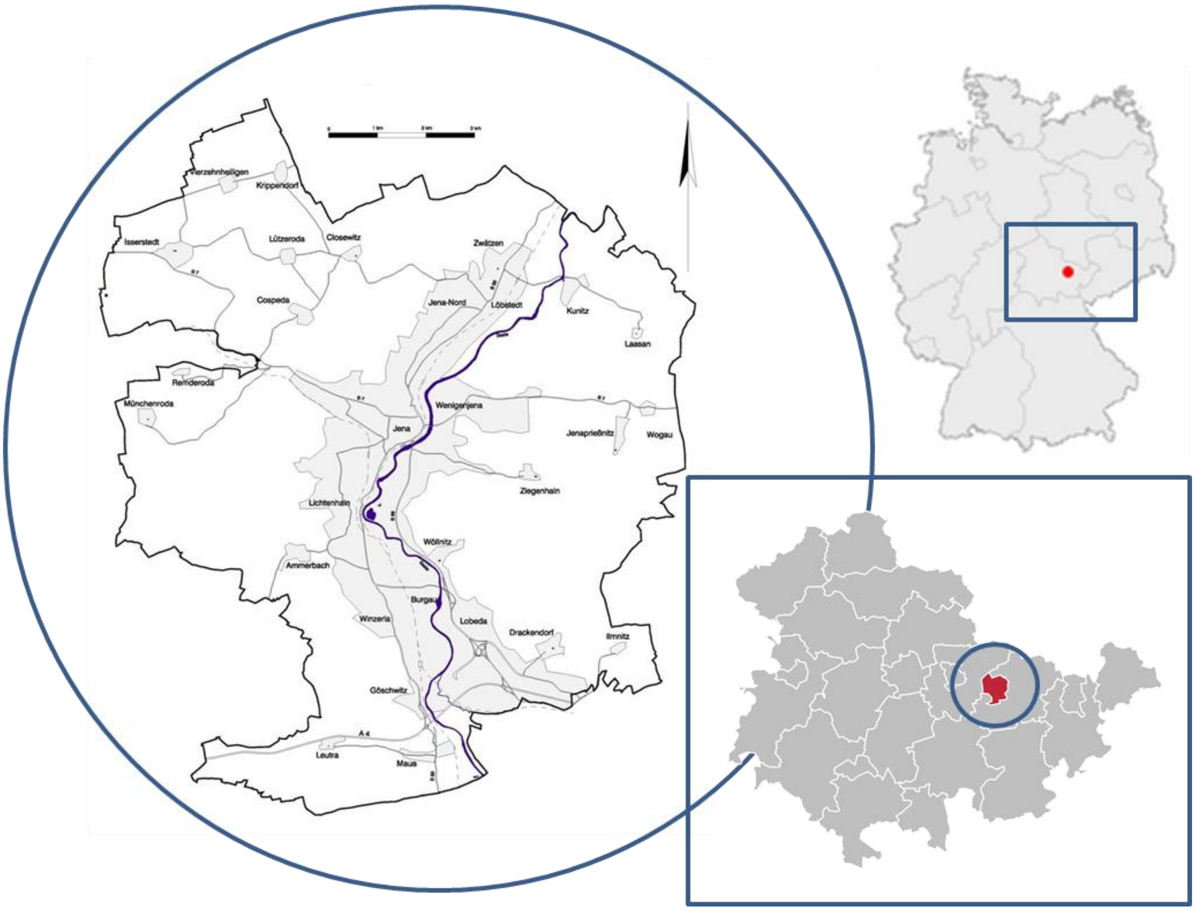

Figure 2: Location of the city of Jena, Federal State of Thuringia, Germany
Source: Own display based on images from Wikipedia (2013, CC BY-SA 3.0)

1.2 Case Study Summary

Jena is a German city, which is due to its specific geographic location (including orographic and topographic conditions) exposed to various climate change related risks, especially heat stress and floods. Based on existing climate projection a substantial increase in the exposure towards these risks is expected.

As the city administration and political decision makers were aware of this fact in 2009 the Department of Urban Development & City Planning in cooperation with the Thuringian Institute for Sustainability and Climate Protection (ThINK) started to develop a handbook on climate proofing urban development. This process, which involved relevant local and regional stakeholders, was finished in 2012. The handbook includes a documentation of climate change related local effects and possible adaptation measures.

Within the BASE project the development of the urban adaptation strategy is analysed inter alia reflecting on the understanding of climate adaptation by relevant actors, role of leadership, steering mechanisms applied, types of knowledge used, stakeholders involved in the process and the multitude of drivers and barriers of this process. Furthermore on the basis of up-to-date climate data a re-analysis of the climate change impacts projected so far will be conducted. The implementation process of the urban adaptation strategy will directly be supported through an adaptation check of 3 major building projects, i.e. economic assessment of preliminary drafts of land development plans under present and projected climate conditions. Due to the specific type of exposure there is a special focus on urban planning initiatives regarding urban heat and climate proofing of infrastructure. The mainstreaming of the adaptation strategy in the existing institutional setting is been reflected on including an analysis of drivers promoting and barriers hindering the implementation process.

1.3 Context

Jena is a prosperous city of 105,000 inhabitants forming together with the neighbouring cities Erfurt and Weimar the central metropolitan area of the state of Thuringia with approximately 500,000 inhabitants. It is located in the very centre of Germany, i.e. 300 km North-east of Frankfurt, 170 km West of Dresden, 250 km South-west of Berlin and 370 km North of Munich. Jena is situated in the hilly landscape of Saale river valley surrounded by shell limestone slopes. The city centre in the valley is situated at 160 m a.s.l., whereas the surrounding mountains rise up to 400 m a.s.l..

Important historic events include:

- First historic record of the city (1236),
- Establishment of the University (1558),
- Numerous intellectuals, artists and writers as Goethe, Schiller, Fichte, Hegel, Feuerbach, Schlegel and Tieck influence the city's spirit (around 1800),
- Development of optical industry (nowadays the city's economic backbone) through the activities of Carl Zeiss, Ernst Abbe, Otto Schott (1848-1884),
- 15% of city's building destroyed by bomb attacks (February/March 1945).

Jena is characterized by a long-standing civic culture, strong engagement of the citizens in public matters and a vivid intellectual, cultural and economic life. It has an international reputation as a

scientific centre and has been among the best ranked business locations within Germany for the last 5 years. About 21,000 students are enrolled at the Friedrich-Schiller-University Jena and about 5,000 at the Jena University of Applied Sciences. More than 4,500 scientists work at the R&D departments of the local companies and the numerous internationally renowned research institutes including many institutes of the leading German research societies.

Since the late 19th century Jena has been one of the world's most important centres of the optical industry. Many of the nowadays operating optical companies have their origin in the former Carl Zeiss factory. The local economy is primarily based on high-tech industry and research. In addition to the optical industry software engineering and biotechnology are relevant economic sectors. At the territory of the former GDR (including Berlin) only 7 listed incorporated companies have their headquarters, which are part of a major German stock index (DAX, MDAX, TecDAX, SDAX). In Berlin 5 of them (real estate, media, software, services) are located and the other 2 (all manufacturing) reside in Jena.

Contrary to most of the East German municipalities population in Jena is growing (see Figure 3). The number of inhabitants increased from 97,000 in 2000 to 106,000 in 2013 and the population forecast for 2030 is 109,090. Subsequently the number of employees also increased from 58,800 in 2002 to 69,300 in 2011 and will further grow up to 74,300 in 2025. Jena is a growing city in a shrinking region. The trend of obsolescence is been mitigated by the influx of students and young families. These developments on one hand enhance the supply of skilled labour but on the other hand also create an ever-increasing demand for land for residential areas and industrial real estates. Demand for industrial and so-called special areas increases steadily from 362 ha p.a. in 2011 to 399 ha p.a. in 2025.

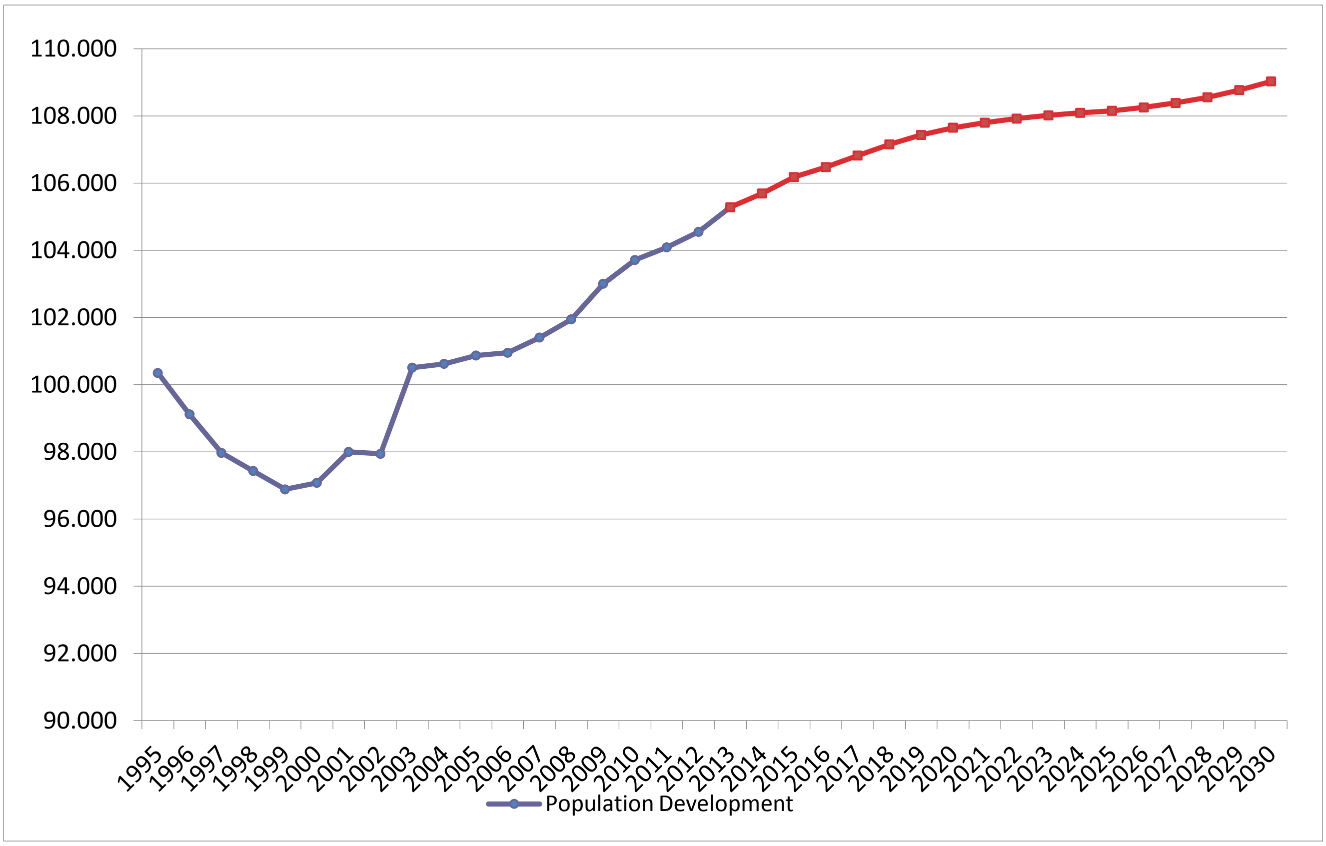

Figure 3: Development of the population in Jena, 1995-2030

1.4 Brief General Information on Climate Change and related issues

Jena is located in the warm-temperate zone of Europe, which is characterized by warm summers and relatively cold winters. Weather conditions, which are primarily determined by locational factors occurring on average on one out of five days, can cause very cold days in winter and heat stress in summer especially in the densely populated areas. The average precipitation of 587 mm p.a. is relatively low compared to other municipalities in the state of Thuringia.

In the last 100 years the average annual temperature (+1.2 K) and the number of summer days (Tmax≥ 25°C) and hot days (Tmax≥ 30°C) increased appreciably. The annual precipitation rate remained rather stable and seasonal precipitation rate increased slightly for the hydrological summer and somewhat more pronounced for the hydrological winter. Based on current climate projections an increase of heat stress events can be expected. Until the end of the century the average maximum temperature in summer will increase by 3 K (CMIP5, RCP 4.5) respectively 7 K (CMIP5, RCP 8.5). The number of hot days will rise from 11 (1981-2010) to 35 (CMIP5, RCP 4.5) respectively 49 (CMIP5, RCP 8.5). The same holds true for seasonal average temperature for the hydrological summer and winter. Annual precipitation rates are very likely to decline. Projections of the seasonal precipitation rates differ substantially depending on the model used. The expected temperature increase and the decrease of precipitation rates will have a negative effect on the climatic water balance in spring and summer.

Table 1: Selected climate parameters (1981-2010, 2021-2050, 2071-2100)

	1981-2010	2021-2050 WETTREG A1B	2021-2050 STAR A1B	2021-2050 CMIP5 RCP4.5	2021-2050 CMIP5 RCP8.5	2071-2100 WETTREG A1B	2071-2100 CMIP5 RCP4.5	2071-2100 CMIP5 RCP8.5
T_{max} in summer quarter (°C)	24	26	25	25.7	26.4	28	27.2	30.2
Number of hots days (T_{max} ≥ 30°C)	11	19	20	18	22	39	35	49
Precipi-tation in summer quarter (mm)	160	185	170	*	*	175	*	135
Number of sultry days (vapour pressure > 18,8 hPa)	2.4	8.8	4.5	-	-	17.8	-	-

Note: *Standard deviation of natural variability of the parameter is higher than the signal determined by the model ensemble.

Heat

The increase of the annual average temperature comes along with an increase of the number of hot days (T_{max} ≥ 30°C), hot nights (T_{min} ≥ 20°C) and most probably heatwaves. It is expected that not only thermal comfort and productivity will be negatively affected by this trend but also that heat related diseases, as for instance cardiovascular complaints, will occur more often. Elderly and ill people as well as children are considered to be most vulnerable to thermal stress.

The exposition to heat stress is highly dependent on the degree and mode of soil sealing, the properties of the building structures and the availability of green and blue structures. On the basis of measured data for the recent past (1971-2000) the number of summer days (Tmax ≥ 25°C) is highest in the city centre and the urban quarters Jena-Nord, Jena-West, Jena-Süd, Wenigenjena, Burgau, Löbstedt and Zwätzen. These areas are predominately classified as city centre, commercial or industrial area. Thermal stress is much lower in the suburban areas and the large housing estates, which are located more distant to the city centre. Fortunately, only few of the facilities taking care of people mostly affected by thermal stress (ill, elderly, young) are located in areas, which are prone to heat stress.

The wind flows coming from the side valleys and the ones streaming down the Saale valley (South → North) play a crucial role for the exchange of air masses and cooling of the metropolitan area. The following figure depicts the metropolitan intra-night cold airflows, which have simulated by the German Weather Service – DWD using the cold air drainage model KLAM_21[1].

In the first part of the night populated areas primarily benefit from cooling winds from the side valleys. Whereas in the second part of the night large-volume Saale valley winds streaming north gain force, even though wind speed is only remarkable above roof-top level.

[1] For further information see Sievers (2005) and Kossmann, Sievers (2007).

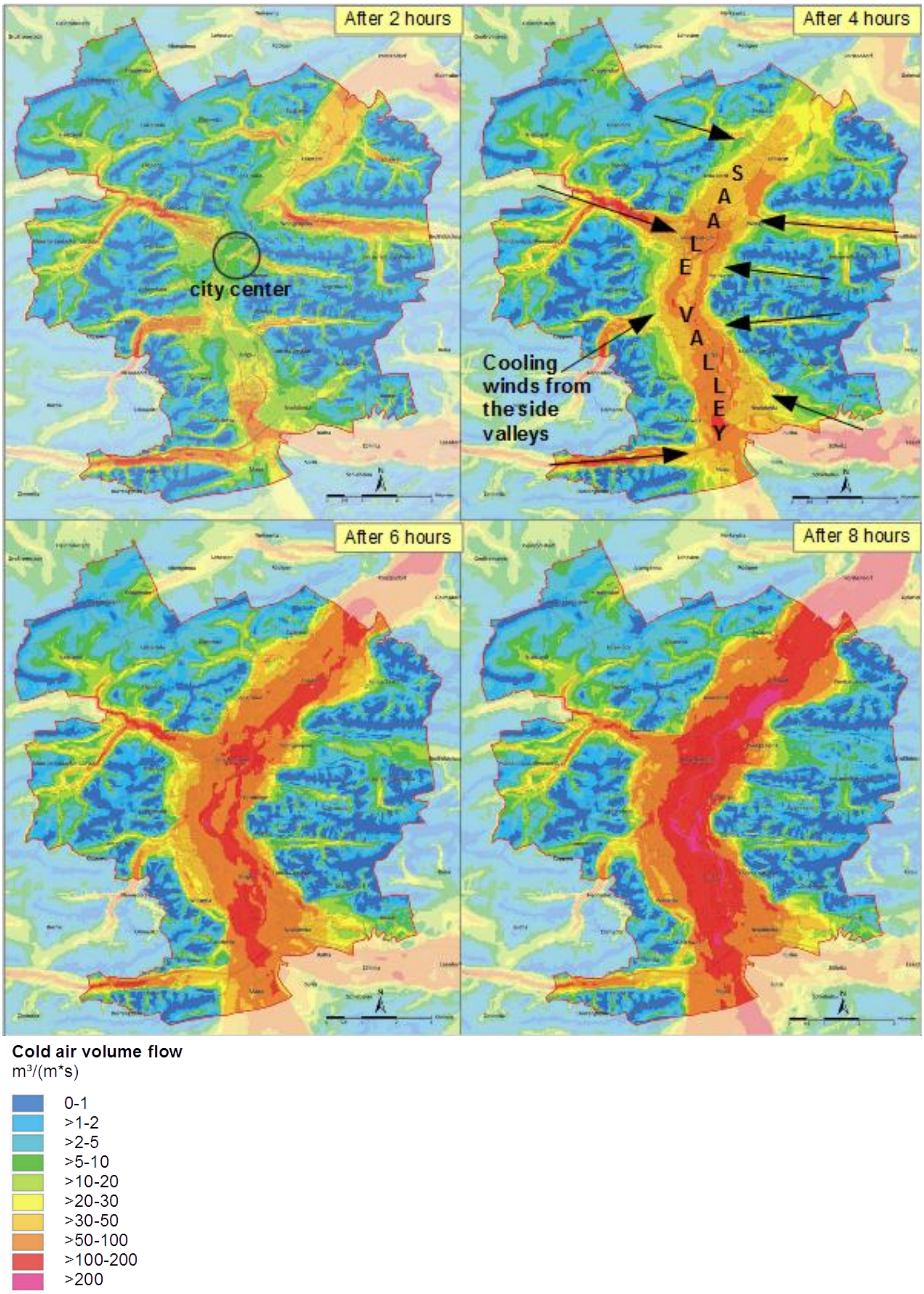

Figure 4: Cold air situation during autochthonous weather conditions after sunset in Jena
Source: Modified figure based on City of Jena (2013, p. 21).

As the city administration is well aware of the districts mostly affected by the heat island effect, a multitude of measures aimed at diminishing heat related risks has been discussed by relevant stakeholders and a selection of the most adequate ones has been included in a database which is accessible for all citizens and urban planners. Whenever major constructions projects are being

planned the risk of heat stress is being regarded and potential countering measures have to be considered.

Floods

In Jena floods are primarily been caused either by the first-order river Saale or by the second-order river Leutra. Additionally, heavy precipitation events can exceed the capacity of the sewer system and lead to sewer overflows. To date evidence regarding the climate change related flood risk for the river Saale is rare and mixed. The ESPON project (http://www.espon.eu) estimates for a 100-year flood event for different sections of the river Saale changes in inundation depths of +/- 1m until the end of the century.[2] For the southern parts of the city, i.e. the large housing estates Lobeda and Winzerla and the industrial area Göschwitz, constant respectively declining inundation depths (0 – -1m) are simulated. For the rest of the city an increase in inundation of up to 1m is expected.[3]

Beyond these estimates there is no information available regarding changes in flood return periods for the river Saale under different climate change scenarios at the level of the state and the municipality at the moment. One of the major problems of estimating the climate change related changes in flooding risk are the complex and varying causes of such events. In 1994 the combination of snowmelt and heavy precipitation events caused a serious flooding while the last flooding in 2013 was primarily due to many second-order rivers discharging into the Saale after many consecutive days of rain.

In spite of lacking scientific proof public debate ever more links the increasing frequency of flooding events to changing climate conditions. Inter alia on the basis of recent events and despite of the immanent uncertainties related to the impacts of climate change the city administration assumes that the flooding risk especially in connection with heavy precipitation events will increase. Therefore, some measures, which have been framed as climate adaptation measures, have already been implemented.

The areas especially exposed to the risk of flooding have been mapped using data of the flood event in summer 2013, modelling data and information about the missions of the fire brigade for the period January 2009 to July 2011. The areas with the highest flood risk are the residential area “Ringwiese” (district Winzerla) and some areas in the districts Wöllnitz, Maua and the city center. Highest material damages can be expected for the industrial area Göschwitz, some areas in the western part of the large housing estate Lobeda and the recreational area Paradies, where the football stadium is located.

Even though the state of Thuringia bears the main responsibility for the flood risk management of the river Saale, the city administration in close cooperation with the State Agency for Environment and Geology and the local fire brigade puts major efforts on identifying areas which are particularly affected by floods.

Working groups involving regional experts have been established to propose viable flood protection measures for the river Saale to the responsible authorities at the state level. First site-specific recommendations include various land management measures as increase of retention area by renaturation of private garden areas and the most affected industrial area, an increase of existing

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[2] Global circulation model ECHAM5/MPI-OM, regional circulation model CCLM, SRES A1B, 2071-2100.

[3] Information provided by courtesy of Prof. Stefan Greiving.

polder area and extensification of farm land along the river Saale. Furthermore, technical flood protection measures, i.e. the elevation of a crossroad and the construction of a dam and two flood control channel, and disaster management measures, i.e. strengthening of communication capacities and the improvement of coping capacities, have been recommended.

The current flood risk at the river Leutra was recently assessed by engineering consultants. On the basis of this analysis more site-specific recommendations have been and will further be developed. An analysis of the flood damage potential which could be the basis for an economic assessment of the potential flood protection measures neither for the Saale nor for the Leutra has yet been carried out. For the 38 first-order rivers in Thuringia currently a common methodology to assess the damage potential is been developed. For the Leutra such an analysis has been mandated by the city administration.

The following maps illustrate risk of erosion by area type for the metropolitan area (see Figure 5) and display the locations which are especially exposed to various the climate change related risks: heat, drought, flooding, erosion and the respective combinations of these risks (see Figure 6).

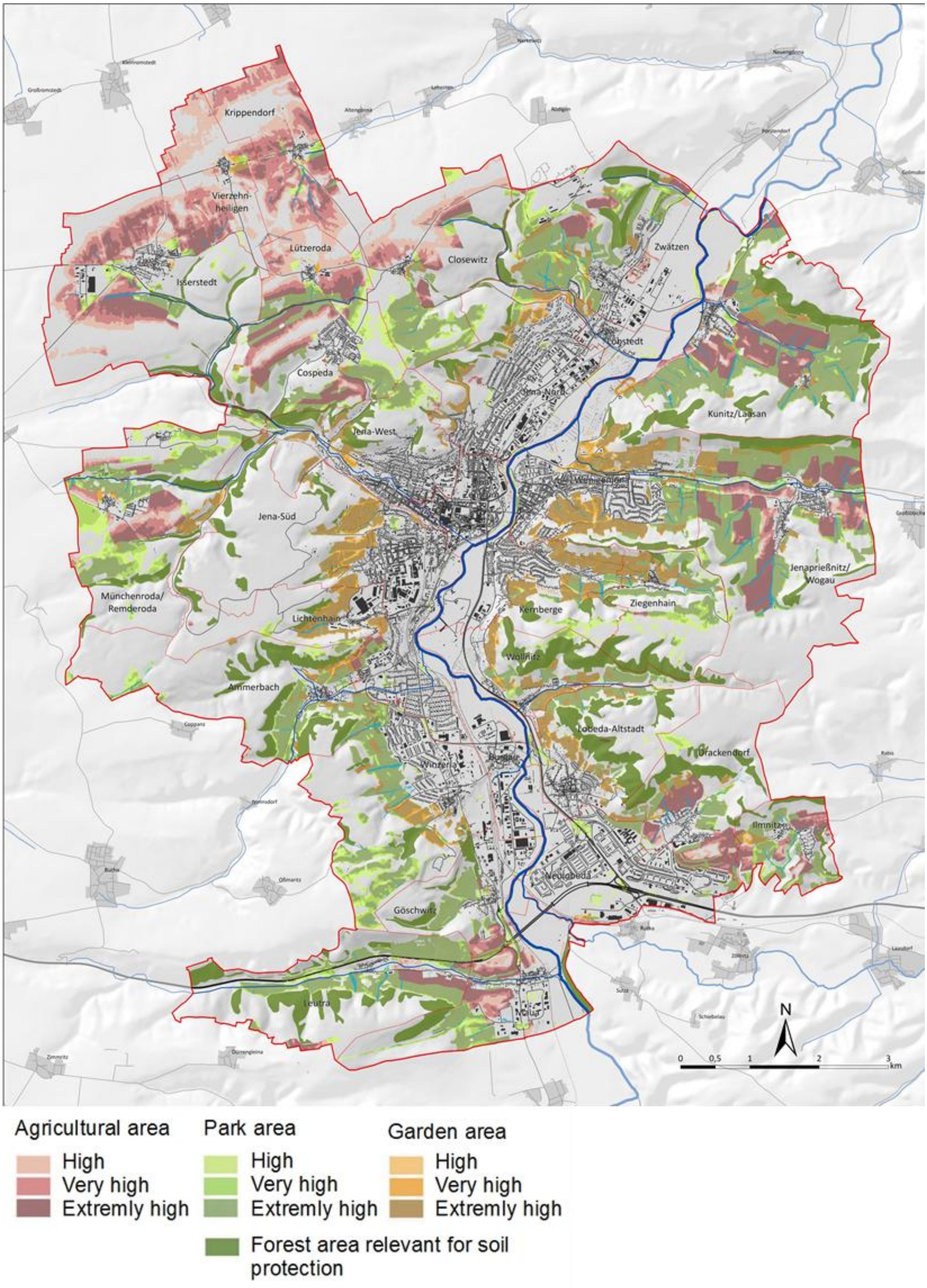

Figure 5: Current risk of erosion by area type in Jena.
Source: Modified figure based on City of Jena (2013, p. 44).

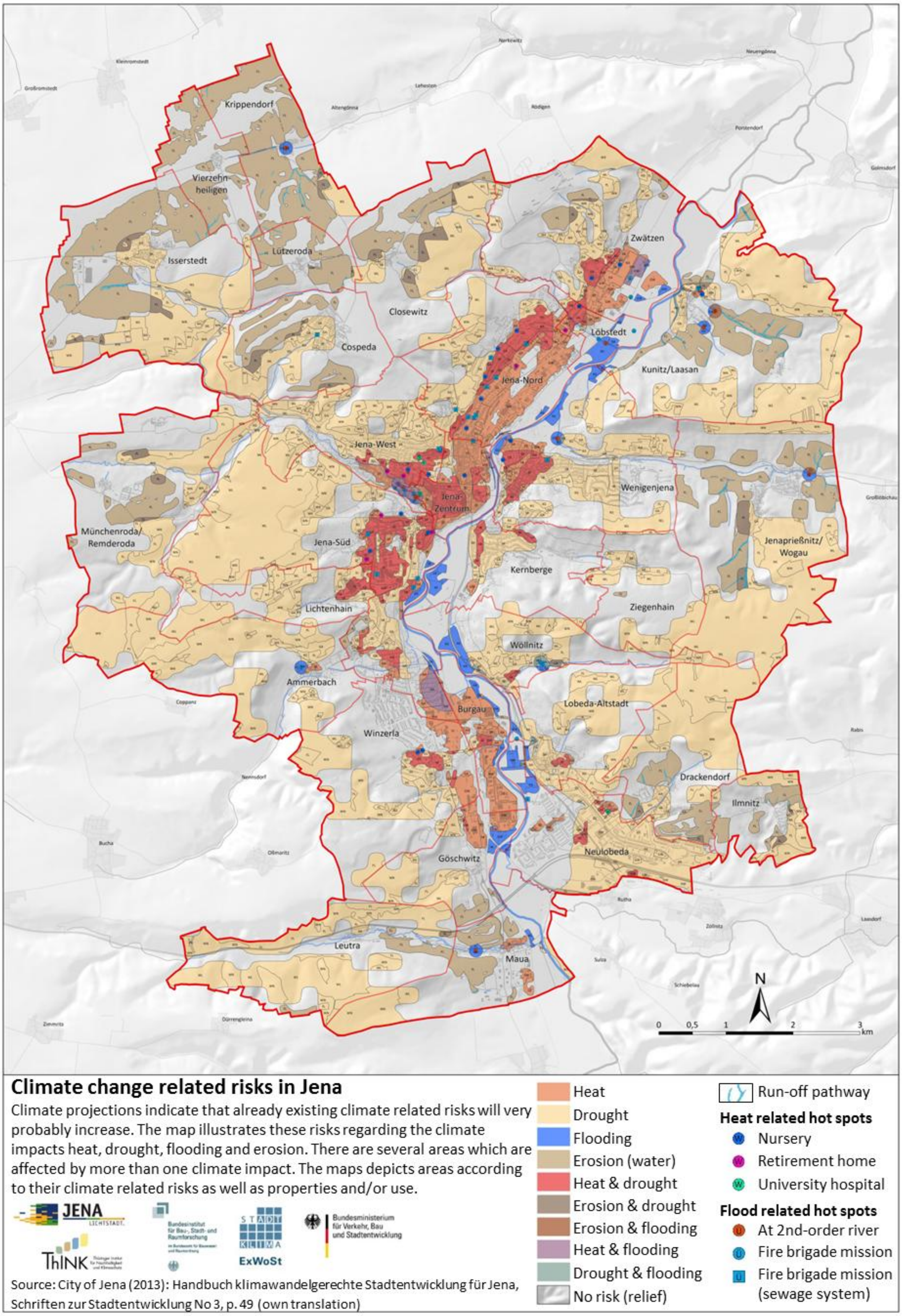

Figure 6: Climate change related risks in Jena
Source: Modified figures based on City of Jena (2013, p. 49).

1.5 Existing Information on Case Study's adaptation history

Due to the specific locational aspects and a well-established public discourse about the exceptional climate conditions in Jena the city administration and political decision makers already for decades were well aware of the city's exposition to various climate-related threats. The IPCC report in 2007 put the topic of climate change further up on the political agenda. In 2005, the first ideas of developing a plan for managing climate change-related impacts were discussed. In 2009, the Department of Urban Development & City Planning (DUDCP) commissioned and financed a pilot study to analyse local climate change impacts, to identify potential adaptation measures, and to better understand the risk perceptions of stakeholders. On the basis of its results, it was decided to develop a local climate change adaptation strategy *Jenaer KlimaAnpassungsStrategie - JenKAS*. The development was initiated as well as steered by DUDCP and financially supported by the federal government of Germany. It involved experts from all relevant departments of the city administration and agencies of the federal state of Thuringia, interested stakeholder groups (e.g., associations, and cooperatives), scientists, and local politicians.

JenKAS was formally adopted by the City Council in May 2013 and consists of various elements. Its backbone is a handbook on climate change sensible urban planning including information on current and future climate conditions and their potential impacts in Jena. The handbook also includes a discussion of legal framework conditions and instruments for climate change adaptation and best practice examples of the successful climate change adaptation in Jena and elsewhere. Furthermore, exemplary economic assessments of adaptation options applying multi-criteria analysis for two projects in Jena are presented. For each city district climate conditions are described in detail in the handbook and risks visualised using a traffic light labelling system (see Figure 7.)

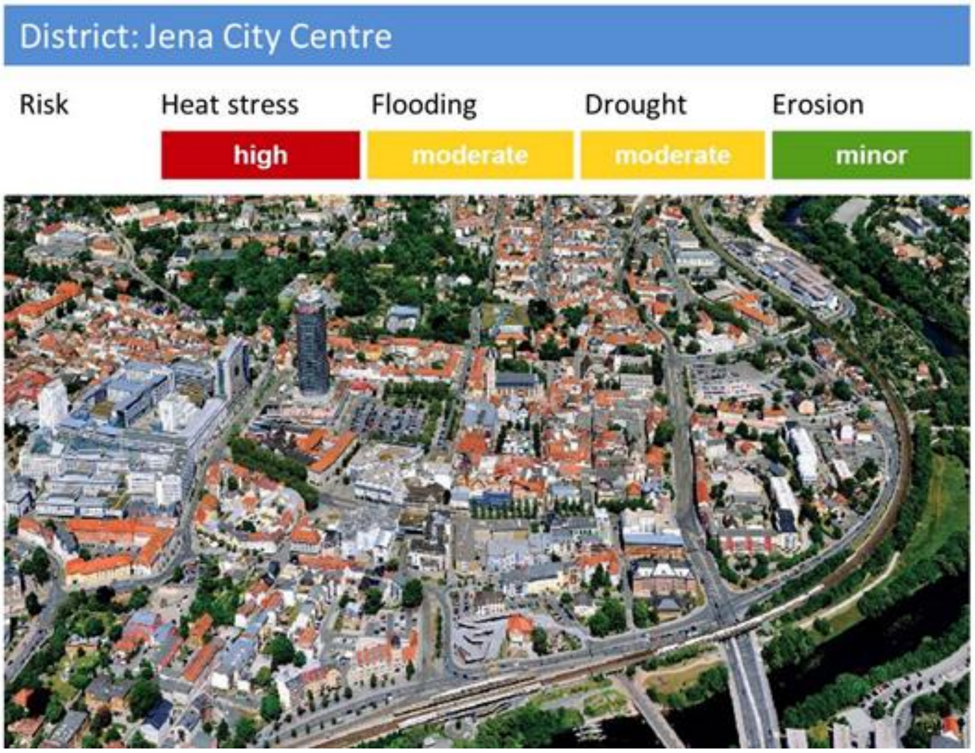

Figure 7: Risk assessment on district level: Traffic light labelling system.
Source: Modified figure based on City of Jena (2013, p. 95).

Moreover, a decision support system called JELKA (Decision support for local climate adaptation in Jena) is introduced which has been developed by the city administration and the Thuringian Institute for Sustainability and Climate Protection (ThINK) to facilitate the implementation of the strategy by making existing information more accessible and provide tailor-made recommendations for different types of stakeholders and/or decision makers.

JELKA (see Figure 8) is a database, which uses an algorithm to prioritise 118 urban adaptation measures by climate impact (e.g. flooding, drought, erosion), field of action (e.g. water management, infrastructure, environmental protection) or spatial unit (city districts). Depending on the special demands and perspectives of the user she obtains suggestions for the most relevant adaptation measures for the respective climate impact, field of action or spatial unit, which is of interest. The Department of Urban Development & City Planning does not only provide the tool for everyone who's interested but also runs trainings to enable local planners to make use of it for their daily work.

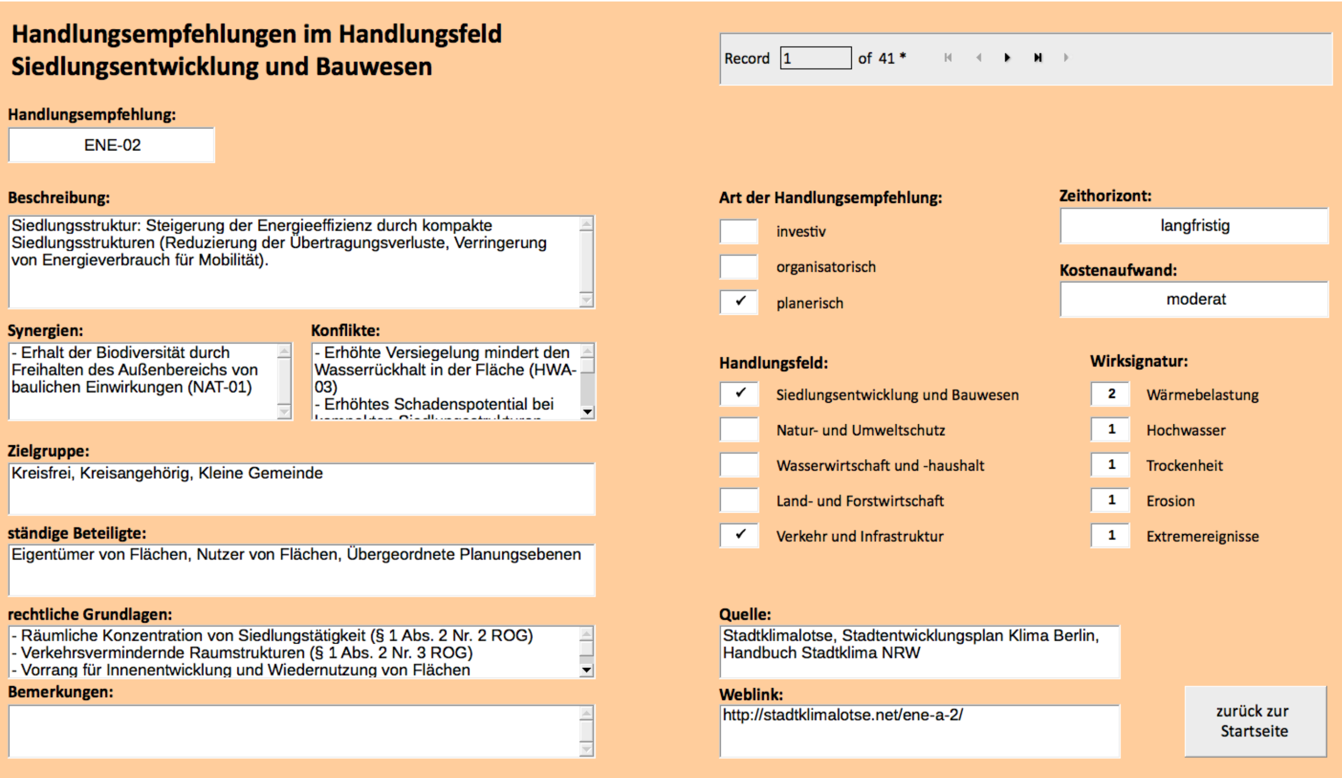

Figure 8: JELKA user interface

A series of maps has been produced to visualise various climate change related risks, e.g. heat stress, drought, river/surface flooding, erosion, and combinations thereof. Additional maps depict information on special issues, e.g. the intra-night volume of cold airflows, which has been simulated using the cold air drainage model KLAM_21 of the German Weather Service – DWD. On the basis of the climate-related risks and potential adaptation measures identified a map was produced illustrating recommendations for urban planning in particularly affected areas (see Figure 9).

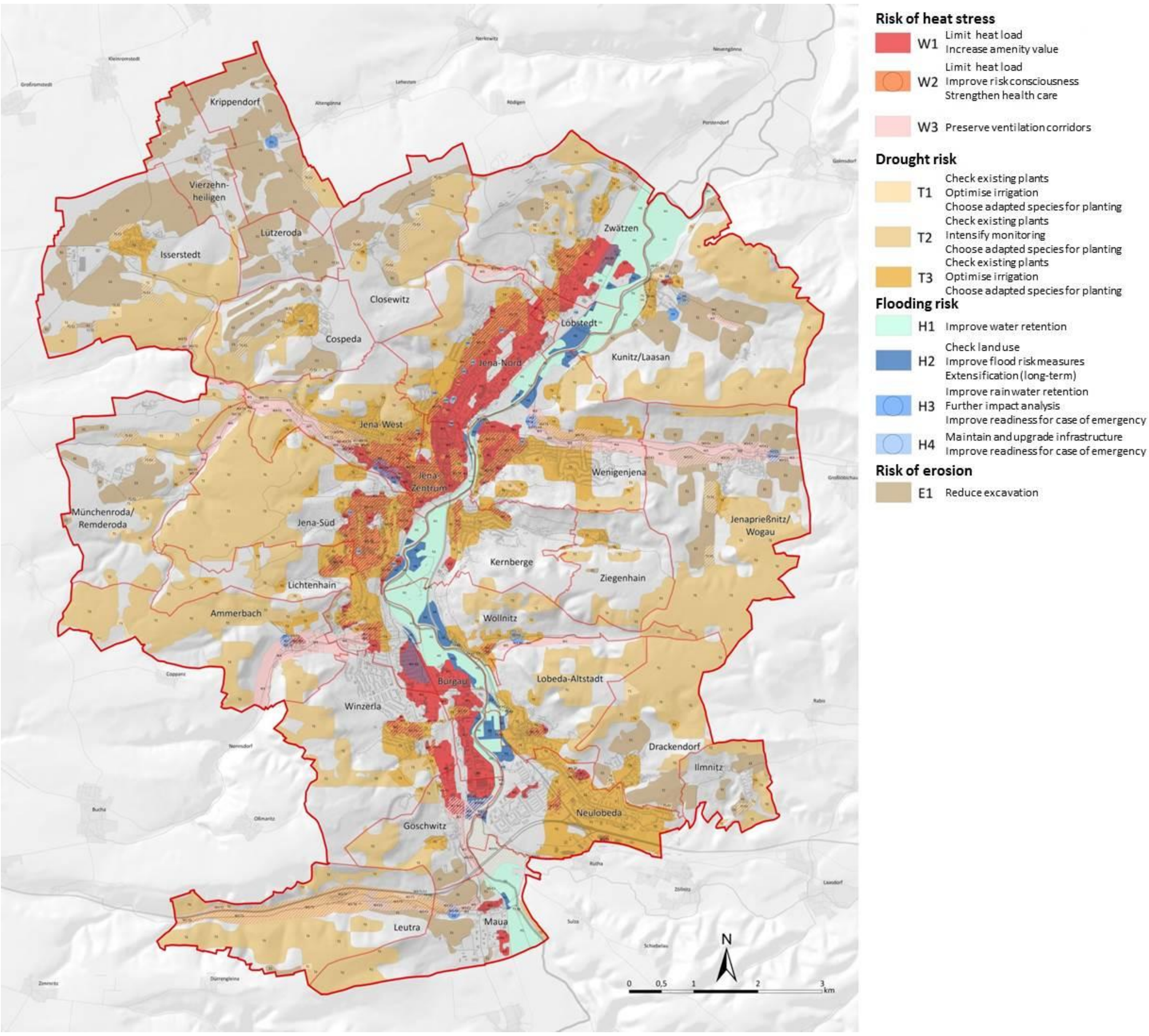

Figure 9: Climate change adaptation related recommendations for urban planning in Jena.
Source: Modified figure based on City of Jena (2013, p. 72).

All climate adaptation related information is accessible through a website (http://jenkas.de) which is been used to keep the public informed about on-going climate adaptation activities.

The main focus of implementing JenKAS is on mainstreaming climate change adaptation into administrative decision-making, i.e., the consideration of adaptation-related aspects in these processes. DUDCP promotes mainstreaming through various in-house activities, e.g. JELKA trainings. As a consequence of these efforts, a constantly growing number of land development plans refer to JenKAS when making recommendations or substantiating restrictions. It is expected that the results of current research efforts, e.g., those of a project that develops site-specific recommendations for the use of tree species taking into consideration climate, locational, and aesthetic aspects, will further promote this uptake. Beyond the actions directed at internal municipal processes, there are several activities addressing local citizens and associations, e.g., a nature trail with display boards financed by local businesses that provide information about important aspects of the changing urban climate as well as the local adaptation strategy.

One attempt to consider future climate change in today's decision-making processes is use of comparative multi-criteria assessments of preliminary construction plans (BASE activities). These assessments aim to support designs, which on one hand suit current and future climate conditions but on the other hand also take into account additional factors affecting decision-making, e.g., financial and aesthetic aspects. The heat stress potential is simulated using the modelling software Urban Heat Tool - UrbaHT, which was developed by local scientists. The software uses an algorithm to process data on various structural and climate factors that can easily be obtained from public sources. The rough estimates determined with UrbaHT do not compare with those of sophisticated software packages for micro-climatic modelling commonly used in Germany, but experience shows that the tool's low data and immediate results enhance the probability of its application and thereby the integration of such considerations into established planning routines.

As local climate change adaptation is an on-going process involving various administrative departments, stakeholders and scientists the „JenKAS working group“ was established. BASE scientists became an active part of this group which meets regularly every 2-3 months to discuss current projects, new project ideas and to share new climate change related insights and thereby preserve the momentum unleashed by the development of JenKAS local climate adaptation strategy.

1.6 Connection with other research projects:

The JenKAS project was the most relevant climate adaptation related research project the city of Jena was involved in. It has been carried out between December 2009 and September 2012. Its major goals were:

- Improvement of the availability of climate data,
- Consideration of climate change related impacts for urban planning,
- Development of options for adaptation action,
- Accessibility of climate change and adaptation related information to all relevant actors,
- Raising awareness of climate change and adaptation among the public.

The results of the project have been published as a handbook on climate proofing urban development in Jena.

Project management: Department of Urban Planning, City of Jena; Thuringian Institute for Sustainability and Climate Protection (ThINK)

Institutional partners: Germany's National Meteorological Service – DWD; Helmholtz Centre for Environmental Research – UFZ; Thuringian Climate Agency at the Thuringian Agency for Environment and Geology; Thuringian Ministry for the Environment, Agriculture, Forestry and Nature Protection; Thuringian Agency for Forestry, Hunt and Fisheries; State Agency for Environmental Protection Saxony-Anhalt

1.7 Case ID, Typologies and Dimensions

Having in mind the following BASE Objectives; Categories of Case Studies, please fill in the following table.

BASE OBJECTIVES
1. Compile and analyze data and information on adaptation measures, their effectiveness. (…)
2. Improve current, develop new and integrate methods and tools to assess climate impacts, vulnerability, risks and adaptation policies (…).
3. Identify conflicts and synergies of adaptation policies at different levels of policy making with other policies (including climate mitigation) within and between sectors. (…)
4. Assess the effectiveness and full costs and benefits of adaptation strategies to be undertaken at local, regional, and national scales using innovative approaches (mainly by integrating bottom-up knowledge/assessment and top-down dynamics/processes) with particular attention on sectors of high social and economic importance.
5. Bridge the gap between specific assessments of adaptation measures and top-down implementation of comprehensive and integrated strategies.
6. Use and develop novel participatory and deliberative tools to enhance the effective use of local contextualized knowledge in adaptation strategies to assess perceptions of adaptation pathways and their co-design by citizens and stakeholders.
7. Disseminate findings by sharing the results of the project with policy-makers, practitioners and other stakeholders. (…)

CASE STUDIES CATEGORIES	
A.	Public administration (municipality, regional, national, european)
B.	Research and education Centres (universities, research centres, projects and groups, schools)
C.	Public companies
D.	Companies (farms, SMEs, big businesses)
E.	Social enterprises (cooperatives, non profit companies, woofing farms, etc)
F.	Consortiums (partnerships, campaigns),
G.	NGOs (environmental NGO, local development NGO, charities, etc)
H.	Transition Initiative
I.	Ecovillage
J.	Informal groups, Movements

Case ID			Typologies and characterization				
Country & Name of CS	BASE Objectives to be answered by the CS	Category of case study	Territorial zones	Scale	Process Direction	Temporal Definition	Timescale[4]
Germany Jena	[x] Objective 1 [x] Objective 2 [ ] Objective 3 [x] Objective 4 [ ] Objective 5 [(x)] Objective 6 [x] Objective 7	[A] Public Administration	[ ] Rural [x] Urban [ ] Coastal [ ] River Basin	[x] Local [ ] Regional [ ] National [ ] Transnational [ ] European /Global	[ ] Bottom-Up [x] Top-Down	[x] Retrospective [x] Prospective	2013- 2015

[4] Please insert year of start and year of end of case study.

1.8 Impacts, Sectors and Implementation

Please tick the relevant boxes for impacts and implementation and insert the number 1 for primary

Impacts		Sectors		Implementation	
Primary CC Impacts (Climate-Adapt)	Primary CC Impacts (BASE)	Primary and Secondary Sector (Climate Adapt)	Primary and secondary Sector (BASE)	Implemented[5]	Phase of Implementation[2]
[x] Extreme Temperatures [ ] Water Scarcity [x] Flooding [ ] Sea level Rise [ ] Droughts [ ] Storms [ ] Ice and Snow	[x] Extreme temperatures [ ] Water scarcity [x] Flooding [ ] Coastal Erosion [ ] Droughts [ ] Soil Erosion [ ] Vector Borne Diseases [ ] Damages from extreme weather related events (storms, ice and snow)	[ ] Agriculture and forest [ ] Biodiversity [ ] Coastal Areas [ ] Disaster risk reduction [ ] Financial [ ] Health [2] Infrastructure [ ] Marine and Fisheries [ ] Water Management [1] Urban	[ ] Agriculture [ ] Biodiversity & Ecosystems [ ] Coastal and Marine systems [ ] Energy [ ] Health and Social Policies [ ] Transport [1] Production Systems and Physical Infrastructures [ ] Water resources [ ] Tourism	[ ] Yes [x] On-going [ ] No	[x] Assessment [x] Planning [x] Implementation [ ] Monitoring [ ] Evaluation

sector and the number 2 for secondary sector.

1.9 Importance and Relevance of Adaptation

Please tick the relevant box for the case study.

[ ] Case developed and implemented as a climate change adaptation measure

[ ] Case developed and implemented and partially funded as a climate change adaptation measure

[x] Case mainly developed and implemented because of other policy objectives, but with significant consideration on climate change adaptation aspects

[5] When the case study consists of a public administration with a top down approach, implementation can be an approved legislation or regulation. When the case study is about practical adaptation measures like a sand dune, for example, implementation should be considered finished when the dune is built in situ.

2 Case study research Methodology

2.1 Research Goals

The main research objective in this case study is to

- Support the planning decision making process through economic evaluations for selected projects.

Secondary research objectives are to

- Analyse the development of the urban adaptation strategy along the lines of the questions raised in chapter 3.5 of the BASE common case study approach. This includes information on the understanding of climate adaptation by relevant actors, the role of leadership, promoting and hindering factors, the steering mechanism applied, types of knowledge used and stakeholders involved in the process.
- Analyse the implementation, particularly the mainstreaming of the adaptation strategy by reflecting on drivers and barriers of the process as well as best practice solutions for fostering the acceptance by and involvement of key stakeholders.

2.2 Stakeholders involved

The exchange with relevant actors in the field of urban planning, disaster risk management as well scientist involved in the development of the urban adaptation strategy is crucial for meeting the goals of this BASE case study. The most important local stakeholders include:

- Department of Urban Development & City Planning, City of Jena
- Department of Building and the Environment, City of Jena
- Fire brigade, City of Jena
- Thuringian Institute for Sustainability and Climate Protection (ThINK)
- Thuringian Climate Agency at the Thuringian Agency for Environment and Geology (TLUG)

2.3 Methodology

Analysis of the development of the local adaptation strategy by the use of

- Expert interviews,
- Archival analysis of meeting minutes, surveys etc.

Decision support for planning/implementing adaptation projects by the use of

- Multi-criteria analysis (incl. Monte Carlo simulations and Sensitivity analysis),
- Cost-benefit analysis (incl. Monte Carlo simulations and Sensitivity analysis).

Analysis of the implementation of the local adaptation strategy by the use of

- Expert interviews,
- Archival analysis of meeting minutes etc.

Note: Partners/Case Studies using PRIMATE tool will be using CBA (to prioritise) and/or MCA (with stochastic PROMETHE II) and the Monte Carlo Uncertainty Analysis, so please check these boxes.

Methods to be used in Case Studies[6]	YES (X) // NO
A) Methods for prioritizing adaptation options	
Cost-Benefit Analysis (CBA)	X
Cost-Effectiveness Analysis (CEA)	
Multi-criteria Analysis (MCA)	X
Analytic Hierarchy Process (AHP)	
B) Quantification of impacts and relationships between factors affecting adaptation	
Causal Diagrams	
Influence Diagrams	
Process-based Modelling	
Welfare variation analysis under restrictions	
C) Uncertainty and sensitivity analysis	
Probabilistic multi model Ensemble	
Monte Carlo simulations (PRIMATE uses this method)	X
Real option analysis	
Climate risk management process	
D) Participatory Methods	
Scenario Workshop	
Participatory Cost Benefit Analysis (PCBA)	
Participatory add-ons to CBA	
Participatory add-ons to Multi Criteria Decision Analysis	X
Participatory add-ons to Adaptation Pathways	
Other (add extra lines if necessary):	

[6] For descriptions and references of the Methods please refer to Milestone 8. For data requests from specific Work Packages please refer to Deliverable 4.1

2.4 Case study Timeline

Please insert and image/graph of the Timeline of your Research Approach, highlighting important milestones and deliverables.

	To M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40
T 5.1												Report to FFCUL	Revision of D5.1																
T 5.2																				Report to UFZ					D5.2				
T 5.3																					Report to DBT		Revision of D5.3		D 5.3				
T 5.4																									Report to U Leeds	Revision of input		D5.4	
T 5.5																										Report to FFCUL			D5.5

2.5 Collaboration with other Partners and Case studies

2.5.1 Collaboration with BASE case studies

Case: Prague (Heat stress assessment); Person: Eliška Lorencová

2.5.2 Collaboration within BASE partners/researchers

Name: Mika Marttunen, Anne-Mari Rytkönen; Partner: SYKE

Name: Ad Jeuken, Laurens Bouwer, Marjolijn Haasnoot; Partner: Deltares

Name: Filipe Alves; Partner: FFCUL

2.6 Research Outputs

2.6.1 Scientific Publications

Scientific papers

Provisional Title: "Multi criteria analysis tools for flood risk management options in Dar es Salaam" by Nathalie Jean Baptiste, Stelios Grafakos, Volker Meyer, Oliver Gebhardt, to be submitted in 2015

Provisional Title: "Economic evaluation of climate change adaptation options – results and lessons learnt from 20 European case studies" by Volker Meyer, Oliver Gebhardt, Filipe Alves, to be submitted in 2016

Provisional Title: "Economic decision support for climate adaptation in urban planning: The case of Jena, Germany" by Oliver Gebhardt, to be submitted in 2016

Provisional Title: "Economic Evaluation of Adaptation Pathways" by Maaike van Aalst, Marjolijn Haasnoot, Volker Meyer, Oliver Gebhardt, to be submitted in 2016

Provisional Title: "Assessment of heat stress levels for urban planning projects using UrbaHT" by Oliver Gebhardt, Jakob Maercker, Eliska Lorencova, to be submitted in 2016

Provisional Title: "Economic decision support for urban climate change adaptation in Germany: Mismatch of supply and demand?!" by Oliver Gebhardt, Volker Meyer, to be submitted in 2016

Books/Books Chapters

Leitfäden für die Anpassung an den Klimawandel – ein Überblick" [Review of guidance for climate change adaptation], In: Andreas Marx (Hrsg.) (2015): Anpassung an den Klimawandel, Springer. (Volker Meyer, Oliver Gebhardt, Felix Meier), Month/Year: December 2015

Information at a glance/Infobox "Local Climate Change Adaptation Strategy of Jena - Jenaer KlimaAnpassungsStrategie (JenKAS)", Second Assessment Report on Climate Change and Cities (ARC3-2), Cambridge University Press, New York, Month/Year: December 2015

2.6.2 Other Publications

Annual report/Newsletter

"Nutzung probabilistischer multikriterieller Bewertungsverfahren bei der urbanen Klimaanpassung" (Use of probabilistic multi-criteria assessments for urban climate change adaptation), Helmholtz-Verbund Regionale Klimaänderungen – REKLIM, Report, p. 16-17, Month/Year: September 2015

2.6.3 Other activities

Scientific conferences

Title: Decision support for climate change adaptation under uncertainty (Platform presentation) Conference: European Climate Change Adaptation Conference 2013, Month/Year: March 2013

Title: Decision support for climate change adaptation under uncertainty (Platform presentation), Conference: Science for the environment 2013, Month/Year: October 2013

Title: Comparing economic tools for evaluation of adaptation pathways to support climate adaptation (Platform presentation by Maaike van Aalst), Conference: Deltas in times of climate change II Month/Year: September 2014

Title: Decision support in climate change adaptation – Supply and demand side perspectives (Session), ” Conference: European Climate Change Adaptation Conference 2015, Month/Year: May 2015

Title: Economic assessments for climate change adaptation in urban planning: The case of Jena, Germany (Platform presentation), Conference: European Climate Change Adaptation Conference 2015, Month/Year: May 2015

Title: Urban and roadside trees in times of climate change (Poster presentation), Conference: European Climate Change Adaptation Conference 2015, Month/Year: May 2015

Invited seminars, presentations at local events, etc.

Title: Ökonomische Instrumente zur Bewertung von Anpassungsmaßnahmen an die Folgen des Klimawandels [Economic approaches for the evaluation of adaptation measures], Conference: Sachsen-Anhalt im Klimawandel: Das Land und seine Kommunen bereiten sich vor, Month/Year: November 2013

Title: Anpassung an den Klimawandel aus ökonomischer Sicht [Adaptation to climate change from an economic perspective], Conference: Flüsse im Wandel. Was bedeutet der Klimawandel für Sachsen-Anhalt?, Month/Year: March 2014

Title: Ökonomische Instrumente zur Bewertung von Anpassungsmaßnahmenan die Folgen des Klimawandels [Economic approaches for the evaluation of adaptation measures], Conference: Hallesche Gesprächsreihe Klimawandel 2014, Month/Year: May 2014

Presentation of status quo of BASE activities in Jena, Event: Meeting inter-departmental working group on climate change adaptation in Jena, Month/Year: October 2014

Presentation of assessment results of the Winzerberge case study in Jena, Event: Meeting with urban planners involved in BASE activities in Jena, Month/Year: December 2014

Presentations of BASE intermediate and final assessment results to decision makers and stakeholders involved in Jena, Event: Meeting inter-departmental working group on climate change adaptation in Jena, Month/Year: April, May, June (2x), September 2015

Interview “Costs and benefits of green roofs in Jena”, Radio broadcast: MDR Info - Regional radio station in Central Germany, Month/Year: April 2015

Interview “Costs and benefits of green roofs”, Radio broadcast: SWR2 - Regional radio station in South-West Germany, Month/Year: June 2015

Interview “Urban trees under conditions of climate change”, Radio broadcast: Nation-wide radio station DLF, Month/Year: June 2015

3 Participation in Climate Change Adaptation

3.1 Background information[7]

Jena is due to its specific location exposed to various climate-related threats, especially heat stress and floods. Given this exposure urban planners and local scientists raised the question how these risks might change over time. In 2005, the first ideas of developing a plan for managing climate change-related impacts were discussed. In 2009, the Department of Urban Development & City Planning (DUDCP) commissioned and financed a pilot study to analyse local climate change impacts, to identify potential adaptation measures, and to better understand the risk perceptions of stakeholders. On the basis of its results, it was decided to develop a local climate change adaptation strategy Jenaer KlimaAnpassungsStrategie - JenKAS. The development was initiated as well as steered by DUDCP and financially supported by the federal government of Germany. It involved experts from all relevant departments of the city administration and agencies of the federal state of Thuringia, interested stakeholder groups (e.g., associations, and cooperatives), scientists, and local politicians.

JenKAS was formally adopted by the City Council in May 2013 and consists of various elements. Its backbone is a handbook on climate sensible urban planning that includes information on current and future climate conditions and their potential local impacts; information on legal aspects of climate change adaptation; exemplary economic assessments of adaptation options; and best practice examples of successful climate change adaptation in Jena and elsewhere. For each city district, impacts are described in detail and related risks are visualised using a traffic light labelling system. Recommendations for urban planning in particularly affected areas are presented in form of a map.

The handbook is complemented by the decision support system Jenaer Entscheidungsunterstützung für lokale Klimawandelanpassung – JELKA. This tool has been developed to make climate risk information more accessible and provide tailor-made recommendations, i.e., suitable adaptation measures for a specific field of action or spatial unit. Thereby, it is meant to accommodate the varying needs of different stakeholders and decision-makers.

The main focus of implementing JenKAS is on mainstreaming climate change adaptation into administrative decision-making, i.e., the consideration of adaptation-related aspects in these processes. DUDCP promotes mainstreaming through various in-house activities, e.g. JELKA trainings. As a consequence of these efforts, a constantly growing number of land development plans refer to JenKAS, when making recommendations or substantiating restrictions. It is expected that the results of current research efforts will further promote this uptake. Beyond the actions directed at internal municipal processes, there are several activities addressing local citizens and associations, e.g., a nature trail with display boards financed by local businesses that provide information about important aspects of the changing urban climate as well as the local adaptation strategy.

Due to the short period of time since the adoption of JenKAS, no systematic evaluation has taken place, yet. However, a first analysis identified several factors promoting local climate change adaptation in Jena, which partly relate to role of participation. The lessons learnt are:

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[7] Substantial parts of this section were transferred from section 1.5 and will be published by the end of 2015 as "Info box - Local Climate Change Adaptation Strategy of Jena" in the Second Assessment Report on Climate Change and Cities (ARC3-2) of the Urban Climate Change Research Network.

- Potential conflicts of adaption and mitigation efforts can be solved or at least mitigated by explicitly addressing these issues at an early stage of strategy and project development.
- The exchange between representatives of different administrative bodies and scientists should be institutionalised and take place on a regular basis.
- Outreach activities do not only raise awareness but also ensure the support of the general public.
- The momentum created by the initial adoption of JenKAS can be maintained through projects that continuously update and expand the existing knowledge base.
- In-house trainings organised by the Department of Urban Development & City Planning are essential to improve the ability of the municipal staff to use data and tools available for supporting adaptation.
- The public commitment of political decision-makers to support local adaptation activities is pivotal, e.g., the adoption of an adaptation strategy by the city council.

3.2 Process Overview

Below the development of the local climate adaptation strategy – JenKAS in Jena is analysed from a participatory perspective.

3.2.1 Initiative/decision to act

The administrative head of the Department of Urban Development and City Planning (DUDCP) of the city of Jena initiated the JenKAS process. Before coming to Jena he was a special advisor for sustainability to the mayor of the city of Dresden. Therefore, by professional background and personal experience (due to Dresden's high exposure to flood risk) he was sensitised to climate change-related risks. He convinced the political head of the DUDCP to pursue a precautionary approach for dealing with climate change-related risks by developing a local climate adaptation strategy.

His efforts were in line with those of a senior scientist from the Department of Geography of the local university, where the idea of developing a system to manage urban climate change impacts has been discussed since 2005. In 2008 the senior scientist proposed to the city administration to develop (in a participatory way) an integrated climate mitigation and adaptation strategy. The DUDCP and the senior scientist decided to join forces as it was apparent that the administration would not have the expertise to develop an adaptation strategy on their own.

The DUDCP prepared a resolution for the development of an urban adaptation strategy, which was adopted by the City council in April 2009. The resolution was the legal basis for a preparatory 6-months pilot project (July - December 2009) and the following development of the urban climate change adaptation strategy (2010-2012).

The fact that for decades there is a public discourse of Jena being one of the warmest cities in Germany (which it is in fact not) supported the initiative of climate change adaptation becoming part of the local political agenda.

3.2.2 Development of potential adaptation options

Preparatory project

There was a first participatory exchange on adaptation options, which already have been implemented and potential prospective adaptation measures.

JenKAS

Intensive participatory exchange on potential adaptation measures led to recommendations of district and policy field-specific adaptation measures to be considered for future urban development and construction projects.

3.2.3 Decision-making

JenKAS was adopted as an informal urban planning principle by resolution of the City council in May 2013. Hence, participation in the decision-making process was restricted to members of the City council.

However, the resolution has been prepared by the DUDCP and (almost) all relevant stakeholders were invited to participate in the development of JenKAS.

One of the motivations of DUDCP to get stakeholders from all relevant fields of action involved (especially in the development of potential adaptation actions) was to create a broad consensus among different stakeholder groups regarding JenKAS. This was considered to be a pivotal requisite not only for the adoption of the strategy by the City council but also for its implementation thereafter.

3.2.4 Implementation

The main focus of the implementation of JenKAS is on mainstreaming climate change adaptation into administrative decision making, i.e. the consideration of adaptation related aspects in these processes. DUDCP promotes the mainstreaming of JenKAS through various in-house activities, e.g. JELKA trainings.

JELKA (Decision support for local climate adaptation in Jena) is a decision support system, which has been developed to facilitate the implementation of the strategy by making existing information accessible and provide tailor-made recommendations, i.e. the most suitable adaptation measures for a specific field of action or spatial unit. Thereby, it is meant to accommodate the varying needs of different stakeholders and/or decision makers.

As a consequence of these efforts a constantly growing number of land development plans refer to JenKAS when making recommendations or substantiating restrictions. It is expected that the results of current and future research efforts, which aim to validate and expand the existing knowledge base, will further promote the implementation of JenKAS.

Beyond the actions directed at internal processes there are several activities addressing local citizens and associations, e.g. a nature trail with display boards financed by local businesses informing about important aspects of the adaptation strategy.

3.3 Initiative/Decision to act

Stakeholder groups involved in the initiative/decision to act

3.3.1 Stakeholders

No involvement

3.3.2 Citizens

No involvement

3.3.3 Experts

Preparatory project

- Financed by local public funds as funding proposal to the German Federal Ministry of the Environment wasn't successful
- Working group "Regional climate and sustainability" of the Department of Geography of the Friedrich Schiller University Jena engaged in the decision the initiate the process

JenKAS

- Mainly financed through a research programme of the German Federal Ministry of Traffic, Construction and Urban Development (co-financed by local funds)
- Thuringian Institute of Sustainability and Climate protection - ThINK; private university spin-off (former working group "Regional climate and sustainability") engaged in the decision to develop an adaptation strategy based on the preparatory project

For further information see 3.1 Process Overview - Initiative/decision to act

3.3.4 Politicians (City Council)

Legal basis for the development of the urban climate change adaptation strategy JenKAS (including the preparatory project) is the resolution by the City council from 22.04.2009.

3.3.5 City administration

Head of the Department of Urban Development and City Planning (DUDCP) was the main promoter of the initiative to start the preparatory project as well as JenKAS.

For further information see 3.2.1.

3.4 Development of potential adaptation options

3.4.1 Stakeholders

Preparatory project

3 separate workshops with specific stakeholder groups

- Construction, traffic, infrastructure

- Ecosystems, agriculture, forestry
- Energy supply, businesses, industry

Most participating stakeholders came from building, infrastructure and service sector.

About 50% of the stakeholders involved came from various departments of the city administration (see "City administration").

2nd biggest stakeholder group: representatives of companies owned or run by the municipality, e.g. public transport company, public real estate management, energy & water supply company.

Some single stakeholders from academia, agricultural cooperatives and nature protection associations.

1 common stakeholder workshop to discuss preliminary results of 3 workshops took place.

1 final dissemination workshop addressing all stakeholders was organised.

1 dissemination workshop addressing the general public, which was at the same time the kick-off meeting for the development of the urban adaptation strategy JenKAS.

Remark:

Urban climate change adaptation was not on many stakeholders' agenda in 2009, therefore, it was difficult to get people involved in the process.

As there was a strong focus on flood-related risks (due to professional and personal background of the head of the DUDCP) health issues have not been at the heart of the debate at the beginning of the process. Another reason was that the primary aim of initiating this process was to climate-proof urban planning activities and the DUDCP had and continues to have limited influence on health-related issues within the city administration. When the relevance of this policy area became apparent (in discussions about heat-related threats) the Department of Health was invited to participate in the process, but did not become part of the preparatory project.

JenKAS

4 separate workshops with specific stakeholder groups

- Agriculture, forestry, green spaces, environmental protection
- Traffic
- Urban development, construction
- Infrastructure

Most stakeholders involved came from various departments of the city administration (see column "City administration").

2nd biggest stakeholder group: representatives of companies owned or run by the municipality, e.g. public transport company, public services public real estate management, energy & water supply company.

Single stakeholders from public authorities of the federal state of Thuringia, academia, agricultural cooperatives, nature protection associations.

Remark:

It was easier to get people involved as many of them respectively other representatives of the respective organisations already took part in the preparatory project (have been conscious of the “problem”, familiar with the process etc.).

The Department of Health has been invited, but was reluctant to participate. Besides the “lack of personnel resources” a major concern was that the involvement might result in some new (legal) obligations to take precautionary actions in order to mitigate the effects of extreme weather-related events. Eventually, representatives took part in the workshop on urban development & construction. A separate workshop on climate change adaptation in the health sector has been organised by the city administration in cooperation with the University Bielefeld as JenKAS implementation activity after the completion of the strategy.

The association of allotment gardeners has not been involved in the JenKAS process. Urban gardeners have only been invited for the presentation of the JenKAS strategy to the general public. They made a statement at this occasion stressing that there was a gap between the relevance of urban green structures (which was stated by many JenKAS presenters) and their non-involvement in the process. The main reason for not including the urban gardeners was that before the JenKAS process started there was a fierce debate about the municipality’s initiative to search for options to relocate some dozen of allotment gardens to zone these lots residential. The steering committee was worried that this particular situation and the allotment gardeners’ uncompromising comportment would restrain open debates and the decision-making processes in the JenKAS workshops.

In preparation of the 4 thematic workshops a questionnaire was sent out to the participants. They were asked to provide information on (1) whether and how the respective public or private bodies already dealt with climate change effects; (2) what climate parameters were considered to be relevant and (3) what kind of data or expertise had been used so far. Participants were asked to reflect on (1) chances and risks related to climate change in their daily work; (2) changes, which can already be noticed and (3) potential risk hot spots within the city. Climate adaptation was addressed by asking (1) whether this was an issue at all; (2) whether adaptation measures have been implemented or planned; (3) whether any estimates regarding the benefits and costs of implemented or planned adaptation measures could be made and (4) what kind of data would be needed to specify, assess and implement adaptation measures.

As an introduction to the workshops scientists of the Thuringian Institute of Sustainability and Climate protection gave an overview about the status quo and expected changes of various climate-related risks relevant for the respective policy field. Then stakeholders and representatives of the various departments of the city administration provided inputs based on the questionnaire. In the end of the workshops it was decided that scientist should develop a one-page description for each potentially relevant adaptation measure (classification, target group, legal aspects, synergies, conflicts, impact, costs, time horizon etc.) and provide this information as an input for the next workshop.

Overall about 120 potential adaptation measures were introduced to the participants of the 4 thematic follow-up workshops. A preliminary selection of potential adaptation measures was discussed in detail, e.g. including practicability and legal aspects, by the participants of the 4

workshops. A final selection of adaptation measures to be recommended for consideration in the context of future urban development and construction projects was agreed upon. These measures have been included in a database JELKA (see 3.1).

3.4.2 Citizens

Interests of citizens have been considered through the involvement of civic associations.

Remark:

There has been some reflecting on whether it would have been possible and would have created some added value, if citizens were directly, i.e. not just through civic associations, involved in the JenKAS process. Based on experiences made at the various JenKAS workshops the ones steering the process came to the conclusion that due to specific goal of the JenKAS process, i.e. to develop recommendation to climate-proof urban planning, and the fact that providing the input needed was very challenging even for the experts involved, this would quite probably not have been the case.

3.4.3 Experts

- Thuringian Institute of Sustainability and Climate protection - ThINK; private university spin-off (former working group “Regional climate and sustainability")
- Thuringian Climate Agency at the Thuringian Agency for Environment and Geology
- Various agencies of the federal state of Thuringia
- Helmholtz Centre for Environmental Research - UFZ

3.4.4 Politicians (City Council)

- Honorary assistant for climate protection and sustainability, who is nowadays the political head of the Department of Urban Development and City Planning (DUDCP).

3.4.5 City administration

- JenKAS steering group at the Department of Urban Development and City Planning (DUDCP)
- Department of Environmental Protection and Construction
- Department of Urban Restructuring (Team Traffic Management),
- Department of Health, Department of Social and Family Affairs, Department of public safety (Fire brigade)

3.5 Decision-making

3.5.1 Stakeholders

No involvement

3.5.2 Citizens

No involvement

3.5.3 Experts

No involvement

3.5.4 Politicians (City Council)

The JenKAS strategy was approved as an informal urban planning principle by the City Council in May 2013.

Remark:

Political decision-making has been intensively prepared through the activities described under 3.4. The final decision regarding the approval of the strategy was taken by the City Council. The risks, measures, approaches, tools etc. described, specified and/or explained in the strategy are recommended to be considered, applied etc. in the context of current and future urban planning projects. The JenKAS strategy has been approved as an informal urban planning principle.

3.5.5 City administration

No involvement

3.6 Implementation

3.6.1 Stakeholders

Various stakeholders, primarily representatives of public bodies, are engaged in the research and/or consultancy projects, which aim to validate and expand the existing knowledge base on climate change impacts as well as adequate responses.

Based on the specific focus of the respective projects relevant stakeholders are invited for participation.

3.6.2 Citizens

Limited involvement

Remark:

Several activities address citizens and local associations, e.g., a nature trail with display boards financed by local businesses that provide information about important aspects of the changing urban climate as well as the local adaptation strategy. Relatively few activities aim to create civic

ownership of the JenKAS strategy. There is a strong focus on facilitating the use of the information and tools provided by JenKAS within the city administration. However, there are several adaptation-enhancing activities, which have been established before JenKAS, e.g. a yearly green façade award.

3.6.3 Experts

ThINK runs trainings/workshops (commissioned by the DUDCP) for employees of the city administration to facilitate the use of JELKA.

There are 1 to 3 research and/or consultancy projects every year, which aim to validate and expand the existing knowledge base on climate change impacts as well as adequate responses, e.g.,:

Projects on the consideration of future climate change in today's decision-making processes in urban planning by means of comparative multi-criteria assessments of preliminary construction plans. (Helmholtz Centre for Environmental Research – UFZ)

Pilot project on the use of existing public (technical) infrastructure, e.g. temperature sensors installed at public buildings, to improve the current basis of urban climate data to enhance the identification of urban heat stress hot spots. (ThINK)

The project "Urban trees under conditions of climate change", which develops site-specific tree planting recommendations taking into consideration climate, locational and aesthetic aspects. (University of Dresden, ThINK, private local landscape planner)

3.6.4 Politicians (City Council)

No involvement

3.6.5 City administration

Primarily urban planners are involved in the implementation of JenKAS.

The growing number of land development plans referring to JenKAS for making recommendations or substantiating restrictions indicates that urban planners increasingly make use of the information provided by JenKAS.

Representatives of other departments of the city administration are involved in the research and/or consultancy projects to validate and expand the existing knowledge base on climate change impacts as well as adequate responses, if their area of responsibility is affected and/or expertise is needed.

4 Climate Change Adaptation Measures and Strategies

4.1 Adaptation Measures under analysis in your case study

4.1.1 Adaptation Measure(s):

- Green structures (trees, bushes, facade greening, roof greening)
- Reflective properties of surfaces (albedo)
- Type and extent of soil sealing
- Composition and properties (size, etc.) of building structures

Various combinations of the adaptation measures are specified and corresponding drafts developed.

4.1.2 Adaptation Measures selection and data availability prior to BASE

The measures under consideration are typical options to diminish heat stress potential and improve the local microclimate.

4.2 Full description of Adaptation Measures

4.2.1 Process

Would, or at which part would, institutions and private stakeholders implement the measure autonomously to adapt to climate change (Adaptive capacity)?

No. Private stakeholders would not redevelop the area surrounding the apartment complex as the area is the property of the municipality.

Does the measure initiate further activities for adaptation to climate change? If yes, please name which!

No

Does adaptation aim for flexibility and reflexivity (i.e. the ability to change as CC and other factors develop)?

Yes

Is the measure effective under different climate scenarios and different socio-economic scenarios? (Y/N)

Yes

Is the adaptation measure iterative? (Y/N)

No

Does the measure contribute to overall sustainable development, alleviate already existing problems and bring benefits for other social, environmental or economic objectives than adaptation (no regret measures)? (Y/N)

Please describe briefly how!

Yes

The redevelopment of the area will benefit residents in multiple ways and can be considered a no regret activity. The municipality is aiming to create a more pleasant environment for the residents. Besides these amenity aspects in the medium- and long-term perspective there will be positive biodiversity effects.

Can adjustments be made later if conditions change again or if changes are different from those expected today? (Y/N)

Yes

4.2.2 Outcome

Relevance and effectiveness of adaptation measures

How important is the climate change threat addressed by the measure? What economic values, ecosystem functions and socio-cultural values are at stake, and to what extent are they affected by climate change impacts? Is there an indication of overriding public interest, e.g. critical infrastructures, public health?

Under current climate conditions there is comparatively low heat stress potential in the large suburban housing estates in Jena, including Winzerla. A substantial increase of the heat stress potential is expected on the basis of existing projections (WettReg2010, scenario A1B). Using the UrbaHT for the periods 2021-2050 and 2071-2100 a moderate respectively a high heat stress potential have been estimated

What portion of the targeted potential damages can be avoided by implementing the measure? (0-100%)

Heat stress related harm in the sense of damage to local residents or the general public health can hardly be estimated for this rather small area. Nevertheless, the heat stress potential of various types of conceptual drafts for the redevelopment of the area for different period of time can be determined. The drafts under discussion are assessed in a comparative manner to limit the site-specific heat stress potential. The tool UrbaHT determines a generic value, which represents the heat stress potential related to the respective draft.

Efficiency

How high are the benefits of the measure relative to the costs? Are the costs justified by the benefits? Please, refer to results of economic evaluation in chapter 5!

A cost-benefit analysis is been done for the adaptation option green roofs. For the results see section 5.2.8.

What are the costs of the administrative implementation of the measure? Are there potential funding under the umbrella of other European policies (e.g. CAP/Cohesion policy)?

No funding is required

Does the measure give an incentive for innovation to different actors (e.g. SMEs) / can it deliver a competitive advantage for the local economy? (Y/N)

No

Does the measure have effects on employment? (Y/N)

No

How long is the time lag between implementation of the adaptation measure and the effect of the measure?

There is no single point in time when the measures become effective. The effect of the redevelopment of the area with regard to heat stress reduction evolves, i.e. improves, in time.

What is the timeframe during which the measure will have an effect?

- Green roof: 40 years
- Pavements: 60 years
- Small-crowned urban trees: 40-50 years
- Large-crowned urban trees: 80-100 years

The lifespan of the different single measures, which will be implemented in the redevelopment process, varies substantially. The decision makers in the city administration assume that there only will be a redevelopment of this area in 50 years from now (irrespective of the lifespan of the measures carried out now).

Does the measure create synergies with mitigation (i.e. reduce GHG emissions or enhance GHG sequestration)? (Y/N)

Yes

Does the measure alleviate or exacerbate other environmental pressures? (Explain briefly)

The redevelopment of the area alleviates environmental pressures as it provides various (co-) benefits, which are not exclusively related to heat stress reduction, e.g. the use of green measures has positive side effects for the biodiversity.

Equity

What are the impacts on different social or economic groups are there expected impacts on particularly vulnerable groups? (Distributional impact)

There are no particular effects for different social groups expected

Does the measure enhance wellbeing and quality of life (e.g. in the urban environment)? (Y/N)

Yes

5 Impacts, Costs and Benefits of Adaptation measures

5.1 Reconstruction of the apartment complex Winzerberge

The Winzerberge reconstruction project aims at reconstructing the public area surrounding an apartment complex of 400 flats (see Figure 10 and Figure 11) in the large housing estate of Winzerla in the south of Jena. The Department of City Planning is in charge of preparing the building project. The planners are supported by the private planning consultancy “plandrei”. Potentially relevant stakeholders are the residential building cooperatives (RBCs) owning the apartment complex and the residents. As the RBCs do not own the area surrounding their buildings they are not obligated to invest in its reconstruction. Residents are in this particular case also not involved the planning process as all tenants moved out before the reconstruction started. New lessee will only move in once the reconstruction process will be finished. As a consequence the Department of City Planning is the most important actor preparing the final decisions to be taken by the city council in 2015.

Figure 10: Apartment complex Winzerberge
Note: Area is marked red.
Source: Landsat Image, Google Earth Pro

On the basis of the winning concept of an architectural competition (see Figure 12) the Department of City Planning developed two drafts (see Figure 13 and Figure 14). For considering future climate change in today’s decision-making variations of these drafts, including different kinds of heat stress mitigating adaptation measures, are comparatively assessed using multi-criteria analysis. These assessments aim to support the design of drafts, which on one hand suit current and future climate conditions best, but on the other hand also take into account additional factors such as financial and aesthetic aspects (see Table 5).

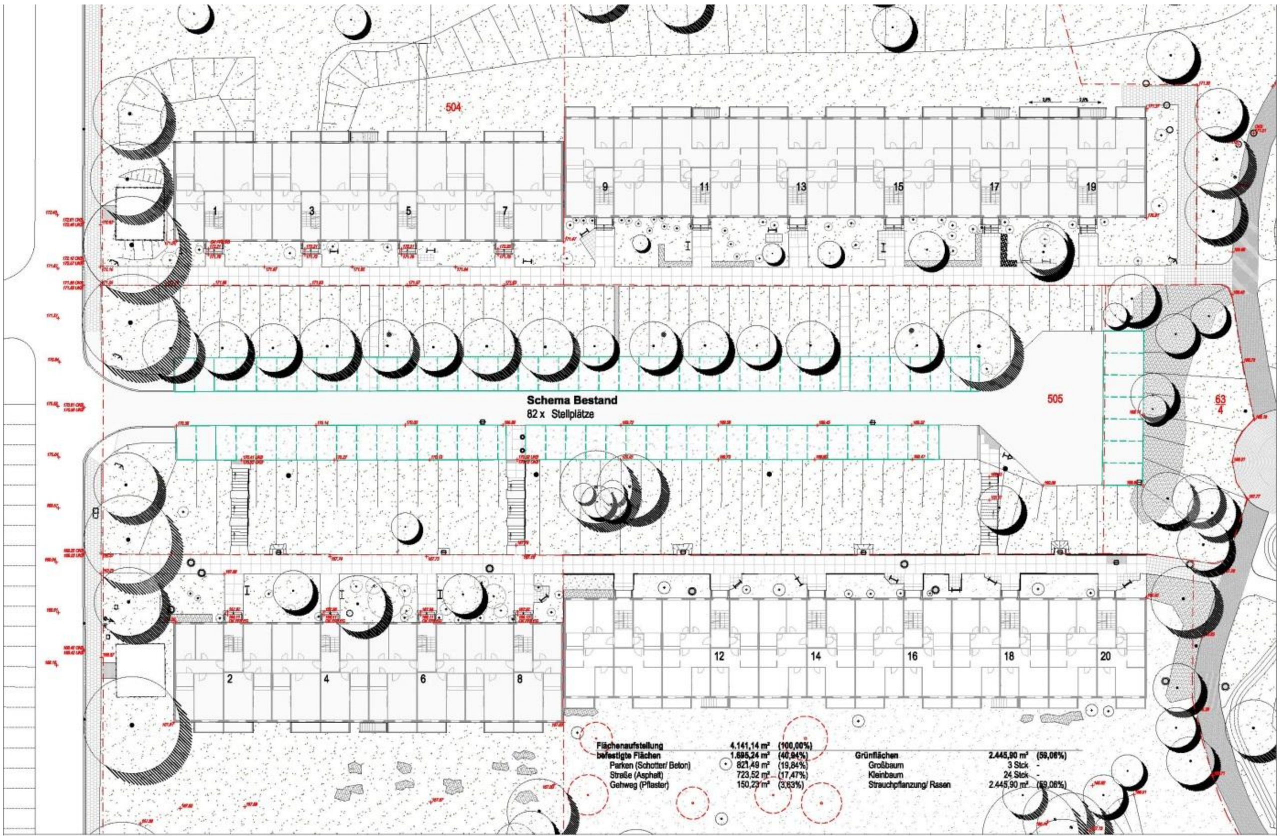

Figure 11: Current status quo of the apartment complex Winzerberge

Figure 12: Winning concept of an architectural competition

5.1.1 Step 1 – Preliminary Risk Assessment and identification of adaptation tipping points

Jena is surrounded by steep shell limestone slopes, which operate as a thermal storage system making it one of the warmest places in Central Germany. Based on current climate projections an increase of heat stress events can be expected. Until the end of the century the average maximum temperature in summer will increase by 3 K (CMIP5, RCP 4.5) respectively 6 K (CMIP5, RCP 8.5) and the number of hot days will be up to three times (CMIP5, RCP 4.5) respectively four times (CMIP5, RCP 8.5) higher than under current climate conditions. For the development of key parameters on the basis of different models and scenarios see Table 2. Despite the fact that the heat stress potential in Jena in general is lower in the suburban areas and the large housing estates located more distant to the city centre, a substantial increase of the number and intensity of heat stress events has been projected also for those areas.

Table 2 Selected climate parameters (1981-2010, 2021-2050, 2071-2100)[8]

	1981-2010	2021-2050 WETTREG A1B	2021-2050 STAR A1B	2021-2050 CMIP5 RCP4.5	2021-2050 CMIP5 RCP8.5	2071-2100 WETTREG A1B	2071-2100 CMIP5 RCP4.5	2071-2100 CMIP5 RCP8.5
T_{max} in summer quarter (°C)	24	26	25	25.7	26.4	28	27.2	30.2
Number of hot days ($T_{max} \geq 30$°C)	11	19	20	18	22	39	35	49
Precipitation in summer quarter (mm)	160	185	170	*	*	175	*	135
Number of sultry days (Vapour pressure > 18,8 hPa)	2.4	8.8	4.5	-	-	17.8	-	-

Note: *Standard deviation of natural variability of the parameter is higher than the signal determined by the model ensemble.

Changes in the site-specific heat stress potential under varying climate conditions can be simulated using the modelling software Urban Heat Tool - UrbaHT. The software uses an algorithm to process data on various structural and climate factors (see Box 1), which can easily be obtained from public sources.[9] The rough estimates (Urban heat island – UHI potential scores) determined with UrbaHT do not compare with those of established software packages for micro-climatic modelling, e.g. Predicted Mean Votes determined with ENVI-met, but the tool's low data requests and immediate results facilitate its integration into established planning routines.

The UHI potential scores range from 0 - no heat stress to 10 - maximum heat stress level (see Figure 15). Table 3 gives an overview of the results obtained for the Winzerberge area, i.e. the heat stress level for the status quo under current and future climate conditions. Measurement data from the German National Meteorological Service (DWD) and climate projection data from the Coupled

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[8] STAR (STAtistically based Regional climate model) and WettReg (WEaTher-Type based REGionalisation) are regional climate models, which belong to the empirical statistical downscaling methods. Both models use global climate data from ECHAM5.

[9] For further information see Step 4 – Data collection.

Model Intercomparison Project - Phase 5 (CMIP5)[10] for Representative Concentration Pathways (RCP) 4.5 and 8.5 provided by the KNMI Climate Explorer are used for the simulations. The scores indicate that present heat stress level is rather low but will increase substantially in future.[11]

Table 3: UrbaHT heat stress potential scores of the Winzerberge area - status quo

Period	Status quo
1981-2010	1.9
2021-2050	
CMIP5 (RCP 4.5)	2.9
CMIP5 (RCP 8.5)	3.3
2071-2100	
CMIP5 (RCP 4.5)	3.7
CMIP5 (RCP 8.5)	5.6

5.1.2 Step 2 – Identification of Adaptation Measure and Adaptation Pathways

The two basic drafts developed by the Department of City Planning in cooperation with the private planning consultancy (see Figure 13 and Figure 14) are varied with regard to the use of tree species with different crown sizes and differently coloured pavements. A small-crowned (Sorbus intermedia „Brouwers“) and a large-crowned tree species (Tilia cordata „Greenspire“) have been selected from a recommendation list published by the Heads of the Departments of Park-keeping (Deutsche Gartenamtsleiterkonferenz – GALK). These tree species are considered to be adapted to the specific urban conditions as well as the changing climate conditions. With regard to the optional colour schemes of the pavements it is assumed that either ordinarily coloured cobblestones with an albedo value of 0.3 or light-coloured material (0.5) are used.

On the basis of these variations the following alternatives are determined:

- Alternative 1 (D1TsPo): Draft 1, use of small-crowned tree species, ordinary pavement
- Alternative 2 (D1TsPl): Draft 1, use of small-crowned tree species, light-coloured pavement
- Alternative 3 (D1TlPo): Draft 1, use of large-crowned tree species, ordinary pavement
- Alternative 4 (D1TlPl): Draft 1, use of large-crowned tree species, light-coloured pavement
- Alternative 5 (D2TsPo): Draft 2, use of small-crowned tree species, ordinary pavement
- Alternative 6 (D2TsPl): Draft 2, use of small-crowned tree species, light-coloured pavement
- Alternative 7 (D2TlPo): Draft 2, use of large-crowned tree species, ordinary pavement
- Alternative 8 (D2TlPl): Draft 2, use of large-crowned tree species, light-coloured pavement

Table 4 gives an overview of the structural parameters of the 8 alternatives.

[10] For further Information on CMIP5 see http://cmip-pcmdi.llnl.gov/cmip5/data_getting_started.html

[11] When interpreting the UHI potential scores one has to take into account that the scale is identical for all climate zones.

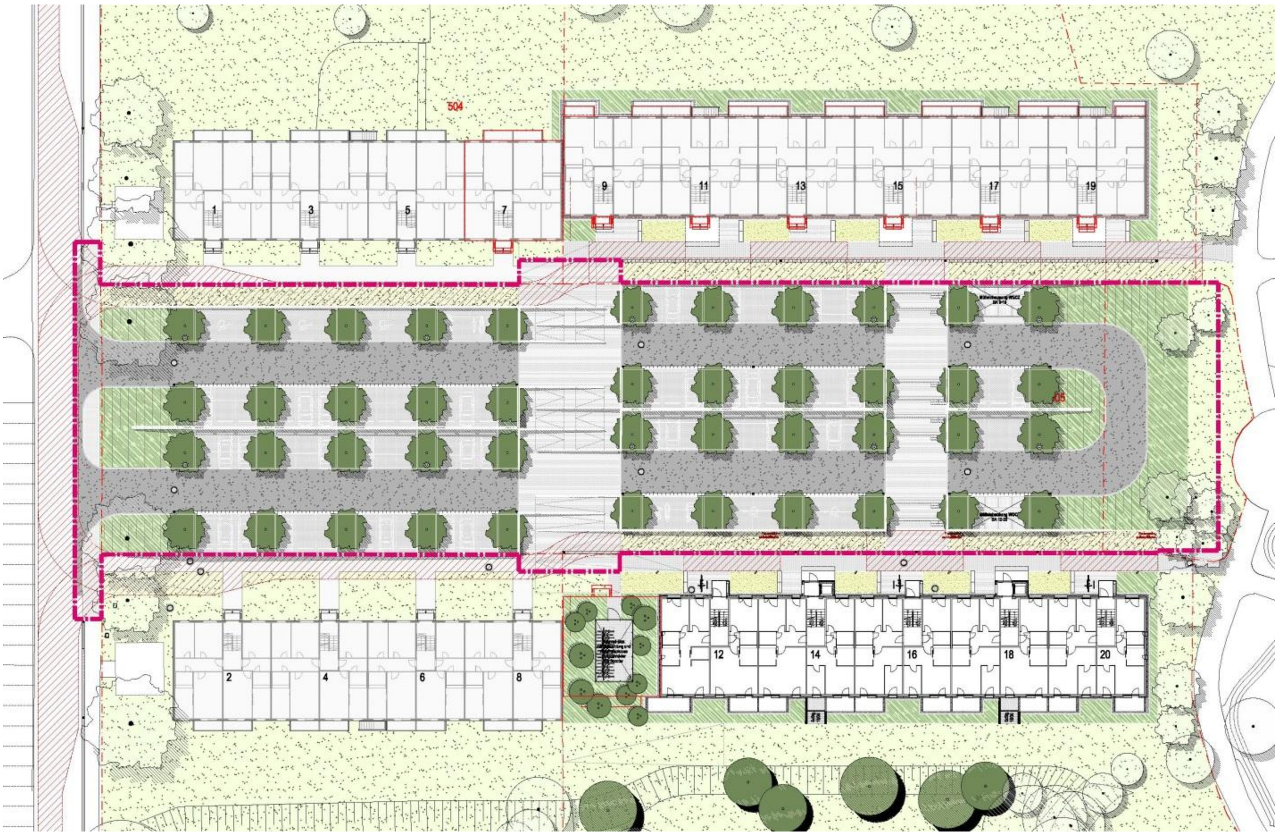

Figure 13: Draft 1

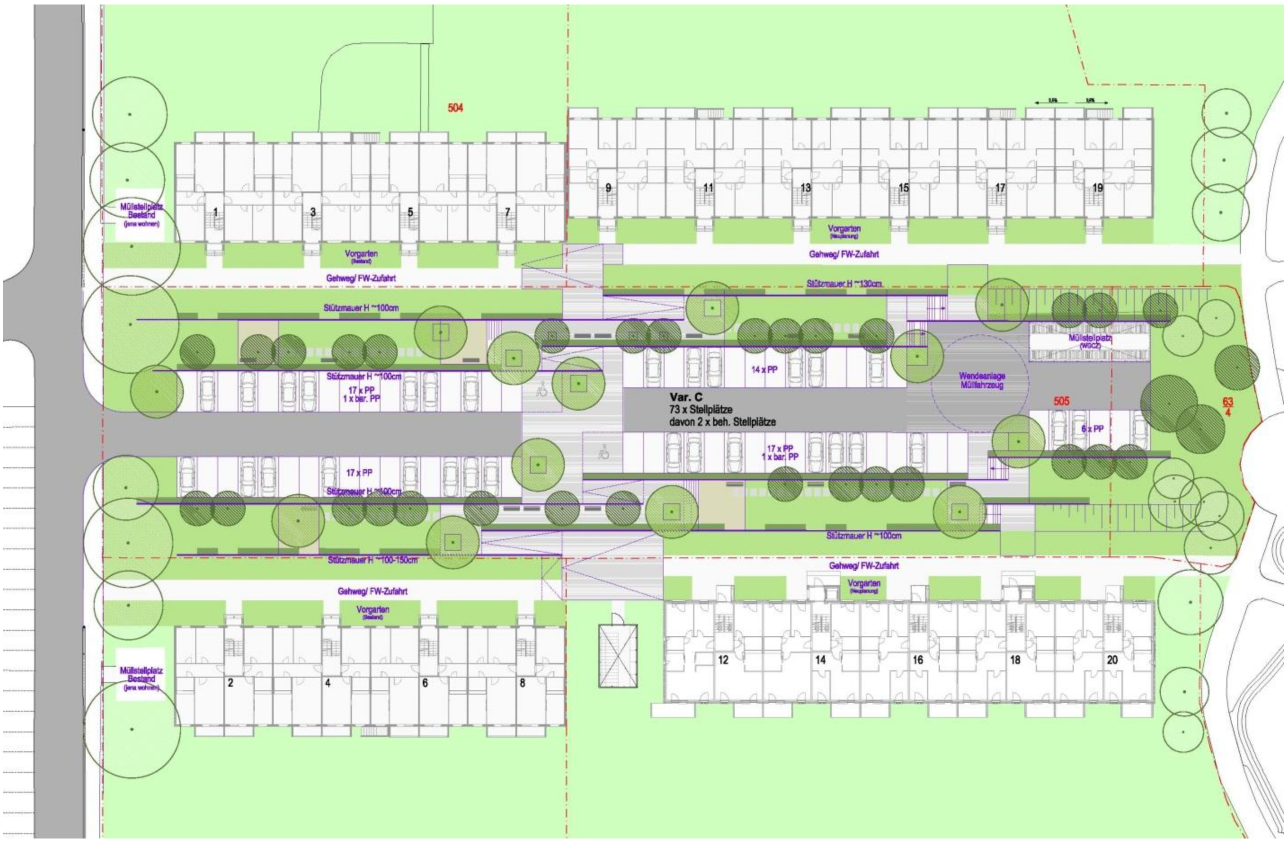

Figure 14: Draft 2

Table 4: Structural parameters of the alternatives

Structural parameter	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Area type	open midrise	open midrise	open midrise	open midrise	open midrise	open midrise	open midrise	open midrise
Share of impervious area without buildings (%)	29.5	29.5	29.5	29.5	27.5	27.5	27.5	27.5
Share of area covered by buildings (%)	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
Average height of buildings (m)	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
Construction type of buildings	in row	in row	in row	in row	in row	in row	in row	in row
Average albedo of surfaces (1981-2010)	0.238	0.240	0.267	0.270	0.243	0.245	0.277	0.280
Average albedo of surfaces (2021-2050)	0.236	0.230	0.264	0.255	0.241	0.233	0.274	0.264
Average albedo of surfaces (2071-2100)	0.244	0.226	0.271	0.244	0.238	0.217	0.270	0.243
Share of blue structures (%)	0	0	0	0	0	0	0	0
Share of lawn area (%)	46.4	46.4	46.4	46.4	47.6	47.6	47.6	47.6
Share of area covered by bushes (%)	0.8	0.8	0.8	0.8	1.7	1.7	1.7	1.7
Share of area covered by trees (1981-2010) (%)	14.0	12.6	14.0	12.6	14.3	12.9	14.3	12.9
Share of area covered by trees (2021-2050) (%)	15.8	20.5	15.8	20.5	16.3	22.4	16.3	22.4
Share of area covered by trees (2071-2100) (%)	17.8	32.1	17.8	32.1	18.5	35.2	18.5	35.2
Irrigation of green structures in summer	yes	yes	yes	yes	yes	yes	yes	yes

Note: The average albedo is calculated as weighted sum of the albedo values of all surfaces. On the basis of the construction plans it is assumed that for all variations of Draft 1 (Draft 2) 70% (80%) of the crowns of the trees cover lawn area and 30% (20%) cover pavements.

5.1.3 Step 3a Selection of evaluation criteria

The following criteria are chosen to compare the alternatives:

Net present costs (monetary) consist of the investment costs and the maintenance costs of the green structures for 40 years (period 2015-2055) respectively 85 years (2015-2100). A rate of 3% p.a. is used for discounting. The UHI potential (quantitative) represents the heat stress level related to the respective alternative. It is determined with the UrbaHT tool. The number of parking lots (quantitative), the architectural quality of the drafts (qualitative) and the amenity value (qualitative) for residents and guests are also considered for the assessment.

5.1.4 Step 3b Selection of evaluation method(s)

Several assessment methods accounting differently for various types of uncertainty can be applied to determine the most appropriate alternative. Empirical evidence shows that multi-criteria analysis (MCA) is a promising tool to support such decision processes in the field of climate change adaptation. Multi-attribute decision-making (MADM), a type of MCA, which compares pre-defined sets of alternatives are often used for applicability reasons. There are MADM concepts, which are based on multi attribute utility theory (MAUT) and so called outranking concepts, e.g. PROMETHEE, which perform pairwise comparisons of the criteria scores of all alternatives.

In contrast to MAUT approaches outranking concepts do not assume that decision-makers are completely aware of their preference structure. Furthermore, they can deal with uncertain, incomplete, differently scaled and inconsistent data. Applied in the traditional way, e.g. PROMETHEE I, they do not allow for compensation of positive and negative criteria scores. Thereby it is possible to discover unsolvable trade-off between alternatives. As PROMETHEE I provides partial pre-orders of alternatives, in these cases rankings will be incomplete. The advantage of identifying non-comparable measures is that the exchange amongst the different stakeholder-groups about the evaluation criteria and their weighting might be promoted. A complete ranking can be obtained if the so-called positive and negative preference flows are aggregated into net preference flows, which can easily be ordered (PROMETHEE II). If there are uncertainties in the criterion values which shall be considered in terms of score ranges, triangular distributions or any other probability functions Stochastic PROMETHEE II can be applied.

For the “Winzerberge” project multiple, differently scaled evaluation criteria are used to comparatively assess the alternative drafts. As for the determination of the UHI potential the RCPs 4.5 and 8.5 are used there is uncertainty concerning the performance of the alternatives with regard to this criterion. Therefore, Stochastic PROMETHEE II is applied for the assessment.

5.1.5 Step 3c Weighting of evaluation criteria

The residential building cooperatives are informed and rather informally involved in the decision making process concerning the reconstruction of the public area at the Winzerberge site. As the RBCs will only be looking for new tenants once the reconstruction of the apartment buildings will be finished no individual residents or resident associations take part in the planning process. Therefore, the employees of the Department of City Planning, who are in charge of the planning process, decide about the evaluation criteria as well as their weighting when balancing the alternative drafts.

Therefore, the weights presented in Table 5 represent the preferences of the local planning authorities. Point allocation has been used to elicit criteria weights. Despite the fact that no formal consideration of stakeholder interests is taken place, planners apparently take into account their professional experiences, i.e. anticipating typical stakeholder interests, when making these decisions.

Table 5: Weighting of evaluation criteria

Criteria	Weights in %
Heat stress potential	25
Costs	20
Parking lots	10
Amenity value	30
Architectural quality	15

5.1.6 Step 4 - Data collection

The data used for the MCA comes from different sources. The private planning consultancy "plandrei" and the construction material company "Rinn Beton- und Naturstein" provide information on investment costs. Maintenance costs of the tree population are supplied by the municipal service company "KSJ", which is responsible for taking care of the green structures on public premises in Jena. The locational heat stress potential (UHI potential) unfolding, if drafts are implemented, is estimated using the modelling software Urban Heat Tool - UrbaHT (see Box 1). The data on the structural parameters is determined as the number of parking lots on the basis of existing plans. The climate data for applying UrbaHT comes from two sources. The measurement data is provided by the German National Meteorological Service (DWD) and CMIP5 climate projection data is been sourced from the KNMI Climate Explorer. Information regarding the alternatives' performance concerning the criteria architectural quality and amenity value is collected through expert judgments from local planners.

Box 1: Urban heat tool – UrbaHT

UrbaHT is a tool for the assessment of site-specific heat stress levels under changing climate conditions and/or for varying configurations of a spatial unit, e.g. as a consequence of the implementation of an urban planning project. On the basis of these assessments users can compare different situations in which either the climate or the construction-related parameters or both of them are change at the same time for the same spatial unit. In a single run any pair of the following 4 states can be compared with UrbaHT:

Table 6: Comparative assessments with UrbaHT

	Current climate conditions	Future climate conditions
Current spatial configuration	Current heat stress level	Heat stress level for future climate conditions
Changed spatial configuration	Heat stress level for changed spatial configuration	Heat stress level for changed spatial configuration and future climate conditions

The software uses an algorithm to process data on various structural and climate factors, which can easily be obtained from public sources. The following input data is requested:

Table 7: Structural and climate input parameters for UrbaHT

Structural parameters	Climate parameters
Area type	Global radiation
Construction type	Average maximum temperature in summer quarter
Portion of impervious area (without buildings)	Average precipitation in summer quarter
Portion of impervious area covered by buildings	Influence of cold air flows for site-specific micro climate
Average height of buildings	Average wind speed
Average albedo value of surfaces	
Portion of water areas	
Portion of green areas (lawn, bushes, trees)	
Irrigation of at least 50% of green areas in summer	
Total population of the city	
Population density of study area	

The UHI potential scores determined with UrbaHT range from 0 (no heat stress) to 10 (maximum heat stress level). The scale is identical for all climate zones. The scores do not reflect, as for instance predicted mean votes, specific levels of thermal (dis)comfort. Therefore, it is recommended to rather interpret changes or differences in UHI potential scores than the absolute heat stress level values.

UHI potential score	Heat stress level
0	None
1	Very low
2	Low
3	Moderate
4	Medium
5	Slightly elevated
6	Moderatly elevated
7	Strongly elevated
8	High
9	Very high
10	Maximum

Figure 15: UrbaHT UHI potential score scale

Table 8: Heat stress potentials of alternatives for the periods 1981-2000, 2021-2050, 2071-2100

Period	Alternative 1			Alternative 2			Alternative 3			Alternative 4		
1981-2010	2.1			2.1			1.8			1.8		
2021-2050												
CMIP5 (RCP 4.5)	3.0			3.0			2.8			2.7		
CMIP5 (RCP 8.5)	3.5			3.4			3.2			3.1		
2071-2100												
CMIP5 (RCP 4.5)	3.8			3.5			3.6			3.4		
CMIP5 (RCP 8.5)	5.6			5.4			5.4			5.2		
Minimum, mean, maximum value	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**
Period 2021-2050	3.0	3.3	3.5	3.0	3.2	3.4	2.8	3.0	3.2	2.7	2.9	3.1
Period 2071-2100	3.8	4.7	5.6	3.5	4.5	5.4	3.6	4.5	5.4	3.4	4.3	5.2
	Alternative 5			**Alternative 6**			**Alternative 7**			**Alternative 8**		
1981-2010	1.9			2.0			1.6			1.6		
2021-2050												
CMIP5 (RCP 4.5)	2.9			2.8			2.6			2.5		
CMIP5 (RCP 8.5)	3.3			3.2			3.0			2.9		
2071-2100												
CMIP5 (RCP 4.5)	3.7			3.4			3.5			3.2		
CMIP5 (RCP 8.5)	5.6			5.3			5.3			4.7		
Minimum, mean, maximum value	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**
Period 2021-2050	2.9	3.1	3.3	2.8	3.0	3.2	2.6	2.8	3.0	2.5	2.7	2.9
Period 2071-2100	3.7	4.7	5.6	3.4	4.4	5.3	3.5	4.4	5.3	3.2	4.0	4.7

Table 9: Data matrix Winzerberge project

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	IT[1]	PT[2]
Net present costs (2021-2050)	1,057,977	1,057,977	1,060,234	1,060,234	1,100,077	1,100,077	1,102,472	1,102,472	10,000	500,000
Net present costs (2071-2100)	1,095,527	1,095,527	1,097,784	1,097,784	1,141,382	1,141,382	1,143,777	1,143,777	10,000	500,000
	Min I MV I Max	**Min I MV I Max**	**Min I MV I Max**	**Min I MV I Max**	**Min I MV I Max**	**Min I MV I Max**	**Min I MV I Max**	**Min I MV I Max**		
UHI potential (2021-2050)	3.0 3.25 3.5	3.0 3.20 3.4	2.8 3.00 3.2	2.7 2.90 3.1	2.9 3.10 3.3	2.8 3.00 3.2	2.6 2.80 3.0	2.5 2.70 2.9	0	3
UHI potential (2071-2100)	3.8 4.70 5.6	3.5 4.45 5.4	3.6 4.50 5.4	3.4 4.30 5.2	3.7 4.65 5.6	3.4 4.35 5.3	3.5 4.40 5.3	3.2 3.95 4.7	0	3
Number of parking lots	78	78	78	78	75	75	75	75	2	20
Architectural quality (5-point Likert scale)[3]	3	3	3	3	2	2	2	2	0	3
Amenity value (5-point Likert scale)[4]	4	4	4	4	2	2	2	2	0	3

Notes: [1,2] The Indifference threshold [IT] and preference threshold [PT] are elements of the outranking concept and in particular the PROMETHEE method that forms the mathematical basis of PRIMATE. They are defined as follows: if the difference between the performances of two alternatives in the respective criterion is less than the indifference threshold the two alternatives are counted as indifferent, such that none is preferred to the other. If the difference is above the preference threshold the alternative with the better performance is strictly preferred to the other (mathematically it received a score of 1). If the difference is in between, the better alternative is weakly preferred to the other and received a score between 0 and 1, such that the score linearly increases with the difference between the performances (…) (Drechsler 2004: p. 3). [3, 4] 1 – very good, 2 – good, 3 – average, 4 – poor, 5 – very poor.

5.1.7 Step 5 – Evaluation and Prioritisation

The MCA compares the alternatives described above. This implies that the status quo is due to the main goal of the planning process, i.e. the redevelopment of the area, not considered for the assessment. Nevertheless, it is interesting to examine, how the heat stress levels corresponding to the respective drafts compare with the UHI potential of the status quo for different climate conditions. Table 10 gives an overview about the results of this comparison. It can be seen that mainly due to the already existing vegetation the status quo performs quite well under current climate conditions. The performance gap widens over time, especially regarding the best performing drafts. Furthermore, simulations give evidence that the heat stress level increases substantially due to the changing climate conditions if the status quo, i.e. the current spatial configuration, does not change. A considerable share of this increase can be avoided if the best performing alternative 8 is implemented.

Table 10: Heat stress potentials of the status quo configuration and the alternatives of the Winzerberge project for the periods 1981-2000, 2021-2050, 2071-2100

Period	Status quo	Alter-native 1	Alter-native 2	Alter-native 3	Alter-native 4	Alter-native 5	Alter-native 6	Alter-native 7	Alter-native 8
1981-2010	1.9	2.1	2.1	1.8	1.8	1.9	2.0	1.6	1.6
2021-2050									
CMIP5 (RCP 4.5)	2.9	3.0	3.0	2.8	2.7	2.9	2.8	2.6	2.5
CMIP5 (RCP 8.5)	3.3	3.5	3.4	3.2	3.1	3.3	3.2	3.0	2.9
2071-2100									
CMIP5 (RCP 4.5)	3.7	3.8	3.5	3.6	3.4	3.7	3.4	3.5	3.2
CMIP5 (RCP 8.5)	5.6	5.6	5.4	5.4	5.2	5.6	5.3	5.3	4.7

The application of the MCA approach Stochastic PROMETHEE II is facilitated by using software for Probabilistic Multi-Attribute Evaluation – PRIMATE (Drechsler 2004), which has already been tested in several pilot projects dealing with various aspects of climate change adaptation at the regional and local level. Therefore, the input data of the Winzerberge evaluation (see Table 9) is entered into and processed with PRIMATE (see Figure 16).

One option for considering uncertainty in criteria values in PRIMATE is through the use of score ranges, triangular or other probability distributions and the application of a Monte Carlo simulation approach. The resulting uncertainty of the final outcomes is documented in PRIMATE (see Figure 18 and Figure 19). Uncertainty in the UHI potential scores is due to the use of two RCPs. For the assessment with PRIMATE a triangular distribution is used (see Figure 17).

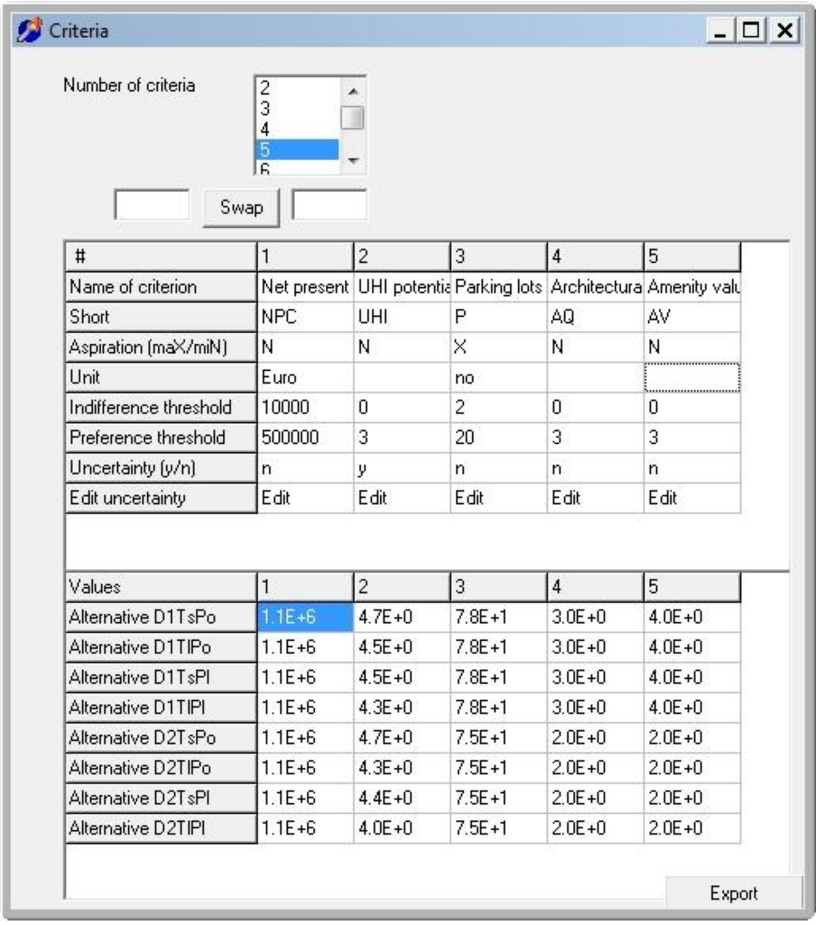

Figure 16: MCA data matrix in PRIMATE (2071-2100)

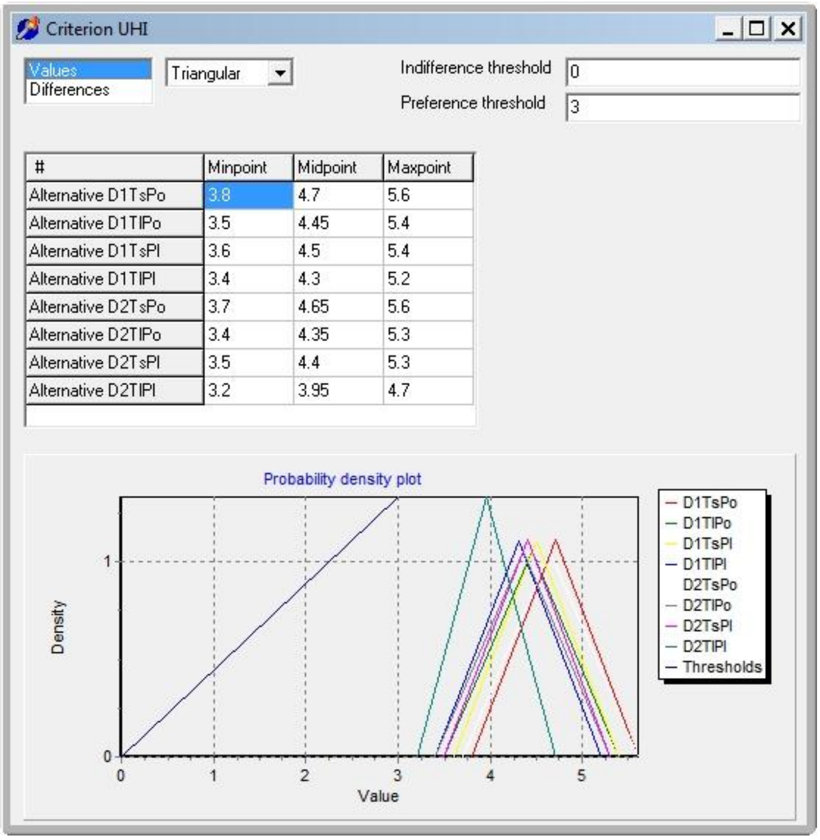

Figure 17: Entering UHI potential scores in PRIMATE (2071-2100)

PRIMATE performs 10,000 runs and calculates for each alternative the outflow, i.e. the positive preference flow and extent to which the alternative outranks all other alternatives, the inflow, i.e. the negative preference flow and extent to which the alternative is outranked by all other alternatives and the net flows, i.e. the aggregation of positive and negative preference flows into a net preference flow. On the basis of these net flows a complete order of the alternatives can be established.

Figure 18 depicts the net flows of all alternatives for the period 2021-2050. The red bars represent the mean values of the net flows determined by 10,000 PRIMATE runs. The higher the net flow the better performs the respective alternative with regard to all evaluation criteria applied. The yellow uncertainty bar represents two standard deviations of the mean value of the net flows, i.e. about 95.4% of the net flows determined fall within this margin.

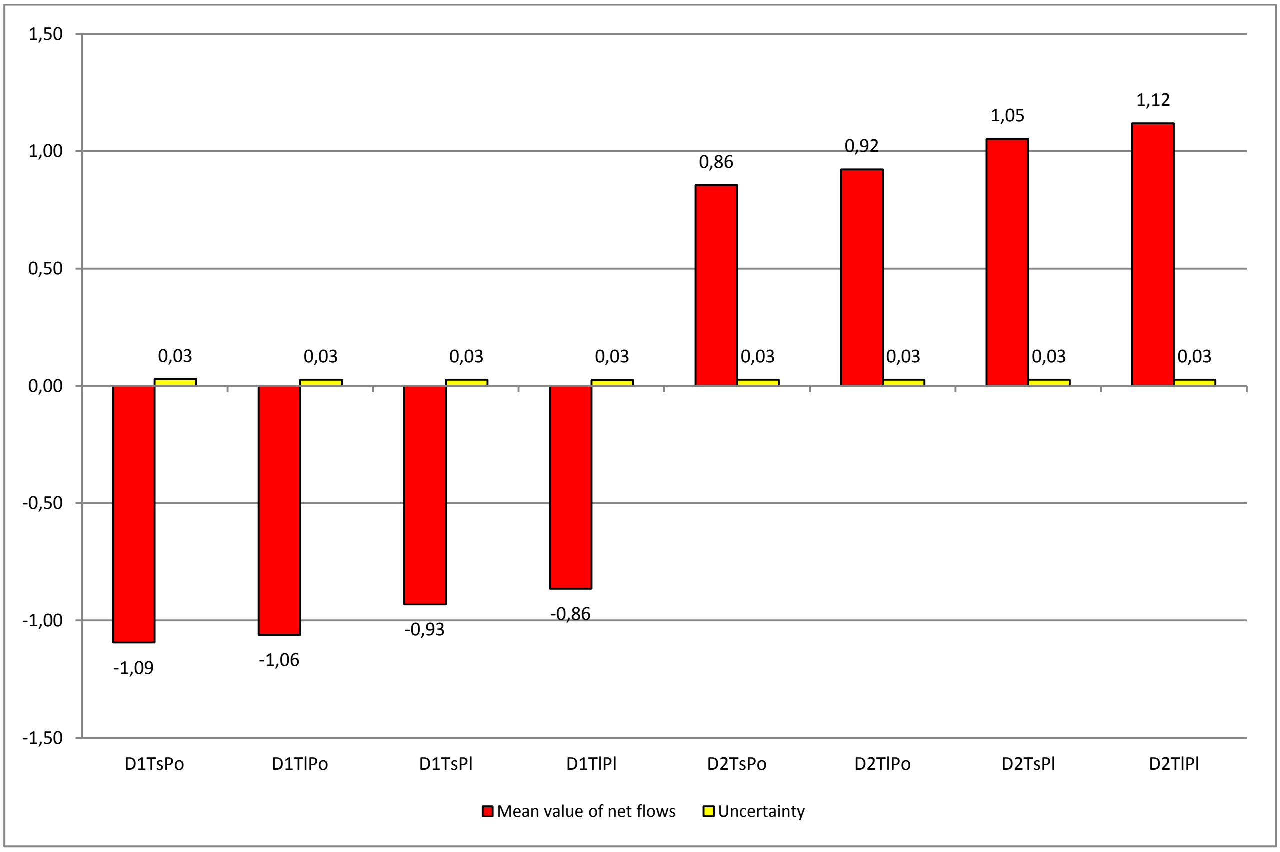

Figure 18: Overall net flows of the alternatives for the period 2021-2050

Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

In the medium term perspective all variations of Draft 2 outperform the alternatives based on Draft 1 (see Figure 18). Alternative 8 (D2TlPl: Draft 2, use of large-crowned tree species, light-coloured pavement) ranks best and Alternative 1 (D1TsPo: Draft 1, use of small-crowned tree species, ordinary pavement) shows the worst overall performance. Uncertainty is negligible, i.e. the result is robust.

The results for the long-term perspective are very similar (see Figure 19). In general it can be noticed that the variations using large-crowned tree species, as some of their beneficial effects only materialise after a certain period of time, perform better than in the long than in the medium term. Again alternative 8 clearly outperforms all other alternatives. The level of uncertainty with regard to

these results is higher as the variation of important climate parameters for RCP 4.5 and RCP 8.5 is more pronounced in the long run. But still the result can be considered to be robust.

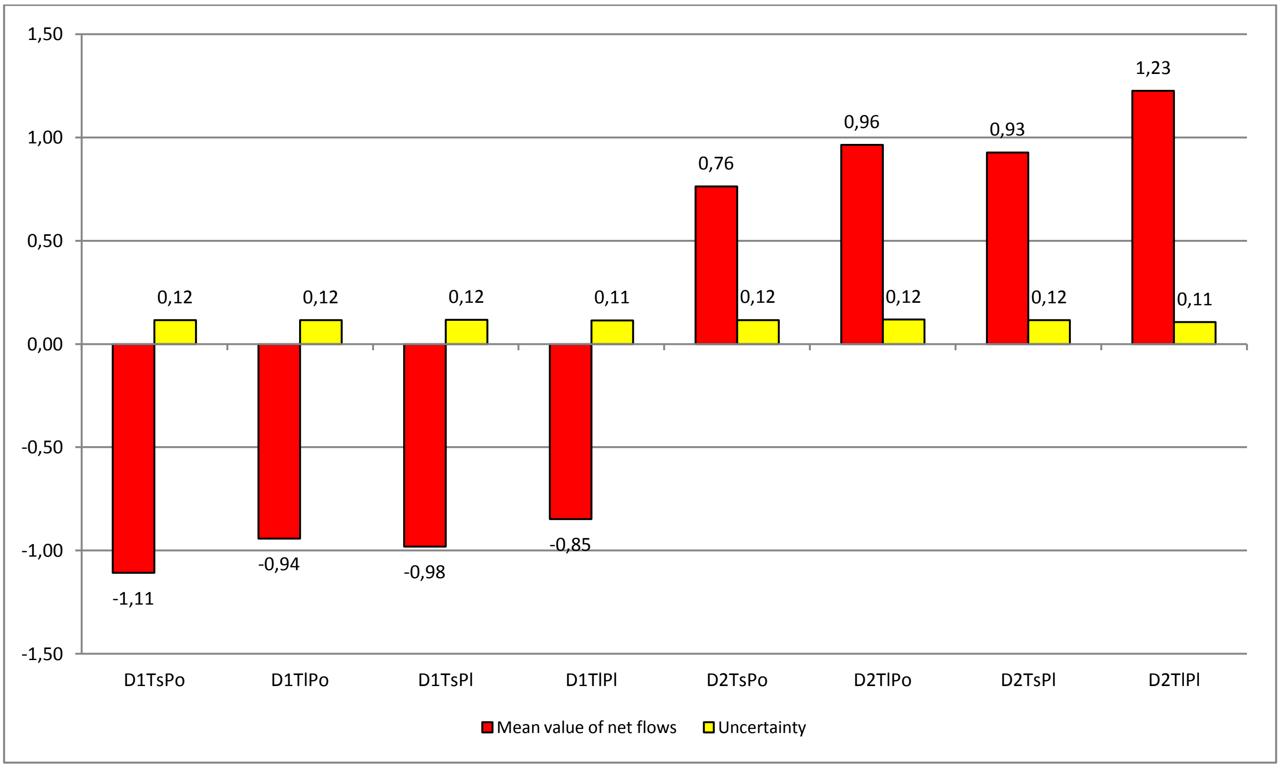

Figure 19: Overall net flows of the alternatives for the period 2071-2100
Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

The UHI potential scores for the alternatives vary quite substantially as can be seen in Table 10. This is confirmed by the net (preference) flows for this criterion (see Figure 20 and Figure 21).

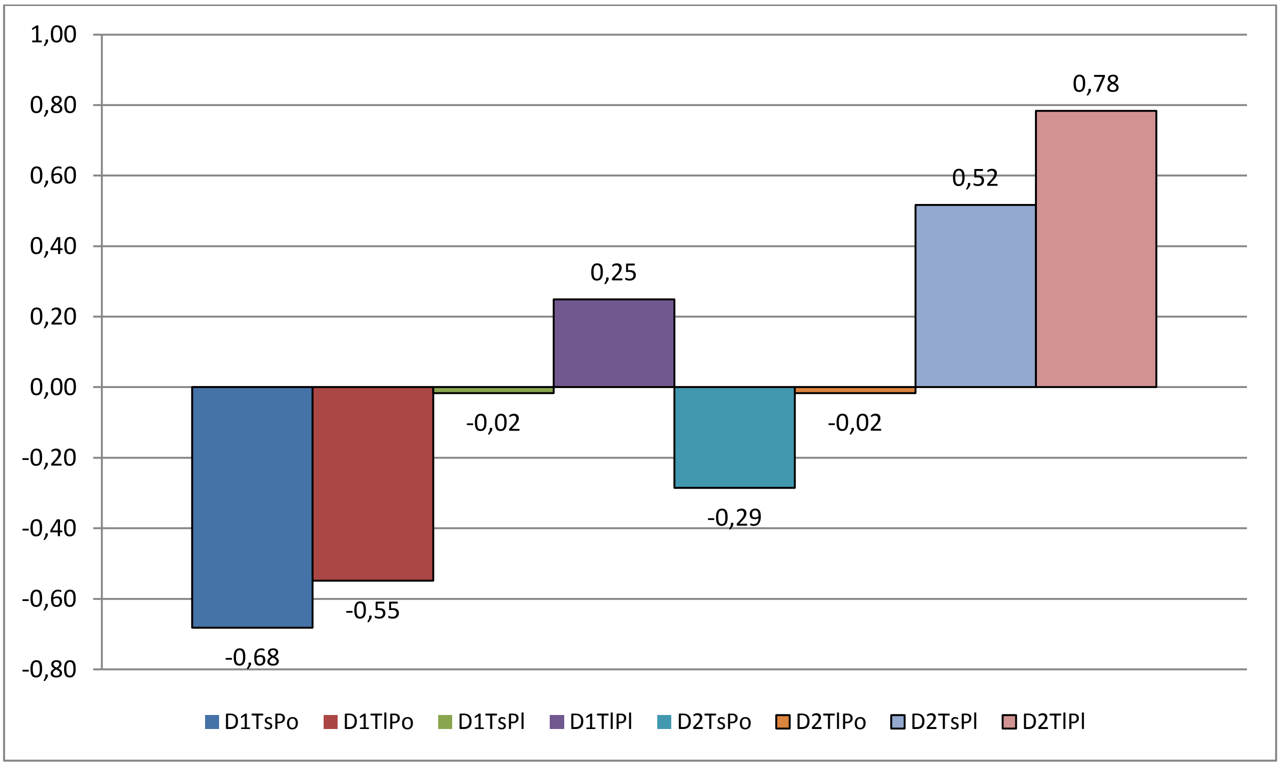

Figure 20: UHI potential net flows of the alternatives for the period 2021-2050

Figure 20 and Figure 21 also illustrate that not all alternatives based on Draft 2 outperform in this respect the ones being based on Draft 1. In the medium term alternative 4 (D1TlPl: Draft 1, use of large-crowned tree species, light-coloured pavement) ranks third and, thereby, outperforms two variations of Draft 2. As already noticed before, variations of Draft 1 and Draft 2 using large-crowned tree species tap their full potential to mitigate heat stress only after a certain period of time. Their performance regarding the criterion UHI potential improves remarkably in the long run. This can easily be seen, if the net flows of the alternatives 3 (D1TsPl), 4 (D1TlPl), 7 (D2TsPl) and 8 (D2TlPl) for the period 2021-2050 and the period 2071-2100 are compared (see Figure 20 and Figure 21).

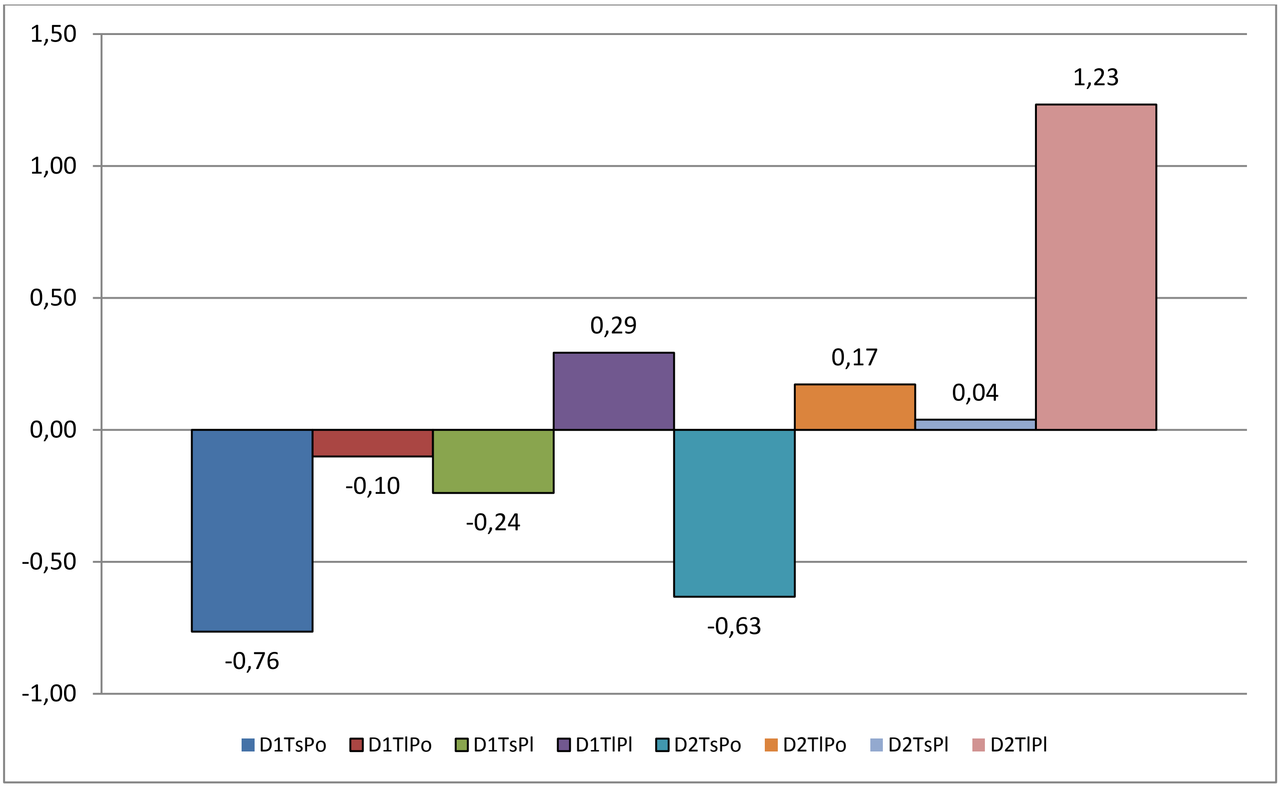

Figure 21: UHI potential net flows of the alternatives for the period 2071-2100

The final result of the assessment can be presented as mean values of the overall net flows (and the corresponding standard deviations) or as a ranking of the alternatives. In the latter case the uncertainty of the result is expressed as a probability of an alternative to rank first, second and so on. Figure 22 illustrates the ranking of the alternatives for the period 2021-2050 and Figure 23 for the period 2071-2100.

For the medium term perspective a comparatively unambiguous ranking of the alternatives is been determined. Unsurprisingly, the ranking is in accordance with the order of the net flows for this period. With a probability of 96% alternative 8 (D2TlPl) ranks first. Even though the final result with regard to the best alternative is almost the same in the long term, i.e. with a probability of 91% alternative 8 ranks first, due to the higher level of uncertainty the overall ranking is much more ambiguous for the period 2071-2100. This holds especially for the alternatives 6 (D2TlPo: 2nd) and 7 (D2TsPl: 3rd) as well as alternative 2 (D1TlPo: 6th) and 3 (D1TsPl: 7th), which also have changed ranks compared to the medium term perspective.

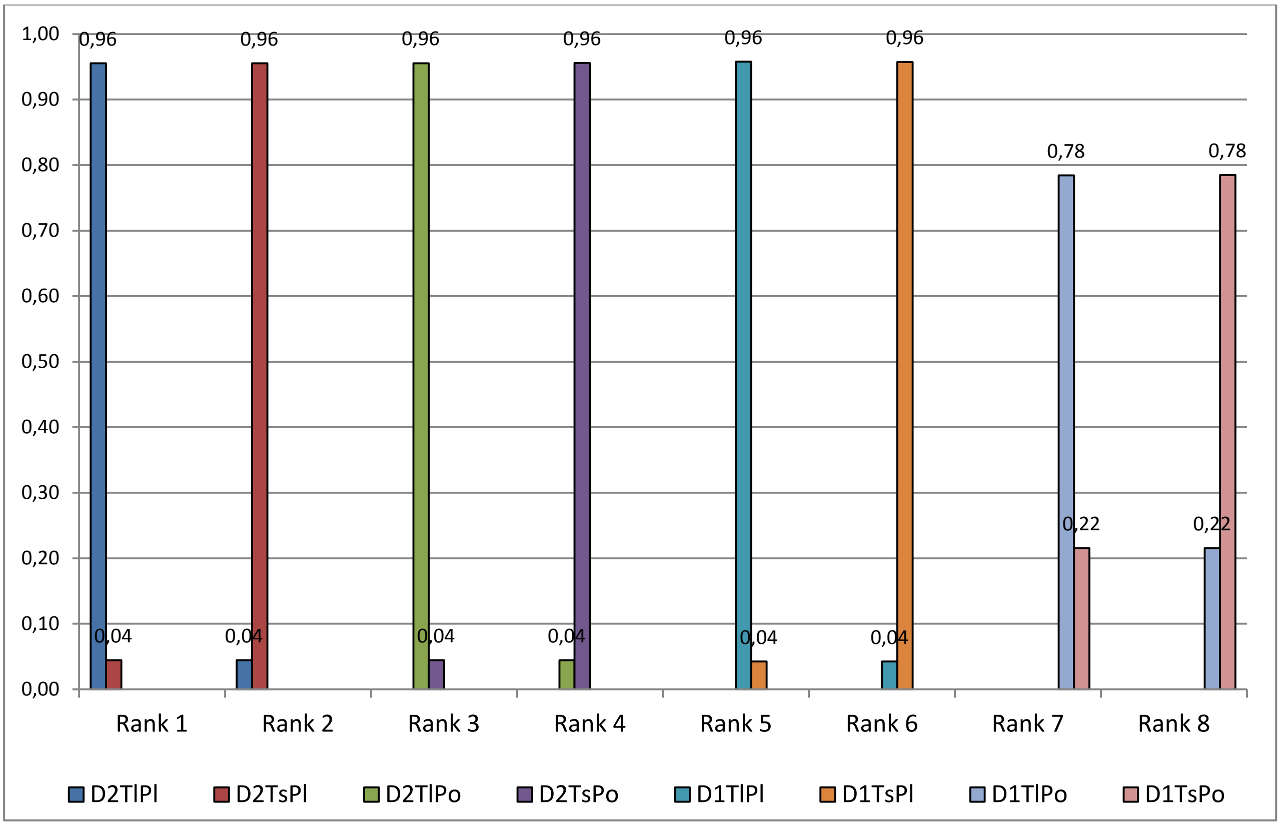

Figure 22: Overall ranking of the alternatives for the period 2021-2050

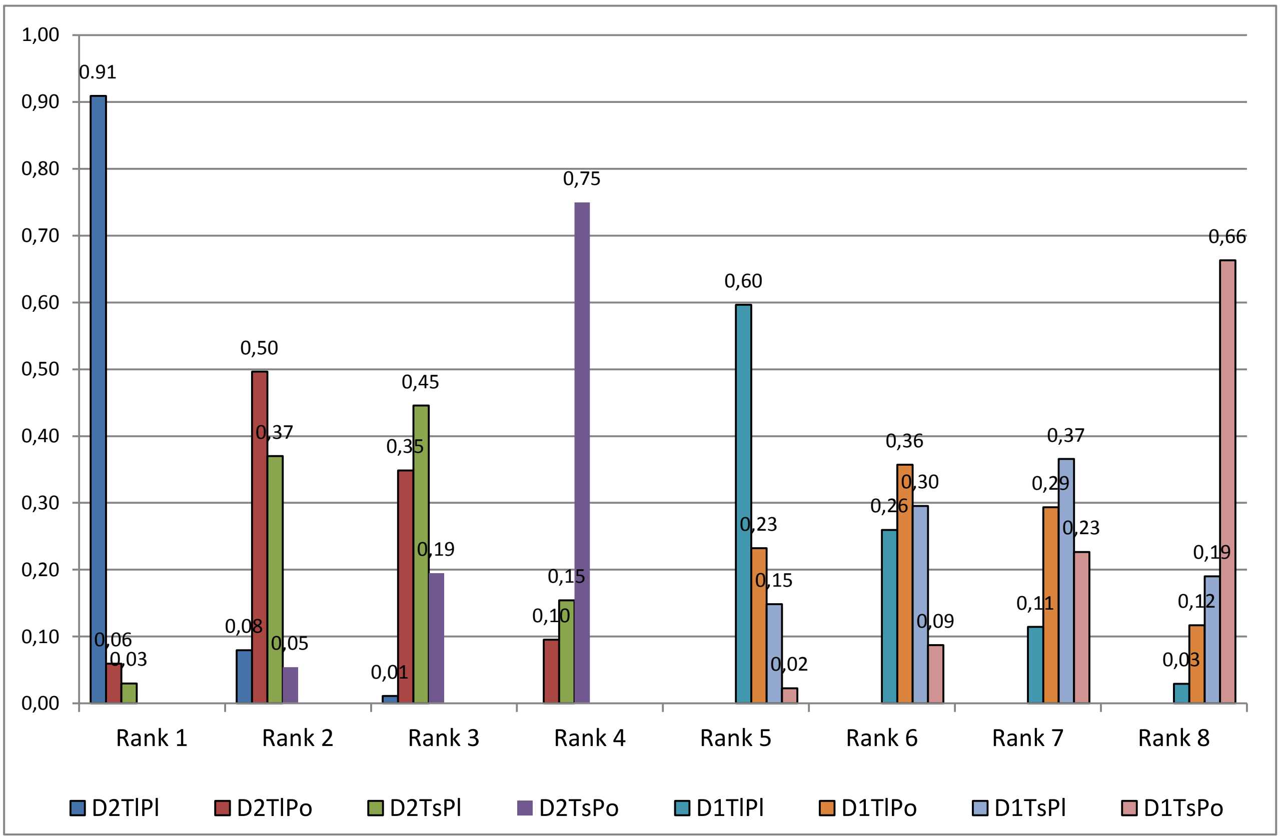

Figure 23: Overall ranking of the alternatives for the period 2071-2100

These are the main results of the multi-criteria assessment for the Winzerberge case study:

- The overall performance of the four variations of Draft 2 is better than the ones being based on Draft 1. Therefore, Draft 2 can be regarded as the superior basic draft.
- Light-coloured pavements as well as large-crowned trees have a beneficial impact on site-specific micro-climatic conditions. In the short and medium term this effect is similar, but as time elapses the positive effect of large-crowned trees continuously increases whereas the benefits of the light-coloured pavements are immediate but static.
- Alternative 8 (D2TlPl: Draft 2, use of large-crowned tree species, light-coloured pavement) outperforms all other alternatives. This holds with a probability of 96% in the medium term and with a probability of 91% also in the long-term perspective. The result is statistically robust.

5.2 Redevelopment of the central urban square Inselplatz

The “Campus Inselplatz” project aims at redeveloping a 3 ha of inner-city greyfield, which is currently used as parking area, into a new campus of the Friedrich Schiller University Jena. In May 2014 a preliminary version of the land development plan for the area has been approved by the city council. The MCA will compare three alternative ways to implement this version of the land development plan. The main decision makers in the process of developing the complex of buildings are the Federal state of Thuringia and the university. The decisions concerning the public area surrounding the buildings are prepared by the Department of City Planning and finally taken by the city council. Still, there are consultations between these three main actors regarding the building structure as well as the public area.

Figure 24: Urban square Inselplatz
Note: Area is marked red.
Source: Landsat Image, Google Earth Pro

Figure 25: Model of the future Inselplatz (preliminary draft)

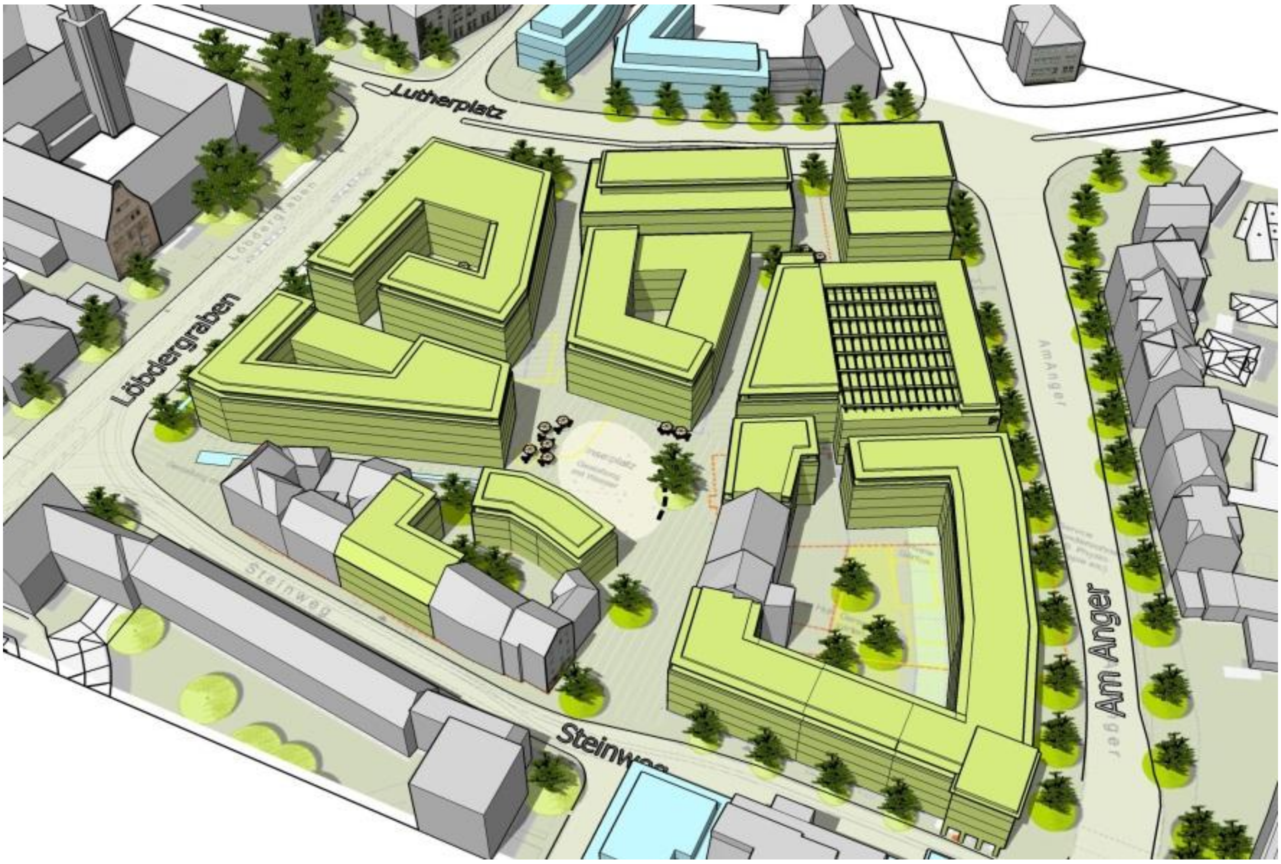

Figure 26: 3-D drawing of the future Inselplatz (preliminary draft)

5.2.1 Step 1 – Preliminary Risk Assessment and identification of adaptation tipping points

Jena is surrounded by steep shell limestone slopes, which operate as a thermal storage system making it one of the warmest places in Central Germany. Based on current climate projections an increase of heat stress events can be expected. Until the end of the century the average maximum temperature in summer will increase by 3 K (CMIP5, RCP 4.5) respectively 6 K (CMIP5, RCP 8.5) and the number of hot days will be up to three times (CMIP5, RCP 4.5) respectively four times (CMIP5, RCP 8.5) higher than under current climate conditions. For the development of key parameters on the basis of different models and scenarios see Table 11.

Table 11: Selected climate parameters (1981-2010, 2021-2050, 2071-2100)[12]

	1981-2010	2021-2050 WETTREG A1B	2021-2050 STAR A1B	2021-2050 CMIP5 RCP4.5	2021-2050 CMIP5 RCP8.5	2071-2100 WETTREG A1B	2071-2100 CMIP5 RCP4.5	2071-2100 CMIP5 RCP8.5
T_{max} in summer quarter (°C)	24	26	25	25.7	26.4	28	27.2	30.2
Number of hot days (T_{max} ≥ 30°C)	11	19	20	18	22	39	35	49
Precipitation in summer quarter (mm)	160	185	170	*	*	175	*	135
Number of sultry days (Vapour pressure > 18,8 hPa)	2.4	8.8	4.5	-	-	17.8	-	-

Note: *Standard deviation of natural variability of the parameter is higher than the signal determined by the model ensemble.

Due to various aspects as the degree of soil sealing, housing density etc. the heat stress potential is comparatively high in the city centre, where the Inselplatz is located. Moreover, a substantial increase of the number and intensity of heat stress events has been projected for the future.

Changes in the site-specific heat stress potential under varying climate conditions can be simulated using the modelling software Urban Heat Tool - UrbaHT. The software uses an algorithm to process data on various structural and climate factors (see Table 7), which can easily be obtained from public sources.[13] The rough estimates (Urban heat island – UHI potential scores) determined with UrbaHT do not compare with those of established software packages for micro-climatic modelling, e.g. Predicted Mean Votes determined with ENVI-met, but the tool's low data requests and immediate results facilitate its integration into established planning routines.

The UHI potential scores range from 0 (no heat stress) to 10 (maximum heat stress level) (see Figure 15). Table 12 gives an overview of the results obtained for the current spatial configuration of the Inselplatz, i.e. the heat stress level for the status quo under current and future climate conditions. Measurement data from the German National Meteorological Service (DWD) and climate projection

[12] STAR (STAtistically based Regional climate model) and WettReg (WEaTher-Type based REGionalisation) are regional climate models, which belong to the empirical statistical downscaling methods. Both models use global climate data from ECHAM5.

[13] For further information see Step 4 – Data collection.

data from the Coupled Model Intercomparison Project - Phase 5 (CMIP5)[14] for Representative Concentration Pathways (RCP) 4.5 and 8.5 provided by the KNMI Climate Explorer are used for the simulations. The scores indicate that present heat stress level is compared to other Parts of the city rather high and will even increase substantially in future.[15]

Table 12: UrbaHT heat stress potential scores of the Inselplatz - status quo

Period	Status quo
1981-2010	3.7
2021-2050	
CMIP5 (RCP 4.5)	4.9
CMIP5 (RCP 8.5)	5.1
2071-2100	
CMIP5 (RCP 4.5)	5.6
CMIP5 (RCP 8.5)	7.4

5.2.2 Step 2 – Identification of Adaptation Measure and Adaptation Pathways

The basis for the MCA is the current version of the land development plan (see Figure 27).

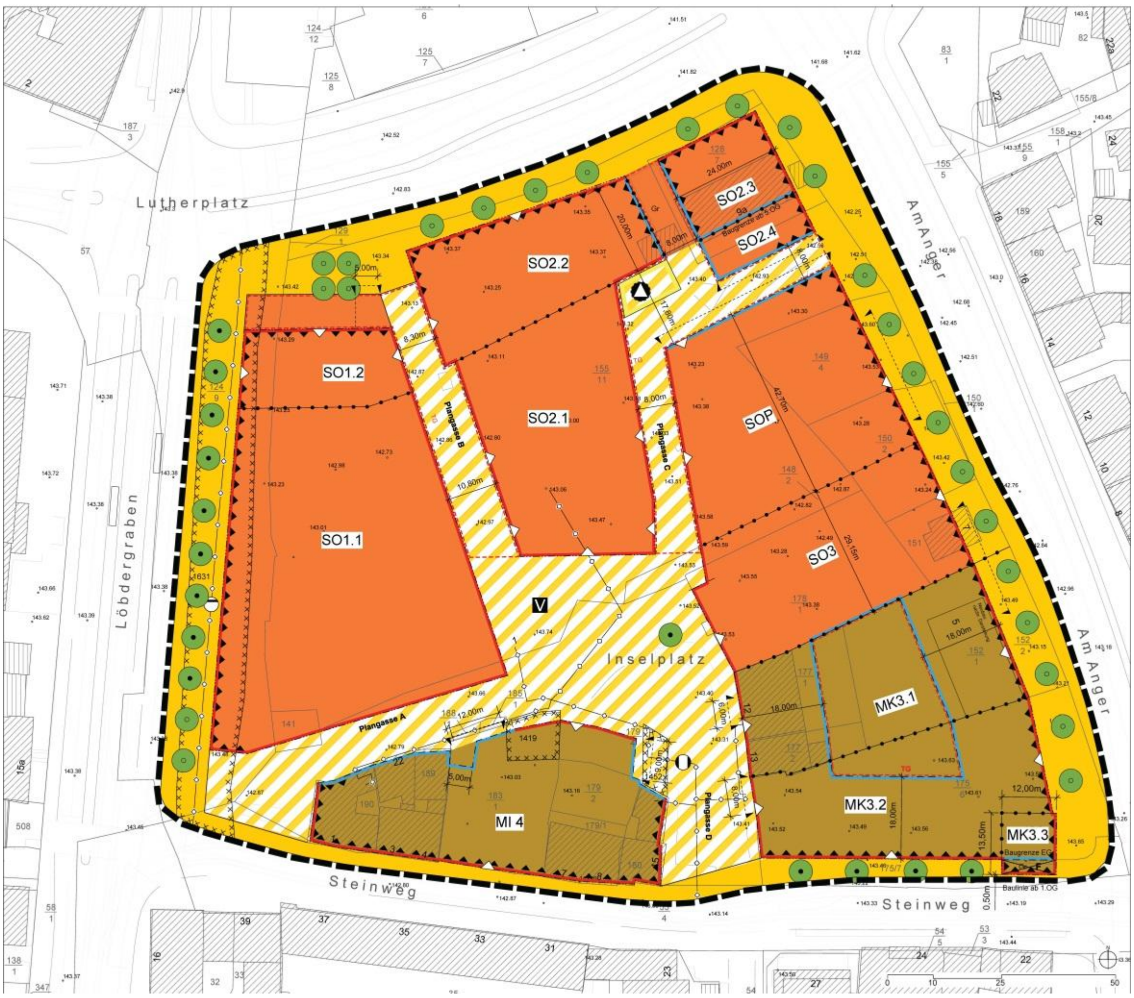

Figure 27: Current version of the land development plan Inselplatz

[14] For further Information on CMIP5 see http://cmip-pcmdi.llnl.gov/cmip5/data_getting_started.html

[15] When interpreting the UHI potential scores one has to keep in mind that the scale is identical for all climate zones.

The variations of the land development plan, which will be compared are described in Table 13 and visualised in Figure 28.

Table 13: Description of adaptation measures Inselplatz

	Alternative 1	**Alternative 2**	**Alternative 3**
Number of trees	Existing trees: 14 New trees: 25	Existing trees: 14 New trees: 29	Existing trees: 14 New trees: 31
Species of newly planted trees	25 small-crowned trees	15 large-crowned trees 14 small-crowned trees	27 large-crowned trees 4 small-crowned trees
Colour schemes of pavements	Entire area: ordinary pavements	Inner area: light-coloured pavements Outer area: ordinary pavements	Entire area: light-coloured pavements
Roof greening of new flat roofs	69% tar-gravel-roof 31% extensive green roof	48% tar-gravel-roof 52% extensive green roof	30% tar-gravel-roof 70% extensive green roof
Artificial water course	None	$40m^2$	$80m^2$

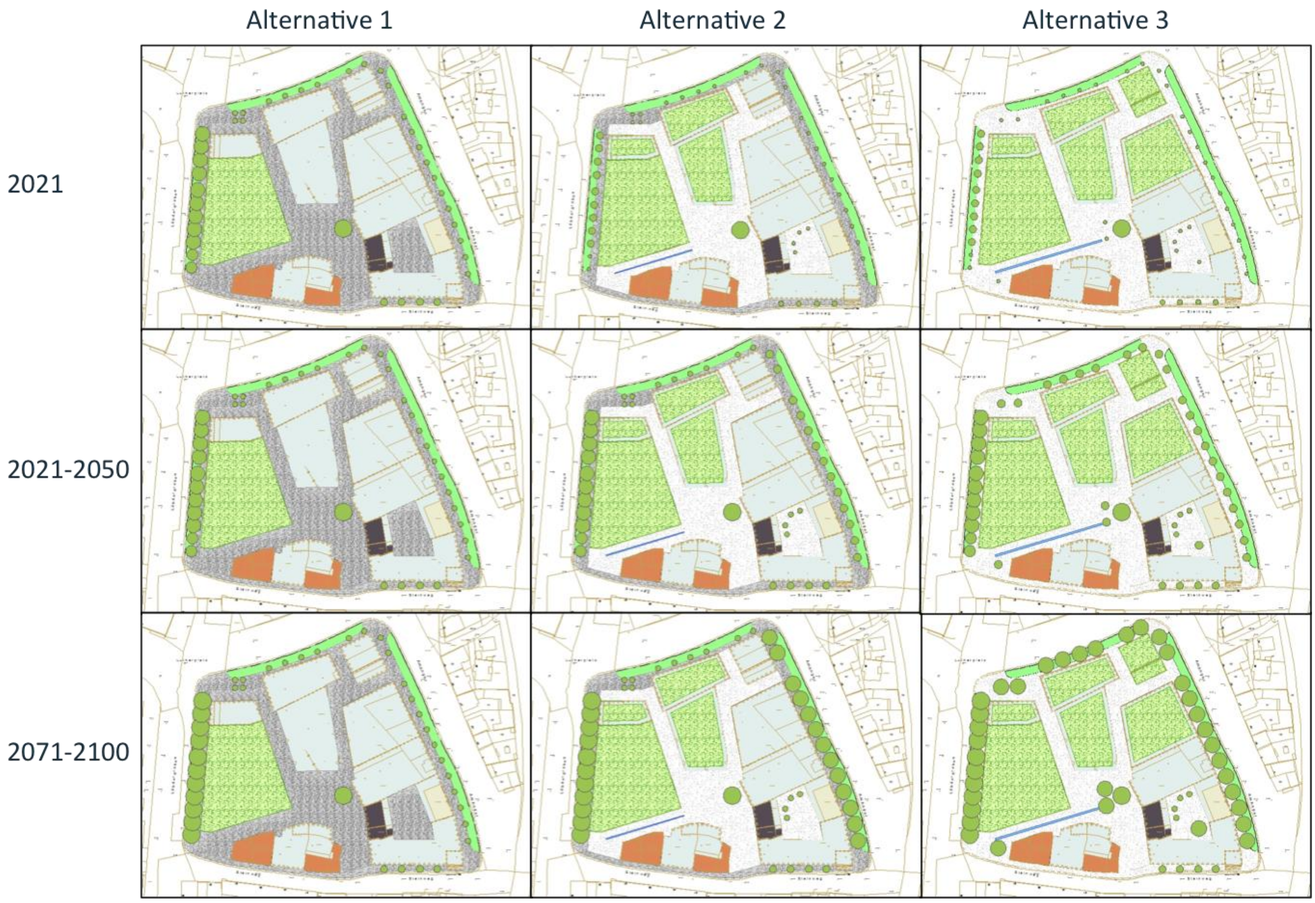

Figure 28: Visualisation of the alternatives for the periods: Date of completion, 2021-2050, 2071-2100

5.2.3 Step 3a Selection of evaluation criteria

The following criteria are chosen to compare the alternatives:

Net present costs (monetary) consist of the investment costs and the maintenance costs of the green roofs, the pavements and green structures, i.e. lawn and trees, and the investment costs of the artificial water courses for 30 years (period 2021-2050) respectively 80 years (2021-2100). For the green roofs a CBA has been performed considering cost differences, i.e. differences in investment, reinvestment, rehabilitation, maintenance costs, and the private benefits including stormwater fee savings, savings in the installation of stormwater management facilities and energy cost savings. The net present value of the three types of roofs is included in the overall net present costs of the three alternatives. As recommended by national guideline in general, e.g. for calculation of the net present costs of the alternatives for the MCA, a discount rate of 1.5% p.a. is applied.

Additionally, some public benefits, i.e. the value of habitat creation value and carbon sequestration are determined for illustrating at least some of the manifold public benefits of green roofs. As a supplementary information for three types of green roofs, two periods, i.e. 40 years (1 life cycle) and 80 years (two life cycles) and three discount rates, i.e. 1.5%, 3% and 5%, the net present value differences per m^2 between a green roof and a tar-and-gravel roof in Jena are calculated.

The heat stress potential (quantitative) represents the heat stress level related to the respective alternative. It is determined with the UrbaHT tool. For the 80 year-assessment period the average scores of both single 30-years periods have been used. The architectural quality of the drafts (qualitative) and the amenity value (qualitative) for residents and guests are also considered for the assessment.

5.2.4 Step 3b Selection of evaluation method(s)

Several assessment methods accounting differently for various types of uncertainty can be applied to determine the most appropriate alternative. Empirical evidence shows that multi-criteria analysis (MCA) is a promising tool to support such decision processes in the field of climate change adaptation. Multi-attribute decision-making (MADM), a type of MCA, which compares pre-defined sets of alternatives, is often used for applicability reasons. There are MADM concepts, which are based on multi-attribute utility theory (MAUT) and so called outranking concepts, e.g. PROMETHEE, which perform pairwise comparisons of the criteria scores of all alternatives.

In contrast to MAUT approaches outranking concepts do not assume that decision-makers are completely aware of their preference structure. Furthermore, they can deal with uncertain, incomplete, differently scaled and inconsistent data. Applied in the traditional way, e.g. PROMETHEE I, they do not allow for compensation of positive and negative criteria scores. Thereby it is possible to discover unsolvable trade-off between alternatives. As PROMETHEE I provides partial pre-orders of alternatives, in these cases rankings will be incomplete. The advantage of identifying non-comparable measures is that the exchange amongst the different stakeholder-groups about the evaluation criteria and their weighting might be promoted. A complete ranking can be obtained if the so-called positive and negative preference flows are aggregated into net preference flows, which can easily be ordered (PROMETHEE II). If there are uncertainties in the criterion values which shall be

considered in terms of score ranges, triangular distributions or any other probability functions Stochastic PROMETHEE II can be applied.

For the Inselplatz project multiple, differently scaled evaluation criteria are used to comparatively assess the alternative drafts. As for the determination of the UHI potential the RCPs 4.5 and 8.5 are used there is uncertainty concerning the performance of the alternatives with regard to this criterion. Therefore, Stochastic PROMETHEE II is applied for the assessment.

A CBA is been carried out for the green roofs and the net present values obtained are considered for the calculation of the net present costs of the alternatives.

5.2.5 Step 3c Weighting of evaluation criteria

It was expected to consider preference (=weighting) sets of various different stakeholders, e.g. planner, politician, citizen, for the MCA. But it turned out that this does not fit to existing planning routines. In real world urban planning processes in Jena there is formal and informal stakeholder participation. The results of these activities are reflected in the drafting and re-drafting process. So this information is somehow "digested" by the planner and to some extent formally and informally regarded in the planning exercise. Therefore, the planner has to be able to produce a somehow "balanced" weighting set when taking her decisions. Otherwise opposition to the final draft will prevent it to be accepted by the City council. Therefore, planners are very keen on considering all relevant stakeholder interests. For the Inselplatz assessment two planners involved in the planning process elicited the weights individually (see Table 14). Both weighting sets have been used for the assessment to somehow control for some kind of perception bias.

Table 14: Criteria weighting Inselplatz

Criteria	Weights in %	
	Urban Planner 1	Urban Planner 2
Heat stress potential	35	20
Costs	20	40
Amenity value	20	20
Architectural quality	25	20

5.2.6 Step 4 – Data collection

The data used for the MCA comes from different sources. Investment cost data is provided by the Department of City Planning, private planning consultancies, private engineering offices, construction material companies and comes from literature. Maintenance costs of the tree population are supplied by the municipal service company KSJ, which is responsible for taking care of the green structures on public premises in Jena. The locational heat stress potential (UHI potential) unfolding, if drafts are implemented, is estimated using the modelling software Urban Heat Tool – UrbaHT (see Box 1). The data on the structural parameters is determined on the basis of existing plans. The climate data for applying UrbaHT comes from two sources. Measurement data is provided by the German National Meteorological Service (DWD). Climate projection data is been sourced from

the KNMI Climate Explorer. Information on the alternatives' performances concerning the criteria architectural quality and amenity value is collected through expert judgments of local planners.

Table 15 and Table 16 give an overview of the data used.

Table 15: Heat stress potentials of alternatives at Inselplatz for the periods 1981-2010, 2021-2050, 2071-2100

Period	Alternative 1			Alternative 2			Alternative 3		
1981-2010		4.8			4.5			4.1	
2021-2050									
CMIP5 (RCP 4.5)		5.8			5.5			5.0	
CMIP5 (RCP 8.5)		6.2			5.9			5.4	
2071-2100									
CMIP5 (RCP 4.5)		6.6			6.3			5.8	
CMIP5 (RCP 8.5)		8.4			8.1			7.6	
Minimum, mean, maximum value	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**
Period 2021-2050	5.8	6	6.2	5.5	5.7	5.9	5	5.2	5.4
Period 2071-2100	6.6	7.5	8.4	6.3	7.2	8.1	5.8	6.7	7.6

Table 16: Data matrix Inselplatz

Criteria	Alternative 1			Alternative 2			Alternative 3			IT[1]	PT[2]
	Min	MV	Max	Min	MV	Max	Min	MV	Max		
Heat stress potential (2021-2050)	5.80	6.00	6.20	5.50	5.70	5.90	5.00	5.20	5.40	0	3
Heat stress potential (2021-2100)	6.20	6.75	7.30	5.90	6.45	7.00	5.40	5.95	6.50	0	3
Net present costs (2021-2050)	3,714,943	3,873,193	4,031,442	3,744,464	3,910,694	4,076,924	3,735,255	3,908,419	4,081,583	10,000	300,000
Net present costs (2021-2100)	4,000,833	4,168,875	4,336,917	4,044,263	4,227,042	4,409,822	4,046,361	4,241,971	4,437,582	10,000	300,000
Amenity value (2021-2050) (5-point Likert scale)[4]	3	3.25	3.5	2	2.5	3	1	1.5	2	0	3
Amenity value (2021-2100) (5-point Likert scale)[4]	3.25	3.375	3.5	2.25	2.5	2.75	1.25	1.5	1.75	0	3
Architectural quality (2021-2050) (5-point Likert scale)[3]	3	3.5	4	2	2.5	3	1	1.5	2	0	3
Architectural quality (2021-2100) (5-point Likert scale)[3]	3.25	3.625	4	2.25	2.625	3	1.25	1.625	2	0	3

Notes: [1,2] The Indifference threshold [IT] and preference threshold [PT] are elements of the outranking concept and in particular the PROMETHEE method that forms the mathematical basis of PRIMATE. They are defined as follows: if the difference between the performances of two alternatives in the respective criterion is less than the indifference threshold the two alternatives are counted as indifferent, such that none is preferred to the other. If the difference is above the preference threshold the alternative with the better performance is strictly preferred to the other (mathematically it received a score of 1). If the difference is in between, the better alternative is weakly preferred to the other and received a score between 0 and 1, such that the score linearly increases with the difference between the performances (…) (Drechsler 2004: p. 3). [3, 4] 1 – very good, 2 – good, 3 – average, 4 – poor, 5 – very poor.

5.2.7 Step 5 – Evaluation and Prioritisation

Figure 29 depicts the net flows of all alternatives for the period 2021-2050. The red bars represent the mean values of the net flows determined by 10,000 PRIMATE runs. The higher the net flow the better performs the respective alternative with regard to all evaluation criteria applied. The yellow uncertainty bar represents two standard deviations of the mean value of the net flows, i.e. about 95.4% of the net flows determined fall within this margin.

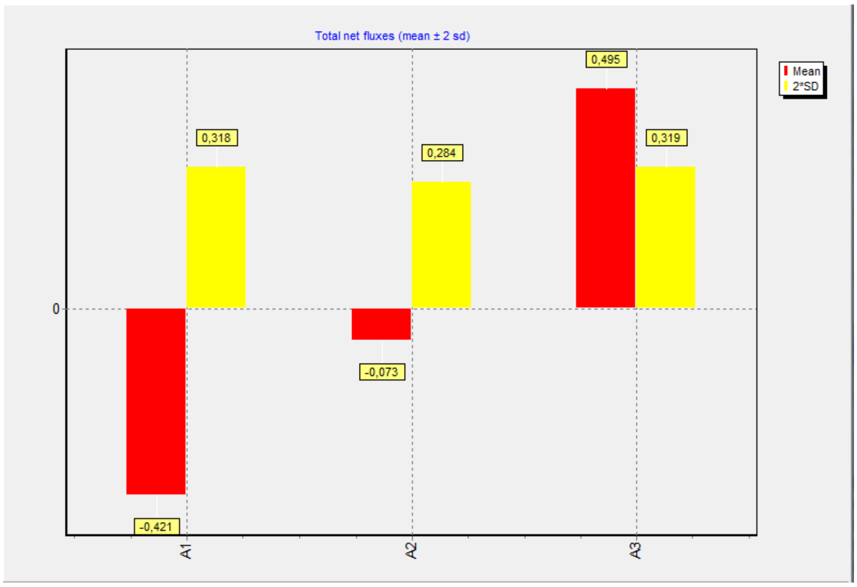

Figure 29: Overall net flows of the alternatives for the period 2021-2050
Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

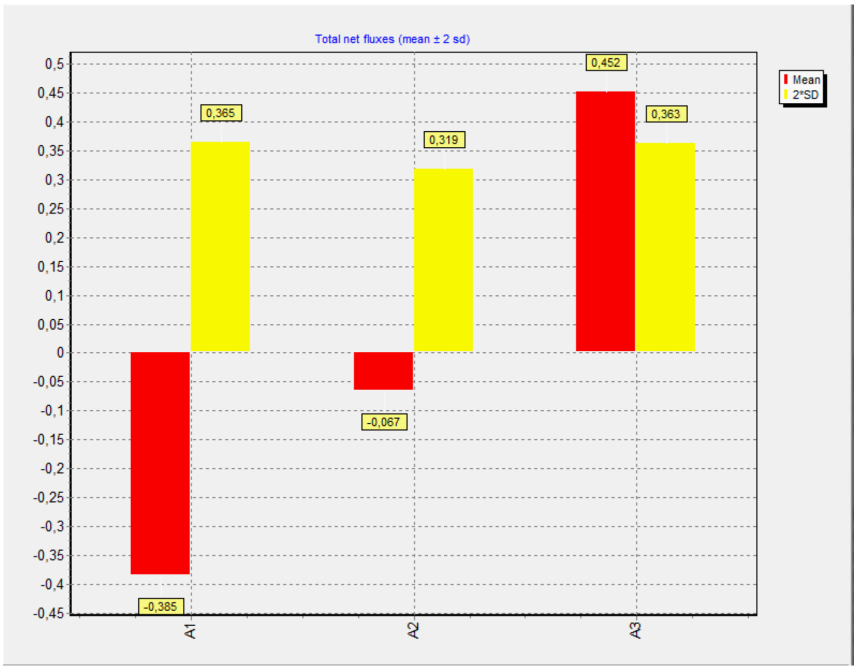

Figure 30: Overall net flows of the alternatives for the period 2071-2100
Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

In the medium term as well as in the long-term Alternative 3 outperforms the other options (see Figure 29 and Figure 30). The level of uncertainty increases in time as the variation of important climate parameters for RCP 4.5 and RCP 8.5 is more pronounced in the long run.

The heat stress potential scores for the three alternatives vary quite substantially as indicated by the net flows of the criterion heat stress potential (HSP) (see Figure 31 and Figure 32). Alternative 3 also performs best in this regard.

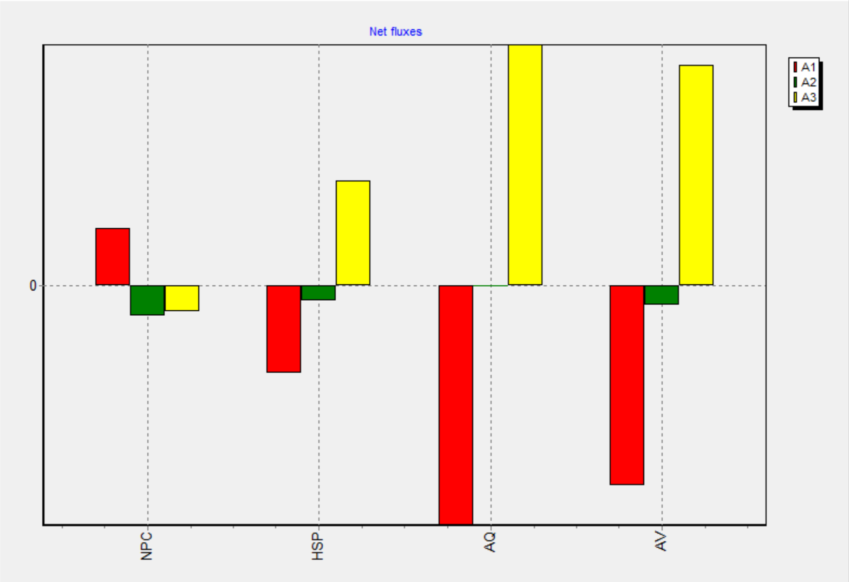

Figure 31: Net flows by criterion for 2021-2050
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar; NPC – net present costs, HSP – heat stress potential, AQ – architectural quality, AV – amenity value.

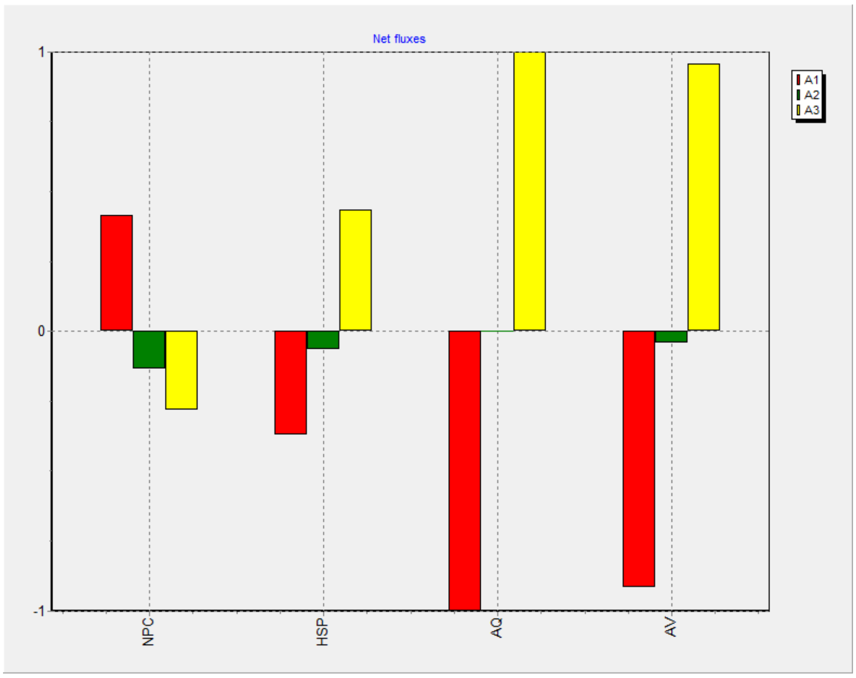

Figure 32: Net flows by criterion for 2071-2100
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar; NPC – net present costs, HSP – heat stress potential, AQ – architectural quality, AV – amenity value.

The final result of the assessment can be presented as mean values of the overall net flows (and the corresponding standard deviations) or as a ranking of the alternatives. In the latter case the uncertainty of the result is expressed as a probability of an alternative to rank first, second and so on. Figure 33 illustrates the ranking of the alternatives for the period 2021-2050 and Figure 34 for the period 2071-2100. Unsurprisingly, the rankings are in accordance with the order of the net flows. With a probability of 97.4% respectively 94.6% Alternative 3 ranks first.

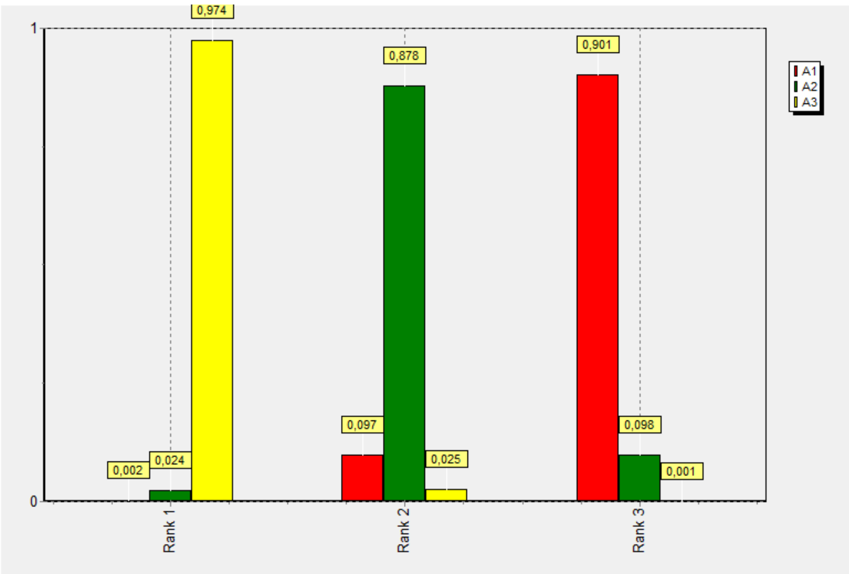

Figure 33: Overall ranking of the alternatives for the period 2021-2050
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar

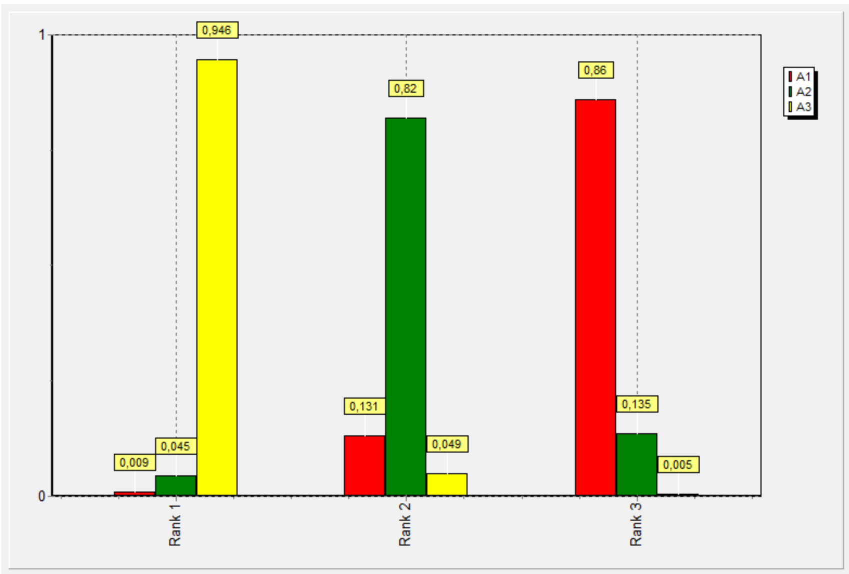

Figure 34: Overall ranking of the alternatives for the period 2071-2100
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar

These are the main results of the multi-criteria assessment for the Inselplatz project:

- Alternative 3 ranks first, alternative 2 second and alternative 1 third in the medium-term (2021-2050) as well as in the long-term perspective (2021-2100).
- In the medium-term perspective the respective probabilities are 97% of alternative 3 ranking first, 88% of alternative 2 ranking second and 90% of alternative 1 ranking third. In the long-term perspective the respective probabilities are 95% of alternative 3 ranking first, 82% of alternative 2 ranking second and 86% of alternative 1 ranking third.
- Results are statistically significant.
- Light-coloured pavements and large-crowned trees have a beneficial impact on site-specific micro-climatic conditions. The (presumably) higher costs also pay-off with regard to the criteria amenity value and architectural quality.
- When comparing the net present costs of a small-crowned and a large-crowned tree over a longer period, e.g. 82 years, regarding tree procurement, planting, replanting and care costs using a 1.5 % discount rate these costs add up to 2,254 EUR for small-crowned tree and 2,121 EUR for large-crowned tree. Furthermore, the latter has a much more beneficial impact on site-specific microclimate.
- The influence of an artificial water course is more ambiguous as it is quite costly and has – due to its dimension – only a limited impact on the microclimate. Its overall value largely depends on how it is assessed with regard to its influence on criteria as amenity value and architectural quality.
- The use of green roofs has a positive impact on the incurring costs when using the discount rate recommended by German authorities, i.e. 1.5%.

5.2.8 Cost-benefit analysis green roofs

The net present costs of the three alternatives, i.e. bundles of adaptation measures, have to include the net costs of the three types of green roofs, which are likely to be implemented. Therefore, a cost-benefit analysis is carried out for the three green roof covers. The CBA includes cost differences, i.e. differences in investment, reinvestment, rehabilitation, maintenance costs, and (private) benefits including stormwater fee savings, savings in the installation of stormwater management facilities and energy cost savings. In addition to these (private) cost and benefit figures which have been considered for the MCA, the habitat creation and carbon sequestration value of the green roof covers are calculated. As recommended by national guideline a discount rate of 1.5% p.a. is applied. For sensitivity analysis discount rates of 3% and 5% are used.

The following assumptions are made based on a review of roof greening guidelines, scientific literature and the specific situation in Jena:

- Assessment periods: 40 years
- Roof characteristics: Flat roof
- Investment costs: [16]
  - Extensive green roof cover: 25 EUR/m^2, 30 EUR/m^2, 35 EUR/m^2
  - Tar-and-gravel roof cover: 10 EUR/m^2
- Maintenance costs:
  - Extensive green roof: 1 EUR/m^2 p.a. (1st year), 0.5 EUR/m^2 p.a. (following years)
  - Tar-and-gravel roof: 0.2 EUR/m^2 p.a.
- Rehabilitation costs (removal, sealing):
  - Extensive green roof: 55 EUR/m^2 (end of 40th year)
  - Tar-and-gravel roof: 45 EUR/m^2 (end of 20th year), 35 EUR/m^2 (end of 40th year)
- Stormwater fee:[17]
  - Stormwater fee in Jena (2013): 0.72 EUR/m^2
  - Run-off coefficient green roof: 0.4
  - Stormwater fee costs extensive green roof: 0.29 EUR/m^2 p.a.
  - Stormwater fee costs tar-and-gravel roof: 0.72 EUR/m^2 p.a.
- Savings from reduced size of installation of stormwater management facilities
  - One-time benefit of 30% of the investment costs of green roof (City of Portland 2008)
  - 7.50 / 9 / 10.50 EUR/m^2
- Energy cost savings
  - 0.25 EUR/m^2 p.a.[18] (Mann 2005 based on Hämmerle 1995, Kolb 1997)
- Habitat creation value[19] (City of Portland 2008):
  - 10% of average costs to create and maintain ecological compensation area in Jena
  - 0.035 EUR/m^2 p.a. (40 years, 1.5%)

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[16] All cost figures are based on Ansel, W.; Baumgarten, H.; Dickhaut. W.; Kruse, E.; Meier, R. (eds.) (2011): Leitfaden Dachbegrünung für Kommunen. Nutzen – Fördermöglichkeiten – Praxisbeispiele. Nürtingen.

[17] § 14a Beitrags- und Gebührensatzung zur Entwässerungssatzung - BGS-EWS des Zweckverbandes „JenaWasser“ (2013)

[18] Mann, Gunter (2005): Ansätze zur objektbezogenen Kosten-Nutzen-Analyse, Stadt und Grün / Das Gartenamt Jg.: 54, Nr.10.

[19] City of Portland, Bureau of Environmental Services (2008): Cost Benefit Evaluation of Ecoroofs. Portland.

- Carbon sequestration:
  - 1.25 kg C/m^2 p.a.[20] (Leigh et al. 2014), social costs of carbon: 35 USD/t CO_2 (26 EUR /t CO_2)
  - 0.033 EUR/m^2 p.a.

The three alternatives compared assume green roofs of different sizes (see Table 13). The size of the green roof covers has an important impact on the overall costs of the roof covers, i.e. the green roof part and the tar-gravel part of the roof cover. Overall roof cover costs for the three alternatives are presented in Table 17 and Table 18.

Table 17: Overall costs of roof covers: 2021-2050

2021-2050, 1.5%		**Min**	**MV**	**Max**
Alternative 1	Net present costs roof cover in EUR	1,032,986	1,050,750	1,068,513
	Net present benefits green roof cover in EUR	53,609	58,938	64,267
	Overall net present costs roof cover in EUR	**979,378**	**991,812**	**1,004,246**
Alternative 2	Net present costs roof cover in EUR	1,014,056	1,044,077	1,074,099
	Net present benefits green roof cover in EUR	90,609	99,616	108,622
	Overall net present costs roof cover in EUR	**923,447**	**944,462**	**965,477**
Alternative 3	Net present costs roof cover in EUR	997,534	1,038,254	1,078,973
	Net present benefits green roof cover in EUR	122,901	135,117	147,333
	Overall net present costs roof cover in EUR	**874,633**	**903,136**	**931,640**

Note: Min = minimum value, MV = mean value, Max = maximum value; based on three types of extensive green roofs

Table 18: Overall costs of roof covers: 2021-2100

2021-2100, 1.5%		**Min**	**MV**	**Max**
Alternative 1	Net present costs roof cover in EUR	1,182,021	1,209,576	1,237,132
	Net present benefits green roof cover in EUR	58,191	63,520	68,849
	Overall net present costs roof cover in EUR	**1,123,830**	**1,146,056**	**1,168,283**
Alternative 2	Net present costs roof cover in EUR	1,183,362	1,229,933	1,276,504
	Net present benefits green roof cover in EUR	98,355	107,361	116,367
	Overall net present costs roof cover in EUR	**1,085,008**	**1,122,572**	**1,160,137**
Alternative 3	Net present costs roof cover in EUR	1,184,533	1,247,700	1,310,867
	Net present benefits green roof cover in EUR	133,408	145,623	157,839
	Overall net present costs roof cover in EUR	**1,051,126**	**1,102,077**	**1,153,027**

Note: Min = minimum value, MV = mean value, Max = maximum value; based on three types of extensive green roofs

It turns out that the bigger the green roof the lower the overall roof cover costs of the respective alternative.

[20] Leigh et al. (2014): Quantifying carbon sequestration of various green roof and ornamental landscape systems, Landscape and Urban Planning, 123, p.41-48.

A comparison of the net present values (40 years, 1.5%, 3% and 5%, only private benefits) of 1 m^2 of an extensive green roof compared to 1 m^2 of a tar-gravel roof leads to the following results:

- Consideration of cost differences and stormwater fee savings of an extensive green roof cover compared to a tar-gravel roof cover savings add up to 0.07 to 0.32 EUR/m^2 p.a. (40 years, 1.5%, most / least expensive green roof type).
- Consideration of additional (private) benefits, i.e. private stormwater management savings, energy cost savings further improves the results in favour of the green roof cover. Savings then add up to 0.52 to 0.70 EUR/m^2 p.a. (40 years, 1.5%, most / least expensive green roof type).
- Higher discount rates reduce the overall savings. When applying a 5% discount rate and only considering cost differences and stormwater fee savings additional costs for a green roof cover of 0.18 EUR/m^2 p.a. accrue. For details see
- Public benefits are rather low compared to private benefits, i.e. the annual value of the habitat created and carbon sequestered are about 0.03 EUR/m^2 each (40 years). In absolute terms the habitat creation value is 1.39 EUR/m^2, i.e. 4,941 EUR for alternative 1, 8,351 EUR for alternative 2, 11,327 EUR for alternative 3. The value of the carbon sequestered by the green roof covers in absolute terms adds up to 116 EUR p.a. for alternative 1, 197 EUR p.a. for alternative 2, 267 EUR p.a. for alternative 3.

The reference option is a tar-gravel roof. Green market cells indicate that the respective type of green roof cover is more efficient than the tar-gravel roof.

- Using the officially recommended discount rate all green roof covers are efficient from a minimum-benefit (cost differences & stormwater fee savings) and from a maximum-benefit (cost differences & stormwater fee savings & private stormwater management & energy savings) perspective (see Table 19).
- Using a 3% discount rate only the most expensive type of green roof cover is not efficient from a minimum-benefit perspective (see Table 20).
- Using a 5% discount rate only the least costly type of green roof cover is efficient from a minimum-benefit perspective. From a maximum-benefit perspective all green roof covers are efficient (see Table 21).

Table 19: Comparison three green roof cover types and tar-gravel roof, 40 years, discount rate 1.5%

	Extensive green roof cover (25 EUR/m²)	**Extensive green roof cover (30 EUR/m²)**	**Extensive green roof cover (35 EUR/m²)**	**Tar-gravel roof cover (10 EUR/m²)**
NPC (cost differences, stormwater fee savings)	80.20	85.20	90.20	92.95
NPB (private stormwater management & energy savings)	15.09	16.59	18.09	
NPV	65.11	68.61	72.11	92.95
Differences in NPV of green roof and tar-gravel-roof per m^2	27.84	24.34	20.84	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.70**	**0.61**	**0.52**	
NPC (cost differences, stormwater fee savings)	80.20	85.20	90.20	92.95
NPB (energy savings)	7.59	7.59	7.59	
NPV	72.61	77.61	82.61	92.95
Differences in NPV of green roof and tar-gravel-roof per m^2	20.34	15.34	10.34	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.51**	**0.38**	**0.26**	
NPC (cost differences, stormwater fee savings)	80.20	85.20	90.20	92.95
Differences in NPV of green roof and tar-gravel-roof per m^2	12.75	7.75	2.75	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.32**	**0.19**	**0.07**	

Note: Green cells indicate all efficient scenarios, i.e. combinations of green roof cover types and benefits to be considered, when comparing a green roof with a tar-gravel roof for a 40-years period using a discount rate of 1.5% p.a. Red cells indicate scenarios, for which the tar-gravel roof is more efficient than the respective green roof type.

Table 20: Comparison three green roof cover types and tar-gravel roof, 40 years, discount rate 3%

	Extensive green roof cover (25 EUR/m²)	Extensive green roof cover (30 EUR/m²)	Extensive green roof cover (35 EUR/m²)	Tar-gravel roof cover (10 EUR/m²)
NPC (cost differences, stormwater fee savings)	61.63	66.63	71.63	69.81
NPB (private stormwater management & energy savings)	13.45	14.95	16.45	
NPV	48.18	51.68	55.18	69.81
Differences in NPV of green roof and tar-gravel-roof per m^2	21.63	18.13	14.63	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.54**	**0.45**	**0.37**	
NPC (cost differences, stormwater fee savings)	61.63	66.63	71.63	69.81
NPB (energy savings)	5.95	5.95	5.95	
NPV	55.68	60.68	65.68	69.81
Differences in NPV of green roof and tar-gravel-roof per m^2	14.13	9.13	4.13	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.35**	**0.23**	**0.10**	
NPC (cost differences, stormwater fee savings)	61.63	66.63	71.63	69.81
Differences in NPV of green roof and tar-gravel-roof per m^2	8.18	3.18	-1.82	
Differences in NPV of green roof and tar-gravel-roof per m^2 p.a.	**0.20**	**0.08**	**-0.05**	

Note: Green cells indicate all efficient scenarios, i.e. combinations of green roof cover types and benefits to be considered, when comparing a green roof with a tar-gravel roof for a 40-years period using a discount rate of 3% p.a. Red cells indicate scenarios, for which the tar-gravel roof is more efficient than the respective green roof type.

Table 21: Comparison three green roof cover types and tar-gravel roof, 40 years, discount rate 5%

	Extensive green roof cover (25 EUR/m²)	Extensive green roof cover (30 EUR/m²)	Extensive green roof cover (35 EUR/m²)	Tar-gravel roof cover (10 EUR/m²)
NPC (cost differences, stormwater fee savings)	47.90	52.90	57.90	50.50
NPB (private stormwater management & energy savings)	12.00	13.50	15.00	
NPV	35.90	39.40	42.90	50.50
Differences in NPV of green roof and tar-gravel-roof per m²	14.61	11.11	7.61	
Differences in NPV of green roof and tar-gravel-roof per m² p.a.	**0.37**	**0.28**	**0.19**	
NPC (cost differences, stormwater fee savings)	47.90	52.90	57.90	50.50
NPB (energy savings)	4.50	4.50	4.50	
NPV	43.40	48.40	53.40	50.50
Differences in NPV of green roof and tar-gravel-roof per m²	7.11	2.11	-2.89	
Differences in NPV of green roof and tar-gravel-roof per m² p.a.	**0.18**	**0.05**	**-0.07**	
NPC (cost differences, stormwater fee savings)	47.90	52.90	57.90	50.50
Differences in NPV of green roof and tar-gravel-roof per m²	2.60	-2.40	-7.40	
Differences in NPV of green roof and tar-gravel-roof per m² p.a.	**0.07**	**-0.06**	**-0.18**	

Note: Green cells indicate all efficient scenarios, i.e. combinations of green roof cover types and benefits to be considered, when comparing a green roof with a tar-gravel roof for a 40-years period using a discount rate of 5% p.a. Red cells indicate scenarios, for which the tar-gravel roof is more efficient than the respective green roof type.

5.3 Development of the new neighbourhood in Zwätzen

In the north of Jena, in the district of Zwätzen, a new neighbourhood will be developed. 350-400 housing units will inhabitant about 850-1.000 residents on a plot of 6.6 ha. The Department of City Planning is in charge of developing the public area in this new neighbourhood. Major stakeholders taking part in the planning process are potential residents and real estate developer. The City Council of Jena will have to approve the final draft of the land development plan for the area. Drafts have been developed by a planning and an architecture office in close cooperation with the Department of City Planning and repeatedly have been discussed internally and presented in participatory workshop in September 2014 to the public. The approval of the final draft of the land development plan by the City Council is expected for the end of 2015.

Figure 35: Edge-of-town location of the new neighbourhood Am Ölste
Note: Are marked red.
Source: Landsat Image, Google Earth Pro

 

Figure 36: Preliminary drafts of the new neighbourhood in Zwätzen presented in early 2014

5.3.1 Step 1 – Preliminary Risk Assessment and identification of adaptation tipping points

Jena is surrounded by steep shell limestone slopes, which operate as a thermal storage system making it one of the warmest places in Central Germany. Based on current climate projections an increase of heat stress events can be expected. Until the end of the century the average maximum temperature in summer will increase by 3 K (CMIP5, RCP 4.5) respectively 6 K (CMIP5, RCP 8.5) and the number of hot days will be up to three times (CMIP5, RCP 4.5) respectively four times (CMIP5, RCP 8.5) higher than under current climate conditions. For the development of key parameters on the basis of different models and scenarios see Table 22. Despite the fact that the heat stress potential is lower in the suburban areas and the large housing estates located more distant to the city centre, e.g. the district Zwätzen, a substantial increase of the number and intensity of heat stress events has been projected also for those areas.

Table 22: Selected climate parameters (1981-2010, 2021-2050, 2071-2100)[21]

	1981-2010	2021-2050 WETTREG A1B	2021-2050 STAR A1B	2021-2050 CMIP5 RCP4.5	2021-2050 CMIP5 RCP8.5	2071-2100 WETTREG A1B	2071-2100 CMIP5 RCP4.5	2071-2100 CMIP5 RCP8.5
T_{max} in summer quarter (°C)	24	26	25	25.7	26.4	28	27.2	30.2
Number of hot days ($T_{max} \geq 30$°C)	11	19	20	18	22	39	35	49
Precipitation in summer quarter (mm)	160	185	170	*	*	175	*	135
Number of sultry days (vapour pressure > 18,8 hPa)	2.4	8.8	4.5	-	-	17.8	-	-

Note: *Standard deviation of natural variability of the parameter is higher than the signal determined by the model ensemble.

[21] STAR (STAtistically based Regional climate model) and WettReg (WEaTher-Type based REGionalisation) are regional climate models, which belong to the empirical statistical downscaling methods. Both models use global climate data from ECHAM5.

5.3.2 Step 2 – Identification of Adaptation Measure and Adaptation Pathways

Various drafts have been discussed internally and with external partners in the 2014. On the basis of the feedback from all relevant stakeholders received at and as a follow-up to a participatory workshop Draft 2 (see Figure 37, right) has been selected. A MCA is carried out comparing systematically potential variations of this draft to consider future climate change in today's decision-making processes. The aim is to support the design of a draft which on one hand suits current and future climate conditions best but on the other hand also take into account additional factors affecting decision making, e.g. financial and aesthetic aspects.

Figure 37: Two drafts of the new neighbourhood in Zwätzen presented at a participatory workshop in September 2014

The variations of the current draft, which will be compared, are described in Table 23.

Table 23: Description of adaptation measures for the new neighbourhood in Zwätzen

	Alternative 1	Alternative 2	Alternative 3
Number of trees	152	246	241
Type of newly planted trees	25 large-crowned trees 127 small-crowned trees	63 large-crowned trees 183 small-crowned trees	142 large-crowned trees 99 small-crowned trees
Colour schemes of pavements	Sidewalks, Recreational area: ordinary pavements	Sidewalks: light-coloured pavements Recreational area: ordinary pavements	Sidewalks, Recreational area: light-coloured pavements
Fountain	None	50m^2	100m^2

Figure 38 presents a visualisation of Alternative 2 in the period 2071-2100.

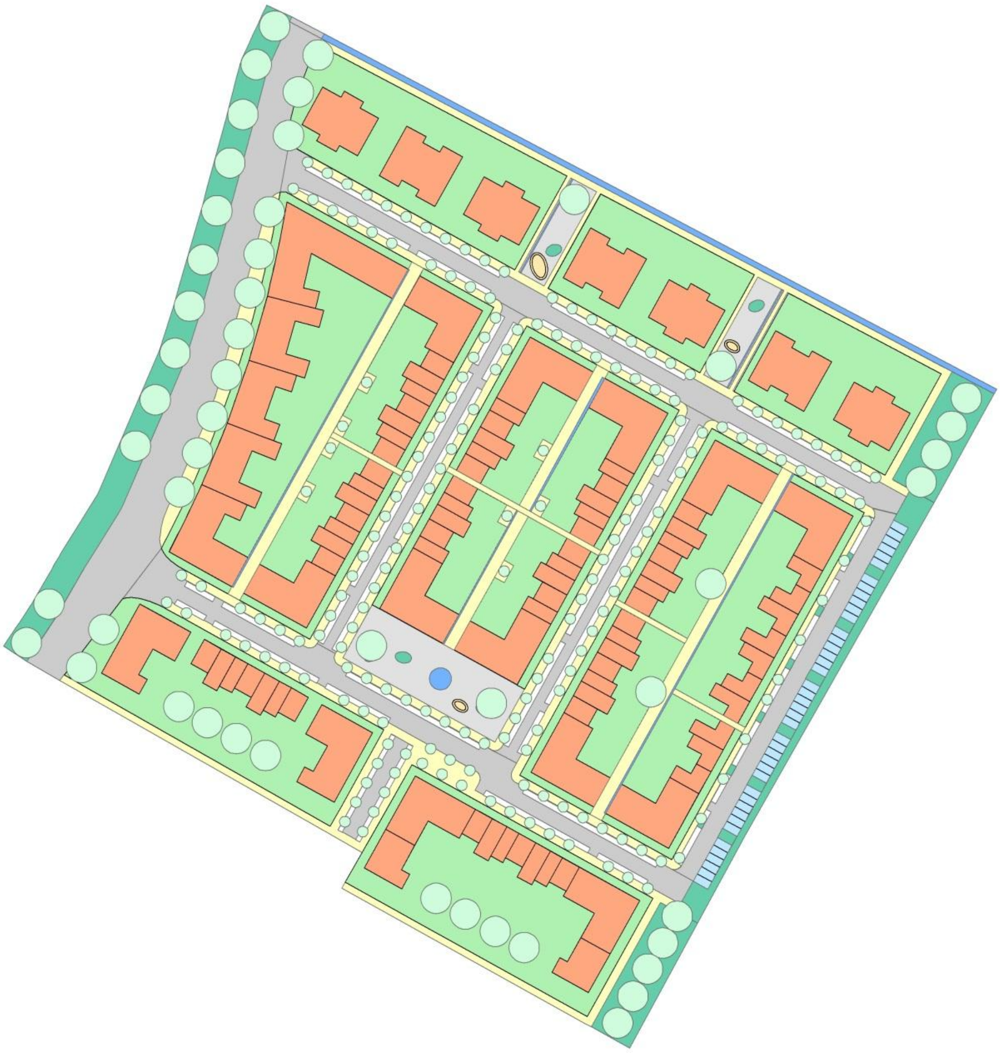

Figure 38: Visualisation of alternative 2, period 2071-2100

5.3.3 Step 3a Selection of evaluation criteria

The following criteria are chosen to compare the alternatives:

Net present costs (monetary) consist of the investment costs and the maintenance costs of the pavements and green structures, i.e. lawn and trees, and the investment costs of the fountain for the period 2018-2050 respectively 2018-2100. As recommended by national guideline a discount rate of 1.5% p.a. is applied.

The heat stress potential (quantitative) represents the heat stress level related to the respective alternative. It is determined with the UrbaHT tool. For the long-term perspective average scores of the three periods indicated are used. For the mid-term perspective average scores of the first two time periods are used. The architectural quality of the drafts (qualitative) and the amenity value (qualitative) for residents and guests are also considered for the assessment. Furthermore, the marketing potential is included in the assessment.

5.3.4 Step 3b Selection of evaluation method(s)

Several assessment methods accounting differently for various types of uncertainty can be applied to determine the most appropriate alternative. Empirical evidence shows that multi-criteria analysis (MCA) is a promising tool to support such decision processes in the field of climate change adaptation. Multi-attribute decision-making (MADM), a type of MCA, which compares pre-defined sets of alternatives are often used for applicability reasons. There are MADM concepts, which are based on multi attribute utility theory (MAUT) and so called outranking concepts, e.g. PROMETHEE, which perform pairwise comparisons of the criteria scores of all alternatives.

In contrast to MAUT approaches outranking concepts do not assume that decision-makers are completely aware of their preference structure. Furthermore, they can deal with uncertain, incomplete, differently scaled and inconsistent data. Applied in the traditional way, e.g. PROMETHEE I, they do not allow for compensation of positive and negative criteria scores. Thereby it is possible to discover unsolvable trade-off between alternatives. As PROMETHEE I provides partial pre-orders of alternatives, in these cases rankings will be incomplete. The advantage of identifying non-comparable measures is that the exchange amongst the different stakeholder-groups about the evaluation criteria and their weighting might be promoted. A complete ranking can be obtained if the so-called positive and negative preference flows are aggregated into net preference flows, which can easily be ordered (PROMETHEE II). If there are uncertainties in the criterion values which shall be considered in terms of score ranges, triangular distributions or any other probability functions Stochastic PROMETHEE II can be applied.

For this project multiple, differently scaled evaluation criteria are used to comparatively assess the alternative drafts. As for the determination of the UHI potential the RCPs 4.5 and 8.5 are used there is uncertainty concerning the performance of the alternatives with regard to this criterion. Therefore, Stochastic PROMETHEE II is applied for the assessment.

5.3.5 Step 3c Weighting of evaluation criteria

The planner being in charge of the project elicited the weights, as he was most familiar with all the feedback received in the course of the planning process and responsible for considering these claims and wishes when re-drafting the plan.

Table 24: Criteria weighting new neighbourhood in Zwätzen

Criteria	Weights in %
Heat stress potential	10
Costs	20
Amenity value	20
Architectural quality	30
Marketing potential	20

5.3.6 Step 4 - Data collection

The data used for the MCA comes from different sources. Investment cost data is provided by the Department of City Planning, private engineering offices, construction material companies and come from literature. Maintenance costs of the tree population are supplied by the municipal service company "KSJ" which is responsible for taking care of the green structures on public premises in Jena. The locational heat stress potential (UHI potential) unfolding, if drafts are implemented, is estimated using the modelling software Urban Heat Tool – UrbaHT. The data on the structural parameters is determined on the basis of existing plans. The climate data for applying UrbaHT comes from two sources. The German National Meteorological Service (DWD) provided measurement data. Climate projection data was sourced from the KNMI Climate Explorer. Information on the alternatives' performances concerning the criteria architectural quality, amenity value and marketing potential is collected through expert judgments from the local planner. Table 25 and Table 26 give an overview of the data used.

Table 25: Heat stress potentials of alternatives at the new neighbourhood in Zwätzen for the periods 1981-2010, 2021-2050, 2071-2100

Period	Alternative 1			Alternative 2			Alternative 3		
1981-2010		2.6			2.4			2.3	
2021-2050									
CMIP5 (RCP 4.5)		3.4			3.2			3.0	
CMIP5 (RCP 8.5)		3.8			3.6			3.5	
2071-2100									
CMIP5 (RCP 4.5)		4.2			3.9			3.7	
CMIP5 (RCP 8.5)		6.1			5.7			5.5	
Minimum, mean, maximum value	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**	**Min**	**MV**	**Max**
Period 2018-2050	3.4	3.60	3.8	3.2	3.4	3.6	3.0	3.25	3.5
Period 2018-2100	4.2	5.15	6.1	3.9	4.8	5.7	3.7	4.60	5.5

Table 26: Data matrix new neighbourhood in Zwätzen

Criteria	Alternative 1			Alternative 2			Alternative 3			IT[1]	PT[2]
	Min	MV	Max	Min	MV	Max	Min	MV	Max		
Heat stress potential (2018-2050)	3.00	3.10	3.20	2.80	2.90	3.00	2.65	2.78	2.90	0	3
Heat stress potential (2018-2100)	3.40	3.78	4.17	3.17	3.53	3.90	3.00	3.38	3.77	0	3
Net present costs (2018-2050)	9,232,599			9,505,652			9,552,137			10,000	400,000
Net present costs (2018-2100)	9,451,709			9,778,607			9,792,079			10,000	400,000
Amenity value (2018-2100) (5-point Likert scale)[4]	3			2			1			0	3
Architectural quality (2018-2100) (5-point Likert scale)[3]	3			2			2			0	3
Marketing potential (2018-2100) (5-point Likert scale)[3]	3			4			4			0	3

Notes: [1,2] The Indifference threshold [IT] and preference threshold [PT] are elements of the outranking concept and in particular the PROMETHEE method that forms the mathematical basis of PRIMATE. They are defined as follows: if the difference between the performances of two alternatives in the respective criterion is less than the indifference threshold the two alternatives are counted as indifferent, such that none is preferred to the other. If the difference is above the preference threshold the alternative with the better performance is strictly preferred to the other (mathematically it received a score of 1). If the difference is in between, the better alternative is weakly preferred to the other and received a score between 0 and 1, such that the score linearly increases with the difference between the performances (…) (Drechsler 2004: p. 3). [3,4] 1 – very good, 2 – good, 3 – average, 4 – poor, 5 – very poor.

5.3.7 Step 5 – Evaluation and Prioritisation

The MCA compares the alternatives described above. This implies that the status quo is due to the main goal of the planning process, i.e. the redevelopment of the area, not considered for the assessment. The application of the MCA approach Stochastic PROMETHEE II is facilitated by using software for Probabilistic Multi-Attribute Evaluation – PRIMATE (Drechsler 2004), which has already been tested in several pilot projects dealing with various aspects of climate change adaptation at the regional and local level. Therefore, the input data is processed with PRIMATE.

One option for considering uncertainty in criteria values in PRIMATE is through the use of score ranges, triangular or other probability distributions and the application of a Monte Carlo simulation approach. The resulting uncertainty of the final outcomes is documented in PRIMATE (see Figure 39 and Figure 40). The input data regarding the development of the heat stress potential is uncertain (see ranges in Table 25). For the assessment with PRIMATE a triangular distribution is used.

PRIMATE performs 10,000 runs and calculates for each alternative the outflow, i.e. the positive preference flow and extent to which the alternative outranks all other alternatives, the inflow, i.e. the negative preference flow and extent to which the alternative is outranked by all other alternatives and the net flows, i.e. the aggregation of positive and negative preference flows into a net preference flow. On the basis of these net flows a complete order of the alternatives can be established.

Figure 39 depicts the net flows of all alternatives for the period 2021-2050. The red bars represent the mean values of the net flows determined by 10,000 PRIMATE runs. The higher the net flow the better performs the respective alternative with regard to all evaluation criteria applied. The yellow uncertainty bar represents two standard deviations of the mean value of the net flows, i.e. about 95.4% of the net flows determined fall within this margin.

In the medium term as well as in the long-term Alternative 3 outperforms the other options (see Figure 39 and Figure 40). The level of uncertainty increases in time as the variation of important climate parameters for RCP 4.5 and RCP 8.5 is more pronounced in the long run.

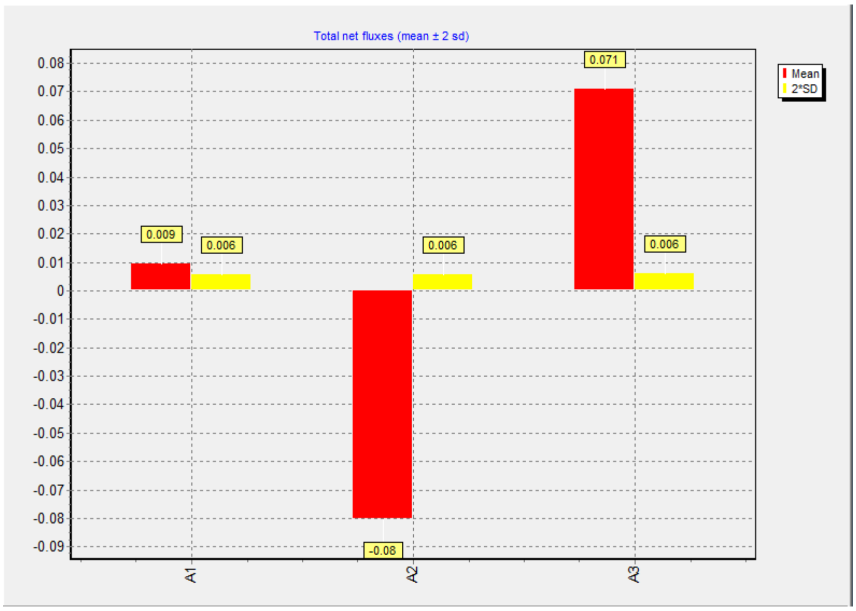

Figure 39: Overall net flows of the alternatives for the period 2021-2050
Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

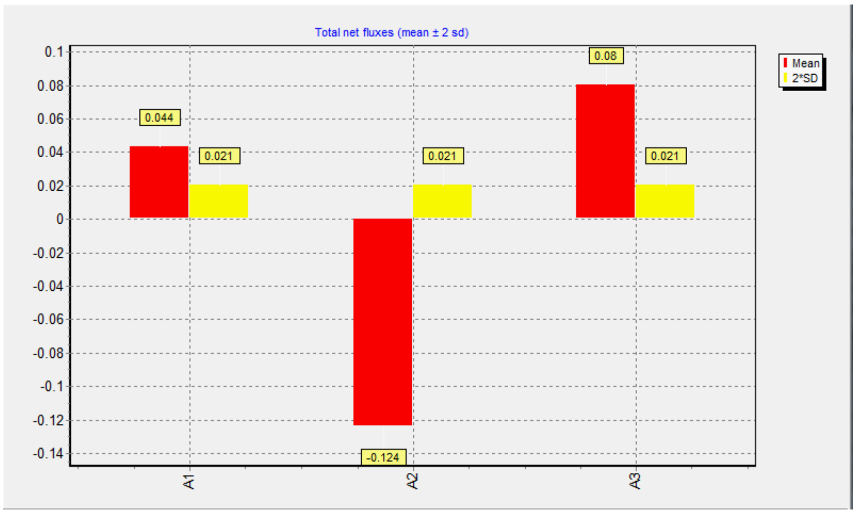

Figure 40: Overall net flows of the alternatives for the period 2071-2100
Note: The uncertainty bar represents two standard deviations of the mean value of the net flows, which means that about 95.4% of the net flows determined by 10,000 PRIMATE runs fall within this margin.

The heat stress potential scores for the three alternatives vary quite substantially as indicated by the net flows of the criterion heat stress potential (HSP) in Figure 41 and Figure 42. Alternative 3 also performs best in this regard.

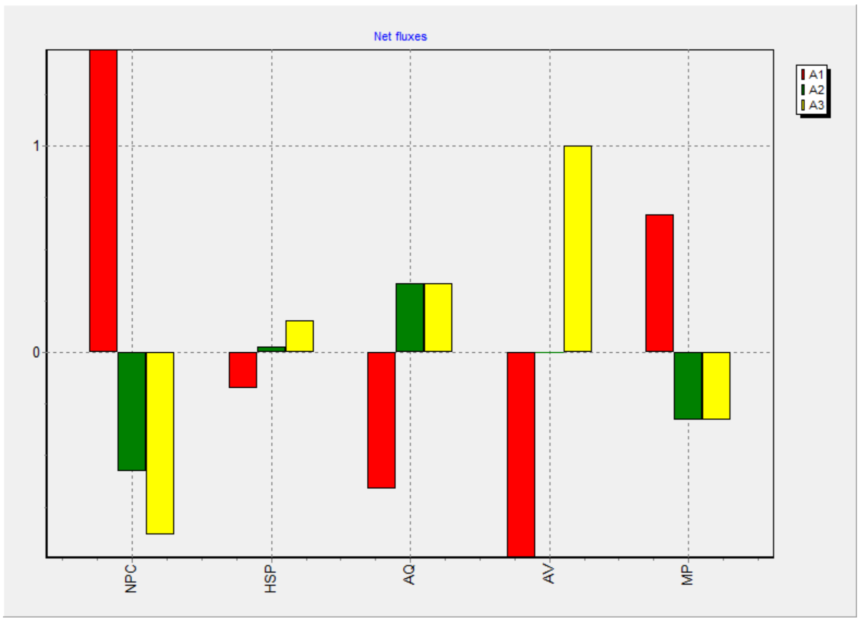

Figure 41: Net flows by criterion for 2021-2050
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar; NPC – net present costs, HSP – heat stress potential, AQ – architectural quality, AV – amenity value.

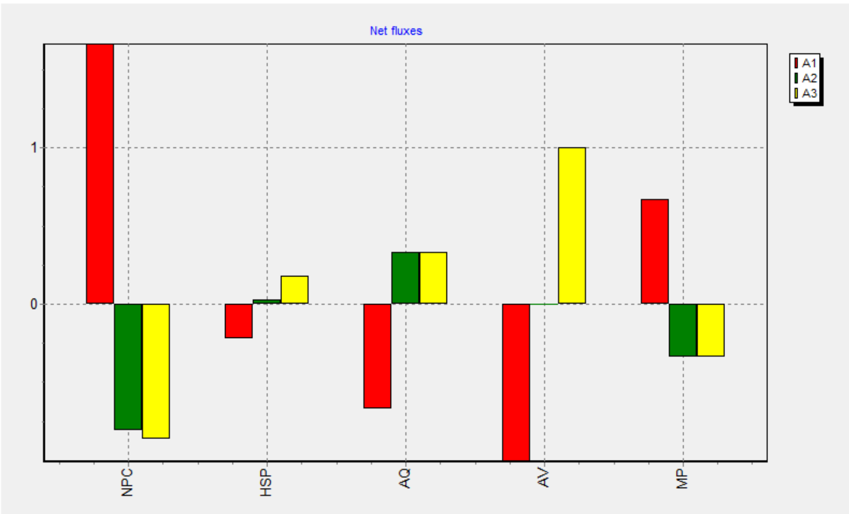

Figure 42: Net flows by criterion for 2071-2100
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar; NPC – net present costs, HSP – heat stress potential, AQ – architectural quality, AV – amenity value.

The final result of the assessment can be presented as mean values of the overall net flows (and the corresponding standard deviations) or as a ranking of the alternatives. In the latter case the uncertainty of the result is expressed as a probability of an alternative to rank first, second and so on. Figure 43 illustrates the ranking of the alternatives for the period 2021-2050 and Figure 44 for the period 2071-2100. Unsurprisingly, the rankings are in accordance with the order of the net flows (see Figure 39 and Figure 40). With a probability of 100% respectively 98% Alternative 3 ranks first.

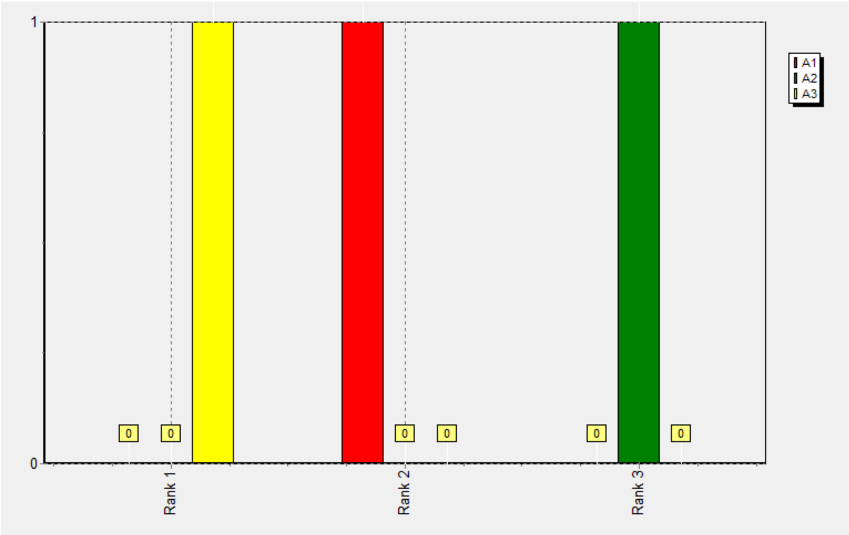

Figure 43: Overall ranking of the alternatives for the period 2021-2050
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar

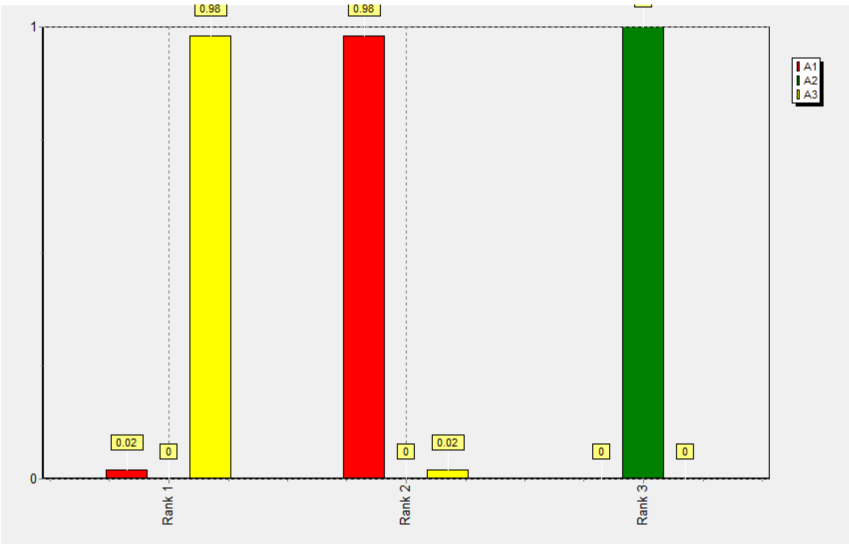

Figure 44: Overall ranking of the alternatives for the period 2071-2100
Notes: Alternative 1 – red bar, Alternative 2 – green bar, Alternative 3 – yellow bar

These are the main results of the multi-criteria assessment for the new neighbourhood in Zwätzen:

- Alternative 3 ranks first, alternative 1 second and alternative 2 third in the medium-term as well as in the long-term perspective.
- In the medium-term perspective this result is certain. In the long-term perspective the respective probabilities for this ranking are 98% of alternative 3 ranking first, 98% of alternative 3 ranking second and 100% of alternative 2 ranking third. Uncertainty in the results is a consequence of the uncertainty in climate input data and comparatively low. Results are statistically significant.
- Performance of alternatives varies substantially across the criteria. With regard to the criteria costs (20%) and marketing potential (20%) alternative 1 clearly outperforms alternative 3, which in turn performs much better regarding the criteria architectural quality (30%), amenity value (20%) and heat stress potential (10%). The at first sight seemingly small differences between alternative 2 and 3 turn out to have a major impact on the overall assessment result.

- The overall effect of the use of light-coloured paving materials as well as large-crowned trees on the heat stress potential and the amenity value is much more beneficial than additional financial burden caused by these adaptation measures.
- Although the greener alternatives perform well with regard to the criteria amenity value and architectural quality, they – against the prevailing assumption – do not always enhance the marketing potential of a property. This points to the negative aspects associated with green infrastructures, e.g. less incidence of light, higher energy costs in winter and other disturbance.

5.4 What are the main lessons learnt from your case study?

The following information relates to all three assessments carried out in Jena.

Transferable results

Light-coloured pavements and large-crowned trees have very beneficial impacts on site-specific microclimate. The slightly higher costs (light-coloured pavements) also pay-off with regard to rather aesthetic aspects. Overall costs (procurement, planting, replanting, care) of small-crowned trees are in a long-term perspective (> 40 years) slightly higher than for large-crowned trees. Artificial water courses have a limited impact on the site-specific microclimate and are quite costly. Their overall value rather dependents on the aesthetic preferences of the stakeholders.

For specific figures, please, see D5.2 Table 3-1.

Lessons learnt with regard to the process of economic evaluation (in urban planning)

First preliminary results suggest that adaptation-related assessments at a later stage of the planning process are more likely to be considered, because at the early planning stages the balancing of many other aspects, which are considered to be more important than climate change adaptation, dominates the exchange between planners and stakeholders.

Potential conflicts of adaption and mitigation efforts can be solved or at least mitigated by explicitly addressing these issues at an early stage of strategy and project development.

The exchange between representatives of different administrative bodies and scientists should be institutionalized and take place on a regular basis. As up to now the low level of formal institutionalisation of adaptation makes it strongly dependent on the determination of interested individuals. Despite a multitude of information and tools climate change adaptation is (still) a subordinated matter in urban planning in Germany.

In-house trainings of planning departments are essential to improve the ability of the municipal staff to use data and tools available for supporting adaptation.

Adaptation-related outreach activities do not only raise awareness but also ensure the support of the general public.

The public commitment of political decision-makers to support local adaptation activities is pivotal.

The momentum created, e.g. by the initial adoption of an adaptation strategy, can be maintained through projects that continuously update and expand the existing knowledge base.

Feasibility of methods

MCA is a useful decision support method for mainstreaming climate change adaptation into urban planning routines.

PRIMATE is capable of dealing with data uncertainties probabilistically and allows for simultaneous consideration of varying stakeholder preferences.

UrbaHT results do not compare with those of sophisticated software packages for micro-climatic modelling, but the tool's comparatively low data requirements and immediate results enhance the probability of application and integration of heat stress-related considerations into established planning routines.

Important data sources

Investment cost data was primarily sourced from the Department of City Planning, private planning consultancies, private engineering offices, construction material companies and literature. Maintenance costs were provided through the municipal service company. The German National Meteorological Service (DWD) provided measurement data. Climate projection data was sourced from the KNMI Climate Explorer. Information on the alternatives' performances concerning the rather aesthetic criteria was collected through expert judgments.

6 Implementation Analysis

The aim of this section is to establish whether adaptation measures can be implemented in the real world context of case studies, and what the key obstacles and opportunities are in doing so. To ensure the answers provided in this section are comprehensive and in line with WP2 and WP7, a checklist is provided below with the main factors that all case holders need to consider in their answers if relevant to the implementation of your case study.

6.1 Checklist

When answering the main questions below ensure you consider each factor listed in the checklist below that might have had a role in the implementation of your case study work. Write in the table how important each factor has been to the implementation of your BASE work and adaptation in general at your case study; where 1 = unimportant, 2 = slightly important, 3 = Important, 4 = Very important, and 5 = Critical). The checklist might not be all-inclusive, so feel free to discuss other factors that are not listed.

Table 27: Rating of the importance of key promoting and hindering factors

Key factors:	Urban planner 1	Urban planner 2
i. **Knowledge and information about climate adaptation**	4-5	5
ii. **Actors** (e.g. leadership, perceptions, understanding of climate adaptation, participation, decision making, stakes, conflicts/synergies)	4	5
iii. **Framing of climate adaptation** (e.g. as sustainability concern, (urban) planning or environmental issue, disaster risk mitigation topic)	4	4
iv. **Local and regional context** (e.g. culture, history, geography, environment, economy)	3-4	4
v. **European, national, regional and local regulatory framework** (e.g. be specific about laws, strategies, policies)	2-3	3
vi. **Institutional context** (e.g. integration of adaptation into existing structures/activities/strategies, decision making, conflicts/synergies, governance arrangements, incentives for engagement)	4-5	4
vii. **Resources** (e.g. financial, human)	4	5
viii. **Nature of adaptation measures** (e.g. no regret, flexibility, important co-benefits, side-effects)	4	3-4
ix. **Other** Political support at local level	4-5	4

Summary

a. Specify sectors covered (e.g. coast, city, agriculture):
   - City planning and urban development

b. Specify adaptation measures covered (e.g. altering cultivation practices, building defences; explain why they were chosen):
   - The report covers the implementation of climate change adaptation in the field of city planning in Jena/Germany by means of the development of the local climate adaptation strategy - JenKAS (retrospective) and the implementation of JenKAS (on-going).

c. Specify climate change impacts covered (e.g. flooding, heat stress, sea level rise):
   - Heat stress (main focus)
   - Pluvial flooding (secondary)

d. Specify main results of activities (e.g. changes, outputs):
   - Better understanding of cost-efficiency and wider suitability, i.e. including further non-monetary aspects, of selected adaptation measures
   - Recommendation a climate-adapted design for three major construction projects
   - Promotion of mainstreaming of climate change adaptation in urban planning

Questions

Answer these six questions giving specific evidence and examples where possible. In principle all implementation activities should be included, i.e. adaptation activities supported by BASE partners as well as those by other actors. If it is possible to inform about the implementation of those adaptation measures assessed for task 5.2, it is very important to do so in order to comply with the DoW. The measures covered can be extensive and/or particular to a case study. They can include for example, the development of plans and strategies, vulnerability/risk assessments, economic assessments such as CBA, MCA, the development of participatory processes/public dialogue, through to the implementation of actual measures including physical measures such as engineering developments and land use change, incentives/subsidies for behavioural change, etc. This list is not all-inclusive and is merely a guide. Your own case study may have very different measures. However, you must be clear what measures you are referring to when answering these questions.

6.2 How have climate change adaptation measures and strategies been advanced in the case study?

Describe the process! *Note:* Retrospective case studies will not answer this question, but have to update the information in section 1.5 of this document on the history of adaptation at their case study. (Approximately 500 words, 2/3 page)

JenKAS was formally **adopted by the City Council in May 2013** as an **informal planning principle**. The strategy's backbone is a handbook on climate sensible urban planning that includes information on current and future climate conditions and their potential local impacts; information on legal aspects of climate change adaptation; exemplary economic assessments of adaptation options; and best practice examples of successful climate change adaptation in Jena and elsewhere. For each city district, impacts are described in detail and related risks are visualized using a traffic-light labelling system. Recommendations for urban planning in particularly affected areas are presented in form of a map. The handbook is complemented by the decision support system Jenaer Entscheidungsunterstützung für lokale Klimawandelanpassung – JELKA. This tool has been developed to make climate risk information more accessible and provide tailor-made recommendations, i.e., suitable adaptation measures for a specific field of action or spatial unit. Thereby, it is meant to accommodate the varying needs of different stakeholders and decision-makers.[22]

The main focus of implementing JenKAS is on mainstreaming climate change adaptation into administrative decision-making, i.e., the consideration of adaptation-related aspects in these processes. The Department of Urban Development and City Planning (DUDCP) promotes the mainstreaming through various in-house activities, e.g. **JELKA trainings.** As a consequence of these efforts, a constantly growing number of **land development plans refer to JenKAS when making recommendations or substantiating restrictions**. It is expected that the results of current **research efforts**, e.g., those of a project that develops **site-specific recommendations for the use of tree species** taking into consideration climate, locational, and aesthetic aspects, will further promote this uptake. Beyond the actions directed at internal municipal processes, there are several activities addressing local citizens and associations, e.g., a **nature trail with display boards** financed by local businesses that provide information about important aspects of the changing urban climate as well as the local adaptation strategy.

One attempt to consider future climate change in today's decision-making processes is **use of comparative multi-criteria assessments** for selected publicly financed projects, which have been carried out in the context of BASE. These assessments aim to support construction plan designs, which on one hand suit current and future climate conditions but on the other hand also take into account additional factors affecting decision-making, e.g., financial and aesthetic aspects.

A **municipal climate change adaptation working group**, which was formed by representatives of different administrative bodies (local and federal state administration) and scientists, meets 4-5 times per year. It was founded to promote the exchange between relevant actors, i.e. enable administrative staff to follow scientific progress, get advice and feedback from scientists regarding their adaptation-related activities but also promote the transfer of practical experiences to the scientific realm.

[22] For more detailed information regarding the development of JenKAS, please, see section 1.5.

6.3 What and who drives (or enables) the adoption and implementation of adaptation measures and strategies/policies?

Note: The development of JenKAS is been understood as one example of implementing climate change adaptation at the local level. Obviously a strategy itself is a very fundamental adaptation measure, which has to be treated separately when analysing promoting and hindering factors. Therefore, information below will be provided separately for the development of JenKAS and its implementation. It will be explained what promoted the development and the implementation of JenKAS and how these aspects related to the key factors specified in the checklist.

6.3.1 Development of JenKAS

2.1 Resolution by the City council from 22.04.2009 (prepared by DUDCP) as legal basis for JenKAS

- IX – Political support by the political head of the DUDCP and the City Council
- I – Knowledge produced in the context of the preparatory project
- II – Personal commitment of the administrative head of the DUDCP, who was supported by a senior scientist, head of the working group "Regional climate and sustainability" at the Department of Geography at the Friedrich Schiller University Jena

2.2 DUDCP takes charge of the process

- II – DUDCP assumed leadership due to personal commitment of its administrative head

2.3 Participation in national research programme

- VII – access to financial resources, personnel and (scientific) networks
- I – knowledge exchange with other pilot cities within the programme

2.4 Information about local climate change impacts

- I – knowledge about local climate change impacts produced in the context of a 6-months preparatory project

2.5 Exchange with local university

- IV – due to the important role of the academic sector (more than 1/3 of the city's population studying or working at the universities and R&D departments of local companies) links between academia and city administration

2.6 Pioneer spirit of city officials and population

- IV – "new" topics often discussed "very early" at the City council (moral courage, climate change mitigation, child labour, animal protection, educational models etc.)

2.7 Climate change adaptation part of professional training of some relevant stakeholder groups

- IV – especially foresters and farmers had basic knowledge about climate change and adaptation options and considered climate adaptation to be a legitimate concern

6.3.2 Implementation of JenKAS

2.8 Urgency to react in the light of projected climate change impacts and already experienced extreme weather-related impacts

- I – knowledge about local climate change impacts produced in the context of the development of JenKAS
- IV – exposition to various climate change related risks, especially heat stress and floods due to specific geographic location (including orographic and topographic conditions) – experience of heat waves (2003, 2010, 2013, 2015) and floodings (1994, 2013)

2.9 Decision-makers at DUDCP follow precautionary principle

- II – Before working in Jena the administrative head of the DUDCP was a special advisor for sustainability to the mayor of the city of Dresden. Therefore, by professional background and personal experience (due to Dresden's high exposure to flood risk) he was sensitised to climate change-related risks. He convinced the political head of the DUDCP to pursue a precautionary approach for dealing with climate change-related risks.

2.10 JenKAS strategy

- V – The existence of a local climate change adaptation strategy, which was politically adopted as an informal urban planning principle, was a pivotal prerequisite for the consideration of climate change adaptation aspects in urban planning routines. Nevertheless, JenKAS is just a necessary, but not a sufficient precondition for mainstreaming climate change adaptation into urban planning.

2.11 Budget allocated for climate change adaptation at the DUDCP

- VII – There is a small yearly budget for supporting climate change activities at the DUDCP, which is spent on trainings and research projects, which validate and update the existing knowledge base regarding local climate change impacts and most suitable adaptation measures.

2.12 Personnel supporting climate change adaptation at the DUDCP

- VII – Two staff members of the DUDCP spend about 20% of their working time on supporting the implementation of JenKAS.

2.13 Networking promoted through JenKAS working group

- I – Exchange with scientists provides new insights regarding changing climate conditions and options to adapt
- VI – The working group is considered to be a key mechanism to steer adaptation related activities, even though it plays no role for official adaptation-related decision-making.
- VII – Administrative staff is informed about funding options for climate change adaptation. Cooperation with scientists enables JenKAS staff to acquire external fund, which complement the local adaptation budget.
- II – Scientists support the adaptation efforts of the municipality by disseminating up to date climate knowledge but they also benefit from the practical experiences shared by the administration as well as from common research projects funded by the municipality or from external sources.

2.14 Adaptation-related research projects

- I – The results of new research projects help to validate and update the knowledge base produced in the context of the development of JenKAS.

2.15 Change of regulatory framework

- V – Amendment of national building code for strengthening climate change adaptation in urban planning
- II – Legal changes communicated to administrative staff through professional trainings, which partly led to a change in personal attitude towards climate change related issues

2.16 Availability of different means to support consideration of adaptation in urban planning within the DUDCP

- II – There are different generations of urban planners working at the DUDCP. In the last decade the use of software tools, e.g. GIS modelling, in the context of the professional training as well as of the daily planning work changed remarkably. Despite further training activities more experienced urban planner prefer to work with maps, spreadsheet analysis and handbooks, where as young professionals are more prone to use decision support tools such as JELKA. Therefore, offering both types of decision support, i.e. a software tools as well as a hard copy handbook, which accommodate the different individual planning routines is a corner stone of an inclusive strategy to facilitate the mainstreaming of climate change adaptation into urban planning

6.4 What obstacles were encountered during the adoption or implementation of adaptation measures and strategies/policies?

Below it will be explained what hindered the development and the implementation of JenKAS and how these aspects related to the key factors specified in the checklist.

6.4.1 Development of JenKAS

3.1 Climate change mitigation activities have already been well-integrated into institutional decision-making when climate change adaptation became a topical concern

- VIII – Climate change adaptation is a competing concern to climate change mitigation.
- II – Administrative staff being responsible for climate mitigation lobbied against initiative to deal with climate change adaptation to ensure that there are no cutbacks of the mitigation budget and that the focus does not shift from fighting the causes of climate change to mitigating its impacts.
- VI – Climate change mitigation has already been well integrated into existing organisational structures and activities. This (at first) hampered the integration of the competing concern climate change adaptation.

3.2 High initial costs for producing valid information on local climate change impacts with a spatial resolution, which is high enough to serve as information basis for urban planning activities

- VII – Limited availability of internal resources and (qualified) personnel to produce the data needed at the quality requested.

3.3 Sectoral risk analysis for 30 city districts very laborious

- VII – Limited availability of internal resources and (qualified) personnel to analyse all city districts regarding 5 climate change-related risks in 5 sectors in the same thorough manner
- VIII – The DUDCP and authors of JenKAS aimed for a high level of detail, i.e. cover all districts, relevant sectors and risks to inform future urban planning processes. This high ambition caused much more work than it was expected in the beginning.

3.4 High dependency on external knowledge

- I – Lack of in-depth knowledge (e.g. regarding metropolitan intra-night cold airflows) to develop recommendations for future urban planning projects
- II – Competencies of existing personnel not sufficient to produce data at the level of detail requested
- VII – Limited availability of personnel already working at the DUDCP, that could have conducted analyses without external support
- VIII – High quality data requested could only be produced by involving external experts from different specialised research institutes and agencies

3.5 Acquisition and production of basic data extremely time-consuming and resource-intensive

- I – Lack of in-depth knowledge needed
- VII – Limited availability of internal resources and (qualified) personnel
- VIII – High quality data requested could only be produced by involving external experts from different specialised research institutes and agencies

3.6 Willingness of relevant stakeholders to commit themselves rather low

- II – Some stakeholders were part of the process but overly critical due to their competing interests; other stakeholders were more reluctant to get involved as there was a lack of understanding of what climate change (adaptation) is about; some representatives were delegated by their respective entities and didn’t perceive climate change adaptation to be an urgent (or even just relevant) matter
- III – The development of JenKAS was lead by the DUDCP. Therefore, there was a strong focus on the adaptation-urban planning nexus. As a result – even though adaptation in many other policy areas and sectors was addressed in the JenKAS process – this special focus, i.e. framing adaptation as an urban planning issue, might have discouraged some stakeholders to also make adaptation one of their top priorities.
- VI – The institutional context didn’t oblige stakeholders or offer incentives to them to engage themselves. At the beginning of the JenKAS process there was no structure or governance arrangement to promote climate change adaptation within the city administration. This means that stakeholders either were delegated to participate by their respective administrative entities or they participated because they were intrinsically motivated. There might have been various rationales for the delegation ranging from interest in getting an insight into and/or providing input to a new policy field within the city administration to peer pressure.

3.7 Limited cross-sectional thinking of stakeholders

- II – Many stakeholders were not very open to discuss and judge the impact of potential adaptation measures across different policy field. They acted as advocates of their respective entities and/or policy areas. This was helpful for identifying potential conflicts of adaptation measures across sectors, but less fruitful for developing compromise solutions.
- VIII – The adaptation strategy aimed for demanded intensive cross-sectional thinking, which constituted a challenge for many stakeholders involved as they were not so experienced with this kind of thinking.

3.8 Great effort (inputs, motivation, moderation etc.) needed to activate stakeholders to contribute

- II – Stakeholders in general didn't act very proactively. Many of them were not very motivated to provide inputs.
- III – The development of JenKAS was lead by the DUDCP. Therefore, there was a strong focus on the adaptation-urban planning nexus. As a result – even though adaptation in many other policy areas and sectors was addressed in the JenKAS process – this special focus, i.e. framing adaptation as an urban planning issue, might have led to the perception that they are parts but not owners of the process. This in turn might have limited their willingness to contribute.
- VI – The institutional framework wasn't design to promote, i.e. to enforce or incentivise, stakeholder participation.

3.9 Some relevant stakeholders could not be invited to participate as their participation would have jeopardised the whole process

- II – The association of allotment gardeners has not been involved in the JenKAS process. The main reason for not including the urban gardeners was that before the JenKAS process started there was a fierce debate about the municipality's initiative to search for options to relocate some dozen of allotment gardens to zone these lots residential. The steering committee was worried that this particular situation and the allotment gardeners' uncompromising comportment would restrain open debates and the decision-making processes in the JenKAS workshops.

3.10 Climate change scepticism

- I – Some stakeholders lacked science-based knowledge on climate (e.g. difference between "weather" and "climate"), climate change and climate change adaptation. Especially stakeholders being delegated often referred to information sourced from popular media for substantiating their doubts about the relevance of the topic.
- II – Some stakeholders didn't perceive the issue of climate change to be so relevant that such a big effort is made to deal with the "supposed" changes of key climate parameters.
- III – Under reference to the discourse of climate change scepticism some stakeholders doubted the relevance of the effort undertaken. They had to be convinced first to contribute to the JenKAS process.

6.4.2 Implementation of JenKAS

3.11 Lack of financial resources of municipal departments and private actors to be involved in adaptation-related activities

- VII – Limited internal resources of the DUDCP (small budget) to promote the implementation of adaptation measures. Available resources are used (1) to improve the climate change adaptation knowledge base on a continuing basis mainly through commissioning research projects and (2) to encourage urban planners by means of internal trainings to make use of the adaptation-related information and tools available.

3.12 Motivation of relevant stakeholders

- II – There are conflicts of interest, e.g., for public servants, who are responsible for promoting climate change mitigation. Employees in charge of facilitating climate change adaptation- and mitigation-related activities are well aware of the fact, that adaptation cannot solve the problem of climate change by itself and that despite all mitigation efforts there is and will be the need for adapting to certain climate changes effects, which cannot be averted anymore. But still both policy areas are competitors with regard to the allocation of resources and the attention of political decision makers.
- VI, V – Despite the fact that JenKAS was confirmed as an informal planning principle by the Jena City Council, to date neither the external regulatory framework, e.g. set by laws or strategies at the national level or the level of the Federal states, nor rather internal institutional aspects, e.g. decision routines, incentives etc., are strong driving forces to promote stakeholder motivation.

3.13 Conflict of goals between climate change adaptation- and mitigation-related considerations in urban planning

- VIII – Some adaptation measures have detrimental effects on climate mitigation. Urban planners in Jena are guided by the urban design concept of the compact city. On the one hand outward urban expansion should be limited and dense urban structures using land resources efficiently should be promoted to improve energy efficiency but on the other hand dense urban structures are likely to restrict the establishment of green infrastructures to mitigate urban heat island effects.

3.14 Lack of (experienced) personnel

- II – Despite the information material and decision support tools available as well as the further qualifications offered (for comprehensible reasons, hence, it’s a new aspect to be considered) still there is a lack of experienced personnel in the city administration and in private and publicly owned companies to use the full potential of the supporting material.
- VII – Financial and personnel resources to support climate-proofing processes are very limited.

3.15 Lack of knowledge regarding external funding options for promoting climate change adaptation

- II – There are very few actors in the municipal climate change adaptation community who are able to act as knowledge brokers helping to access external funding to promote adaptation activities. This information is primarily provided by external actors such as scientists or consultants, who are involved in the JenKAS working group.

3.16 Uncertainty of climate change impacts and adaptation benefits

- I – There is high level of uncertainty regarding the benefits of an adaptation measure. This uncertainty relates to the development of relevant climate parameters, their impacts and the ability of a particular measure to mitigate these impacts. Proper estimation of the benefits requires complex and sometimes costly modelling efforts and still the reliability and explanatory power of the results might be limited (substantial uncertainty margins).
- VIII – Assessments, which are legally admissible are often time- and resource consuming (finances, qualified personnel).

3.17 Climate change scepticism

- I – Some stakeholders lack science-based knowledge on climate (e.g. difference between "weather" and "climate"), climate change and climate change adaptation and, therefore, they
- II – Some stakeholders didn't perceive the issue of climate change to be so relevant that such a big effort is made to deal with the "supposed" changes of key climate parameters.
- III – Under reference to the discourse of climate change scepticism some stakeholders doubted the relevance of the effort undertaken. They had to be convinced first to contribute to the JenKAS process.

3.18 Misuse of JenKAS to protect vested rights

- II – Single citizens, local politicians or particular interest groups refer to the JenKAS strategy in order to hamper new planning projects, e.g. by highlighting the importance of preserving cold and fresh air production areas. Often particular sections of the strategy are used to raise complaints without taking into consideration the wider climate change adaptation perspective.

3.19 Critique of political actors

- VIII – Environmental concerns about the planting of so-called invasive (tree) species, which are well adapted to current and future climate conditions, but also potentially supersede indigenous species

3.20 Increasing demand for land for residential areas and industrial real estates

- IV – Jena is a growing city in a shrinking region. The trend of obsolescence is been mitigated by the influx of students and young families. These developments on one hand enhance the supply of skilled labour but on the other hand also create an ever-increasing demand for land for residential areas and industrial real estates. This need to zone land for residential and industrial use has detrimental effects on the preservation and expansion of green infrastructures.

3.21 Perceived cost effectiveness or efficiency of adaptation measures

- II – Some of the benefits of adaptation measures are either hard to quantify/monetise or very uncertain. But this does not hold for all the effects. E.g. assessing the benefits of a green roof compared to a tar-gravel roof is manageable. Even when making very conservative assumptions (i.e. assuming rather high investment green roof costs and taking into consideration only benefits which are independent from climate projections) over the entire roof life period in the most German municipalities a green roof is more efficient than a tar-gravel roof (for calculations for Jena see section 5.2.8). But still many investment decisions are taken based on the *perceived* cost effectiveness or efficiency of (adaptation) measures, i.e. no thorough economic analysis is conducted.

3.22 Investment or planning horizon of relevant actors

- II – As uncertainty about future developments increases substantially as time elapses individuals tend to plan for a not too distant future
- VI – The institutional context rather favours short-term over long-term planning

6.5 If any obstacles were overcome, how was this achieved?

4.1 Ad 3.1, 3.13

- Responsibility for climate change adaptation and climate protection has been separated, i.e. the department of environmental protection deals with climate protection and the department of city planning deals with climate change adaptation related activities.
- There is an exchange between these entities as there are delegate representatives in the respective working groups, who ensure the information flow on current activities.
- In the context of almost every planning project both concerns are considered in the decision process.
- Example: Urban planners in Jena are guided by the urban design concept of the compact city. The aim for dense urban structures implies certain land use restrictions (e.g. for green infrastructures). This (potential) conflict was balanced by recommending that planners should retain the compact city as a guiding principle but also ensure that the clean and cold air can flow from the green air production areas to the inner-city residential and commercial areas. A map representing intra-night airflows was made available to planners to inform them about these essential corridors.

4.2 Ad 3.2, 3.11, 3.15

- Intensification of the networking especially with academic partners to improve the knowledge base and get access to external financial sources, i.e. mainly funding through national and European research programmes

4.3 Ad 3.3, 3.5

- Strengthen internal workforce and reinforce cooperations with external partners

4.4 Ad 3.6, 3.8, 3.12

- Somebody has to lead the process and make it appear to be a relevant concern to convince undecided stakeholders and decision-makers to commit themselves

4.5 Ad 3.9, 3.10, 3.17, 3.19

- Prevent escalations/vicious circles; stay persistent; (try to) get stakeholders and decision-makers involved at an early stage, prevent crises of confidence

4.6 Ad 3.10, 3.17

- Intensified participation of the general public

4.7 Ad 3.16

- Scientists should see themselves as being part of the adaptation process, i.e. acting responsibly when giving advice under the condition of (deep) uncertainty (not meaning giving no advice because data is too uncertain)

4.8 Ad 3.13

- The potential conflict of climate change adaptation and mitigation goals was balanced by recommending that planners should retain the compact city as a guiding principle but also ensure that the clean and cold air can flow from the green air production areas to the inner-city residential and commercial areas. A map representing intra-night airflows was made available to planners to inform them about these essential corridors.

6.6 What are the future prospects of the climate change adaptation activities in the case study?

5.1 Current observations of weather anomalies confirm high relevance of preparing for changing climate conditions

5.2 Consideration of climate change adaptation aspects in the planning process will become a routine for urban planners as it is already common with regard to other environmental concerns.

5.3 Many other actors, e.g. fire brigade, disaster managers, (urban) foresters, will also increasingly consider climate change adaptation in their daily work.

5.4 There are first positive signals that building sector will make use of information provided in the context of the JenKAS initiative.

5.5 JenKAS working group will continue to stimulate climate change adaptation.

5.6 New projects to validate and update the knowledge base are already planned for the next 2-3 years (extent and depth of analysis depends on acquisition of external resources)

5.7 An increase and reliable assurance of financial resources is a precondition to ensure that local knowledge about climate impacts and potential adaptation measures is kept up to date.

5.8 Mainstreaming adaptation into urban planning relies on up to date, locally specific information. If – for some reason – an update and/or extension of the knowledge base won't be possible anymore, in the medium-term perspective this would also have a negative impact on the mainstreaming activities.

6.7 What is the key message from this case study (and which could work in other cases as well)?

6.1 Potential conflicts of adaption and mitigation efforts can be solved or at least mitigated by explicitly addressing these issues at an early stage of strategy and project development and searching for synergic solutions.

6.2 The exchange between representatives of different administrative bodies and scientists should be institutionalised and take place on a regular basis to promote knowledge transfer.

6.3 Outreach activities do not only raise awareness but also ensure the support of the general public.

6.4 The momentum created by the initial adoption of a local adaptation strategy can be maintained through projects that continuously update and expand the existing knowledge base.

6.5 In-house trainings are essential to improve the ability of the municipal staff to use data and tools available for supporting adaptation. But although making information digitally available offers many advantages, e.g. more detailed explanation, options for customising or updating information, the provision of information should be adapted to the existing routines. In Jena primarily very young professionals used the decision support software whereas most of the planners preferred to use the hard copy of the handbook.

6.6 The public commitment of political decision-makers to support local adaptation activities is pivotal, e.g., the adoption of an adaptation strategy by the city council.

6.7 Due to high initial costs financial support is needed (especially by small municipalities) to kick-off adaptation activities.

6.8 External appreciation of local adaptation activities fosters "internal" recognition by administrative and political decision-makers

6.9. Any climate change related activity, e.g. COPs, best practice examples in public media etc., helps making climate change mitigation and adaptation a mainstream topic, which in turn support local climate change-related initiatives.

7 Development of new tools for adaptation planning and implementation

New tool(s) further developed and used during BASE: UrbaHT

The tool UrbaHT is able to estimate micro-climatic effects related to urban planning projects for a spatial unit. It provides information on the intensity of urban heat stress based on comprehensive parameter calculations. Thereby it indicates changes in the heat stress potential if one or more parameters are altered. Users can compare different situations in which either the climate or the construction-related parameters or both of them are change at the same time for the same spatial unit. So the following comparative assessment can be done (see Box 1).

The innovative aspect of this approach is that in general the data needed to run the tool can easily be obtained from public sources. The quality of the data used is documented in the final results. UrbaHT enables local planners to (roughly) estimate heat stress potentials without resource and time consuming simulations using software packages as for instance ENVI-met. Even though the high degree of applicability comes at the cost of less accuracy, experience shows that this might be a necessary trade-off if considerations of climate change are to be integrated into established planning routines. Due to the disadvantages of the high usability of the tool for building projects of outstanding importance additional more elaborate micro-climatic analyses have to be commissioned.

Table 28: Strenghts and Weaknesses of UrbaHT

Strengths	**Weaknesses**
Unambiguous and suitable input parameters for UHI assessment: Parameters have been chosen by the developers based on a comprehensive literature review and experts consultations Comparatively low data requirements: Information needed is often accessible Easy-to-use: Information on the data to be entered by the user is provided by the tool Applicable at various scales: Spatial units are not restricted	Assessment is not been physical modelling and therefore (probably) less accurate Tool can only be applied for comparative analysis, i.e. there are strong limitations regarding the interpretation of absolute values Average values for each parameter are used, i.e. no data on extreme (climate) values is considered and the spatial unit is regarded to be homogeneous
Opportunities	**Threats**
Easy-to-use tool with comparatively low data requirements for assessments of heat stress potentials for any spatial unit	Inaccuracy due to methodological approach Data requirements based on information easily available for various scales in Germany, i.e. data availability might be more limited for other countries

8 References

Copyright licence: CC BY-SA 3.0 (http://commons.wikimedia.org/wiki/File:Thuringia_districts_J.svg) [Figure in the General Case Study Description]

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