Adaptation Strategy and Action Programme 2012 – 2016

LIVING WITH CLIMATE CHANGE – HANNOVER ADAPTS

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STATE CAPITAL HANNOVER

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Introduction

The subject Climate Change is present in the media more and more frequently, because the consequences of climate change are already perceptible in Germany, too. The number of very hot days per year is constantly rising and the heavy rainfall events in Bavaria in 2016 made evident, that climate change should be taken seriously. We are well advised to face its challenges and to think and act preventatively.

In this process, we follow two different lines of actions in Hannover: on the one side, since the climate protection coordinating office was founded in the year 1994 we have been cooperating with many actors on the reduction of greenhouse gas emissions, which are responsible for climate change. We have made it our objective to reduce these emissions until 2050 by 95% in comparison to 1990.

On the other side, Hannover has dealt with the consequences of climate change at an early stage and worked out a local adaptation strategy in 2012 already. Furthermore, with joining the Mayors Adapt Initiative (initiative of the Covenant of Mayors for the adaptation to climate change) we have committed ourselves in 2014 *to contribute to the overall objective of the EU-strategy for the adaptation to climate change and to strengthen the climate resilience of Europe. This means the extension of provisions by the community and the improvement of our response capacity with regard to the impacts of climate change by:*

- *the development of a comprehensive (autonomous) local adaptation strategy for our community and*
- *the integration of the adaptation to climate change into our existing respective planning.*

The adaptation to climate change is also a central issue of our city development concept "My Hannover 2030" that has been published by the State Capital Hannover in February 2016. Under the overall objective to maintain a high standard of living and quality of open spaces it states specifically:

"My Hannover 2030 has a well-balanced and healthy urban climate, is on the way towards a climate-neutral city, maintains a climate-adapted urban development and supports the resilience."

Living with Climate Change – Hannover adapts!

With this brochure, the State Capital Hannover reports, how we meet this challenge. It presents the adaptation strategy towards changed climate conditions of the city in the future and the initially implemented measures. In this context, it becomes evident, how variegated the fields of actions are, in which adaptations to climate change are necessary.

Even if the impacts of the changing climate are not perceived as a burden in Hannover at present, the implemented measures improve the quality of life in our city already.

I wish you an inspiring reading!

Yours

Sabine Tegtmeyer-Dette
First City Councillor
Director of Economic and Environmental Affairs

1 Living with Climate Change

"Climate Change is no longer speculated about, it is reality." This was the result of climate researchers who cooperated within the framework of the UN Climate Council and published the Fourth Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) in 2007. In 2013, the Fifth IPCC Assessment Report on Climate Change was published. It confirms: The ongoing climate change is fact and is caused mainly by human influences (Source: Earth Perspectives).

Nowadays it is consensus in climate research, that the rising concentration of anthropogenic, i.e. manmade greenhouse gases (CO^2, Methane etc.) are the main cause of the global warming. The IPCC, whose analyses are covering the worldwide state of research in this area, mentions in its Fifth Assessment Report from 2013, that this is "extremely likely" which is equivalent of a probability of 95 – 100 percent.

The IPCC report is the "worldwide most important assessment report on climate research". Since 2010, more than 3000 experts from more than 70 countries contribute to the comprehensive report, including more than 100 from Germany (German Aeronautics and Space Research Centre, 2014). The IPCC statements carry so much weight, because they are examined in a unique multi-step examination procedure and are therefore very reliable and well-balanced. The 195 member states of the World Climate Council adopt the scientific major statements of the IPCC reports and thereby acknowledge them officially.

The major statements of the 5th Assessment Report on Climate Change:

Since the beginning of the regular instrumental measuring of the surface air temperature in the year 1881, there was no year warmer than 2014 up to then. But the following year already pushed the actual record year onto the second place. 2015 was globally the warmest year since weather records began. Almost every month of that year showed maximum values of the average global temperature. Only a second warmest January and a third warmest April fell slightly out of line (Federal Environmental Agency, 2016).

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming and understanding of the climate system.
(IPCC 2013, Climate Change 2013: The Physical Science Basis. Summary for Policymakers)

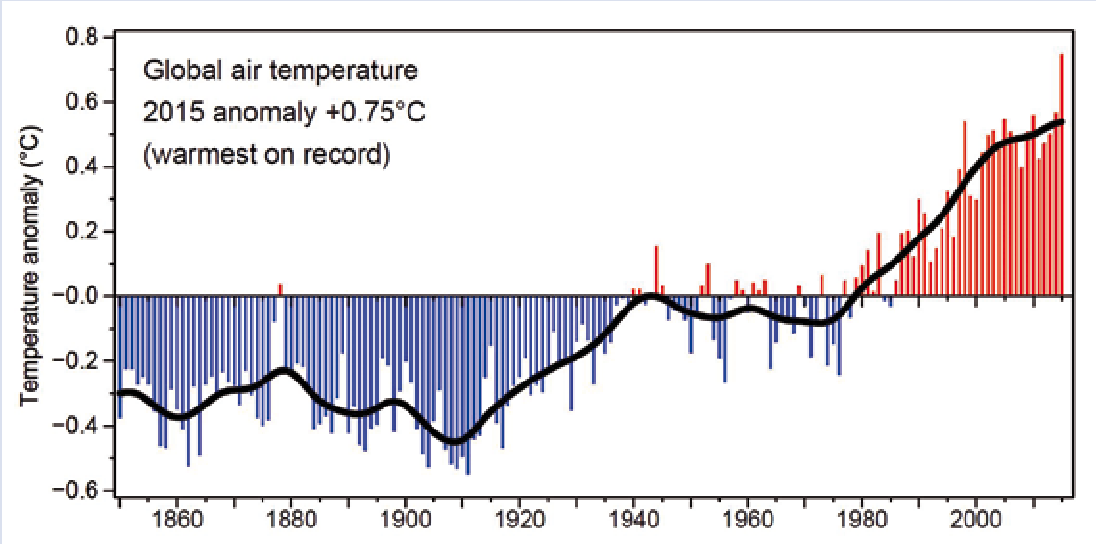


Figure 1: Deviations of the Average Global Surface Air Temperature from the Mean Value in the Reference Time Period 1961 – 1990 (red and blue bars), the continuous black line represents the non-linear trend.
(Source: Climate Research Unit, University of East Anglia, 2015)

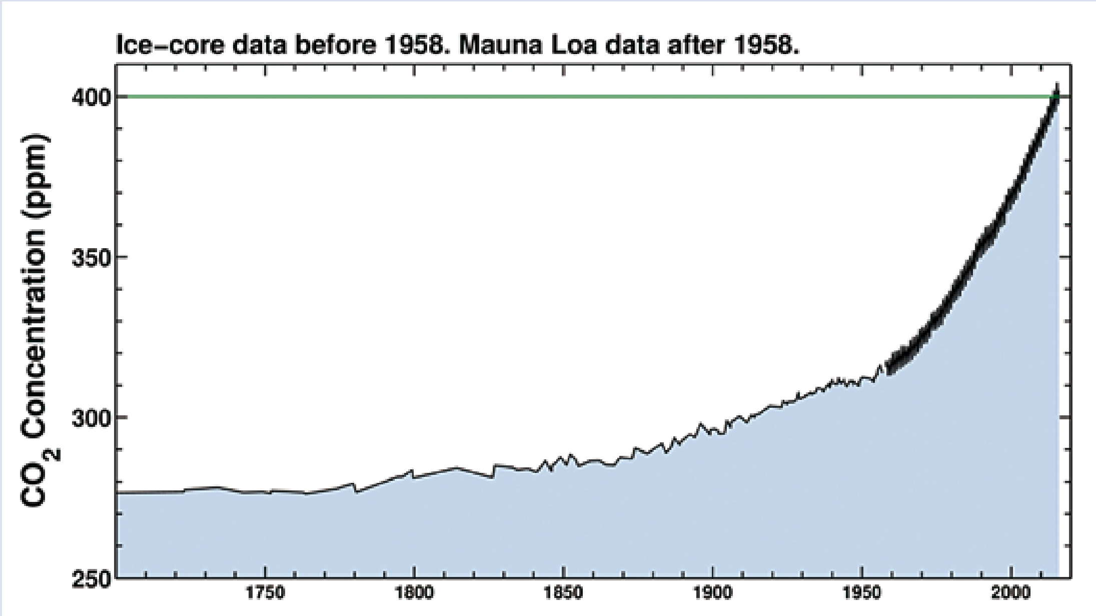


Figure 2: The Atmospheric CO^2-Concentration since the Year 1700. Data of the NOAA (National Oceanic and Atmospheric Administration) from Hawaii since 1958, before that Calculation by means of Ice Drillings.
(Copyright/Source: Scripps Institution of Oceanography, UC San Diego)

The 16 warmest years lie – with one exception – in the first 16 years of the new millennium. The average global surface air temperature has increased by 0.85°C between 1850 and 2012 (see Figure 1). In 2015, this deviation amounted to 0.9°C already. In April 2014, the CO^2-concentration in the atmosphere at the worldwide oldest measuring station Mauna Loa (Hawaii) has risen to the highest value in the history of mankind, namely 401 ppm (parts per million). Before the beginning of industrialisation, the CO^2-concentration was only 280 ppm (see Figure 2).

The global warming will – also in Germany – have far-reaching consequences for people's living conditions. The implications of a global warming up to 2 degrees Celsius over the pre-industrial level is considered by scientists and climate experts to be just barely manageable. A warming beyond this level would result in serious damages for humans and nature and in very large economic costs. Therefore, the reduction of greenhouse gases in all countries is the major objective of all climate protection measures. Because the climate reacts to external influences with a delay of several decades, a global warming of 2 degrees by the middle or at latest the end of this century will, in spite of the already initiated climate protection measures, more than likely not be able to be prevented. As a result, together with the measures for the reduction of global warming and its consequences (mitigation), measures for the adjustment towards climate change (adaptation) have to be implemented at the same time.

"It is a matter of avoiding the uncontrollable and controlling the unavoidable."
(Prof. Hans Joachim Schellnhuber, Director of the Potsdam Institute for Climate Impact Research and Climate Protection Officer of the Federal Government)

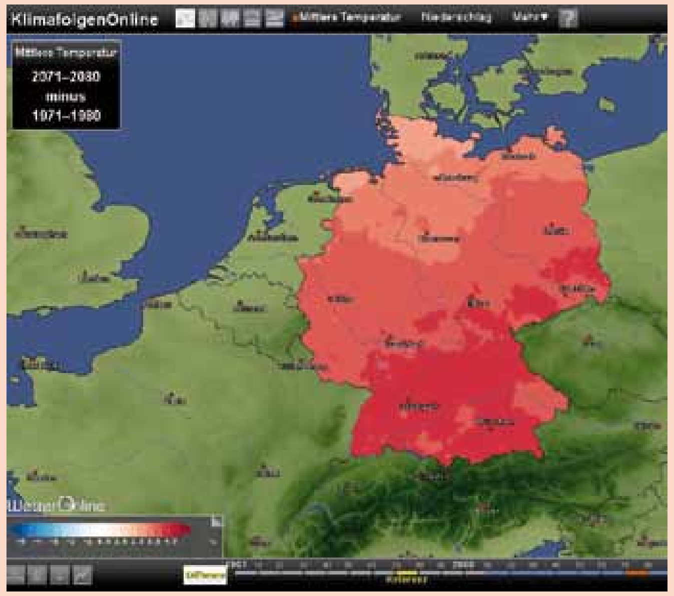


Figure 3: A comparison of the average annual temperatures of the 1970s with those expected for the 2070s in Germany shows a significant increase – on average a rise of 3.5°C within 100 years
(Source: KlimafolgenOnline.de)

In December 2008, the Federal Government adopted the German Strategy for Adaptation to Climate Change. In order to further develop this strategy, the Federal Government drew up an "Action Plan Adaptation" in coordination with the Federal States and leading municipal associations in 2011. The national strategy process for the adaptation is meant to contribute towards the development or improvement of preconditions for the identification of adaptation needs and of adaptation concepts as well as measures on a local level. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety maintains a dialogue with the communities since 2009. In July 2011, the German Parliament passed the Law for the Promotion of Climate Protection in Conjunction with Developing Cities and Communities and respective changes of the Building Code (Federal Government 2011). Thus, the objective to promote the climate protection and the climate adaptation by means of the urban development planning was integrated into the fundamental issues of § 1 of the Building Code. This way, the requirements of climate protection shall be taken into account through measures, that counteract climate change as well as such, that serve the adaptation to climate change (§1 a (5) BauGB). The instruments of the urban development planning provide the opportunity, to consider the requirements of climate protection and climate adaptation in the cause of the preparatory planning (land utilisation plan) as well as the mandatory planning (development plan) by means of the available presentations and determinations, for example through the creation and/or conservation of open spaces. This also applies to green or fresh air areas, plantings, scope and arrangement of constructions including boundaries/the exclusion of certain usages, regulations in respect to the drainage, limitation and seepage of rainwater etc. Thus, the aspects of climate protection and climate adaptation are components of the consideration regarding public and private concerns, that has to be carried out in the course of drafting urban land-use plans.

1.1 Climate Change in Germany

Due to an ever-increasing amount of data, refined climate models and more efficient computers, relatively reliable statements about future climate conditions (even for individual regions of Germany) are meanwhile possible. The Federal Environmental Agency (UBA) summarizes the state of research as follows:
"In comparison between the possible climate in the years 2071 to 2100 and the period 1961 to 1990 [reference time period] the climate models show, that

- the temperatures in Germany rise varying regionally and seasonally on average by about +3.5 degrees Celsius (summer: +1.5 degrees up to +5 degrees Celsius; winter: +2 degrees up to +4.5 degrees Celsius);
- there will be fewer days of frost, more hot days and more tropical nights and the number and length of heat waves will increase;
- the summer precipitation will be reduced by up to 30 percent and at the same time the frequency of heavy precipitation will increase;
- an increase of the total amount of precipitation in winter has rather to be anticipated for the majority of regions in Germany (circa minus four percent up to plus 20 percent). The strongest increase has thereby to be expected for Northern Germany. On the other hand, no significant change, rather even a slight reduction has to be expected for the most southern parts. In future, heavy rainfalls will be recorded more often in winter, too;
- likewise, extreme wind velocities will occur more often in future;
- a reduction of glaciers and snow covering in the Alps has to be taken into consideration;
- the sea level could lie with on average 30 centimetres significantly higher." (UBA 2013)

1.2 Climate Change in the Hannover Region

Long-term measurement series since 1936 are available at the Climate Observation Station Hannover Langenhagen of the German Meteorological Service. Trends of the climate development can be derived due to the long row of data. As a result, the data show clearly, that climate changes have already taken place in the Hannover Region. The number of summer days (maximum temperature ≥ 25°C) as well as the number of very hot days (maximum temperature ≥ 30°C) show an upward trend since 1950. Tropical nights (minimum temperature ≥ 20°C) only occur in certain years since 1986 but seem to become more frequent since 2007.

The comparison between different time periods of temperature data series from 1950 to 2013 shows, that the mean temperature has risen in general. While the temperature in the period 1951 to 1970 amounts to 8.6°C on average, it amounts to 9.6°C in the period 1981 to 2010, an increase of 1 degree Celsius. So, climate change has already begun and it will continue in the future.

Assisted by models, it is possible to create scenarios of future climate developments. Based on the international model (ECHAM) and an average global warming of 2 degrees, future climate changes resulting from the global warming can be transferred onto the Hannover Region by means of the national Climate Impact Calculation Model (CLM, REMO). As a result, an average rise in temperature of 3 degrees has to be expected for the Hannover Region until the end of this century (Meteoterra/GEO-NET 2015).

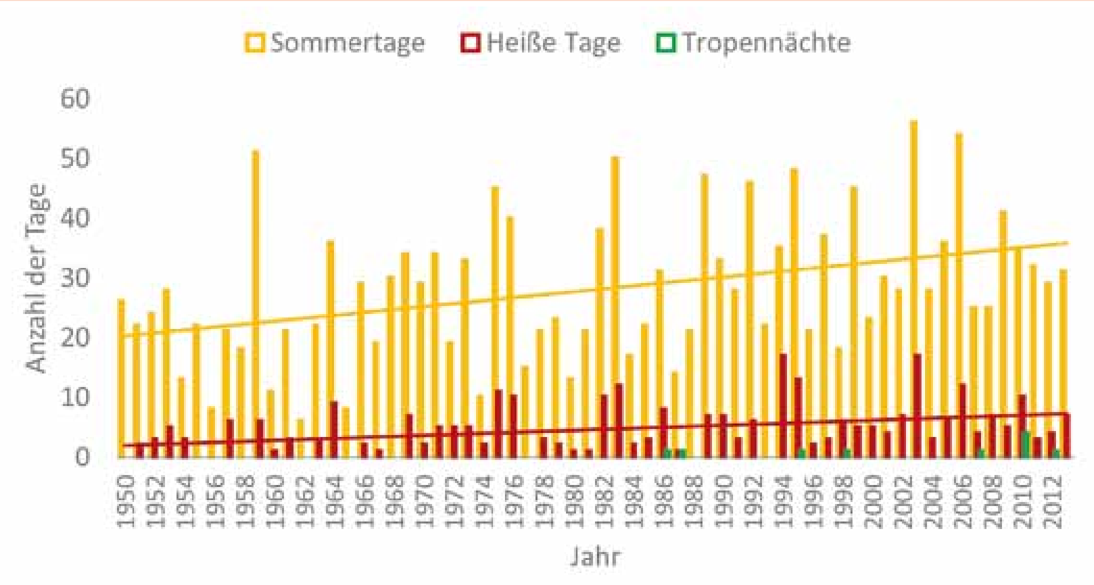


Figure 4: Number of summer days (yellow), very hot days (red) and tropical nights (green) in Hannover-Langenhagen in the years 1950 to 2013
(Source: Meteoterra/GEO-NET 2015)

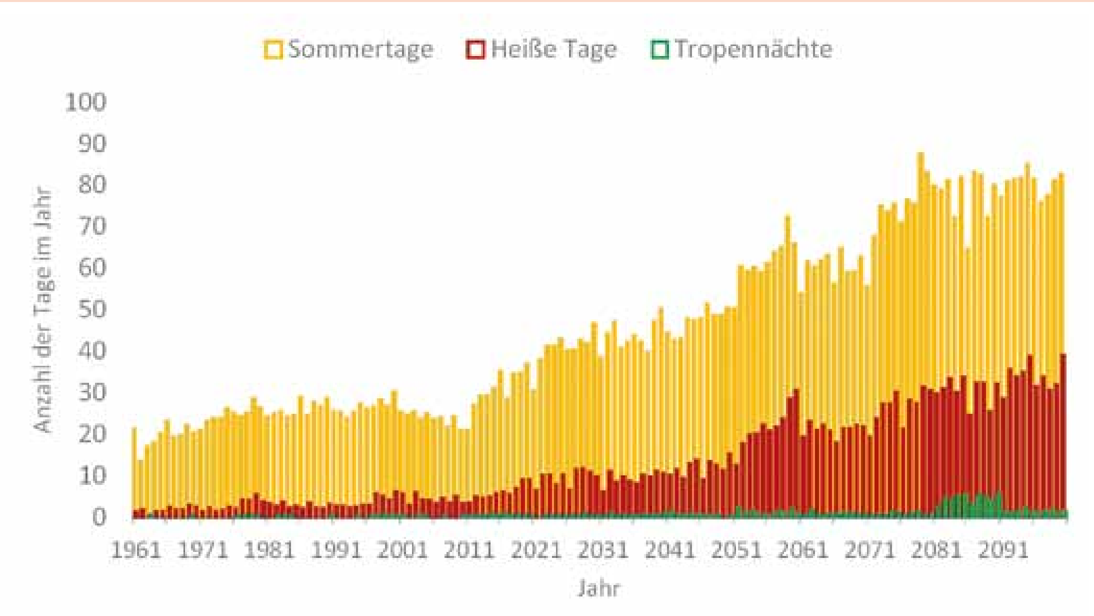


Figure 5: Modelled number of summer days (yellow), very hot days (red) and tropical nights (green) for Hannover-Langenhagen in the period 1961 – 2100 (Data basis: WETTREG 2010, scenario A1B, mean value over ten model runs)
(Source: Meteoterra/GEO-NET 2015)

Figure 6: View from the Auestraße to Schwarzer Bär in the Linden district of Hannover. A highly sealed urban area, the climate of which differs significantly from that of the green surrounding area.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

The trend regarding the summer days and very hot days already determined by the data of the German Meteorological Service will continue to increase. They will occur – similar to tropical nights – more and more often. Very hot summers like in 2003 (56 summer- and 17 very hot days) will very likely resemble the normal case from 2050 on.

The annual distribution of precipitation will change as well. The probability of occurrence of dry (precipitation-free) days and with that, the length of dry spells, for example, will continually increase in the course of the 21st Century. The number of days with low to moderate precipitation will also decrease.

1.3 Urban Climate and Climate Forecasts for Hannover

In densely built-up residential areas the climate change is overlaid by the effects of the urban climate. According to the sealing level and size of the dense construction, the climate in the cities is in comparison to the surrounding areas characterized amongst others by higher temperatures ("heat island"), a lower relative humidity, a lower average wind velocity, but also a higher gustiness of winds. The urban climate effects with consequences for the health of people will be additionally increased through the changing climate. So, the average global warming of 0.85 degrees Celsius between 1850 and 2012 results for the "Megacity" Tokyo in a warming of 3 degrees Celsius, for example.
Climate change will lead to an increase of the thermal load and heat stress for the population in inner-city agglomerations. According to the modelling of meteorological parameters for the climate change in the Hannover City area, commissioned by the Capital City in 2010, a significant increase in the number of very hot days with a maximum temperature of more than 30 degrees and of tropical nights with air temperatures not under 20 degrees has to be expected. In the densely built-up and highly sealed inner city the average number of very hot days will more than double from 9.6 (period 2001 – 2010) to 21.9 in the period 2090 to 2099. The average number of tropical nights will clearly rise from 1.4 to 9.8 nights. Especially in districts with block- and block-edge building, the number of very hot days and tropical nights will increase considerably. For the district Vahrenwald, for example, a rise of very hot days from an average of 8.7 to 19.1 and of tropical nights from an average of 1.2 to 9.2 has been calculated for the above-mentioned time period (see Figure 5). The climate projections show further, that the heat periods will last longer and their start will be moved into the spring, a season in which the human organism is not yet accustomed to the heat and therefore reacts more sensitively to thermal stress.

Figure 7: Warm summer days are enjoyed by many people in the open, e.g. in a street café
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

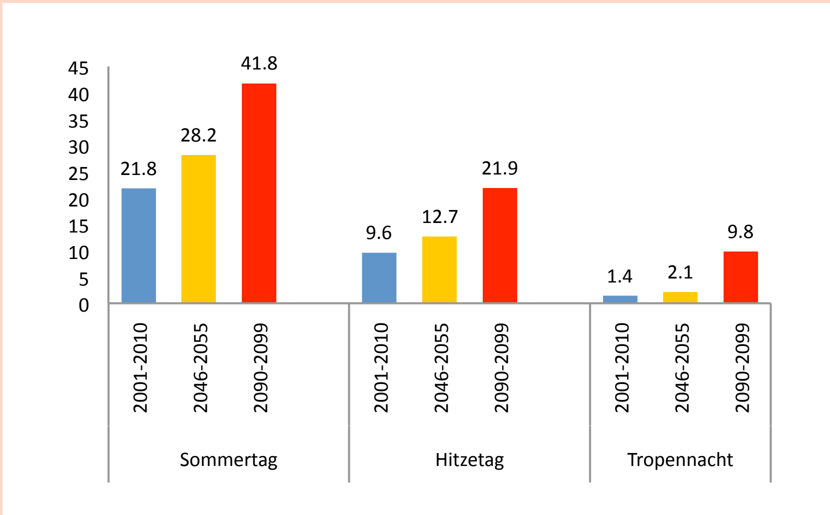
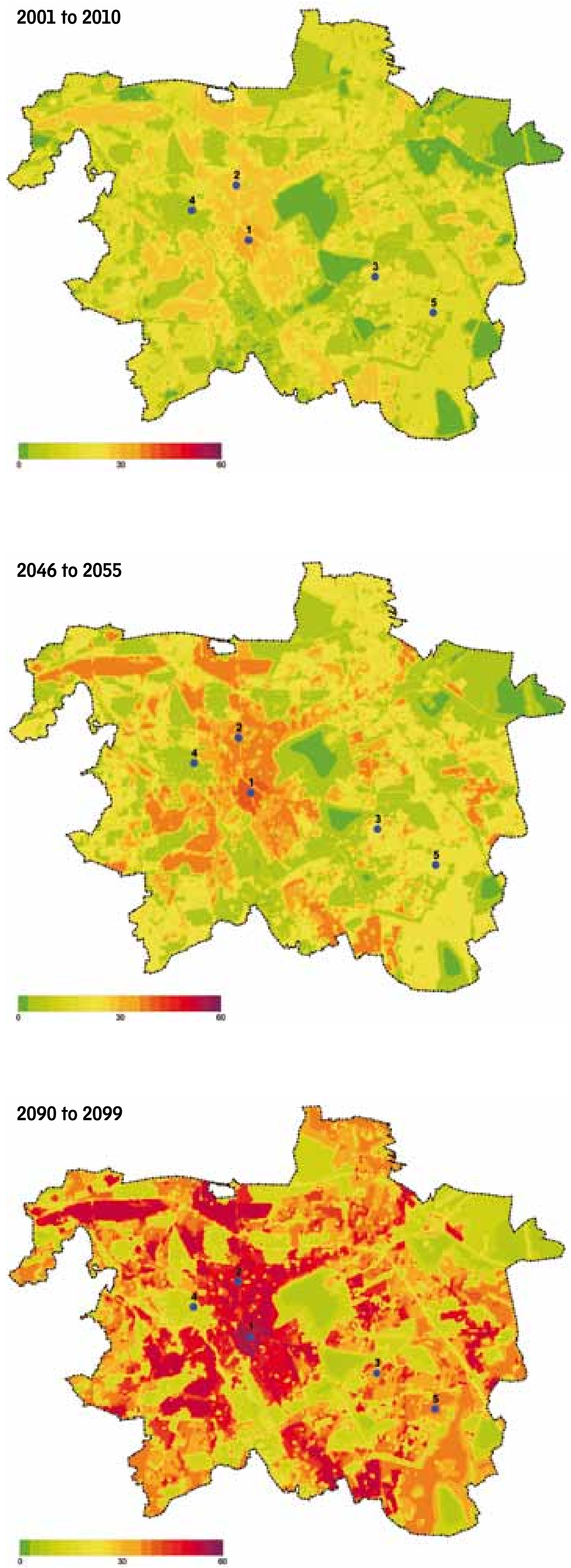


Figure 8: Average annual frequency of climatic events in the inner city of Hannover for the time horizons 2001 to 2010, 2046 to 2055 and 2090 to 2099.
(Data source: GEO-NET 2011)

Especially older and weakened persons (but also small children) will be affected by the heat stress. At the background of the demographic change and the observed trend, that older people move back from the surrounding areas into the city again (shorter ways, higher range of services), the number of (heat sensitive) people affected will increase. Effects of the heat stress (especially due to tropical nights, because the nightly recovery phase after a very hot day is missing) can be health impairments (e.g. cardiovascular illnesses), which can under certain circumstances even lead to death. During the very hot summer of 2003, 55,000 additional death cases were reported in Europe, 7,000 of which in Germany. According to a study of the German Meteorological Service a rise of the death rate resulting from coronary heart diseases by the factor 3 to 5 is calculated until the end of the century (DWD 2015). Alongside a higher health endangerment, longer heat periods cause a negative impact on the well-being (quality of life) and the physical fitness of the city population, whereby the productivity and thus also the urban economy can be affected.

Together with climate change an increase in infectious diseases, which nowadays only appear in hotter climates or are spread by host animals that feel well in hotter climates, is possible (e.g. Tick-borne meningoencephalitis (TBE) and Lyme borreliosis by ticks).



Reference points:

1) *Inner city – central building*
2) *Nordstadt - block- and block-edge building*
3) *Kirchrode – dispersed single- and terraced house building*
4) *Georgengarten – park area with trees and shrubs*
5) *Kronsberg – open space used for agricultural purposes*

The reference points stand for different building density or open spaces within the city respectively. The type of building structure (density, construction volume) and the share of urban green spaces have a large influence on the amount of thermal load in the respective city district.

Figure 9: Summer heat load under the influence of climate change in the Capital City Hannover – average number of days with heavy heat load
(Source: GEO-NET 2011)

Figure 10: 1st of June 2016: Pedestrians flee from heavy rain and thunderstorm in the Hannover City Centre.
(Image rights: dpa)

Figure 11:
Torrents turn car driving into a special experience on this day.
(Image rights: dpa)

Another consequence of climate change will be the shifting of the distribution of the annual precipitation. In summer the amounts of precipitation will diminish, longer lasting dry periods with negative effects for city forests, green spaces and waters will occur more often. Due to the drying out of the topsoil and a higher danger of erosion, a more frequent occurrence of problems with dust is possible. In winter, higher amounts of precipitation are expected which leads to an increased danger of flood events. Furthermore, it is expected, that the frequency and intensity of local heavy rain events rise significantly (IPCC 2014). That means for a densely built-up and sealed urban area an increased vulnerability in face of these climate changes, e.g. through torrents and flooding with a respective danger for buildings and the associated infrastructure, like streets and canalization. Following the change in the precipitation patterns, flooding situations in running waters can be intensified. If heavy rain events occur during longer dry periods with respective low water levels, the water quality can be affected due to combined sewer overflows1.

Furthermore, stronger fluctuations of the groundwater level are to be expected due to the shifting of the annual precipitation distribution. The gale forces will increase, too and – especially in the city with an accumulation of valuable real estate – cause considerable economic damages.

1 In a combined sewer system, domestic, commercial and industrial waste water is led to the sewage plant together with rainwater. In case of extreme precipitation events, for which the canalisation and the sewage plant are not dimensioned, the size of the canalisation network and the capacity of the sewage plant are not sufficient to supply the total amount of mixed water for treatment. Therefore, a part of the sewage highly diluted with precipitation water is led into a flowing water through a combined sewage spillway (combined sewer overflow).

2 Adaptation Strategy for Hannover

"The future sustainability of our cities depends substantially on their anticipatory adaptation to climate change."
(Rainer Bomba, State Secretary, Federal Ministry of Transport, Building and Urban Affairs, 2010)

Although the climate simulations forecast the most serious changes only for the second half of this century, the course has to be set today already for a climate-adapted sustainable development of Hannover. Because the consequences of climate change are perceptible, e.g. on the basis of damages caused by heavy rain events and summer drought periods which require counteractive measures.

The adaptation strategy relates primarily to future problems caused by

- overheating of the city (heatwaves, tropical nights),
- changed precipitation patterns (heavy precipitation, danger of flooding),
- summer drought periods.

The adaptation strategy compiled by the city administration lays the focus on eight actions, which are especially important for the City of Hannover in their point of view. They are closely based on the "Position Paper on Adaptation to Climate Change" by the Expert Commission Environment of the Association of German Cities, that was published in June 2012.

During the selection of measures, cross-linking and interdependencies between the (sub-) systems in the city have to be considered and several positive effects have to be coupled. One outstanding example is the measure "Roof Greening" that combines numerous positive effects: It reduces the heating-up of buildings, serves for the retention of rainwater, the moisturizing and cooling of the ambient air and is habitat for insects and other animals. On top of that the greened roof reduces the thermal loss of the building and with it the heating requirement and CO^2-emission (is therefore not only a measure of adaptation but also of climate protection) and improves the life expectancy of the roof.

2.1 Targets of the Hanoverian Adaptation Strategy

The adaptation strategy is meant to communicate the possible consequences and chances of climate change as well as suitable adaption options to the policy makers, so that adaptation can be taken into account more intensely in political and economic planning and decision processes in future. Especially where medium to long-term structural decisions (e.g. space utilisation) and investment decisions (e.g. infrastructure, forestry) are concerned, the consequences of climate change have to be taken into account as early as possible.

The adaptation strategy shall contribute to the timely adoption of measures for the minimization of negative impacts of climate change in the city. Thereby, the feasibility and affordability of measures constitute an important requirement for their implementation. The later action is taken, the more complicated and expensive the measure or the damage repair will be.

The adaptation strategy does not pursue the compilation of a complete adaptation plan, but rather offers recommendations to possible actions and names important components towards the adaptation. Because the implications through climate change are not precisely predictable, the adaptation strategy has to be able to react flexibly on changes and new insights. As a rule, adaptation measures have a multitude of positive aspects. Independent of the climate changes that have to be expected, they lead to the creation of healthy and pleasant living conditions and thereby to an increased quality of life in the City of Hannover.

"Ideal City Climate" is a state of atmosphere in urban areas, variable in space and time, whereby, if possible, no anthropogenically produced pollutants are found in the air and a widest possible number of urban microclimates avoiding extremes is offered to the city residents within walking distance.
(Expert Commission Biometeorology of the German Meteorological Society)

2.2 Development of the Strategy

Since spring 2009, the Division Environmental Protection of the City of Hannover is intensely involved with the subject "Climate Change and Adaptation". The reason was, amongst others, the resolution of the German Adaptation Strategy by the Federal Government in December 2008. At first, a thesis paper "Adaptation Strategies towards Climate Change" was compiled in November 2009. It deals with the possible changes in Hannover caused by climate change, names adaptation measures, which are already included in the administrative action and further measures that are still considered to be necessary. The following first steps towards an adaptation strategy were planned:

1. Compilation of a special plan "Climate" as basis for further planning
2. Conducting a workshop on climate change and adaptation strategies for city- and green area planners and others involved
3. Launching municipal promotion programmes, e.g. for roof- and façade greening
4. Founding a network of urban and external actors.

The cross-departmental development of the adaptation strategy for Hannover started in spring 2010 with an introductory seminar, in which planners of city planning, green space planning and urban wastewater management as well as other interested staff members of the city administration took part. In the course of this further training, information about the expected climate change in the Hannover Region and the City of Hannover as well as possible adaptation measures towards the mitigation of expected impacts (e.g. heat waves, flooding) was provided. Following this workshop, three working groups were established dealing with three aspects of climate change:

- Heat waves, tropical nights – effects on human health
- Change of the precipitation distribution, increase of heavy precipitations – consequences for the urban wastewater management, dealing with increased danger of flooding
- Increase of summer drought periods – impact on agricultural and forestry areas as well as nature conservation (especially water protection).

An overview about the participating special divisions of the working groups is shown on the following chart. Because "Climate" does not end at the city boundaries, expert divisions of the Hannover Region were integrated. (The numbers point out the organisational unit). The results of the individual working groups were central component in the development of the adaptation strategy for the City of Hannover. Together with the establishment of the working groups, a network of urban and external actors came into being, which was extended in the further course of the adaptation strategy development and will surely be extended even further in future.

The "Adaptation Strategy to Climate Change for the Capital City Hannover" was made public in April 2012 with the Printed Information Matter 0933/2012.

State Capital Hannover	
Department Mayor's Office	15.2 Principle Matters
Department Facility Management	19.02 Central Engineering Tasks
Department Planning and Urban Development	61.1 Urban Planning
	61.4 Urban Renewal and Housing
Department Civil Engineering	66.3 Street Maintenance, Water and Bridge Construction
Department Environment and City Greenspace	67.1 Environmental Protection
	67.2 Planning and Construction
	67.3 Public Greenspaces
	67.7 Forestry, Landscape Areas and Nature Conservation
Urban Wastewater Treatment Hannover	68.1 Planning and Construction

Region Hannover	
Department Environment	36.02 Climate Protection and Environmental Management
	36.09 Water Protection (Central Functions)
Department Health	53.06 General Infection Protection and Environmental Medicine
Department Planning and Regional Development	61.01 Regional Planning

2.3 Action Programme 2012 – 2016

In January 2012, the city administration was commissioned by the Council of the Capital City Hannover to compile and to implement a "Programme for the Minimization of the Consequences of the Global Warming" termed for five years with the target to maintain the quality of life in the city in spite of climate change or even to improve it. In order to enable the implementation of initial measures, the programme was provided with funds to a total of 1,050,000 Euros for the period 2012 to 2016.

The thereupon compiled action programme was introduced to the council and the public in July 2012 by means of Printed Information Matter 1554/2012.

3 Fields of Action and Examples of Initial Adaptation Measures

Figure 12: Greened roof in the Hannover City Centre
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

The adaptation strategy is divided into eight fields of action which were defined as especially important within the framework of the working group phase (see point 2.2):

- Action Field 1: Flood Protection
- Action Field 2: Rainwater Management and Handling of Heavy Rain Events
- Action Field 3: Preventive Soil and Groundwater Protection
- Action Field 4: Roof Greening
- Action Field 5: Climate-adapted Vegetation
- Action Field 6: Climate-adapted Urban Planning and Climate-adapted Construction
- Action Field 7: Specific Map Climate Adaptation
- Action Field 8: Public Relations and Educational Activities

Hereafter, these fields of action will be presented more detailed, whereby at first the individual fundamental significance will be highlighted and, following that, the state of implementation of specific measures will be explained.

Some of the measures have already been implemented, others are currently being or will shortly be implemented (planning finalized). Partially it was necessary to support single measures with funding programmes (e.g. with the Roof- and Façade Greening Programme). Alongside that, there are additional measures, the implementation of which is considered necessary and is planned for the future. Not all adaptation measures have been financed and implemented within the framework of the Action Programme 2012 – 2016, but were funded in the framework of other measures (e.g. Flood Protection, Street Restructuring).

3.1 Flood Protection

3.1.1 Flood Protection

Flood events – meant are overflows by river flooding (overflows following heavy rain events will be covered in Action Field 2: Rainwater Management) – occur more and more often in the recent years. Reason for this could be climate changes. There is a high likelihood that extreme weather conditions, that lead for example to a one-hundred-year rain event, will happen more often than before in future.

Figure 13: With the reconstruction of the Benno-Ohnesorg-Bridge, the outflow width has been expanded by 21 metres.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Figure 14: The new dike body with dike defence path in the Ricklingen District in February 2015
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

There are flood protection systems like dikes in the City of Hannover but in spite of that, large residential areas like Calenberger Neustadt and large parts of Ricklingen would nevertheless be flooded in case of a one-hundred-year flood event.

Therefore, in the year 2006 the City has decided to protect large parts of the city area against a one-hundred-year flood event (State Capital Hannover 2006). For this purpose, the Action Programme Flood Protection in Hannover was set up with an investment volume of about 30 million Euros which contains the expansion of the outflow width on the river Ihme in the Calenberger Neustadt between the Legions Bridge and Leinert Bridge as well as the extension of the dikes in Ricklingen. Partial measures like the reconstruction of the Benno-Ohnesorg-Bridge and the redesign of the Ihme embankment (including the renovation of the former gasworks site at Glocksee) to the new Ihmepark have been completed in 2012. The implementation of the further measures (the extension of the existing dike in Ricklingen as well as minor improvements at the Leine River in the area of Königsworther Straße and in Linden-Nord) had begun in 2012 and was planned to be completed by the end of 2016.

The implementation of the flood protection measures achieves a significant improvement of the technical flood protection and with it a higher level of protection for the City of Hannover.

3.1.2 Preventive Flood Protection

The constructional flood protection only represents one component of flood protection, the sensitising and awareness-raising of the population regarding the preventive flood protection is as important.

In 2015, a central flood protection coordination office has been set up by the Capital City of Hannover for the evaluation of past flooding events, for the analysis of weaknesses, for the optimisation of the Hanoverian flooding protection system and for the information of the population. By this office, that has been affiliated with the urban wastewater management, the planning and implementations for the flood protection in Hannover are coordinated in cross-departmental dialogue. The aim is to adapt the Hanoverian flood protection to changing framework conditions with all parties concerned and to develop it strategically.

Residents living in the flooding endangered areas must be aware of this situation, so that they can take preventive measures in their individual responsibility, e.g. by the protection of cellar rooms against flooding and flood-protected storage of valuables. Included in a preventive flood protection is a respective architecture (constructive protection- and preventative measures). Extensive information regarding this has been provided by the municipal wastewater management on its internet page (www.stadtentwaesserung-hannover.de).

The civil protection includes flooding management plans as well as optimized early warning systems, automatized water level indicators and emergency exercises.

Figure 15: The near-naturally designed bed of the Rossbruchgraben, situated above the Hollerithallee in the City District Marienwerder
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

3.1.3 Renaturation of Flowing Waters

Caused by human interventions into the natural catchment areas of waters or into the waters themselves, the originally structurally rich flowing waters have been severely changed. With the straightening of watercourses and the usage of river meadows, especially inundation areas were lost. In the case of flooding events, the loss of these natural retention areas leads to higher peak flood water run-offs. The straightening of the watercourses accelerates the flow-offs and leads in the underflows of the waters (and especially in the Leine River) to a rising high-water level. To the wider negative implications caused by human intervention belong the loss of animal- and plant species, the deterioration of the water quality and the changing ground-water formation.
There has been a council order since 1996 that stipulates to develop the Hanoverian flowing waters more near-nature and structured again. The therefore developed "Programme Near-nature Water Structuring" is put into practise by the primarily responsible urban wastewater management. A total of 37 flowing waters was integrated into the programme. Measures were already carried out on the majority of the waters.
Integral parts of the conversion measures are, amongst others, the creation of high water profiles with variably designed slope angles and berms (horizontal subsection within an embankment) in medium water height, the creation of reserve river meadows by the construction of structurally rich riparian strips and the expansion of flow-off profiles as well as the activation of flooding areas by the removal of dikes in the Leine River Meadow as it happens e.g. in the Stöcken area. An expansion of the water profiles was put into practise for example during the renaturation of the Fösse River, the Hirtenbach, the Laher Graben and the Wietze River. The measures are aiming, amongst others, at slowing down the outflow of the flowing waters and at moderating the flooding events.

3.2 Rainwater Management and Handling of Heavy Rain Events

"The trough of a low-pressure area over the North Sea crosses Germany eastwards and carries along humid and at first still mild sea air. Thereby it comes to partially showery or thundery rain. Especially in the second half of the day showers and THUNDERSTORMS can occur which are so violent, that locally HEAVY RAIN, HAIL and SEVERE GALES cannot be excluded. Also in the night to Saturday the weather stays unstable with showers and thunderstorms, especially in the South and the Middle."
(Weather forecast for Hannover from 5.8.2011, DWD)

On unsealed areas grown over with vegetation, a large part of the rainwater can be (temporarily) stored. A part of the water seeps into the earth, a part is held back by the vegetation and evaporates or is after absorption by the plants emitted into the atmosphere through the leaf surfaces (Transpiration). Only a relatively small share of the rainwater runs off delayed over the surface.
On sealed surfaces, e.g. streets and roofs, only a very small share of the rainwater evaporates, a seepage does not take place. Therefore, a large share of the rainwater runs off the surface without delay.

Normally this surface runoff arrives at the sewage plant through the canalisation (mixed water canalisation) or into the flowing waters (separating canalisation or discharge from the mixed water canalisation). In case of extremely strong rain showers, so called heavy rainfall events, for which the canal network cannot be dimensioned for technical and economic reasons, the water amounts can nevertheless not completely be absorbed by the canalisation. As a result, congestions of the canalisation net can happen.
Over and above, the surface runoff situation can get worse through the situation, that the street inlets get blocked by floating refuse (e.g. foliage) or that the capacity of the inlet profile is too low for the arising water amounts, whereby the rainwater cannot be retained and consequently spills over.

In order to retain surface water and avoid the danger of flooding, the City of Hannover takes up to now the following countermeasures (State Capital Hannover, 2000):

Through the urban development planning:

- Determination of rainwater seepage
- Determination of technical temporary storages for the throttling of the flow off
- Installation of rainwater retention basins
- Determination of roof greening (see point 3.4)

Since 1993 rainwater management is a firm component of the urban planning. In the course of the development plan procedure it is examined in a multi-step process, whether and how the subsoil is suitable for a rainwater management/ seepage and which seepage/retention system is appropriate. In order to reach an optimization, the following priorities and planning variations (from "optimal" – in case of 1. – to "should be avoided if possible" – in case of 6. -) have to be met bindingly and will be systematically tested:

1. complete) rainwater seepage in troughs
2. (complete) rainwater seepage in trough-trench systems
3. rainwater - drainage into troughs and retention in rainwater retention basins (dry/wet)
4. rainwater - drainage via troughs into flowing waters/trenches
5. rainwater - drainage via troughs into the rainwater canalization
6. (if possible not any longer) drainage of rainwater from streets and roof areas into the rainwater canalization

Excerpt from the Ecological Standards, Capital City Hannover 2009

Figure 16: Limited function of the street inlet caused by rain-wash of plant material, here on the Trammplatz in front of the New Town Hall.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Through other measures:

- Usage of rainwater as process water
- Indirect promotion of desealing of private areas through fee-splitting
- Renaturation of flowing waters (see point 3.1.2)

Because local heavy rain events will happen more often in future due to climate change and a higher amount of precipitation has to be expected during the winter months, further measures/strategies will be necessary. In order to react to the impacts of climate change accordingly and preventatively, a "water-sensible" planning culture has to be pursued. Innovative solutions and new images of "Water in the City" are asked for. That also includes the acceptance of water in places where it is not usually found. For the avoidance of flooding and for the relief of the sewer system, a rainwater management is necessary which retains the precipitation water (without causing damage) on the surface as long as possible. The following measures are therefore examined:

- Identify city districts/street areas (e.g. sinks), which are especially threatened by floods in case of heavy rain.
- Relief of these areas through suspension of lateral (canalisation) inlets or connection of these areas to less burdened sewers / areas.
- Creation of additional seepage areas (also independent from development planning procedures).
- Targeted control of the runoffs for rainwater including the respective design of these areas (emergency waterways) by inclusion of heavy rain events into the planning of streets, ways and places; extension of traffic areas as backwater areas.
- Adaption of the design of street profiles, curbs and house entrances to a water drainage necessary in case of heavy rain events.
- Temporary usage of areas with a low damage potential like green areas, parking places etc. as emergency overflow areas (multi- and interim usage of areas).
- Retention of rainwater through technical temporary storages (cisterns). Usage of the water for the irrigation of public spaces during dry weather periods.
- Desealing of paved surfaces, especially in highly sealed city districts and permanent greening of these areas. (Examples: Desealing of no longer required / over dimensioned traffic areas; enlargement of tree-grids in the inner city, desealing of inner courtyards, reduction of the traffic area at the "Hohes Ufer" through construction of a green corridor according to the programme "City 2020").

"Over and above heavy precipitation causes severe damages especially in cities. Therefore, adaptation measures aiming at a "water sensible" city design are of great importance. We recommend to design decentralized rainwater seepage and surfaces in such a way, that they can be used for leisure activities under normal weather conditions, but serve for the water retention in case of weather events."
(Jochen Flasbarth, UBA, statement at press conference: "Adaptation to Extreme Weather Events in the Climate of Tomorrow" on 15th February 2011 in Berlin)

Tip: The Hannover Urban Wastewater Management informs interested landowners in a 10-minute film detailed about measures to protect their own piece of ground or their own house from flooding through extreme rainwater events. A special subject in this is the installation of a backwater protection.

Implementation of the Action Programme

Supported by the action programme, initial desealing measures have been financed. Further details about this can be found in chapters 3.3 and 3.5.

Besides that, measures for the rainwater retention during heavy rain events were promoted. Thus, new retention space was created through the restoration of silted up trenches in the Seelhorst Forest, which ensures a regular water level of the Dreibirken Brook/Seelhorst Brook (see Figure 17). High water peaks are reduced in this way. That has positive effects for the residential areas in the underflow as well as for the water ecology of the brooks. The retention of surface water in the forest area also saves the building of a rain retention basin.

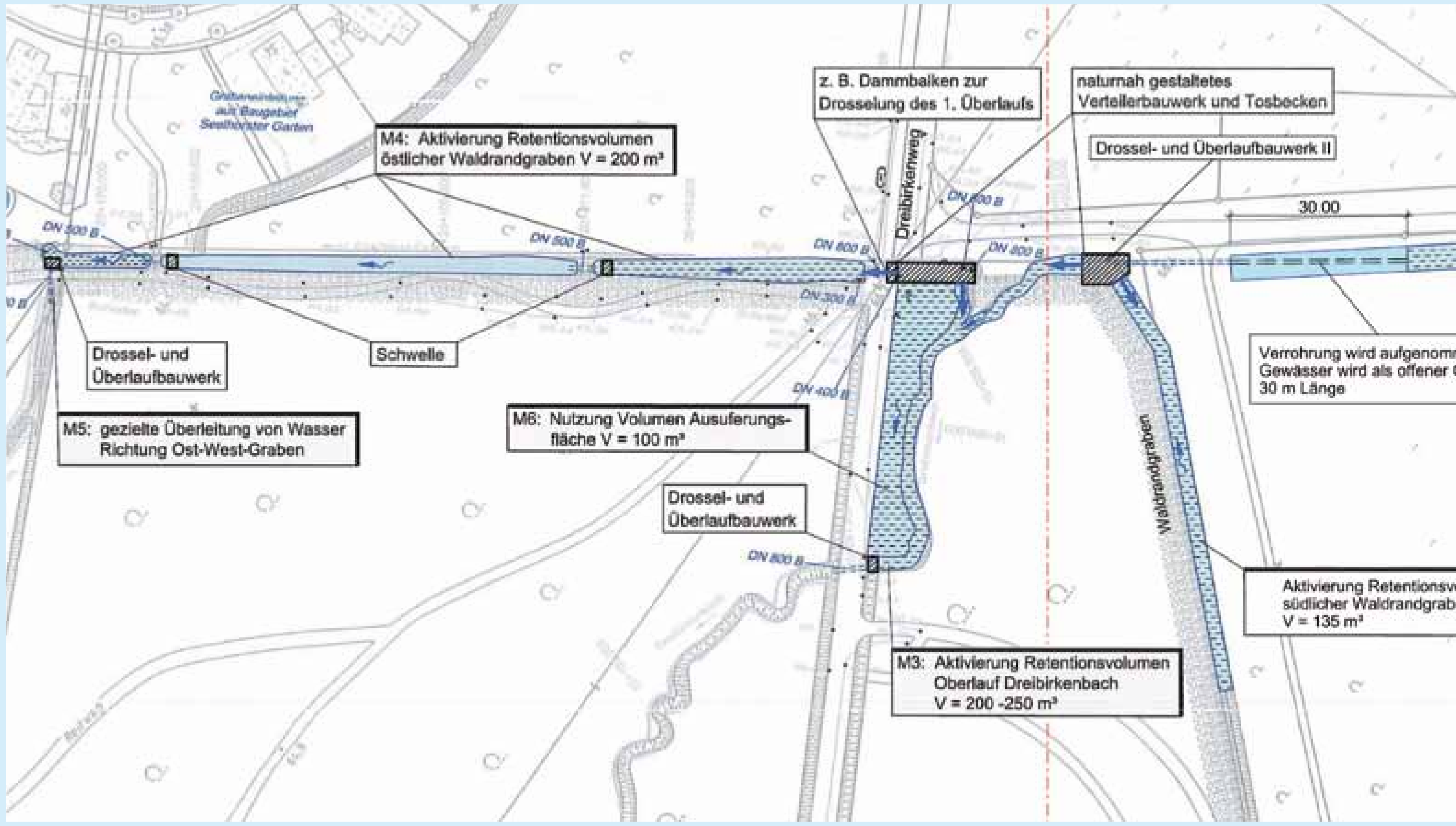


Figure 17: Section of the location map "Retention Measures Seelhorst Forest"
(Map: Hannover Urban Wastewater Management)

Figure 18: The bus lane on Friedrichswall unsealed and turned into a grass area. On top of this, several new trees were planted along the edges of the area.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

3.3 Preventive Soil and Groundwater Protection

The manifold functions of the soil, which are described in § 2 sentence 2 of the German Federal Soil Protection Act, must be protected from possible negative impacts of climate change and its balancing functions must be maintained and improved. Near-nature soils with a fertile humus cover and multiple communities of soil organisms contribute considerably to the improvement of the city climate. Due to the lower surface heating and the higher evaporation of near-nature soils in comparison to sealed areas, the prognosed increasing heat congestions can locally be diminished. The water retention function of near-nature soils contributes to the reduction of impacts of heavy rain events and summer dry periods caused by the expected changes in the precipitation patterns.

A special role is played by the carbon rich soils (e.g. swamp soils and mineral soils influenced by ground- and backwater), which are very important in view of their function as greenhouse gas storage. The destruction of these soils leads to a significant discharge of carbon dioxide and other climate-relevant gases into the atmosphere and contributes considerably to the advancement of climate change in this way.

In spite of the human usage, cultivation and excess planning of soils, the risks of soil compaction, water- and wind erosion, strong changes in the soil water household, decreasing humus contents and the mobilization of contaminants must be reduced as far as possible.

Aim of the future treatment of urban soils is to steer the soil use and overplanning in such a way, that the positive climatic effects of the soils are kept and climate change should only have a minimal effect on the natural functions of the soils, if possible.

In 2009, the city administration commissioned a digital soil function map for the evaluation of soils and their functions, which enables a comprehensive assessment of the worthiness of protection of the soils in the Hannover City area. In a further step a registration of those soils, that can be assessed as especially climate-effective, is meant to follow. Climate-effective soils are of special importance for the climate protection as carbon reservoirs (e.g. swamp soils) and for the mitigation of the climate change effects (e.g. soils with a high water storage potential). At the same time, climate-effective soils can also react very sensitively to the impacts of climate change.

The precipitation pattern altered by climate change will in any case have an effect on the groundwater levels, the groundwater fluctuations will increase. As a result, the soils in certain areas of the city can dry out in summer causing soil subsidence, in the winter months it can lead to "damp cellars". But higher groundwater levels can also cause, that contaminated soil horizons, which had not been affected by groundwater up to now (e.g. spacious backfills in the inner city) get at least from time to time groundwater contact whereby a raised contaminant influx into the groundwater takes place. This aspect has to be considered, when areas are sealed and also in the framework of the groundwater quality monitoring, that has been carried out since 2003.
The soil and groundwater information is integrated in the statements regarding the urban development planning.

The following further measures will be assessed:
- Maintenance of near-nature soils (and the vegetation growing on them) with special consideration of their climate-effective functions.
- Continuation of the area recycling: return of former industrial and commercial areas into the usage and revitalisation of areas through remediation of contaminated sites, restoration or improvement of the utilisation function (positive examples are the Ahrberg Quarter and the Pelikan Quarter).
- Desealing of non-contaminated areas and restoration of natural soil functions (see point 3.2).
- Humus increasing management/processing of communal green, park and forest areas.
- Alternative irrigation concepts for inner-city green spaces, if these have to be irrigated during longer dry periods in order to maintain their function. Drinking water and groundwater should be used as little as possible for the irrigation of green areas.

Implementation of the action programme

In 2013, a traffic area of about 4000 m² could be unsealed and thereafter greened. This refers to the bus lane on Friedrichswall, which led past the New Town Hall between Willy-Brandt-Allee and Lavesallee (see Figure 18).
Further desealing on a smaller scale was carried out since 2012 in connection with the renovation of tree locations (see point 3.5).

3.4 Roof Greening

Greened roofs often represent the smallest green spaces in the city area. Especially in densely populated and highly sealed city districts with stretches of roads without room for city trees left, the only possibility that remains is to develop roofs as vegetation areas. Primarily, roof greening improves the micro-climatic conditions on the building itself without achieving a long-distance effect. The thermal effects lie mainly in the reduction of extreme temperatures in the course of the year. The vegetation layer and its evaporation reduce the heating of roof surfaces caused by intensive solar radiation in summer and the loss of heat for the house in winter. This leads to a balanced climatization of the rooms and reduces the heating energy requirement.

> "While gravel roofs and black bitumen pasteboard heat up to between 50°C and over 80°C, the maximum temperatures on greened roofs amount to between about 20°C and 25°C.)
> *(Climate Fibula for Urban Development Stuttgart)*

Besides these climatic effects, roof greenings can improve the air quality in the city area because they bind and filter out air pollutants (especially particulate matter).
Another positive effect is the rainwater retention, as 70 (extensive greening) to 90 percent (intensive greening) of the precipitation is caught in the vegetation layer and released into the city air through evaporation again (Sieker et al, 2002). This contributes to the cooling of the air in highly sealed city districts. Remaining runoffs are temporarily stored in the substrate layer and released time-delayed into the canalisation. Peak discharges (in case of heavy rain events) are reduced through greened roofs by 50 percent compared to non-greened roofs.

Furthermore, roof greenings offer a habitat for numerous plants and animals and increase thereby the biodiversity especially in densely populated urban quarters. For humans they attain a welfare effect through the improvement of their working- and living environment, that should not be underestimated.

Another decisive advantage of roof greening lies in the increased life expectancy of the roof insulation. It is effectively protected against ultraviolet radiation, hailstorms, heat and cold. Temperature-related tensions are reduced.

Greened roofs don't exclude the installation of photovoltaics. On the contrary: by means of roof greening, the degree of efficiency of the system is enhanced, because the performance of the modules is reduced by about 0.5 % per degree Celsius when heated. Because a temperature of 35°C is usually not exceeded on greened roofs, the modules on these roofs stay cooler and therefore a high level of performance is maintained. For this reason, the administration pursues in its own portfolio the parallel realisation of extensive roof greening and photovoltaic systems on flat roofs and advises third parties respectively.

There are restrictions in view of the necessary acceptance of the increased costs and due to static conditions, if they don't permit a dual use because of the weight.

The Maintenance Depot Stammestraße – a perfect example for the combination of roof greening and photovoltaic system

As compensation measure for additional sealings and as a contribution towards a sustainable ecological construction, an extensive roof greening was installed on the newly constructed social building of the city's maintenance depot Stammestraße 102 in the year 2007. The area covered by a substrate layer of at least 7 cm spans over about 1,300m² (see Figure 19).
More than half of the precipitation quantity can be retained due to the roof greening. A large portion of this water evaporates, the rest runs off time-delayed, is temporarily stored in a cistern and used as service water for cleaning the operational vehicles and work machines in the washing hall.
The photovoltaic system consists of 120 polycrystalline solar modules with a performance of 24.6 kWp on a surface of 200 m². In the year 2014 the output of this system amounted to about 17,327 kWh.

Since the introduction of "Guidelines for the Handling of Roof Greening in Development Planning" in June 1994, roof greenings are stipulated in the framework of urban development planning for new constructions in the city area and are accepted as measures of intervention reduction in connection with the intervention and compensation scheme. Roof greening is principally stipulated for subterranean garages in all construction areas as well as for all flat roofs with an inclination of less than 20 degrees in commercial, industrial and special areas and block interior areas that are visible from the surrounding buildings. The greening is assessed in each individual case for flat roofs in core areas and garage facilities/communal garages.

The actual mapping of greened roofs in the year 2016 showed that over these regulations or voluntary efforts 3,131 roofs with a total area of about 836,200 m^2 have been greened. The greened roofs can primarily be found in commercial areas, but in residential areas mainly subterranean garages and single garages are greened. Thereby the number and size of greened roofs increases from the inner city to the outskirts. The largest greened roof has a size of 9,645 m^2.
About 300,000 m^3 precipitation water less per year flows (in relation to the total annual precipitation amount in Hannover) off these greened roof areas into the urban sewage system in comparison to conventional (sealed) flat roofs. This amount of water retained on the greened roofs evaporates and contributes thereby to the improvement of the city's bioclimate.

An indirect promotion of the roof greening is achieved by the split sewage fee. For house and property owners, who – e.g. through greening of their roof areas – retain and manage the rainwater that evolves on their property, the precipitation water fee is reduced according to § 4 (3) of the Fee Statutes of the Hannover Urban Wastewater Management by 50 percent for the greened area, which at present amounts to 0.34 Euro/ m^2/year.

Implementation of the Action Programme

As the above-mentioned inducement was obviously insufficient to encourage the house and property owners in the direction of greening roofs of private houses in their portfolio, in 2012 the model project "More Nature in the City: Roof and Façade Greening" was developed by the non-governmental organisation "Friends of the Earth Germany (BUND)" for the City of Hannover and the Hannover Region, which offers a direct funding now.

The project started in the City District Linden at first, which is characterised by a high level of sealing and at the same time a high population density. Here, building owners were intensely informed through a campaign about the advantages of roof and façade greening as well as the funding opportunities that were made available by the city. After one year the project was expanded to cover the entire city area. Funded are up to a third of the eligible costs of a measure. In case of roof sizes up to 250 m^2 this amounts to a maximum of 3,000 Euros, with more than 250 m^2 to a maximum of 10,000 Euros. Apart from the roof greening, façade greening is funded up to a third of the costs. This amounts to a maximum of 3,500 Euros with a greening of multi-layer exterior wall structures (thermal insulation system, suspended façades) and a maximum of 500 Euros with all other façade greenings.
Until the beginning of August 2016, a total of 10,000 m^2 roof greening was funded. This takes into consideration roofs of garages, huts, extensions, residential buildings, commercial buildings and subterranean garages. Up to now, 20 projects concerning façade greenings were funded.

Because the city wants to set a good example, roofs of urban buildings are greened as well. So, the new fire station at Weidendamm, the new extension to the youth centre in Anderten and the new adult education centre at the "Hohes Ufer" were equipped with greened roofs, which were financed by funds of the "Programme for the Adaptation to Climate Change" in 2014 and 2015 respectively. Further roof areas of urban buildings that are suitable for greening have already been evaluated. These include flat roofs of the Integrated Comprehensive School Linden, that require renovation and the roof of the planned extension for the mensa of the Primary School Stammestraße. The total roof area of these urban buildings amounts to about 8,200 m^2.

Figure 19: In addition to the roof greening, a photovoltaic system was installed on the roof of the maintenance depot Stammestraße.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Figure 20: Greened roof on a building of the Hannover University of Veterinary Medicine
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

3.5 Climate-adapted Vegetation

Vegetation has a large influence on the urban climate and has a positive effect on its surroundings. A body of air flowing over green areas adapts to their properties. The air is cleaned, the moisture of the air is increased by the evaporation of plants and the temperature is lowered. If the body of air changes its position e.g. resulting from corridor winds into a neighbouring residential area, its positive properties will be carried further, the heat-burdened residential area will be cooled. Trees with large crowns are climate-effective elements within a city. Especially their cooling effect in summer and their function as providers of shade are of great importance for the reduction of thermal stress.

But the plants themselves are affected by climate change. Summer heat- and dry periods lead to impairments: they dry out or discard their leaves. Thereby their bioclimatic function (creators of cool air, air moisturizers) is strongly reduced. So, in Hannover copper beeches had already to be felled, which were damaged by "Climate Stress" over several years. New plantings require many years until they are able to take over the function of the removed trees equivalently.

In respect of the replacement plantings, the conditions altered by climate change must be taken into consideration. Therefore, the following measures are carried out especially in the heat burdened, densely populated city quarters:

- Replanting of trees in public open spaces following the recommendations of the Climate-Species-Matrix (Klima-Arten-Matrix, KLAM) for street trees and forest trees (Roloff, Bonn, Gillner 2008) as well as the List "Street Trees" (Working Group Street Trees of the Landscape Architects' Conference – Gartenamtsleiterkonferenz, GALK). This includes a trial of new drought-tolerant and hardy species and varieties (see Annex 2).
- Designation of thermally burdened zones in the city for the choice of adapted species of street- and urban space trees (see Action 7). In heavier burdened zones, the preferred planting of alien shrub species can be sensible. For scenically affected urban spaces, the priority for the planting of native shrub species prevails.
- Site restoration measures on existing tree grates by means of enlargement, deepening and substrate exchange. These serve for the extension of root volumes, the improvement of water storage capacities and for a better ventilation of the root areas as well as the stabilisation of the trees, so they get more resistant against storms.
- Each newly planted street tree is provided with a sufficiently large root area with water-storing capable substrate (if possible 12 m3 or more). In places where salt freights are not to be expected, the gradient of the surrounding grounds is directed towards the tree trunk so that rainwater is collected in the grate and can seep in.
- Regarding necessary irrigation measures, alternatives to drinking water are looked for (see Action 2). In the northern city area, for example, there are two supply points on the Mittelland Canal from which water is taken for the irrigation of nearby located green areas. The usage of water from rain retention basins during longer dry periods is examined (in individual cases).

Figure 21: The tree grate of the sycamore at Kröpcke was furnished with a compaction-resistant "structurally stable" substrate in the course of its restoration.
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Implementation of the Action Programme

"Trees make water evaporate through their leaves, the thereby set free evaporation heat cools the air around the trees. So even 6 trees in a 500 m long and 10 m wide street canyon cause, that with summer temperatures of 35 degrees, the air temperature is lowered by 5 degrees."
(Guido Halbig, German Meteorological Service – Berlin 7th June 2010)

Initial measures were carried out in the Philipsbornstraße in 2012/13. There was a row of street trees consisting of Norway maple and Sycamore trees in the southern section. Most of the tree locations along the street were considered as unsuitable for a sustainable growth in their previous form. The street trees growing here were to a high proportion weakened, partially dying or already felled. The tree population was threatened to disappear further in the coming years. A complex site restoration of the most desolate southern section, in front of the listed façade of the Conti-Tec AG, maintaining the already strongly damaged tree population, was not meaningful in view of the negative development forecast. At all the other tree locations, restoration measures for the stabilising and maintenance of the existing tree population were necessary.

Therefore, from 2012/2013 the green area administration carried out a fundamental renewal of the tree population in the southern part of Philipsbornstraße. With trees, worthy of preservation, the root areas were restored and where possible extended. In the course of the new planting of two species adapted to the urban climate (Ginkgo tree and Honey locust), a complete exchange of the substrate as well as the construction of deep stratifications and root ventilation trenches were necessary preliminary work (see Figure 22). The costs per site restoration on existing trees amounted to 1250 Euros per tree and for the site preparation and new planting 3500 Euros per tree.

This project now serves as a model character for dealing with deteriorating street tree populations, which are hardly able to fulfil their climatic function any longer in future.

In 2012, there has already been a tree restoration at the Kröpcke in the city centre (see Figure 21). The sycamore at the Kröpcke Clock had up to now only a relatively small unfortified root area. During the renovation of the concrete cover of the Kröpcke Underground Station, the root space of the sycamore could be significantly expanded. The filling with new substrate in combination with tree fertilizer, soil improvement matter and drain pipes improved the site conditions greatly. As the measures could be included into the running construction process, they could be implemented relatively cost-effective without an additional delay of the construction period.

In 2014, a total of 14 trees were planted on both sides of the street (see Figure 24) in an up to then non-greened section of Sallstraße to shade the pavements and roadways. This will have a positive effect on the temperature field of the street. The shading by the trees can lower the near-ground temperature on a sunny summer day by up to 12 °C in comparison to a non-shaded street.

In future, the city administration will focus increasingly on single tree locations and smaller tree populations in the highly condensed and in summer overheated inner city areas and residential areas near the centre. These measures, which are focussed on rather small-scale improvements, will be evaluated by a success control or by a monitoring of the tree growth after the restoration respectively. In case of positive results, such measures could also be recommended as effective local improvement measures in the future.

3.6 Climate-adapted Urban Planning and Climate-adapted Construction

"Construction in medium density, inclusive greened spaces, water surfaces and areas of mixed usage, reduces the greenhouse gases and contributes to the adaptation."
(Climate Alliance, AMICA-Project, 2007)

Abb. 23: Diese Lindenallee in Herrenhausen bietet während sommerlicher Hitzewellen Schatten und Kühle.
(Foto: FB Umwelt und Stadtgrün, LHH)

Target of a sustainable City planning is the permanent assurance of a good quality of life for the inhabitants in all parts of the city. To this belong healthy living and working, the supply with goods of everyday requirement as well as easy accessibility of all necessary resources, leisure and nearby recreation possibilities and a maximum level of security against the impacts of catastrophes and bad weather events.
The climate changes, that have to be expected, require a rethinking of the traditional practise for planning and construction of buildings and the layout of open spaces as well as in parts the integration of new building standards, adapted to the changed conditions.

Particularly the spatial interconnectedness of open spaces and built-up areas, hence the city structure as an entity, can buffer negative impacts of climate change. To what extent the existing structures are sufficient and whether additions will be required at certain points, in order to maintain the residential location Hannover as worth living in, has to be carefully assessed in the course of every new planning as well as during the overplanning of the portfolio.
Substantial for a climate-adapted urban planning is also the consideration of the requirements and rhythms of life of the population, changed with the climate, as well as the active inclusion of the residents in the development and realisation of climate-adapted behaviour patterns.

Following this, possible measures of different levels are compiled. In general, it has to be regarded, that a number especially of the very concrete measures should not be applied extensively, but rather selective at the right place. This makes sense because they will in this case already come into effect optimally and/or are simply too expensive or not practicable when carried out extensively. In any case, it should be examined, whether the inclusion of a measure, for example into a planning project, is reasonable.

Figure 22: Restoration of a tree grate in Philipsbornstraße
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

3.6.1 Actions for Buildings

Regarding measures of climate adaptation for buildings, it has be differentiated between existing buildings and new constructions. A future-oriented planning can include materials and constructions for a new building, that are suitable to withstand climatic changes as acceptable as possible for humans. For the choice of measures, it is also possible, to refer to experiences made in other parts of the earth, where the climate is similar to the one, that we will have in future.
But the largest part of the city consists of existing older buildings. These can in most cases be retrofitted respectively if they, e.g. in the course of anyway planned restoration measures, undergo a comprehensive restoration and modernisation, taking into consideration climate adaptation aspects. But very few measures, which e.g. refer to the casing position and alignment of the building, cannot be retrofitted any more. For the reason of sustainability alone, it should be strived for the maintenance of the building stock, but in individual cases the cost-benefit relationship can require a demolition and new construction at the same place.

Sun Protection

When planning a building, it makes sense to pay more attention to the availability of shading in and at the building in future. In that way, an overheating of the interiors can be counteracted and the quality of occupancy optimised. The direct solar radiation can be minimized through integrated structural shade creators (arcades, sun sails, pergolas, arbour walks) as well as through structural installations on façades and window surfaces.

To accomplish this, a southern orientation of the main window surface area of the building is advantageous in comparison to an east/west orientation, as the vertically standing southern sun requires a lesser shading effort.
Principally, the summer heat protection[2] has to be considered more strongly in the future building and window design. Furthermore, shade-giving deciduous trees in front of buildings can offer shade in summer and can nevertheless ensure incidence of light through their transparency (after shedding their leaves) in winter. Thereby it has to be more intensely watched, that the trees near to the buildings are storm-resistant and also cope with the changed weather conditions of the future (see Action 5). When choosing the planting site and the respective tree species, it is important to bring the shading requirement in accordance with the growing necessity of using solar energy. Because for the today already possible and in future to be expected energy efficient construction methods, the active as well as the passive use of solar energy are of a special importance. The active use of solar energy by solar systems for the generation of electricity or production of heat (for heating and warm water) is achieved by installations on roofs and façades. It is especially important in densely populated urban areas because other forms of renewable energy only conditionally come into question. The heat gains through passive use of solar radiation (greenhouse principle) cover a share of the heat requirement in case of energy-efficient construction methods. An orientation for this is provided by the requirements for the passive house method of construction.

Figure 24: New street trees in the Sallstraße
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Figure 25: Sun protection through arcade (centre), sunshades (background) and sun shield (left edge, middle)
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Construction Material/Insulation

An energy-optimized construction method is, alongside its contribution towards climate protection and sustainability, also appropriate to generate a comfortable indoor climate despite the climate change. The utilisation of materials which store energy can ensure that the inside temperature is subject to smaller fluctuations in the course of the day. Therefore, it is sensible to use massive materials on the inner layer of buildings for a good heat and cold insulation. On the outside, the usage of light insulation materials is sufficient.

Large-scale glass architecture is questionable in terms of energy efficiency and requires a careful planning especially in regard to the summer heat protection.

The portfolio of buildings has to be subjected successively (by and by) to an energetic restoration. The restoration requirement differs greatly depending on the date of origin of quarters and buildings. Whereas especially older buildings from the period of promoterism or the thirties of the previous century often possess positive basic conditions (e.g. thickness of outside walls, materials used) and only have to be optimized on certain weak points (e.g. windows, roof insulation), the buildings of the fifties and sixties of the last century have often to undergo a much more complex restoration. Also, the energetically insufficient glass façades in the office stock of the eighties and nineties of the last century require higher expenditures in order to reach up-to-date energetic standards and a good indoor climate. With the energetic restoration of the building stock it is important, to integrate urban design and monumental aspects at an early stage.

Because of the more frequent extreme weather events to be expected, more attention should be paid to the wind safety of windows and roofs. Hail-resistant materials should be preferably used in endangered locations.

Climatizing

Even in spite of rising temperatures, a classical climatizing with active cooling should, if possible, be avoided in private as well as in office and public buildings. This has the disadvantage that it is accompanied by a significant energetic and therefore climate-damaging extra expenditure as unwanted side-effect and leads to an additional heating of the city in this way. Instead of this passive measures, like better thermal protection through a building envelope (especially roof insulation) and, above all, the avoidance and reduction of interior heat sources (artificial lighting – use of daylight, technical appliances, standby etc.) should receive attention at first. This can effectively be supplemented by an optimized nocturnal cooling (as free as possible aeration during the night) and a temporary exterior shading. Further information is compiled in Annex 1. On the basis of very efficient equipment features, strategies for the passive summer cooling in highly energy-efficient building standards, like passive houses, are sufficient in most cases depending on the utilisation of the building.

For the necessity of active cooling in case of special utilisation requirements (hygiene, security technology, non-reduceable interior heat loads, legal provisions etc.) or increased demands due to changed boundary climatic conditions, the passive house concept offers, with a very low effort, the additional very economical active cooling possibility of fresh air cooling using the anyway existing ventilation system for the summer, which allows excellent comfort conditions in the rooms.

2 The summer heat protection is already a firm specification component of the energy saving regulations and of the passive house project planning.

Figure 26: The Trammplatz in front of the New Town Hall – on hot days, the fountains offer a welcome cooling possibility in the city
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

Design and Colour of Façades

Light-coloured surfaces on façades and roofs lead through the Albedo-effect (reflection capacity) to substantially reduced heating of individual buildings as well as of the city as a whole. Due to the reflection of the light, a great deal of the energy is not at all absorbed by the buildings. In contrast to this, dark materials absorb a great amount of energy which is released into the nearer surrounding successively. That is why, in future, the city administration will take into consideration the reflection capacity of materials used alongside design aspects regarding new constructions as well as the restoration of façades.

Greening of Roofs and Façades

The urban climate can be positively influenced through roof greening. Up to now, roofs are often unused reserve surfaces for the creation of green areas (see 3.4). The greening of house façades also has – similar to the roof greening – positive effects on the thermic, air hygienic and energetic potential of a building. Façade greenings improve the microclimatic conditions on buildings by reducing temperature extremes in the course of the year. Alongside these climatic effects, façade greenings can also improve the air quality because they bind dust and air pollutants. Furthermore, they provide habitats for the urban animal life and reduce the noise exposure, because a greened wall reflects less sound than a smooth wall.

Orientation and Siting of Buildings

Next to the aspects of shading, an optimal building position has to be taken into consideration during the new planning of a construction area, to guarantee a sufficient air movement. Orientation, height and shape of buildings are essential for good shading possibilities and sufficient air movement. This has to be harmonized with the energy efficient construction methods like passive or zero-energy houses, that are required for climate protection.

3.6.2 Actions for Open Spaces and Urban Structure

The high proportion of green spaces in Hannover and especially their well-networked structures contribute significantly to the present and future climate suitability of the city. Depending on the characteristics and situation of the green- and open spaces, their importance and their positive effect have to be judged differently.

Hannover possesses a graduated system of green spaces, close to homes, city districts and quarters as well as wide-ranging ones. Larger areas, like the Leine and Wietze River Meadows, the Georgengarten, allotment gardens and cemetery areas maintain a high climate-ecological effectiveness as compensation areas, which is permanently perceptible and provable during long-lasting weather conditions. Smaller green spaces can support this effect, if they are located in the neighbourhood of the more cold-air productive (large) green spaces. Smaller green spaces localized within the built-up areas (e.g. city squares, courtyards) do not provide a cooling effect on the neighbouring settlement areas due to their limited cold air production, but represent important "climate oasis" (bioclimatic comfort islands) within the stress regions.
In order to fulfil their function as compensation factor well, especially during the hottest season, greening elements that stay green even during long-lasting dry periods, as e.g. trees and bushes, are generally of higher importance than areas with only surface-near rooting plants which quickly become dry and dusty without artificial irrigation.

Open Spaces

For the further development of open spaces, the City of Hannover aims to unseal outside facilities on buildings and sealed open spaces as much as possible and to include seeping areas in the design. Shade giving greens, e.g. deciduous trees with large crowns and pergolas as well as structural shade creators, e.g. arcades, arbour walks and sun sails, can increase the quality of stay in the open. Hereby, along with green spaces in the proper sense, also the shading of streets, ways, parking places, stopping places and the greening of private and public properties (e.g. courtyards) through the planting of trees and bushes has to be aspired, because this as a whole ensures the reduction of heating-up and an improved quality of stay.

Concerning the choice of plants, evergreen ground cover plants have to be preferred and not just grass areas to be laid out. It makes sense to preserve the existing green at strongly frequented and used areas through additional irrigation even during long lasting heat periods. Thus, dust can be bound and the area maintained usable. Private and public cisterns facilitate the irrigation.

Although fountains and moving water in general bring about higher costs, they can at selected places contribute strongly to the local cooling and moisturizing of the air. Standing water is, because of the negative side effects ("mosquito plague" and hazard of the transmission of infectious diseases, rotting process due to sinking water level etc.) to be avoided, if possible.
The Albedo-effect can also be used in open spaces, e.g. through light-coloured ground-coverings, in order to reduce a heating-up of sealed areas. In this context, it has to be considered, that no unwanted dazzling effect is caused by the coverings.

Urban Structure

The city of short ways remains to be an important target for the urban planning especially in times of climate change. Compact building structures are, in favour of maintaining directly adjacent open spaces, especially suited to develop a climate-adapted urban structure in already densely built-up locations, to point out and to increase the attractiveness of alternatives to the motorized traffic and thereby counteract the heating-up.
In this context, the preservation of cool air generating open spaces, fresh air corridors and the graduated green system of close-to-home, city-district-near and wide-ranging green spaces are, of course, essential in this respect. A large-scale connection between urban and regional linking of open spaces should be ensured, because they represent important cool air delivering areas for the City of Hannover.
Provided an analysis of existing and presumably newly occurring "Hot Spots" has been carried out, the laying out of new green spaces can be necessary to counteract an overheating of the densely built-up city areas. An interlinking of the new greenspaces with existing ones ensures the development of a climate-adapted urban structure in this way.
It makes sense to connect a compact, area-saving development of settlements with an open space structure concept, that limits the residential development in the interior area to an adequate construction density. In the long run, a further compaction should take priority over an unlimited exterior development.

"Fresh air is a non-replaceable basis of human existence. Other than water, as a rule it cannot be pumped through a long-distance pipeline into settlement areas, but it must emerge locally and be able to reach its sphere of action."
(Günther Wetzel in the UVP-Report 22, Issue 5, 2008)

Figure 27: The Ihme River and its green embankments form an important fresh air corridor for Hannover.
(Photo: Karl Johaentges)

Figure 28: Visualizing a construction field in Hilligenwöhren, Bothfeld
(Plan: Architects blauraum, Hamburg)

3.6.3 Hilligenwöhren – a Climate-adapted Residential Area

A good example of climate adaptation is the new building project Hilligenwöhren. On the former agronomically used area in the City District Hannover-Bothfeld, a new residential quarter will be erected in the coming years. The reason for the development of this residential area is the "Living Concept Hannover 2025". Because of the constant growth of the City of Hannover, the prevailing housing shortage has to be counteracted. On this account, the building space initiative was started with the creation of new building land in the urban area. In 2012, the Gundlach Company Group acquired the area of about 4.5 hectares, on which about 250 accommodation units will be built.

On the initiative of the city, the combined project "Climate-adapted, Sustainable Housing and Living in the Quarter" in German: "Klimaangepasstes, nachhaltiges Wohnen und Leben im Quartier", short "KlimaWohL – Hilligenwöhren" was started in Hannover-Bothfeld. The title as well as the content of the project are meant to express, that climate adapted housing and living are seen as necessity and shall be lived by the future residents of the new quarter.

The creation of a climate-adapted quarter means in effect, that in advance many different aspects and measures have to be taken into consideration. One of the measures applied in the Pilot Project KlimaWohL – Hilligenwöhren is the functional preservation of two cool air corridors, which run from north to south. The utilisation of climate change adapted shrub species belongs to this as well. Furthermore, the greening of roofs and façades are planned and the rainwater management concept stipulates, that the rainwater shall only be allowed to seep away in the project area and emergency waterways as well as emergency overflows are available in case of heavy rain events. On top of this, great importance is placed on building materials from renewable raw materials and the building phase is meant to produce as little waste as possible. The creation of climate comfort islands, like a shaded quarter square, house gardens and tenant gardens belongs to the measures as well as energy-efficient building and the use of regenerative energies. Included are also the consideration of locations for car sharing offers including electric vehicles and the possibility to rent out bicycles. Furthermore, social structures and demography will be taken into account in the pilot project. The quarter shall offer accommodation for all age groups and all social classes.

Thereby, a good mixture between affordable housing, ownership and living space for senior citizens is intended, furthermore, there shall be communal meeting possibilities for the residents.

A special feature of the project is not only a close cooperation between public domain (City of Hannover) and a private investor (Gundlach). The pilot project was chosen by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety as a communal beacon project for the development of local and regional cooperation and will be financially supported.

The support of the project is termed for three years (March 2016 to February 2019). The objectives of the pilot project are to test the previously named climate adaptation measures actively and systematically as well as to develop a model thereon, which can serve accompanying for further projects. This is not only meant to provide exemplary impulses for the Capital City Hannover, but also be available for other municipalities.

Figure 29: Kick-off event of the architecture competition
(Photo: Gundlach GmbH & Co. KG)

As a result, a "Hannover-Model" shall be established, which provides for the development of information-, consultation- and meshing tools and shows target-group-specific and process-related design guidelines, while the different climate adaptation measures are applied.

Thereby, actors from different fields (planning, administration, politics and general public etc.) shall be brought together. The model developed in the project shall not only take into consideration the construction phase of new building projects, but already be used in the conception phase and subsequently also in the utilisation phase.

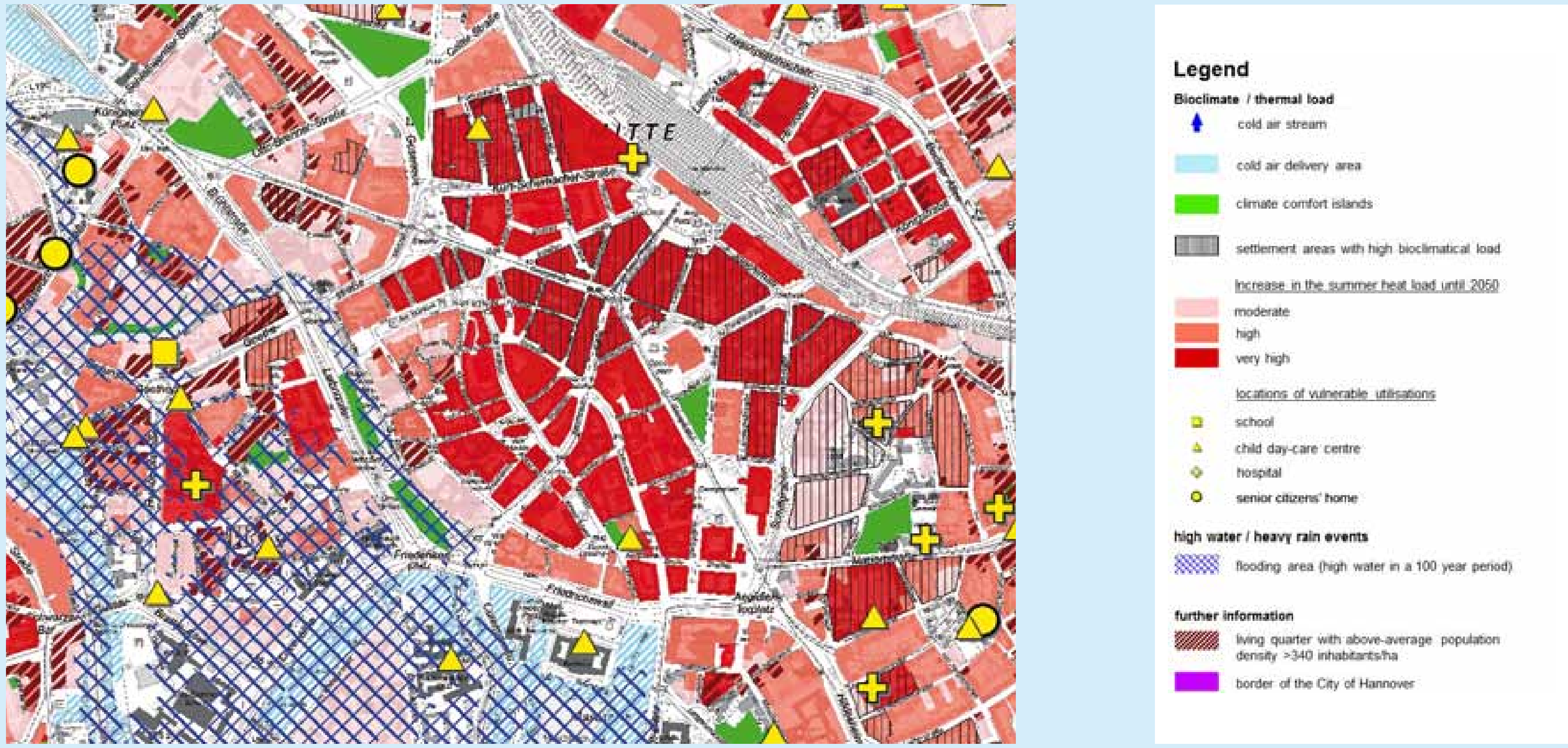


Figure 30: Section of the Expert Map Climate Adaptation
(Photo: Department Environment and Urban Greenspace, State Capital Hannover)

3.7 Specific Map Climate Adaptation

In order to steer the urban development in the direction of a "climate-adapted" city, the aspects of climate change must already be considered prior to the planning stage, e.g. of construction planning and of urban development planning and be integrated in the plans. Therefore, the administration developed a "Specific Map Climate Adaptation" on the basis of the Map of Climate Functions for the City of Hannover at the scale of the Land-use Plan. It is meant to serve as decision support tool for the implementation of adaptation measures and as basis for all climate-relevant planning. The specific map was published in December 2013.

The Specific Map Climate Adaptation contains the below mentioned information, which is significant for the planning. The basis here fore is constituted by the existing data collections and guide plans of the specialist departments, e.g. the Map of Climate and Emission Ecological Functions for the City of Hannover (2006) and the Map of Summer Heat Load under the Influence of Climate Change in the Capital City Hannover (2011).

Cool Air Delivering Areas and Important Cool Air Channels

Cool air is generated on agriculturally used areas (meadows, fields), in larger parks and forests as well as in the area of allotment gardens and cemeteries. On these areas, the surfaces and therefore also the overlaying air masses cool down quickly, especially with good nightly radiation conditions. This cool air can be transported over long distances by cool air channels into the warmed-up inner city. The effectiveness of the cool air delivering area increases with its size. Cool air channels are of a special importance, if they support the advance of cool air towards the inner-city area into the higher bioclimatically burdened zones. A building development within those channels would strongly limit their function.

Climate Comfort Islands

Cool air is also generated on these areas. But they are, however, smaller than 20,000 m². The smallest climate comfort island shown on the specific map measures 180 m². These islands include public places, greened playgrounds and sport fields, large courtyards, smaller open spaces, like fields and wasteland, smaller cemeteries and larger gardens. Because of their smaller size, they do not unfold the climatic long-distance effect of a cool air generating area, but play nevertheless an important role as bioclimatic comfort islands in the city. They carry out this function primarily, if they exhibit a mosaic of different micro climates (shaded and sunlit areas, water surfaces). Their welfare effect is mainly limited to the area itself. Because they do not generate cool air flows of their own in general, they have no impact on the neighbouring buildings. These green spaces appear as cool islands within the heated-up buildings and offer, especially on very hot days, pleasant places of stay for the city residents.

In spite of their lower cool air production they are nevertheless - especially in the densely populated and highly sealed city centre – of importance. An overbuilding of these areas would lead to an increase of the heat burden. Individual heat islands would merge into a larger heat island.

Bioclimatically Higher Burdened Settlement Areas

Under the term "Bioclimate", the entirety of all atmospheric influencing variables on the human organism is summarized. The most important meteorological variables in this respect are air temperature, air humidity, wind velocity and radiation. They influence, amongst others, the so called "felt temperature".

In the city, the bioclimate is influenced significantly by the buildings. The word "heat island" describes the on average higher temperature in a densely built-up city compared to the surrounding region. It emerges from a surplus of heat as a result of a dense construction and a high level of sealing, because the exchange of air masses is reduced, less cooling is caused by evaporation and the degree of heat storage in buildings is accordingly high. The temperature difference to the surrounding region can amount to 8°C in Hannover during the night. Especially during the nights in the height of summer, the heat island causes a higher heat stress for humans and leads to a limited quality of life.

In the specific map, those areas are depicted, that actually show an increased bioclimatic burden during summer heat periods. These areas have at first got a dense building structure and a high level of sealing, secondly, they are no longer ventilated during the nightly periods of thermal loads. Due to obstacles or longer distances to greened open spaces, the nightly generated cool air streams do not reach these areas.

Increase of the Summer Heat Burden until the Middle of the Century

In the course of climate change, the summer heat burden will increase significantly for the population, especially in the cities. In the sense of a vulnerability analysis the specific map points out areas in the city, in which a significant rise in the summer heat burden will take place until the middle of the century. The gradation covers the categories moderate, high and very high increase.

Locations of Sensitive Utilisation

Certain population groups are especially affected by the inner-city heat burden. This includes older and weakened people, sick persons and also small children. In the course of heat periods, schoolchildren can be impaired in their learning ability during lessons. Special provisions apply to these population groups or their specific facilities respectively, mainly if they stay in areas with higher bioclimatic burdens or in areas with a high or very high increase of summer heat stress. The planning of new sites, e.g. for day-care centres, also has to take this into consideration.
Schools, day-care centres, and hospitals as well as accommodations, urban nursing homes and care centres for the elderly are pointed out as locations of sensitive utilisation.

Settlement Areas with an Above-average Population Density

Basis for the valuation of population density is the sum of residents per block area. The mean value for Hannover is 170 inhabitants per hectare. A residential area with above-average population density was defined by more than 340 inhabitants per hectare. In regions where residential areas with a high population density coincide with higher bioclimatic burdened areas or areas with a high or very high increase of summer heat stress, the number of persons affected by heat stress is particularly high. In these residential areas, measures for the reduction of the burden e.g. greening, shading etc. are especially important.

Floodplains

Pictured are the floodplains in the City of Hannover that are defined by law and those that are secured temporarily. In these areas, the regulations of the Law on the Improvement of Preventive Flood Protection have to be adhered to.
With these subjects, the specific map is not at all completed. It remains open for further subjects concerning climate adaptation. These will be entered by and by. So, for example, the designation of thermic stress zones for the urban vegetation (especially for street trees) and the designation of settlement areas, that are especially endangered by heavy rain events, are planned.

3.8 Public Relations and Educational Activities

The educational and public relations work serves not only for informing the public about the possible impacts of climate change and the adaptation measures of the City of Hannover, but also for raising the awareness, that a change in lifestyle and consumer habits in the private area will be necessary in future, so that climate protection and climate adaptation can be successful.

With an information stand, the *Adaptation Strategy to Climate Change for the Capital City Hannover* was presented to the public by a poster regarding the climate impacts and the required adaptation measures on 12th May 2012 and during the "Car-free Sunday" on 1st June 2014.
The city administration published several flyers and brochures about climate adaptation for the information of the citizens:

- Flyer "Great Heat – What to do?" Tips for behaviour on hot days
- Brochure on dealing with soils during building measures (Information for people wishing to build)
- Flyer "Make Your House fit for the Future! Urban funding Programme for House Owners"
- Information leaflet "Green Walls for Hannover – Better Climate through Green Façades"

Together with the Adult Education Centre Hannover, the city administration started a series of lectures on the subject Climate Change in spring 2013, which focused on the different impacts of global warming and possible adaptation measures. Up to now, the following partial aspects of climate change have been highlighted:

- More Water in the City? New Perspectives for the Planning. *(22nd March 2013)*
- Healthy Soil – Good Climate. Influence of Climate Change on Soils. *(5th December 2013)*
- Does Climate Change Endanger my House? Extreme Weather Events and Risk Provisioning. *(24th April 2014)*
- Climate, Weather, Heat. What do we Expect in the Future? Influence of Climate Changes on Weather and Wellbeing. *(18th September 2014)*
- Climate Change and Urban Biological Diversity *(15th April 2015)*
- City Trees in the (Climate) Change *(23rd November 2015)*
- Heavy Rain, High Water … What do we do with the Flood? *(22nd March 2016)*
- Humans and Climate Change *(8th March 2017)*

Figure 31: Notification flyer for a lecture in the Adult Education Centre Hannover. This (and the other lectures) was also advertised on the webpage of the Capital City Hannover and through the passenger television in the city trams.

4 Research

For the implementation of adaptation measures to climate change, an accompanying expert advisory service is partially necessary. Firstly, examinations will be necessary in order to collect data for the specific map climate adaptation (e.g. registration of climate-relevant soils), secondly, the efficiency of measures shall be reviewed and optimized through model calculations and measurement campaigns. This applies especially to the planning of new building areas. If possible in an early planning stage, it is examined with the use of a climate functions map and in some cases through climate model calculations, whether the building has negative effects on cool air generation areas, cool air channels and on the bioclimatic situation of neighbouring building sites. Furthermore, recommendations can be derived from the model, how the bioclimatic situation in the building area can be optimized by an altered planning. This climate modelling has been carried out up to now for the building areas Zero:E-Park (Wettbergen), Büntekamp, Wasserstadt Limmer, Am Marstall, Fuhsestraße, Klagesmarkt and Hilligenwöhren.

The GIS-based Map of Climate and Emission Ecological Functions for the City of Hannover (climate functions map) was compiled in the year 2006. In the recent years, the data on land utilization and the state of the art techniques for the performance of climate analyses have developed considerably. Therefore, the city administration has commissioned a new calculation of the climate ecological functions and processes in the period 2015/16 by means of an updated data base and the improved FITNAH climate model. Thereby, a user-oriented planning map climate was also developed which fulfils the present requirements towards the consideration of the protected asset climate in the spatial planning. Central element is hereby the adaptation to climate change with the range of topics "Urban Heat Burden". The climate analysis was carried out by the GEO-NET Umweltconsulting GmbH Hannover, that forms a working group with the Meteorological Institute at the University of Hannover (Prof. Groß).

4.1 Climate Examination of an Urban Space by the Example of the State Capital Hannover

The "Examination of the Urban Climate with the Special Aspect of the Subterranean Tunnel System of the Public Transport by the Example of the State Capital Hannover" is a shared project between the Lower Saxony Ministry for Environment, Energy and Climate Protection, of the German Meteorological Service (DWD) and the State Capital Hannover. The project focusses thematically on the subjects health provision in the course of climate adaptation, sustainable urban development and preventive civil protection. In general, the issue of impacts of climate change in conjunction with the effects of longer heat periods and the resulting requirements for the future urban- and traffic development shall be pursued. Thereby, not only the conditions in the directly habituated "surface area" are of interest, but also a review of the subterranean living space of public transport tunnels and stations with its modified climate conditions has to be carried out.

Figure 32: Mobile climate monitoring station of the German Meteorological Service in Bremen
(Photo: DWD)

For the intended measuring programme it is planned, to equip three trams with meteorological measuring sensor systems on the exterior and one tram with an additional system in the interior. In the interior, the heat radiation, air temperature as well as the relative humidity shall be monitored for a period of at least three years along the railroad beds, in tunnels and subterranean stations. These profile measurements with the tram are supplemented by two aboveground temporary measuring stations of the German Meteorological Service (DWD), at which the air temperature, relative humidity, wind direction and wind velocity are recorded also for a period of at least three years. In addition, the measuring concept is rounded off by profile measurements with a respectively equipped vehicle during selected weather conditions.

Alongside this inspection programme, the erection of a station "Hannover", belonging to DWD Urban Climate Measuring Network, is planned. It is meant to deliver climate data from the densely built-up inner city area for the longest possible period of time.

4.2 Concentration of the Groundwater Measuring Network

Since the beginning of the 2000s it became evident, that raised groundwater levels appeared quite frequently in some of the regularly monitored groundwater level measuring stations. These exceeded the predicted, up to then assumed to be highest, groundwater levels, which resulted from the measurement series until the end of the seventies. The climate models prognosed an in future significantly changed precipitation pattern for the Northern German area. According to this, a reduction of the average precipitation amounts by 10 – 20% has to be expected in summer, in winter, on the other hand, a rise by 15 – 25% has to be reckoned with. Apart from that, the share of heavy rain events is meant to increase. The changed precipitation pattern will in any case have an effect on the groundwater level, the groundwater level fluctuations will intensify. This can cause soil subsidence in certain regions of the city area through drying out of the soil in summer, in the winter months on the other hand "wet cellars". Another impact can be an increased extraction of pollutants into the groundwater (see 3.3).
For these reasons, a new groundwater map was compiled in 2013, that depicts the average as well as the highest to be expected groundwater levels based on the actual data. This map is not only an important planning basis for the city, but also for people wishing to build as well as architects etc., who can stipulate requirements for the building structure by means of the highest expected groundwater level. Apart from that, it constitutes an indispensable basis for environmental-geologic questions; through the regular actualization it will be possible in future to recognize long-term changes of the urban groundwater balance.

In the course of updating, it became evident, that the momentary active groundwater measuring network is incomplete in certain areas, so that a sufficiently precise interpolation of the water level data is not possible or delivers implausible results. Altogether more than 40 areas with existing knowledge gaps were identified. Now it is necessary, to close these gaps until at least five years before the next actualization, which is planned for 2022/2023. This is the only possibility to ensure, that a sufficiently resilient data base is available until then. In some of the areas, existing inactive groundwater measuring points could be reactivated with relatively little effort. In other areas, the installation of new groundwater measuring points is necessary. About two thirds of the gap closings could be realised by now. In order to safely detect extreme events of the ground water levels, data loggers are increasingly used.

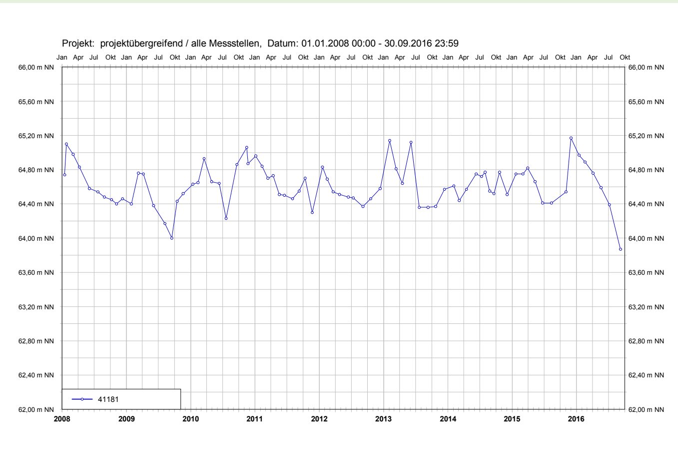


Figure 33: Groundwater measuring point of the Capital City Hannover with groundwater hydrograph (small chart)
(Photo: Department Environment and Urban Greenspace)

4.3 Impacts of Climate Change on the Water Resources and the Flooding Effects in Residential Areas

In the meantime, as described, the impacts of climate change have reached a high level of significance for the communal practise. Central aspects are the rising heat as well as the development of flooding risks of waters and canalisations as a result of more frequent heavy rainfalls. The owner-operated municipal enterprise Urban Wastewater Management of the Capital City Hannover is permanently integrated as partner in the project "Water Balance of Waters Characterised by Settlements (WaSiG) – Planning Instruments and Operating Concepts" for the period 2015 to 2018. In this joint project of the Federal Ministry of Education and Research (BMBF), transferable knowledge is gained about possible impacts of climate change on the water balance and flooding characteristics in settlement areas in conjunction with management measures. The determination of the acceptance of population and the communal actors as well as the integration of new measures into the communal planning- and administrative processes are further important elements, that are developed at present. The impacts and the resilience of the (near-nature) decentralized rainwater management are analysed in conjunction with the consequences of climate change, amongst others, by example of the EXPO 2000 project "Water Concept for the Residential Area Hannover-Kronsberg". This new City District Kronsberg, developed as EXPO 2000 project for sustainable building, was at that time already equipped area-wide with the most different facilities for a decentralised rainwater management, which now, after more than 15 years, can undergo an overall inspection.

These inspections are of actual importance for the growing Capital City Hannover, because e.g. at the moment, a function plan for the 50-hectare sized southern extension of this city district is compiled by the administration with external support. Target is, as things stand at present, to erect about 3,500 housing units for approximately 8,000 residents.

The measures of rainwater management are not only expected to achieve, amongst others, a discharge restraining effect, but also a positive effect on the urban climate, if the evaporation can be significantly increased. Nevertheless, there are still questions in view of the necessary infrastructural adaption, to which initial answers and action approaches have already been defined during the recent years.

The participation of the citizens in opinion building processes regarding the communal politics and the planning processes has reached a high level of importance in the communities. In addition to the formal participation procedures, surveys, planning workshops and other open forums also contribute to an urban development close to the citizens here.
Of a very great importance for the future planning practise are the results regarding the acceptance of management measures, the resilience of measures towards climate change as well as costs and operation. Here, significant contributions for the basics of a communal planning practise are compiled in conjunction with the other partners.

Figure 34: Lived adaptation – high water at the Ihme Centre 2013
(Photo: Department Environment and Urban Greenspace)

4.4 Forecasts of Urban Torrents

Because of the extreme rain events of the recent years in the Federal Republic of Germany, and not least because of the advancement of digital tools, the research field in the area of torrents and flooding provision has grown. Guidelines and recommendations for the communal approach to the subject Flooding Provision have been compiled by specialist associations and different cities, often in connection with research projects. At present, the Urban Wastewater Management Hannover takes part in the research project EVUS "Actual-time Forecast of Urban Torrents and the Related Water Contamination" of the Federal Ministry of Education and Research (BMBF). The project has started in the middle of 2015 with a duration of 3 years. As output from this project, we expect more detailed knowledge of processes which can occur in case of an extreme rain event in Hannover. These insights shall, as far as transferable and useful, be incorporated in a flooding provision concept for Hannover.

Excerpt from the Project Description:

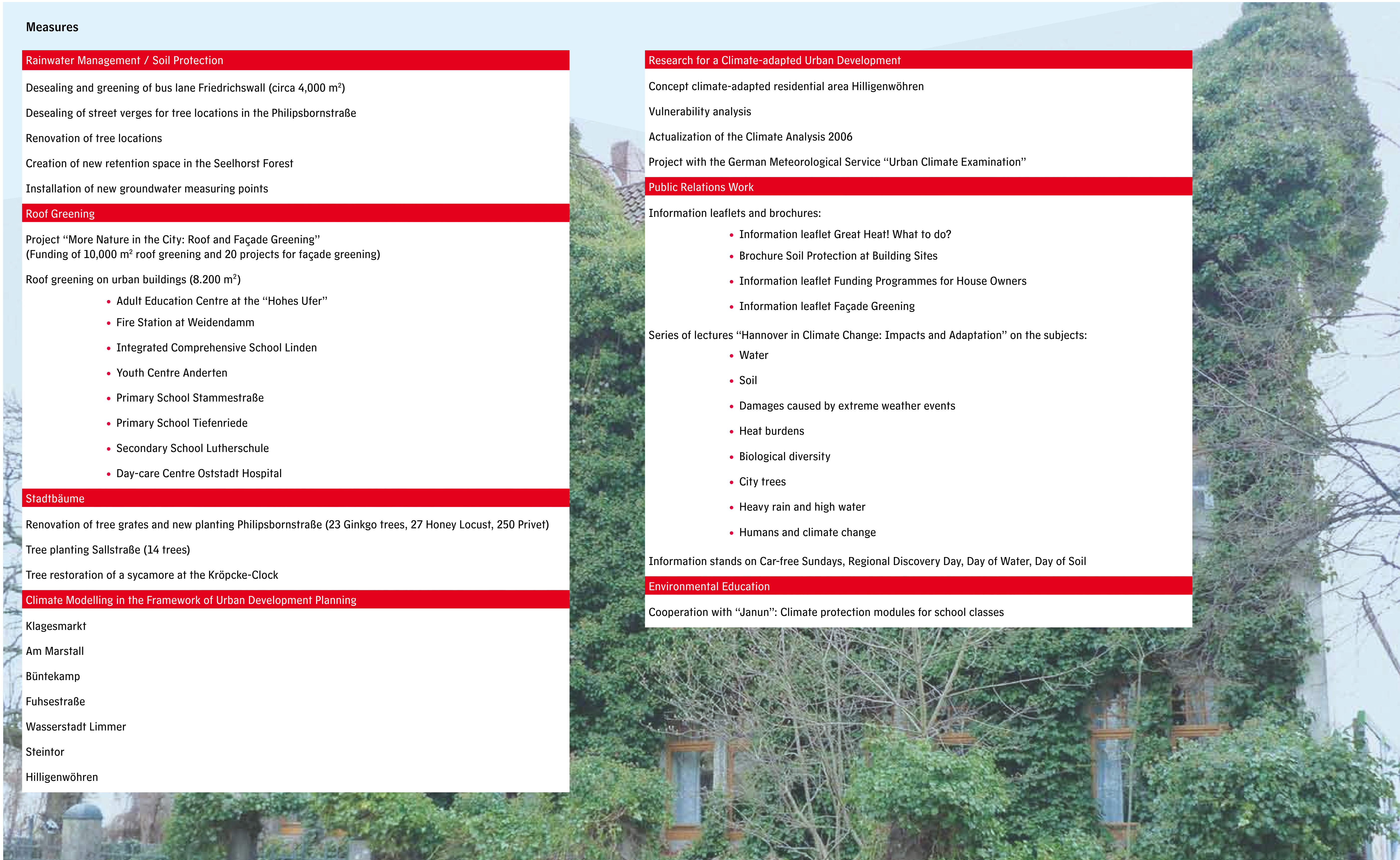
Urban torrents are caused by local and fast severe weather events with very heavy precipitation, that lead to a collapse of the urban drainage system. Such events carry a high damage potential and will gain in importance in connection with the increase of extreme weather events that has to be expected in future. Cascading (following each other) damage events during an urban torrent can also be caused by the unwanted release of harmful substances. The transportation times to critical points in the urban water system and to locations of leakages into the underground are short during an overflooding. This can create a danger for the quality of groundwater and surface water. Early warning systems require the forecast of precipitation and the related flow- and transport scenarios. Such forecasting systems present a great challenge, especially because of the required as long as possible prediction period. The compilation of such a forecasting system for the City of Hannover is planned in the EVUS project. The forecast includes the prediction of precipitation, of flow and transport in the canalisation system on the surface and in the underground of the city area and a rapid damage warning. Two models with different degrees of complexity are developed for the flow. A so called physically based model is utilised, which completely depicts the physical processes of the flow in order to calculate possible flow scenarios. Because of the complexity of such models, they cannot be used for real-time forecasts. Therefore, a simplified database-metamodel is developed from the scenarios with physically based model forecasts, which allows a real-time forecast with a computing time of minutes. The flow simulations are combined with an overflooding damage model, in order to identify critical locations, at which the flow should be reproduced especially well. A survey is carried out for the development and validation of models. Crowdsourcing methods (use "the Wisdom of Many" helped by the internet) are employed in order to be able to use as much real-time information as possible for the calibration and control of the flow- and transport modelling and eventually for the precipitation forecast. For this purpose, an application for the communication of information with smartphones regarding overflooding shall be developed. For the visualisation of the forecasts and for the direct adaption of observations, a web based user interface will be developed.

5 Literature

- Arbeitskreis Stadtbäume der Gartenamtsleiterkonferenz *(2016)*: GALK-Liste der Straßenbäume, *Stand 15.2.2016*
- Deutscher Städtetag, Fachkommission Umwelt *(2012)*: Positionspapier zur Anpassung an den Klimawandel – Empfehlungen und Maßnahmen der Städte
- Deutscher Wetterdienst (DWD) *(2015)*: Klimawandel könnte künftig mehr Hitzetote fordern; Pressemeldung vom *Juli 2015*
- Deutsches Zentrum für Luft und Raumfahrt e. V. (Hrsg.), beauftragt vom BMBF *(2014)*: Perspektive Erde, Forschung zum globalen Wandel, Heft 02/2014
- GEO-NET *(2006)*: Erstellung einer GIS-basierten Karte der klima- und immissionsökologischen Funktionen für die Stadt Hannover unter Verwendung des 3D Klima- und Ausbreitungsmodells FITNAH
- GEO-NET *(2006)*: Karte der sommerlichen Wärmebelastung unter dem Einfluss des Klimawandels in der Landeshauptstadt Hannover
- Gerstengarbe, Friedrich-Wilhelm / Harald Welzer *(2013)*: Zwei Grad mehr in Deutschland. Wie der Klimawandel unseren Alltag verändern wird. Frankfurt am Main
- IPPC *(2013)*: Zusammenfassung für politische Entscheidungsträger. In: Klimaänderung 2013: Wissenschaftliche Grundlagen. Beitrag der Arbeitsgruppe I zum Fünften Sachstandsbericht des Zwischenstaatlichen Ausschusses für Klimaänderungen [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauerls, Y.Xia, V. Bex and P.M. Midgley (Hrsg.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Deutsche Übersetzung durch ProClim, Deutsche IPCC-Koordinierungsstelle, Österreichisches Umweltbundesamt, Bern/Bonn/Wien, 2014.
- IPPC *(2014)*: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global und Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32
- Landeshauptstadt Hannover (LHH) *(2000)*: Naturnaher Umgang mit Regenwasser, Schriftenreihe kommunaler Umweltschutz, Heft 30, *2000*
- Landeshauptstadt Hannover (LHH) *(2006)*: Beschlussdrucksache 1242/2006, „Umsetzung der Hochwasserschutzmaßnahmen in der Landeshauptstadt Hannover"
- Landeshauptstadt Hannover (LHH) *(2007)*: Beschlussdrucksache 1440/2007, „Ökologische Standards beim Bauen im kommunalen Einflussbereich"
- Landeshauptstadt Hannover (LHH) *(2012)*: Informationsdrucksache 0933/2012, „Anpassungsstrategie zum Klimawandel für die Landeshauptstadt Hannover"
- Landeshauptstadt Hannover (LHH) *(2012)*: Informationsdrucksache 1554/2012 „Programm zur Minimierung der Folgen der Klimaerwärmung"
- Meteoterra/GEO-NET *(2015)*: Grundlagen und Empfehlungen für eine Klimaanpassungsstrategie der Region Hannover
- Morice, C.P., Kennedy, J.J., Rayner, N.A. and Jones, P. D. *(2012)*: Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: the HadCRUT4 dataset. Journal of Geophysical Reserach, 117 (http://www.cru.uea.ac.uk/cru/info/warming)
- Roloff, Bonn, Gillner *(2008)*: Klimawandel und Baumartenwahl in der Stadt – Entscheidungsfindung mit der Klima-Arten-Matrix (KLAM), Dresden
- Sieker, Friedhelm u. a. *(2002)*: Naturnahe Regenwasserbewirtschaftung in Siedlungsgebieten, 2., neu bearb. Auflage – Renningen-Malsheim
- Stadtentwässerung Hannover *(2012)*: Konzept zur Stabilisierung des Wasserhaushalts im Seelhorstwald, Endbericht
- Umweltbundesamt (UBA) (2013): Welche Klimaänderungen sind für Deutschland zu erwarten? http://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/folgen-des-klimawandels/klimamodelle-szenarien/erwartete-klimaaenderungen
- Umweltbundesamt (UBA) *(2016)*: Chronik weltweiter Temperaturen, Niederschläge und Extremereignisse seit 2010 (Hintergrund // Mai 2016)
- Swiss Academy of Science, Deutsche IPPC Koordinierungsstelle, Umweltbundesamt (Hrsg.) *(2013)*: IPPC 2013. Klimaänderung 2013: Wissenschaftliche Grundlagen. Zusammenfassung für politische Entscheidungsträger

6 Annex

6.1 Implemented Measures of the "Programme for the Minimization of Impacts of Global Warming"



Measures

Rainwater Management / Soil Protection

Desealing and greening of bus lane Friedrichswall (circa 4,000 m²)

Desealing of street verges for tree locations in the Philipsbornstraße

Renovation of tree locations

Creation of new retention space in the Seelhorst Forest

Installation of new groundwater measuring points

Roof Greening

Project "More Nature in the City: Roof and Façade Greening"
(Funding of 10,000 m² roof greening and 20 projects for façade greening)

Roof greening on urban buildings (8.200 m²)

- Adult Education Centre at the "Hohes Ufer"
- Fire Station at Weidendamm
- Integrated Comprehensive School Linden
- Youth Centre Anderten
- Primary School Stammestraße
- Primary School Tiefenriede
- Secondary School Lutherschule
- Day-care Centre Oststadt Hospital

Stadtbäume

Renovation of tree grates and new planting Philipsbornstraße (23 Ginkgo trees, 27 Honey Locust, 250 Privet)

Tree planting Sallstraße (14 trees)

Tree restoration of a sycamore at the Kröpcke-Clock

Climate Modelling in the Framework of Urban Development Planning

Klagesmarkt

Am Marstall

Büntekamp

Fuhsestraße

Wasserstadt Limmer

Steintor

Hilligenwöhren

Research for a Climate-adapted Urban Development

Concept climate-adapted residential area Hilligenwöhren

Vulnerability analysis

Actualization of the Climate Analysis 2006

Project with the German Meteorological Service "Urban Climate Examination"

Public Relations Work

Information leaflets and brochures:

- Information leaflet Great Heat! What to do?
- Brochure Soil Protection at Building Sites
- Information leaflet Funding Programmes for House Owners
- Information leaflet Façade Greening

Series of lectures "Hannover in Climate Change: Impacts and Adaptation" on the subjects:

- Water
- Soil
- Damages caused by extreme weather events
- Heat burdens
- Biological diversity
- City trees
- Heavy rain and high water
- Humans and climate change

Information stands on Car-free Sundays, Regional Discovery Day, Day of Water, Day of Soil

Environmental Education

Cooperation with "Janun": Climate protection modules for school classes

6.2 Information on Procedures for Sun Protection / Night Aeration

Problem Definition / Conflict Area

This information about procedures offers decision guidance regarding the avoidance of overheating in schools, day-care centres, administration buildings, homes, nurseries etc., it is applicable for the renovation as well as for new constructions.

The existing conflict area regarding our buildings with the basic points:

- Some buildings heat up too much in summer,
- The air quality is meant to be kept between 1000 and 2000 ppm CO^2,
- Energy efficiency; we do not want to let the heat escape out of the window,

requires a multi-layer solving approach. One decisive factor for a well-functioning building is the avoidance of heat influxes in summer.

Terminology

Sun protection: Reduces the energy influx through sun radiation and at the same time reduces the dazzling effect caused by sunlight.
Glare protection: Prevents the dazzling effect caused by sunlight, as it can occur through e.g. too high light density on light-coloured surfaces or mirroring on shiny surfaces (e.g. monitors).

Sun Protection

Is only necessary for south- as well as east-/west-oriented rooms (see working aid 3)

1. With southeast- to southwest-orientation, an exterior static sun protection should be utilized. Where natural shading by trees and buildings etc. is missing, an additional solar protection glazing, for example with a g-value of 34% and an interior glare protection (curtain) can be necessary.
2. Can a static sun protection not be installed, the next choice is the exterior dynamic sun protection with movable shutters, roller blinds or an in-between-pane solar protection (blind). These systems are operated fully automatically and work from a global radiation of 200W/m². Nevertheless, the user has the possibility to intervene manually. The electrical version has the advantage, that it can be retracted weather-controlled, which is not necessary with in-between-pane solar protection. In comparison to the static sun protection, an increased maintenance effort has to be considered. Here, a further glare protection is not required. Solar protection glazing is not necessary.
3. If the exterior systems are not employable, for example on listed buildings, a solar protection glazing with interior sun-/glare protection can be used.

Air Quality

Irrespective of how good the sun protection is, the building heats up in the course of the warm season, the room temperatures escalate, a reason for this are the internal loads. This process is just slowed down by sun protection, but not avoided. In order to keep the room temperatures bearable, the warmth has to be discharged with the help of natural ventilation during the cooler night hours. In the course of the room usage (e.g. lessons) a CO^2-concentration in the room air of 1,500 ppm should not be exceeded. This is equivalent to a minimum air quality of IDA 3 according to DIN EN13779. Short-term exceedances are nevertheless not harmful for the health (the maximum workplace concentration for an 8-hour exposition adds up to 5,000 ppm). Surveys have shown, that this can be accomplished with shock aeration during the breaks and additionally a 5-minute airing-out in the course of the lesson.

Natural Aeration

Advantages

- No energy requirement for air transportation
- Lower maintenance effort
- Simple technique
- No (hardly any) channel net required

Disadvantages

- The windows intended for the nightly airing-out require an electrical opening/closing mechanism
- Limited operability
- Risk potential weather conditions e.g. wind-driven rain
- Risk potential break-ins
- Heat recovery only limited possible
- Draft occurrences
- Invading of birds and small animals

Implementation

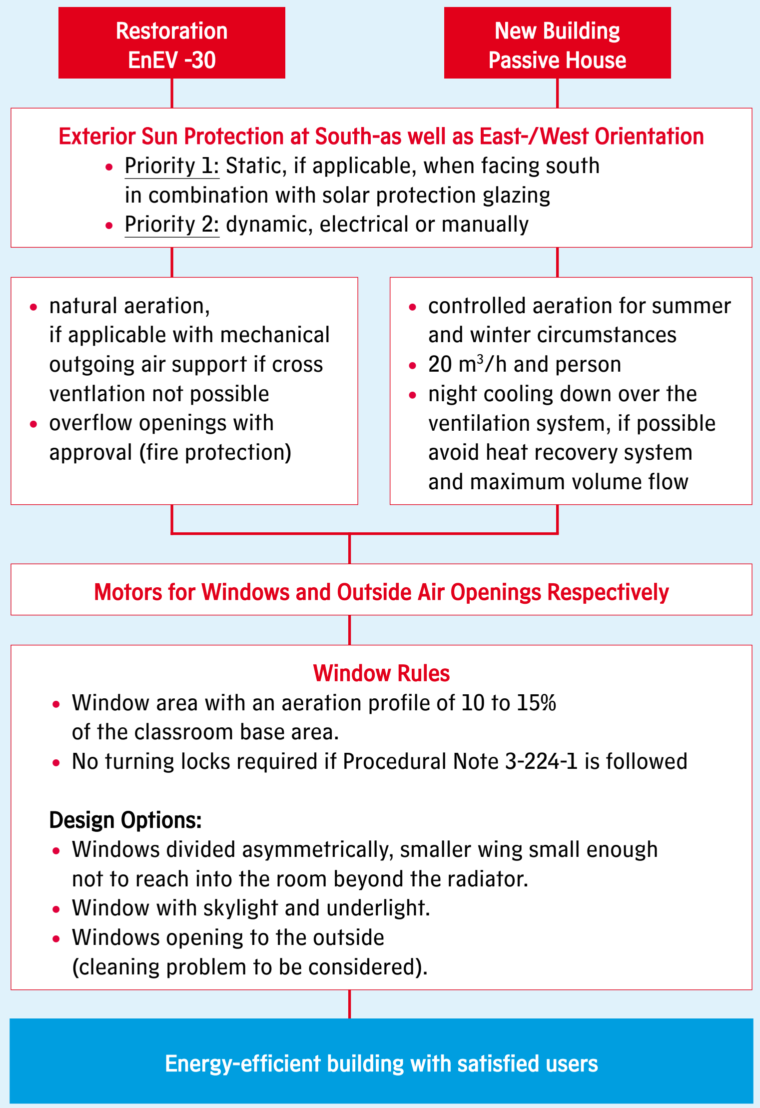
The following concepts are conceivable, the simplest solution, No. 1, should be sought. If it cannot be implemented, No. 2 will be examined, then No. 3 and so forth, until finally the solution most suitable for the planned construction is found.

1. Cross ventilation, room wise, with skylights and/or ventilation flaps
   - Verification air exchange with Passive House Planning Package (phpp) – calculation module (temperature difference for nightly airing-out: 1K, for all-day summer airing-out: 4K; wind velocity for nightly airing-out: 1m/s, for all-day summer airing-out: 1m/s), (by construction planner or energy consultant).
   - Burglary protection
   - Operation concept
2. Cross ventilation, connected rooms, with skylights and/or ventilation flaps, ducts and air transfer, without ventilator.
   - Verification air exchange with simulation calculation (by construction planner or energy consultant)
   - Burglary protection
   - Fire protection concept
   - Crosstalk attenuator
   - Operation concept
3. Aeration with outside air via skylights or ventilation flaps, outgoing air ventilator-supported, if necessary with air transfer. In case of a solution with centralized outgoing aeration and decentralized outside air, the utilization of a heat recovery system for the process water preparation or heating system support has to be considered.
   - Verification air exchange with simulation calculation (by construction planner or energy consultant)
   - Burglary protection
   - Fire protection concept
   - Crosstalk attenuator
   - Operation concept
4. Mechanical ventilation system, in case of new buildings Passive House Planning Package (phpp)-conform, in case of renovation with heat recovery system and bypass.

- Verification air exchange (night aeration) (by construction planner or energy consultant)
- Operation concept

Furthermore, the following points have to be regarded

- Fire protection: For the transfer of extract air into the corridor, authorized air transfer elements, for example fire dampers with tripping over smoke detectors to be used.
- Outside air replacement through windows or outside air elements in the façade, electrical actuator drives for windows and outside air elements necessary.
- Intelligent control required, wind and rain sensors, global radiation, inside and outside temperatures, pushbutton, “heating off when window open”
- Night aeration with at least 4-fold air exchange can be realised as a rule in school with the probably existing room ventilation systems. The air volume “School” results as follows:
- Air volume 20 … 25 m³/h and pupil equals with 30 pupils 600 … 750 m³/h and classroom, at 60 m² 3m height and n = 4-1 it amounts to 720 m³/h which means system is sufficient for night aeration.
- If room ventilation systems are employed, outdoor air rates are sufficient, that limit the maximum CO^2-concentration in the room air to 1,500 ppm. For this, the room ventilation system can also be combined with window airing-out during the breaks. This leads to outside air rates between 20 and 30 m³/p*h, representing an air quality of IDA 3 (average room air quality) according to DIN EN 13779. Interior loads: relocation of installations that need cooling into the outside or cellar rooms facing north.
- Activation of storage mass without neglecting acoustic requirements.
- Building physics, avoidance of structural damages



6.3 Climate Change and Selection of Tree Species in the City – Decision-making with the Climate-Species-Matrix (Klima-Arten-Matrix, KLAM)

Classification of important tree species according to their suitability for use in the city area after the prognosed climate change (bold: native species)
(Excerpt from the list by ROLOFF, BONN and GILLNER, 2008)

1.1 Trees which are valuated as very suitable in both categories (drought tolerance , winter hardiness [frost sensitivity, frost-proofment, late frost endangerment])

Botanical Name	Common Name
Acer campestre* L. subsp. *campestre	**Field maple**
Acer negundo L. subsp. *negundo*	Box elder
Acer x zoeschense Pax	Zoeschen maple
***Alnus incana* (L.) Moench**	**Speckled alder**
Cladrastis sinensis Hemsl.	Chinese yellowwood
Fraxinus pallisiae Wimott ex Pallis	Pallis' ash
Juniperus communis* L. subsp. *communis	**Common juniper**
Juniperus scopulorum Sarg.	Rocky Mountain juniper
Juniperus virginiana L.	Eastern red-cedar
Ostrya carpinifolia Scop.	European hop-hornbeam
Phellodendron sachalinense (Fr. Schmidt) Sarg.	Sakhalin cork tree
Pinus heldreichii H. Christ	Bosnian pine
Pinus nigra Arnold subsp. *nigra*	Black pine
Pinus sylvestris* L. var. *sylvestris	**Scots pine**
Prunus avium* (L.) L. var. *avium	**Wild cherry**
Quercus bicolor Willd.	Swamp white oak
Quercus macrocarpa Michx. var. *macrocarpa*	Bur oak
Robinia pseudoacacia L.	Black locust
Robinia viscosa Vent.	Clammy locust
***Sorbus aria* (L.) Crantz**	**Common whitebeam**
***Sorbus badensis* Düll.**	**Baden whitebeam**
***Sorbus x thuringiaca* (Ilse) Fritsch**	**Thuringian whitebeam**
Tilia mandshurica Rupr.et Maxim.	Manchurian Lime
Ulmus pumila L. var. *pumila* (*U. mandschurica* Nakai)	Siberian elm

1.2 Trees which are valuated as very suitable in the category drought tolerance and as suitable in the category winter hardiness

Botanical Name	Common Name
Acer opalus* Mill. subsp. *opalus	**Italian maple**
Acer rubrum L.	Red Maple
Ailanthus altissima (Mill.) Swingle	Tree of Heaven
Carya tomentosa (Lam. ex Poir.) Nutt.	Mockernut hickory
Catalpa speciosa (Warder ex Barney) Engelm.	Northern catalpa
Cedrus brevifolia (Hook.f.) Henry	Cyprus cedar
Cedrus libani A.Rich. subsp. *libani*	Cedar of Lebanon
Celtis caucasica Willd.	Caucasian hackberry
Celtis occidentalis L. var. *occidentalis*	American hackberry
Cupressus arizonica Greene var. *arizonica*	Arizona cypress
Diospyros lotus L.	Date-plum
Fraxinus angustifolia Vahl subsp. *angustifolia*	Narrow-leafed ash
Fraxinus quadrangulata Michx.	Blue ash
Ginkgo biloba L. Ginkgo	Ginkgo tree
Gleditsia japonica Micq.	Japanese honey locust
Gleditsia triacanthos L.	Honey locust
Maackia amurensis Rupr. et Maxim. var. *amurensis*	Amur maackia
Ostrya virginiana (Mill.) K. Koch Virginische	American hop-hornbeam
Pinus bungeana Zucc.ex Endl.	Bunge's pine
Pinus ponderosa Douglas ex C. Lawson	Ponderosa pine
Pinus rigida Mill.	Pitch pine
Platanus x hispanica Münchh. (P. x acerifolia Ait.)	London planetree
***Populus alba* L.**	**Silver poplar**
***Quercus cerris* L.**	**Turkey oak**
Quercus coccinea Münchh.	Scarlet oak
Quercus frainetto Ten.	Hungarian oak
Quercus macranthera Fisch. et C.A. Mey. ex	Persian oak
Quercus montana Willd. (*Q. prinus* L.)	Chestnut oak
Quercus muehlenbergii Engelm.	Chinkapin oak
Quercus pubescens* Willd. subsp. *pubescens	**Downy oak**
Sophora japonica L.	Japanese pagoda tree
***Sorbus domestica* L.**	**Service tree**
***Sorbus latifolia* (Lam.) Pers.**	**Broad-leaved whitebeam**
***Sorbus torminalis* (L.) Crantz**	**Wild service tree**
Thuja orientalis L. (*Platycladus orientalis* (L.) Franco)	Chinese thuja
Tilia tomentosa Moench	Silver lime

2.1 Trees which are valuated as suitable in the category drought tolerance and as very suitable in the category winter hardiness

Botanical Name	Common Name
Acer buergerianum Miq.	Trident maple
***Acer platanoides* L.**	**Norway maple**
Aesculus x carnea Hayne	Red horse-chestnut
Alnus x spaethii Callier Spaeths	Spaeth's alder
***Betula pendula* Roth**	**Silver birch**
***Carpinus betulus* L.**	**European hornbeam**
Fraxinus pennsylvanica Marshall var. *pennsylvanica*	Green ash, Red ash
Malus tschonoskii (Maxim.) C.K. Schneid.	Pillar apple
Picea omorika (Pancic) Purk.	Serbian spruce
Populus x berolinensis (K. Koch) Dippel	Berlin poplar
***Populus tremula* L.**	**Common aspen**
***Sorbus intermedia* (Ehrh.) Pers.**	**Swedish whitebeam**
***Tilia cordata* Mill.**	**Small-leaved lime**
Tilia x euchlora K. Koch	Caucasian lime

2.2 Trees which are valuated as suitable in both categories (drought tolerance, winter hardiness)

Botanical Name	Common Name
Alnus cordata (Loisel.) Desf.	Italian alder
Carya ovata (Mill.) K.Koch	Shagbark hickory
Castanea sativa Mill.	Sweet chestnut
Celtis bungeana Blume	Bunge's hackberry
Corylus colurna L.	Turkish hazel
x Cupressocyparis leylandii Dallim.	Leyland cypress
Diospyros virginiana L.	American persimmon
Eucommia ulmoides Oliv.	Gutta-percha-tree
***Fraxinus excelsior* L.**	**Common ash**
Gymnocladus dioicus (L.) K. Koch	Kentucky coffee tree
Nyssa sylvatica Marshall	Black tupelo
Phellodendron amurense Rupr.	Amur cork tree
Pinus peuce Griseb.	Macedonian pine
Platanus occidentalis L.	American sycamore
***Pyrus communis* L.**	**Common pear**
***Pyrus pyraster* Burgsd.**	**European wild pear**
Quercus imbricaria Michx.	Shingle oak
Quercus palustris Münchh.	Pin oak
***Quercus robur ssp. sessiliflora* (Salisb.) A. DC. (*Q. petraea* (Matth.) Liebl.)**	**Pedunculate oak**
Quercus rubra L.	Northern red oak
Ulmus parvifolia Jacq.	Chinese elm
Zelkova serrata (Thunb. Ex Murray)	Japanese zelkova

Landeshauptstadt Hannover

CAPITAL CITY HANNOVER
THE MAYOR AND CEO OF THE CITY OF HANOVER

DIRECTORATE OF ECONOMIC AND ENVIRONMENTAL AFFAIRS
DEPARTMENT ENVIRONMENT AND URBAN GREENSPACE
DIVISION ENVIRONMENTAL PROTECTION

Arndtstraße 1
30167 Hannover
67.1@hannover-stadt.de

Text:
Dirk Schmidt und
Caroline Bank, Elisabeth Kirscht, Susanne Luft,
Jens Pohl, Jennifer Schneider, Norbert Voßler,
Ingrid Weitzel, Hans-Otto Weusthoff, Monika Winnecke

Editorial:
Silke Beck, Dirk Schmidt

Translation:
Eleanor and Manfred Lemke

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