

1. The City under Climate Change - The Adaptation Strategy for the City of Hanover

Dirk Schmidt

City of Hannover

Environmental Protection Sector

<https://doi.org/10.15488/6748>

Abstract

The paper shows the impacts of climate change in the city of Hannover. Problems with heat load and extreme weather events (heavy rain, summer droughts) are already in existence. In the future, these impacts are expected more often and more extreme. Hannover has dealt with the consequences of climate change at an early stage and has already developed a local adaptation strategy in 2012. The strategy comprises of eight fields of action, which were defined as particularly significant. The article describes the adaptation measures which are implemented in the last years and which are necessary in future to maintain the quality of life for the people living in Hannover.

***The Complex
of Problems
Regarding the
Urban Climate***

The climate of a city differs significantly from that of a widely undeveloped landscape. This is primarily due to the changes caused by human building activity (housing, trade and industry, traffic areas), whereby the soil and surface characteristics, the water balance and the air composition are changed sustainably. The typical urban climate is influenced by the degree of sealing and the proportion of green space, the building structure (height, density, shape and arrangement of the buildings), the heat storage capacity as well as the thermal conductivity of the artificial surfaces and by air pollutants and waste heat.

The larger a city, the more intensive is the formation of a heat island and therefore the temperature difference to the undeveloped surrounding area. This is pronounced distinctively during summer nights, and it amounts to a maximum of seven to eight degrees centigrade in Hannover. This is also illustrated in the climate analysis map of the City of Hannover, that was developed in 2016 (GEO-NET 2016). During a summer night, the warmest sectors are found in the inner city and on the large industry and trade areas, the coolest sectors at the outskirts and in the river meadow.

The city climate is most distinctly formed during so-called autochthonous weather conditions. These are low-wind high-pressure weather conditions with dominating local influences. These weather conditions can appear annually on 15 to 25 per cent of the days in Lower Saxony.

Besides local climatic changes, the high extent of sealing has further consequences for the city. Due to the sustainably changed soil and water balance, heavy rain events can more often lead to flooding and thereby damages to streets and buildings. There are examples of this in many German cities. Severe flooding as a result of heavy rain with corresponding damages occurred in Dortmund and Bad Honnef on 20th June 2013, in several communities in Bavaria and Baden-Württemberg on 29th May 2016 as well as in Hannover on 22nd June 2017.

***Intensification
of Negative
Consequences
for the City of
Hannover due
to the Climate
Change***

The negative consequences of the dense urban building development will appear more often and more extreme with the continuing climate change. In Hannover, the following changes are to be expected:

1. Increased heat load, heat waves, a significant rise in the number of hot days and tropical nights with negative effects on human health
2. Changes in the distribution of precipitation, an increase in heavy rain and extreme weather events resulting in an increase in the risk of flooding and damages to buildings and associated infrastructure
3. Increase in periods of summer droughts with negative effects on agriculture, forestry and water management.

For the City of Hannover, the summer heat stress, changing under the influence of climate change in the course of this century, was simulated by means of a model calculation. Depending on the building structure (density of construction or proportion of green respectively) the number of days with heat stress varies in parts significantly.

In the inner city of Hannover, the number of very hot days (days with a maximum temperature of more than 30°C) will increase from actually nine to ten very hot days per year to 12 to 13 very hot days until the middle of the century. By the end of the century, there will be 21 to 22 very hot days on average (see Figure 1). As a result, the number of very hot days in the inner-city sector will more than double until the end of the century. Within the green areas, like the Herrenhausen Gardens, the number of very hot days will increase from actually two to three days up to nine to ten days until the end of the century (GEO-NET 2006).

Therefore, it can be concluded that the areas, in which the consequences of the global warming will become particularly evident, are characterised by an urban structure with a high building density, a high building volume and a low level of green facilities.

On top of that, the climate projections show, that the heat periods will last longer and their start will be moved into the springtime, a season, in which the human organism is not yet accustomed to the heat and therefore reacts more sensitive to heat stress. People affected by heat stress will mainly be older and weakened persons but small children, too. Against the background of the demographic change and the observed trend, that older people move from the surrounding regions into the city again (shorter ways, a higher level of service offers) the number of affected (heat sensitive) people will increase even more.

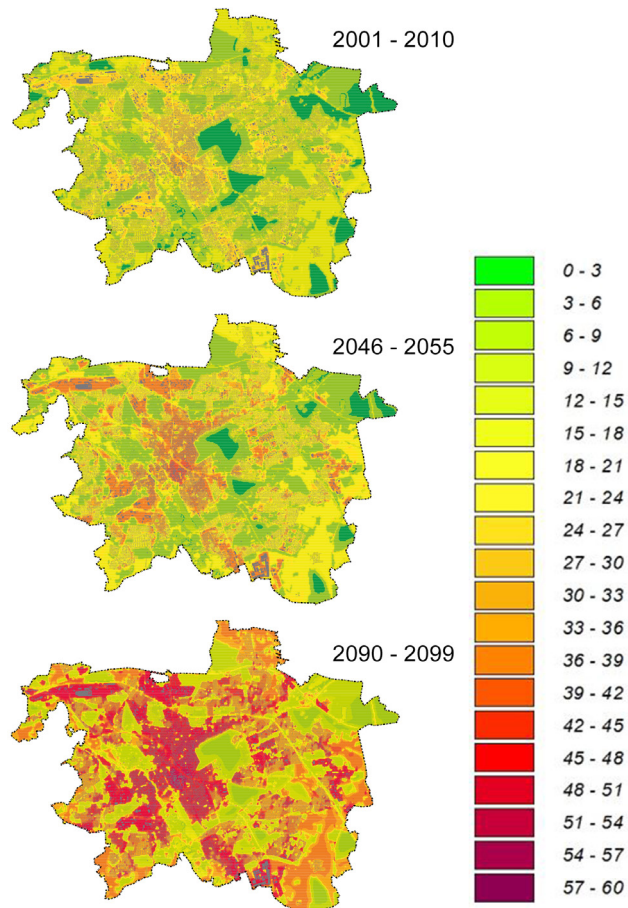


Fig. 1. Summer Heat Stress under the Influence of Climate Change in the State Capital Hannover – Average Number of Days with Strong Heat Stress at the Beginning, the Middle and at the End of this Century. (Geo-Net 2011)

The Adaptation Strategy for the City of Hannover

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. Since 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. What started with a thesis paper "Adaptation Strategies towards Climate Change" led in 2010 into the cross-departmental development of the adaption strategy for Hannover.

With regard to the expected changes caused by climate change (see above), three working groups were established, which developed adaption measures for different subjects. The results of the individual working groups were a central component in the development of the adaption strategy for the City of Hannover.

The "Adaption Strategy to Climate Change for the Capital City Hannover" was made public in April 2012. It comprises of eight fields of action, which were defined as especially important within the framework of the working group phase.

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

For the implementation of the initial adaption measures, the "Programme for the Minimization of the Consequences of the Global Warming" was compiled and provided with funds to a total of 1,050,000 Euros for the period 2012 to 2016. Furthermore, some measures were funded through other programmes (e.g. Flood Protection, Street Restructuring).

**Examples from
the Action
Programme**

**Action Field 1:
Flood Protection**

The Action Programme “Flood Protection in Hannover” with an investment volume of about 30 million Euros covers several actions. At first, the outflow width of the river Ihme in the area “Schwarzer Bär” had to be expanded. Therefore, the Benno-Ohnesorg-Bridge had to be reconstructed (see Figure 2). The old bridge formed a bottleneck, which slowed down the floodwater runoff and caused floodings in the south bordering city regions. With the new bridge, the span was significantly increased by 21 metres. As a further measure, the foreland on the east side of the river was dug out by 1.5 to four metres over the length of 1.2 kilometres, and thus the volume for flood retention was increased.

Besides that, the extension of the dyke in the city district Ricklingen was part of the action programme. There had been a gap in the existing protection systems which was closed by means of an earth wall and a protective wall.

In the past, the originally near-natural rivers and brooks were strongly straightened and with the usage of the near-natural meadows flood plains were lost. In the course of flood events, the loss of natural retention areas leads to the increase of the high-water mark, particularly in the lower course of waters (and especially in the Leine river). In 1996 the Hannover Council decided to develop the Hanoverian flowing waters more near-nature and structured again. Integral parts are, amongst others, the creation of high-water profiles with variably designed slope angles and berms 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. The measures are aiming at slowing down the outflow of the flowing waters and thus moderating the flooding events. Meanwhile, 22 waters have been completely or partially redesigned near to nature since 1996.



Fig. 2. The Reconstruction of the Benno-Ohnesorg-Bridge with the Newly Designed Ihme Embankment. (DEPARTMENT ENVIRONMENT AND URBAN GREENSPACE, STATE CAPITAL HANNOVER)

An important part of the adaption strategy concerns the rainwater management. The aim is water-sensible urban development. Floodings should be avoided as far as possible and the canalisation relieved through the retention of water on the surface as long as possible (without causing damages). Particular importance in this respect is laid upon the multi-usage of areas. Innovative solutions and new views of “Water in the City” are required. This also includes the acceptance of water at places, where it is usually not found.

**Action Field 2:
Rainwater
Management
in the Handling
of Heavy Rain
Events**

The following measures are examined and where possible implemented:

- Identification of 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 the inclusion of heavy rain events into the planning of streets, ways and places; extension of traffic areas as backwater areas.
- Adaptation of the design of street profiles, curbs and house entrances to water drainage necessary in case of heavy rain

events.

- Temporary usage of green areas as emergency overflow areas (multi- and interim usage of areas).
- Retention of rainwater through temporary technical 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-dimensional traffic areas; enlargement of tree-grids in the inner city, desealing of inner courtyards, reduction of the traffic area at the “Hohes Ufer” through the construction of a green corridor according to the programme City 2020).

An example of rainwater management in a development area is the “Zero:e park” on the southern periphery of Hannover. 300 private homes were erected here in a passive house method of construction. A trough-trench system manages the drainage of this area. Surplus water is retained in three dry rainwater retention basins and led throttled into the receiving water (Hirtenbach). Despite the sealing, no more water is led into the receiving water as was before the development of the former farmland.

The development area “Herzkamp” in the Bothfeld city district (250 housing units) which is actually under construction, is completely built without a rainwater canalisation. The rainwater is drained away in road-accompanying troughs and troughs within greenspaces. In the case of heavy rain events, emergency waterways and overflows take care of a damage-free discharge into the greenspaces bordering the construction area.

***Action Field 3:
Preventive Soil
and Groundwater
Protection***

Near-nature soils contribute 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, heat extremes can locally be diminished. The water retention function of near-nature soils contributes to the reduction of impacts of heavy rain events and dry summer periods. Therefore, the positive climatic effects of the soil should be maintained as much as possible, and the soils have to be protected in the best possible way against the impacts of climate change.

The adaptive measures contain:

- Maintenance of near-nature soils that are still existing in the city
- The reutilisation of already built-up areas
- Desealing of areas and
- Restoration of natural soil functions.

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

The adaption strategy of the City of Hannover also provides for a promotion programme for façade and roof greening. This programme started in 2012 and is offered in cooperation with the non-governmental organisation BUND (“Friends of the Earth Germany”) for the Hannover Region. The BUND informs building owners about the advantages of roof and façade greening as well as the funding opportunities that were made available by the City of Hannover. Funded are up to a third of the eligible costs of a measure. In case of roof sizes up to 250 m², this amounts to a maximum of 3,000 Euros, with more than 250 m² 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.

Action Field 4: Roof Greening

Ideally, the greened roof should be combined with a photovoltaic system (see Figure 3). The experiences of recent years have shown that the efficiency of these systems is better than on tarmac or gravel roofs.

The positive effects of a roof greening are:

- Retention of precipitation (up to 70% with extensive and up to 90 per cent with intensive greening)
- Reduction of peak discharges by 50% (remaining runoffs are released time-delayed into the canalisation)

- Cooling of the surroundings by water discharge and evaporation (evapotranspiration)

Furthermore, roof greenings offer a habitat for numerous plants and animals and increase, thereby the biodiversity, especially in densely populated urban quarters.



Fig. 3. On the roof of the maintenance depot Stammestraße a photovoltaic system was installed in addition to the roof greening. (DEPARTMENT ENVIRONMENT AND URBAN GREENSPACE, STATE CAPITAL HANNOVER)

A mapping of greened roofs in the year 2016 showed that in the City of Hannover 3,131 roofs with a total area of about 836,200 m² have been greened. The greened roofs can primarily be found in commercial areas. In residential areas mainly subterranean garages and single garages are greened. Thereby the number and size of greened roofs increase from the inner city to the outskirts. The largest greened roof has a size of 9,645 m².

**Action Field 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 evaporation of plants increases the moisture of the air, 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.

However, 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.

With all replacement plantings of trees and bushes in the future, 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:

- Choice of shrub species that are better suited to the future climate situation (choice from the Climate-Species-Matrix; Klima-Arten-Matrix, KLAM)
- Irrigation of the urban green areas. In this context, alternatives to drinking water are preferred (cisterns, rain retention basins)
- Enlargement (desealing) and substrate exchange at tree grates in order to increase the vitality of the trees

A fundamental renewal of the tree population in the southern part of Philipsbornstraße was carried out in 2012/2013. The row of street trees standing there, consisting of Norway maple and Sycamore trees was in a desolate condition. After the removal of the trees, the root areas were restored, the tree grates enlarged by desealing measures and with Ginkgo tree and Honey locust two drought-tolerant species were planted.

In 2014, a total of 14 trees were planted on both sides of the street in an up to then a 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.

**Action Field 6:
Climate-adapted Urban
Planning and
Climate-adapted
Construction**

The 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 daily 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.

Sustainable city planning empowers the so much needed consensus for action against climate change worldwide.

The climate changes that have to be expected require a re-thinking 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 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.

With regard to the city structure, it is especially important to continue specifying "The City of Short Ways" in future as an essential target for the city administration. 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.

Especially important in this context is, of course, the preservation of cold-air productive open spaces, fresh air corridors and the graduated green system of close-to-home, city-district-near and wide-ranging green spaces. 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. Interlinking of the new green-spaces 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. A redensification should furthermore take priority over an unlimited exterior development.

Further elements / measures for a climate-adapted city are:

- Shade giving greens (deciduous trees with large crowns and pergolas) as well as structural shade creators (arcades, sun sails)
- Fountains (moving water) at places with a high thermal load (see Figure 4)
- Optimising the cooling of buildings (avoiding the usage of air conditioning systems)
- Light-coloured surfaces and façades (usage of the Albedo-effect)



Fig. 4. The Trammplatz in front of the New Town Hall – on hot days, the fountains offer a welcome cooling possibility in the city. (DEPARTMENT ENVIRONMENT AND URBAN GREENSPACE, STATE CAPITAL HANNOVER)

**Action Field 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 before the planning stage, e.g. of construction planning and urban development planning and be integrated in the plans. Therefore, a “Specific Map Climate Adaptation” at the scale of the Land-use Plan was developed as part of the adaption strategy. It is meant to serve as a decision support tool for the implementation of adaptation measures and as a basis for all climate-relevant planning.

The specific map shows, for example, important cool air delivering areas and bioclimatically higher burdened settlement areas. Climate comfort islands are displayed, smaller cool air delivering areas (less than 2 hectares) like greened inner courtyards and public places with a welfare impact which is in general limited to the area itself and does not unfold a long-distance effect (like larger cool air delivering areas do). The climate comfort islands offer, especially on very hot days, pleasant places of stay for the city residents. Furthermore, the specific map points out areas, in which a significant rise in the heat burden will take place until the middle of the century. Moreover, institutions like day-care centres and hospitals are shown, in which people stay

who react more sensitive to heat stress. Additional information of the map relates to the floodplains along the rivers that are defined by law and residential areas with an above-average population density.

It is planned, to include further subjects in the specific map in future.

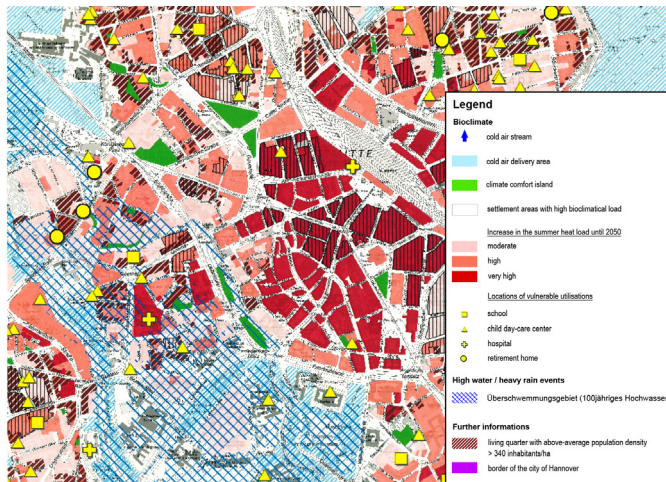


Fig. 5. Excerpt from the Specific Map Climate Adaption (on the right: Legend). (DEPARTMENT ENVIRONMENT AND URBAN GREENSPACE, STATE CAPITAL HANNOVER)

It is very important that the population will be informed about the subject of climate change and the possibilities of adaptation measures. Because the citizens of the city are not only persons affected by the climate change but also actors who themselves are responsible for the implementation of adaption measures, for example through a change in behaviour during heat periods or through taking precautionary measures on their houses to protect them flooding or storms.

Action Field 8: Public Relations and Educational Activities

The City of Hannover offers material on the subject of climate change for day-care centres and schools. Furthermore, it informs citizens by flyers and brochures (e. g. Tips for behaviour on hot days) but also through public lectures. Between 2013 and 2017 the city organised in cooperation with the Adult Education Centre Hannover a series of events totalling eight lectures on different aspects of the climate change.

Conclusion Climate change represents great challenges for the cities. Especially larger cities will feel the consequences of the climate change even stronger because their climatic conditions have changed due to strong sealing and dense building as well as through waste heat from factories, air-conditioning and cooling systems, central heating and car exhaust gases. The city is warmer, dryer and less exposed to the wind than the rural surrounding. Climate change will increase this effect even more. This requires short-term measures, to protect for example the health of citizens but also long-term measures, for example in the urban development planning in order to counteract inner-city heat islands, to minimize the danger of flooding during heavy rain events or to adapt the city trees to the changed climate conditions.

The Capital City Hannover had already published an adaption strategy to the climate change in 2012, that contains eight fields of action with a bundle of measures. In the same year, the “Programme for the Minimization of Impacts of Global Warming” was compiled, and the initial adaption measures were implemented.

The aim of a long-term adaption strategy is, to maintain the quality of life for the people living in Hannover at the present high level and where possible even to increase them through adaption measures to the changed climatic conditions, that are initiated as early as possible. Therefore, it is necessary to think ahead and to act, whereby a climate-adapted urban development is maintained, and the resilience is promoted.

Bibliography

- GEO-NET, 2006: Karte der sommerlichen Wärmebelastung unter dem Einfluss des Klimawandels in der Landeshauptstadt Hannover.
- GEO-NET, 2011: Werkstattbericht: Klimawandel in Hannover – Thermischer Wirkungskomplex
- GEO-NET, 2016: Analyse der klimaökologischen Funktionen und Prozesse für das Stadtgebiet von Hannover
- LANDESHAUPTSTADT HANNOVER, 2017: Leben mit dem Klimawandel – Hannover passt sich an. Schriftenreihe kommunaler Umweltschutz, Heft 53 (2), geänderte Auflage. Hannover.
- ROLOFF, A., BONN, S. & GILLNER, S., 2008: Klimawandel und Baumartenwahl in der Stadt – Entscheidungsfindung mit der Klima-Arten-Matrix (KLAM), Dresden