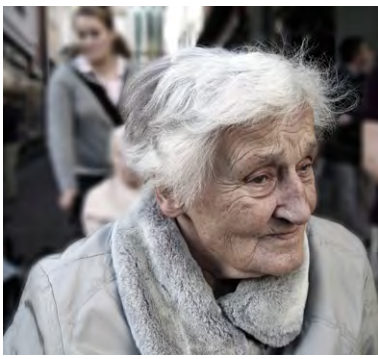










Climate Protection Part Concept

Adapting to the Impacts of Climate Change in Berlin – AFOK

Executive Summary

Content

This brochure is a summary of the draft for an 'Adaptation Concept of the Impact of Climate Change in Berlin' (AFOK), which has been developed from end of 2014 to early 2016 on behalf of the Berlin Senate Department for Urban Development and Environment. It has been funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safty (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, BMUB).

The AFOK final report has two parts: Part I: Main report. Part II: Supplementary Material. The report has been published by a research consortium led by the Potsdam Institute for Climate Impact Research (PIK) in July 2016: Reusswig, F.; Becker, C.; Lass, W.; Haag, L.; Hirschfeld, J.; Knorr, A.; Lüdeke, M.K.B.; Neuhaus, A.; Pankoke, C.; Rupp, J., Walther, C.; Walz, S.; Weyer, G.; Wiesemann, E. (2016): Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept. Teil I: Hauptbericht; Teil II: Materialien. Potsdam, Berlin. Juli 2016 [Adaptation Concept of the Impacts of Climate Change in Berlin (AFOK). Climate Protection Partial Concept. Part I: Main Report; Part II: Supplementing Material; available in German only]. Juli 2016.

Download of the AFOK final report at: http://www.stadtentwicklung.berlin.de/umwelt/klimaschutz/klimawandel/de/anpassungskonzept_berlin/index.shtml

Adapting to climate change: A general interest for the growing city

The world's climate is changing. The effects are also felt in Berlin. They will accelerate, as we stand at the beginning of a profound change. For our growing city, this represents a major challenge. We must find ways to further strengthen Berlin not only as an economic, social and cultural center, but also to develop it in carbon neutral and climate-adapted manner. This is the only way to avert or to reduce the damage to the city and its citizens. We will ensure that - even under modified climatic conditions - Berlin's growth will continue to contribute to our goal: maintain Berlin's qualities as an attractive, efficient and livable European metropolis.

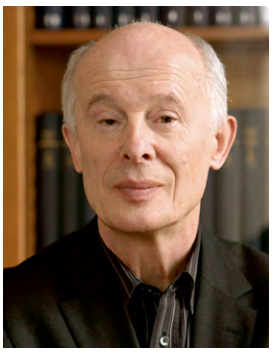
For this purpose, we will implement the tools we have developed together with the urban community, such as the Urban Development Concept (StEK) 2030, the Berlin Energy and Climate Protection Programme (BEK) 2030, or many other specific plans and projects. With the Berlin Energy Transition Act (Berliner Energiewendegesetz, EWG Bln), which came into effect by April 5, 2016, we dispose of the legal basis also for a comprehensive adaptation process.

On behalf of my administration, the Potsdam Institute for Climate Impact Research has in collaboration with other partners and experts, elaborated a 'Berlin Concept for Adaptation to the Impacts of Climate Change' (AFOK). It provides the strategic framework for adapting nature, the economy and society to climate change while at the same time preserving the quality of urban life.

This brochure is meant to bring the AFOK closer to you and shall help to develop an understanding and passion for the future task of climate change adaptation.

Andreas Geisel

Senator for Urban Development and Environment



Adaptation or mitigation, which is a priority in facing climate change risks? The unequivocal answer is: both. Both are essential. Therefore, it is good that Berlin does both. The Berlin Energy and Climate Protection Programme want to reduce the emission of greenhouse gases and aims at carbon neutrality until 2050. The 'Berlin Concept for Adaptation to the Impacts of Climate Change' (AFOK) presents another building block for Berlin's climate policy. We are pleased that this is happening on the solid ground of science, and that the Potsdam Institute for Climate Impact Research (PIK) was able to assist in the elaboration of both concepts.

We must now renounce fossil fuels, if we want to limit climate change to a manageable level. The immediate reduction of emissions and divestment are important tools: withdrawing public funds from climate-damaging investments in coal or oil in order to put the released funds in clean and sustainable technologies. The 'Paris Accord', enacted at the COP 21 in December 2015, has set clear goals here.

Even a climate neutral Berlin will have to adapt to a changing climate. We have already deposited too much CO_2 in the atmosphere; it will remain effective there for centuries. Our Earth responds slowly however relentlessly to climate change. Climate change is a global reality already today, even in Germany. Heat waves and extreme rain events are increasing. Without adaptation, the consequences of climate change in Berlin would lead to considerable damages. All the more important it is that the Berlin Senate now quickly starts with the implementation of the measures provided by AFOK.

Hans Joachim Schellnhuber

Director of the Potsdam-Institute for Climate Impacts Research

1. Introduction

Adaptation to climate change – a challenge for Berlin

Since the beginning of industrialisation, the Global Mean Temperature (GMT) has been gradually rising. Scientific research has shown that humankind is responsible for the major part of this increase. Therefore, it is called anthropogenic - caused by humans - climate change.
The major driving force is primarily the burning of fossil fuels (coal, oil, and natural gas), large-scale deforestation, and agricultural production, not at least livestock. The related emission of greenhouse gases (CO_2, CH_4, N_2O, and others) is changing the chemical composition of the atmosphere and hence its radiation balance. While the global mean temperature has been rising by about 0.8 °C during the past 100 years, Europe has been warming by about 1.3 °C in the same period. According to IPCC, this warming is accompanied by the change of rainfall patterns, melting glaciers and polar ice caps, rising sea levels and increasing weather extremes.

The first decade of the 21st century is among the world's warmest years since the beginning of instrumental weather records more than 100 years ago.

In terms of temperature, the years 2014 and 2015 have been Germany's hottest two years since the beginning of instrumental measurement in 1881.

Climate change has just begun. Due to the inertia of the climate system, the temperature continues to rise even if we should succeed to stabilize greenhouse gas emissions at current levels. However, that is not to be expected. Despite the Paris Agreement, signed at the end of 2015, global emissions continue to rise. If this trend is to be upheld, the global mean temperature might increase to a range of 2 to 6 °C by 2100.

Berlin will inevitably be affected. Our city is adjusted to a past climate that we assume to be 'normal'. The same applies to our environment, as well as to people, buildings and the urban infrastructure.

The expectable climate change will modify this historical 'fit' of the city and its climate in an historical unprecedented manner. Our understanding of what is being normal will be considerably shifted. The record heat wave summer of 2003, claimed at least 50,000 lives and additional heat stress related deaths in this unusually warm summer. By 2050, this kind of summer will become a normal one. By 2100, the summer of 2003 will be felt as a particularly cold one.

Berlin must actively adapt in order to reduce the damages from future climate change, but also to exploit the future opportunities that climate change might bring. It is in no way sufficient to wait and see, or hope for the spontaneous adaptive capacity of the urban society. The latter will be needed. But it cannot be activated without reliable future climate scenarios, without a detailed analysis of vulnerabilities and coordinated adaptation strategy by the Senate of Berlin. AFOK forms a basis for all this.

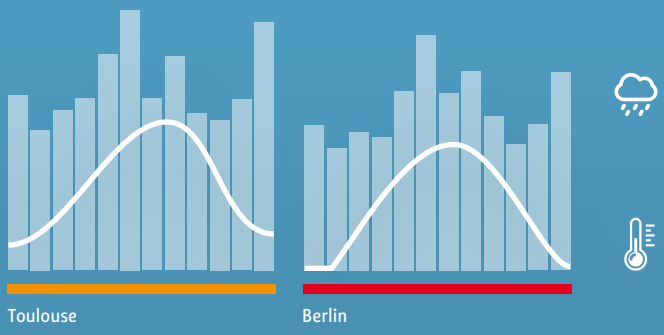


Fig. 1: According to the AFOK scenarios, Berlin's climate (monthly temperature and rainfall patterns) of 2100 will resemble today's climate of the city of Toulouse in Southern France.

Berlin

2100

In 2100, Berlin might have the climate that Toulouse has today

2016

Toulouse

Berlin acts: The AFOK as part of an overall strategy for adaptation to climate change

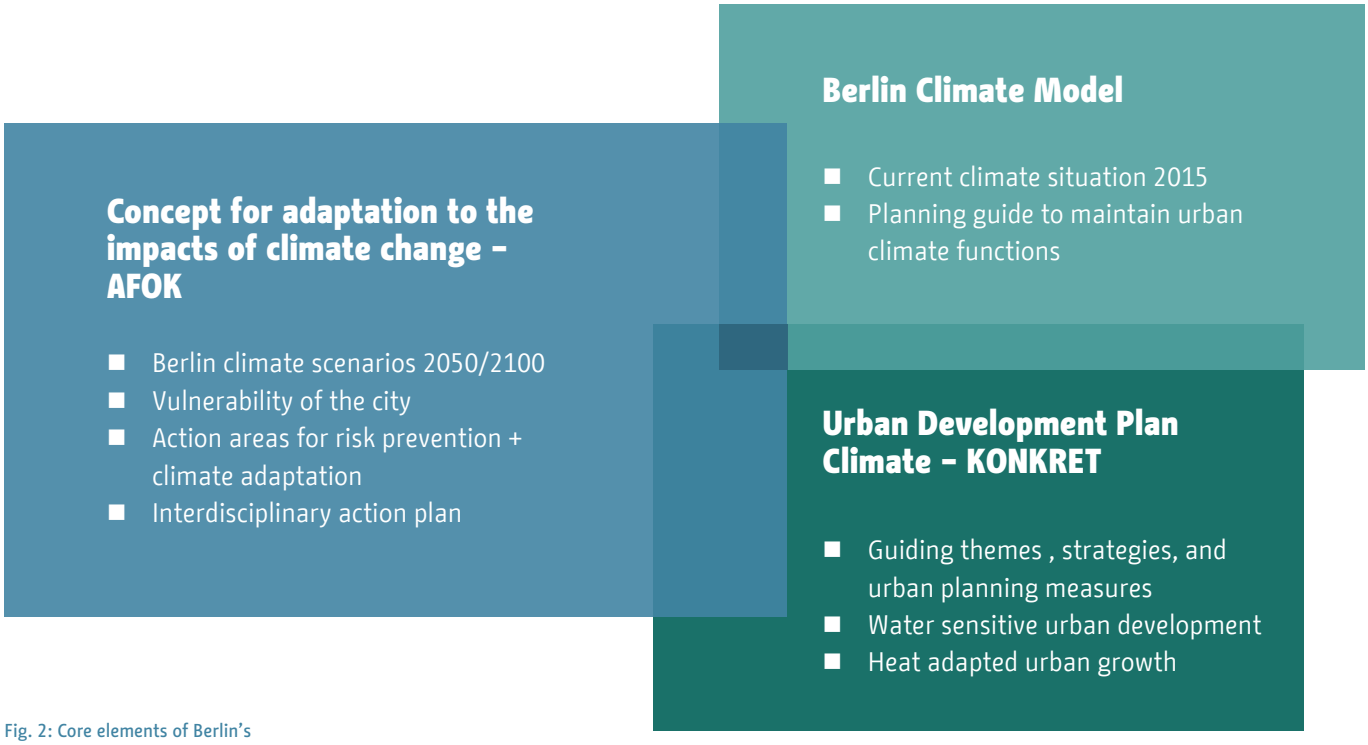


Fig. 2: Core elements of Berlin's climate change adaptation strategy.

Not just since cooperating with the AFOK Berlin has started taking charge of climate change impacts and how to deal with it. The first report on the consequences of climate change for Berlin was already issued as early as 2009, and in 2011 the Urban Development Plan Climate (StEP Klima) was presented by the Senate. In 2015/16 an updated version has been worked out, focusing on the specific challenges of Berlin's recent growth. StEP Klima KONKRET (StEP Climate Concrete) is addressing future climate change under a deliberately space-oriented planning perspective. Since 2016, the Environmental Atlas, Berlin's map and info server on environmental issues, provides a new climate model ('Planning Advices Urban Climate'), showing what areas suffer from adverse climatic conditions already today, and where Berlin has capability of relief.

The AFOK is addressing Berlin's future climate and it selects a sectoral, not a space perspective. It thus takes up the objectives of the Berlin Energy Transition Act (EWG Bln), stipulating the improved adaptive capacity of natural, social and economic systems as well as the preservation of the functionality of urban infrastructures and the quality of life as an obligation for the Berlin Senate.



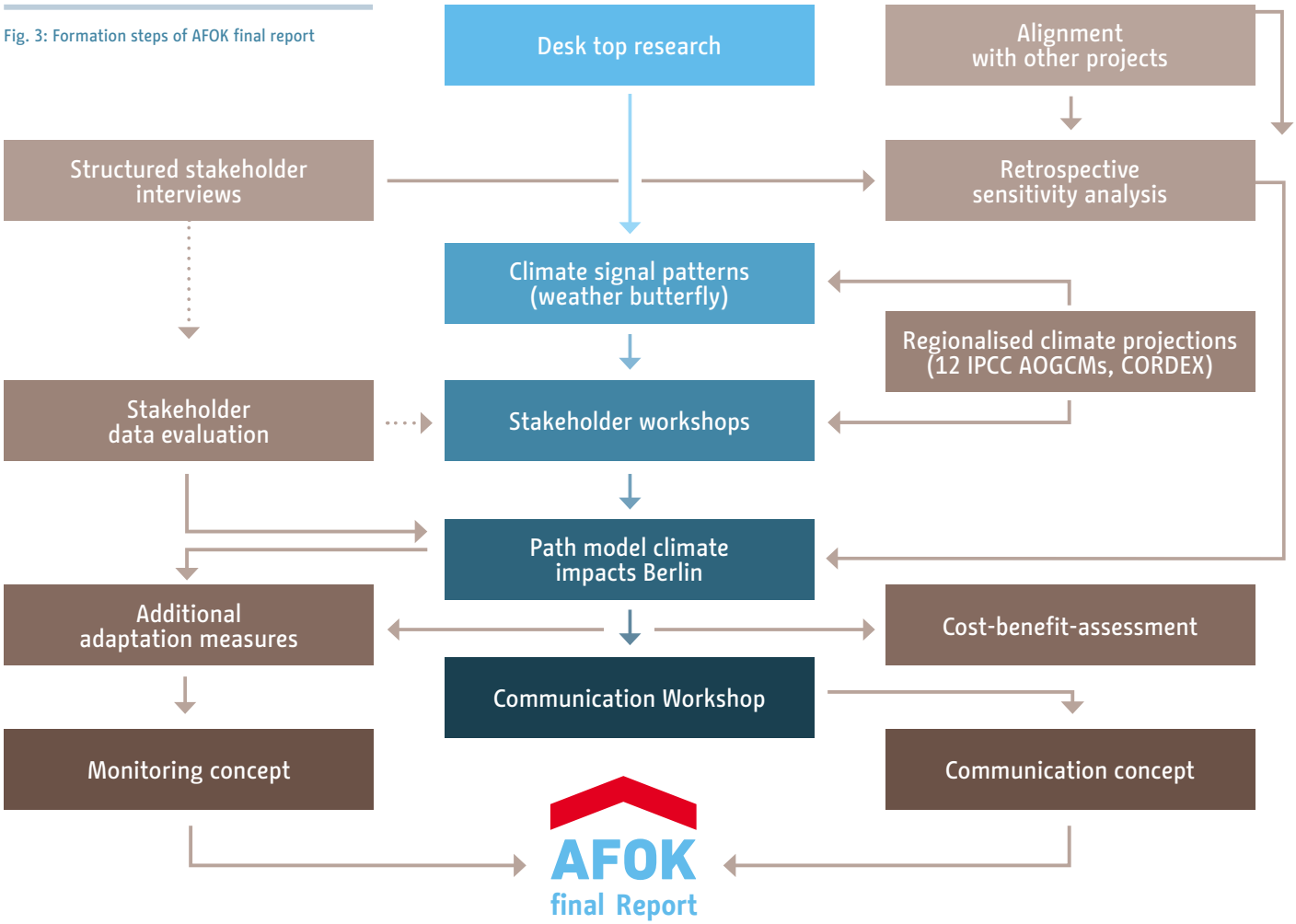
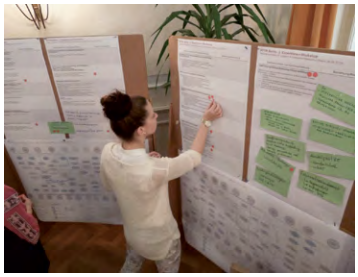



Fig. 3: Formation steps of AFOK final report

Together with StEP Climate/StEP Climate KONKRET and the Planning Advices Urban Climate, the AFOK provides a powerful framework for an overall climate adaptation strategy for Berlin. Based on current global and regional scenarios it describes the climatic changes that Berlin is facing in the near (2050) and distant (2100) future and identifies against this background the vulnerabilities for various socio-ecological sectors. In addition, AFOK offers strategic starting points and concrete proposals of measures that aim to actively counteract future challenges and to reduce damages if possible.

AFOK has been worked out in a transdisciplinary work process and in a close dialogue with the expert community and the administration. More than 100 people brought their knowledge and experience into the process via stakeholder interviews and three workshops.

Fig. 4: At the AFOK stakeholder workshops the expert public was able to discuss two major issues in plenary and group discussions: 'What are the future impacts of climate change for Berlin?' (vulnerability) and 'What can we do about it?' (measures).

2. Regional Climate in Berlin 2050 and 2100

Methodology

Since we cannot predict the future climate, we have to assess it based upon climate models. Currently there is a multitude of them, each endowed with specific strengths and weaknesses. There is no way to tell with certainty today which one will have been the one that has predicted the future correctly. It would therefore unwise to put all eggs in one basket and rely on only one climate model. For some time past a so-called scientific standard has generally been accepted to consider model ensembles which means including several future models. This has been done in this report. For the vulnerability analysis and the development of measures of AFOK, 12 combinations of six regional and five global climate models were used. A standard parameter served as an emission scenario that assumes global warming in the range of 2.6° to 4.8 °C until the end of the 21st century.

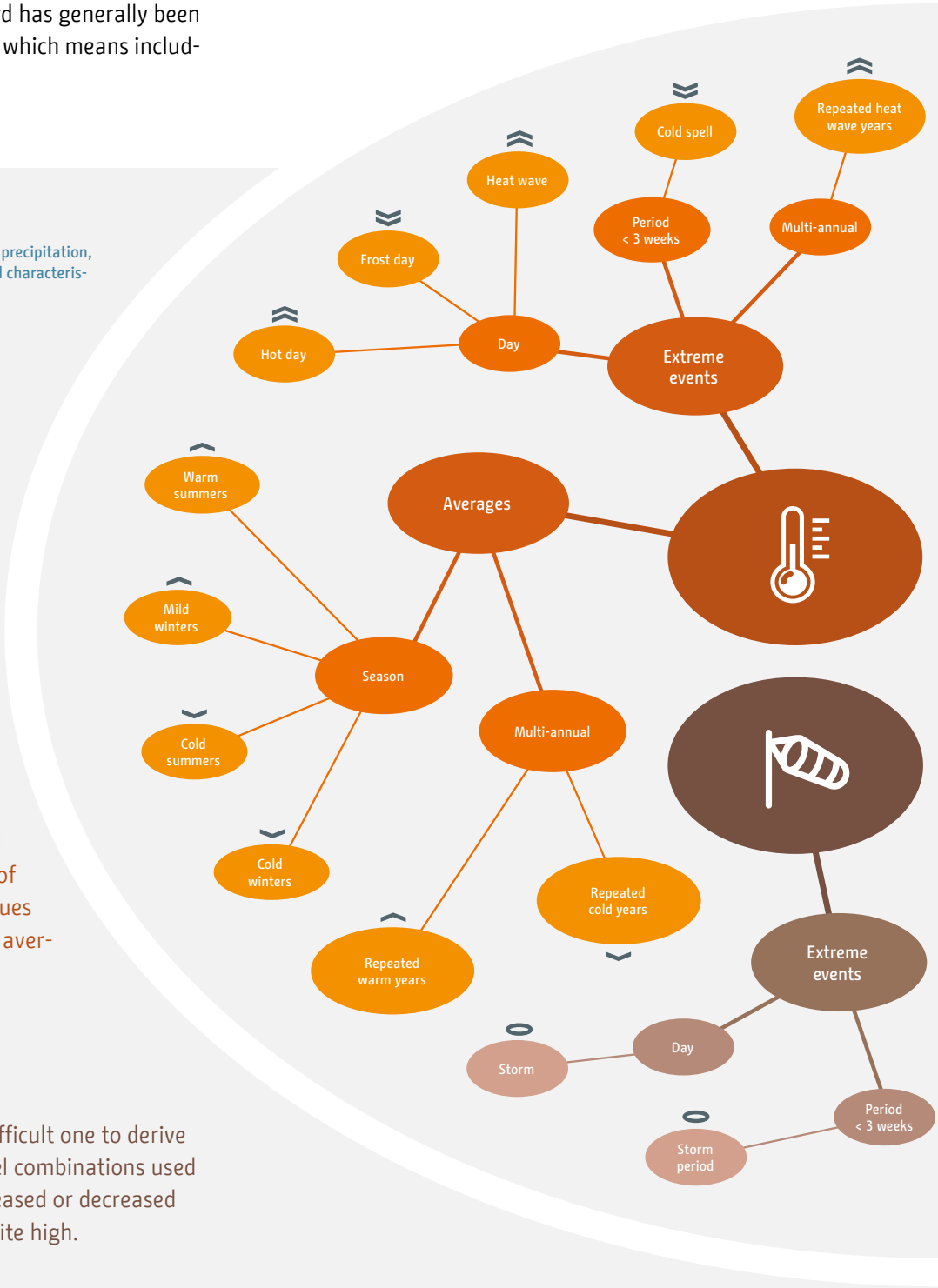


Fig. 5: The three key climate phenomena temperature, precipitation, and wind and the expected trends in different temporal characteristics (the AFOK 'Weather Butterfly').

Temperature

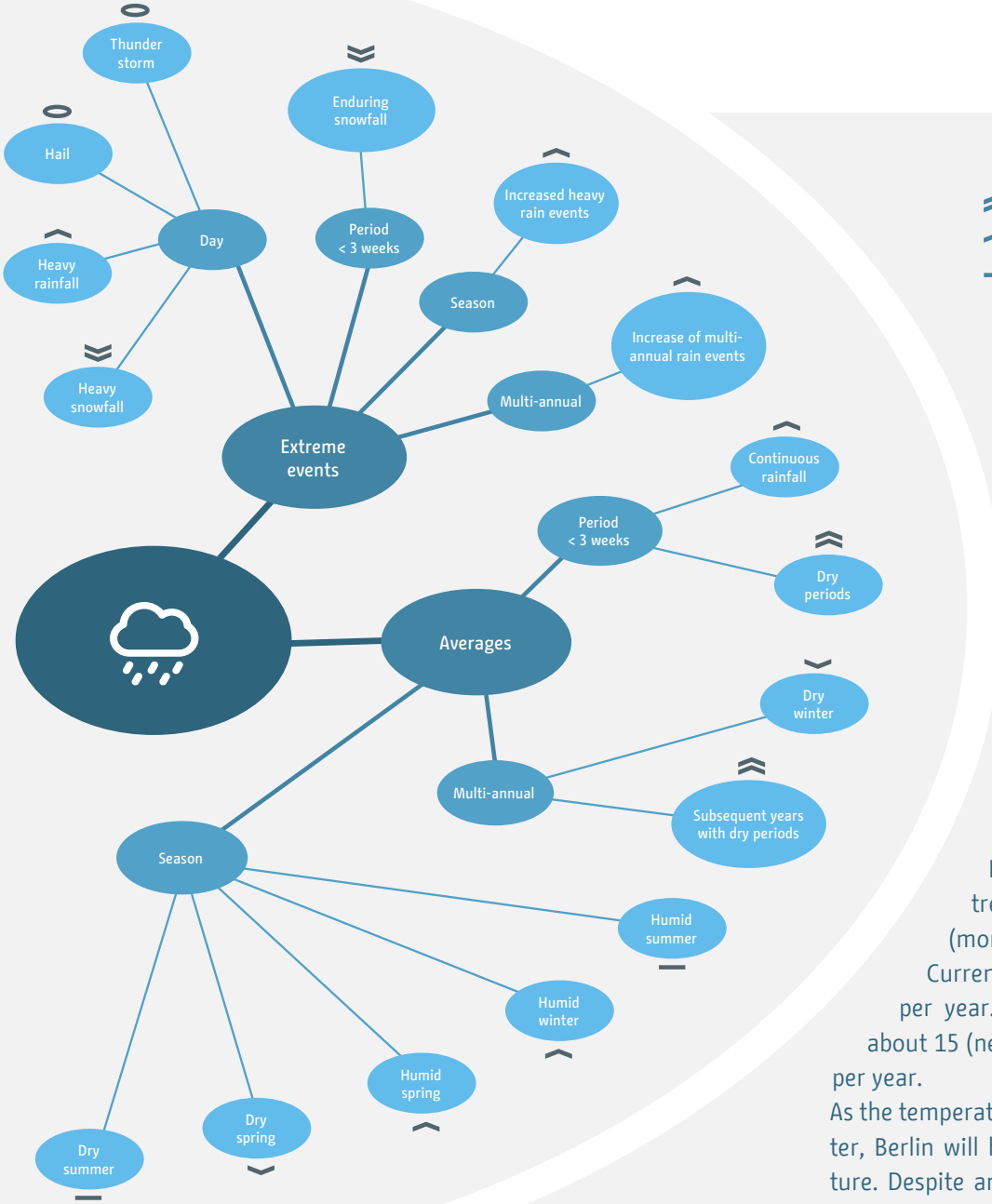
Raising temperatures in the Berlin region have already been observed in the recent past. For the near future, a further increase in the average daily maximum temperatures of about 1.2 °C, for the distant future additional 3.2 °C can be expected. This increase will be particularly striking during autumn and winter. Summers in Berlin will also become warmer. Towards the mid of the century, summers will be about 1 °C warmer than today, towards the end about 3 °C. It is one of the 'hallmarks' of climate change that the extreme values will increase more markedly than the averages.

Wind

The variable wind speed is the most difficult one to derive from the models. Until 2100, the model combinations used here do not show a clear trend of increased or decreased storm events. But uncertainties are quite high.

Climate Signals in detail

As a result, one therefore does not receive a single value for a specific climate parameter per time unit, but a frequency distribution of the various model results. As a basis for the AFOK vulnerability assessment and the development of measures, we assumed the range of outcomes that a majority of two thirds of the models used predicted.Subsequently, from the entire time span covered by the models until 2100 two focus periods have been selected as benchmarks for the AFOK impact assessment: the 'time slice' from 2031 to 2060 (termed 'near future'), and the 2071-2100 period (termed 'distant future'). The most relevant model results have been summarized graphically in the so-called 'weather butterfly' (cf. Figure 5), systematizing the key weather parameters in their respective characteristic in time.



Strong increase
Increase
No change
Strong decrease
Decrease
No projection possible

Precipitation

Due to climate change, Berlin will experience an increase of average annual precipitation of about 3 to 10% (near future) and 7.5 to 18% (distant future). The strongest increase can be expected in spring and winter, while it will be less marked in autumn and, especially, in summer. Particularly important is a trend in extremes: the increase of heavy rain events (more than 10mm precipitation per day). Currently, Berlin sees about 11 of these events per year. Under climate change, there will be about 15 (near future) or 17 (distant future) events per year.

As the temperatures will increase especially during winter, Berlin will have considerably less snow in the future. Despite an average increase in precipitation, we will experience more dry periods, combined with periods of heavy rainfall at other times.

3. Vulnerabilities and Measures

How vulnerable is Berlin to climate change impacts? The vulnerability of the city depends on several factors. The first one is the concrete character of climatic changes that have to be expected, such as temperature, precipitation, and wind, as has been shown in chapter 2. But the extent of potential loss due to climatic changes does also depend upon two further factors. Firstly, the exposition of something or somebody to weather signals is important. Heat waves for example will affect people working outside much heavier than people sitting in air -conditioned offices. The 'exposition' of the former is much higher than that of the latter. A second factor is the 'sensitivity' of a system. Small children or chronically ill people for example are much more sensitive to the risks of enduring heat waves than healthy adults.

A final decisive factor that determines the vulnerability of a system is its adaptive capacity. If urban infrastructures, buildings, organizational routines and individual behaviour are attuned to changing boundary conditions, their adaptive capacity will increase and their vulnerability decreases. This is exactly what the AFOK measures aim at: reducing or even avoiding potential losses and thus reducing Berlin's vulnerability.

In the following, the assessment of vulnerability to climate change will be presented separately for different fields of action, as exposition, sensitivity and adaptive capacity vary from sector to sector.

Berlin is not an island – Indirect effects of climate change

Climate change is a global phenomenon and its consequences will be felt differently across the world. Due to its geographical location in the center of Europe, its role as the German capital and the diverse functional interrelations Berlin is also indirectly vulnerable to climate impacts that occur elsewhere - for example, in southern Germany, France or Africa. In addition to the risks posed by so-called 'tipping points' in the climate system (such as the weakening of the Gulf stream), the following indirect effects can be observed in part already today:

- Environmental and climate refugees: In addition to many other causes, there are also increasing extreme events like floods and droughts that threaten the livelihoods of millions of people, especially in developing countries. For many of them flight is the only escape. Europe and Berlin are increasingly becoming the target areas.
- Foreign trade: Berlin's industry is heavily dependent on exports (50 percent) and import also plays a major role. Besides the EU, the regional focus is on the United States of America, Russia, Turkey and the Asia-Pacific region. Climate change affects markets and supply chains.
- Tourism: in 2015 foreign guests booked 45% of all overnight stays in Berlin. Travelers could carry diseases or be directly affected by climate change.
- Transport: Via its roads, rail, aviation and waterways, Berlin is connected to the world. Impairments caused by storms, heat waves or heavy rainfall elsewhere can lead to severe disruptions in Berlin.
- Power supply: Berlin's power grid is mainly placed underground and thus less vulnerable to weather extremes. However, due to its power import of about 40%, Berlin remains vulnerable towards weather impacts on the German and European power grids.

Adaptation to climate change at national and global levels will indirectly reduce Berlin's vulnerability. Successful adaptation in Berlin does not only help its local citizens.

Action Area Human Health and Civil Protection

The health of Berlin's population will be affected by climate change not only due to gradual changes of weather parameters, but also by an increased amount of weather extremes (e.g. heavy rain, heat waves).
Among minor complications such as sleep disturbance or impaired labour productivity, hot days and heat waves can lead to cardiovascular emergencies (up to heat strokes), cases of dehydration (the 'drying out' due to lack of fluid intake), and respiratory diseases (such as chronic obstructive pulmonary disease; COPD).

> ***Particularly distressing for the human organism is the presence of several hot days in a row, in which even at night no appreciable cooling occurs and most people cannot really recuperate.***

Studies suggest that heat stress results in a 43% higher mortality risk, especially in patients with chronic lung disease. Overall, especially the elderly, sick people and young children are at risk. Growing population numbers with a significant increase of the very old - so the demographic forecasts for Berlin - indicate an even higher future vulnerability. The result: an increase in hospital admissions (morbidity) and deaths (mortality). According to studies, Berlin has already experienced about 1,400 additional heat related deaths annually in the 2001 to 2010 period.
But climate change also entails 'creeping' health dangers, as living conditions for plants, animals and microorganisms gradually. This also allows new pathogens – usually mediated through new or native disease carriers ('vectors' such as mice, mosquitoes or ticks) – to settle areas that have been thus far 'blocked' to them by unfavourable weather conditions. Ticks for example, which can transmit Lyme disease, have not been a major problem for Berlin so far, could become more frequent here due to milder winters.

Fig. 6: Children need special skin protection against solar radiation.

Fig. 7: Climate change could increase skin cancer cases.

Fig. 8: 'Ambrosia Network Berlin': Ragweed eradication action in Berlin Adlershof on June 26, 2015.

Fig. 9: Climate change increases the risk that vector-borne diseases spread out – here Aedes albopictus.

Fig. 10: Sufficient fluid intake is particularly important for seniors.

Climate change may also lead to the appearance of new host organisms, bringing along pathogens of diseases hitherto unknown in our latitudes. Exotic species such as Aedes albopictus or Aedes japonicus propagate to northern latitudes. For none of these species proven evidence exists in the Berlin area, but they have already reached the geographical latitude of Berlin. Pyrexical tropical diseases, with often fatal outcomes, can occur more often. However, remaining uncertainties are high and hence further research is needed.

Measures

- Upgrading of early warning systems
- Improvement of individual physical fitness
- Adjustment of medication and counselling
- Augmenting rescue services and civil protection
- (Elderly) care programme for climate adaptation
- Hospital programme for climate adaptation
- Securing a sufficient drinking supply
- Adaptation/ improvement of operational health and safety
- Flexibility of working and opening times
- Heat adapted food and beverage offers
- Exploration of climate-related health risks
- Allergy-sensitive landscape planning

Influenced by climate change one can already today verify prolonged blossom periods of plants, associated with higher burdens on people suffering from pollinosis (allergies, which are transmitted through the air). Currently about 700,000 Berliners are suffering from pollinosis today, and climate change will most probably increase the number of people affected. If not treated, chronic asthma is looming. High dust levels in the air, a typical concomitant of heat waves, are additionally promoting the occurrence of allergies.

Another point of concern in Berlin is Ambrosia artemisiifolia, or common ragweed. This plant, an invasive species from North America, produces highly allergenic pollen and finds more favourable living conditions in the course of climate change. The same is true for the oak processionary: The backs of older caterpillars are covered with poisonous hairs containing an urticating toxin, which may cause skin irritation and asthma. In hot and dry conditions the oak processionary is spreading as a dreaded forest pest. Finally, the increasing risk of skin cancer due to an increased solar exposure must not be underestimated: Skin cancer ranges among the ten most common cancers in Berlin between 2000 and 2014 - with a tendency to increase.

The Berlin population must be made aware of the risks of climate change. We need a coordinated early warning system for heat events that effectively reaches those at risk in hospitals, day care centres, nursing homes, and day care organisations.

Doctors and pharmacists play an important role as competent and community multipliers. The first successful attempts at the Berlin Charité show: as a perspective, we need the climate-adapted hospital to protect vulnerable patient groups against heat stress. The drinking water supply in public places must be gradually expanded on a low threshold (drinking fountain) network. Particularly exposed occupational groups need to be better protected. In the long run, the working and operating hours have to come to the test bed. In a hooter climate, food can spoil more easily and should be better checked accordingly. During hotter phases, canteens should offer lighter meals. In general, we need better health monitoring, more research on the specific effects of climate change on public health, and an urban and open space planning that supports changing public health requirements.

Fig. 11: Rescuers are facing new challenges under climate change – for example in support of major events.

New challenges for civil protection

In addition to the Senate, the districts and the Berlin Fire Department, many private relief and rescue organisations are important actors of civil protection: the Arbeiter-Samariter-Bund e.V. (ASB) for example, or the German Red Cross (DRK), the volunteer fire fighters (FF), the Johanniter-Unfall-Hilfe e.V. (JUH), the Malteser Hilfsdienst (MHD) or the Federal Agency for Technical Relief (THW) are important pillars of the Berlin civil protection.

The adaptive capacity of the Berlin rescue services and civil protection – especially of the Fire Department as a core – can be classified as high. However, climate change will be associated with an increase in weather induced everyday risks, such as floods, emergencies due to heat stress, and – to a lesser degree – more fires due to more summer dry periods. More heat peaks and more heavy rainfall will occur in future summers in close succession, confronting the emergency services with new challenges. The so-called 'extraordinary incidents' will occur more often, asking for an improved coordination of the Fire Department, the police, and public as well as private rescue services. The Berlin Fire Department already today is offering disaster information and warning services for smartphones, SMS and E-mail (KATWARN). More people need to be interested in the use of these systems. In the medium term the vehicle fleet in the emergency services must be restocked, education and training have to take into account new risk situations, and the public needs to be included into the civil protection system.

Action area Buildings, Urban Development, Green and Public Space

Due to their dense construction volume, their reduced evaporation and the multiple barriers to the exchange of air, cities are significantly warmer than their surrounding countryside. This phenomenon is also known as 'Urban Heat Island' (UHI) effect.

The core urban areas within the Berlin S-Bahn-Ring are on average around 5 °C warmer than the mostly open areas of the surroundings of Berlin.

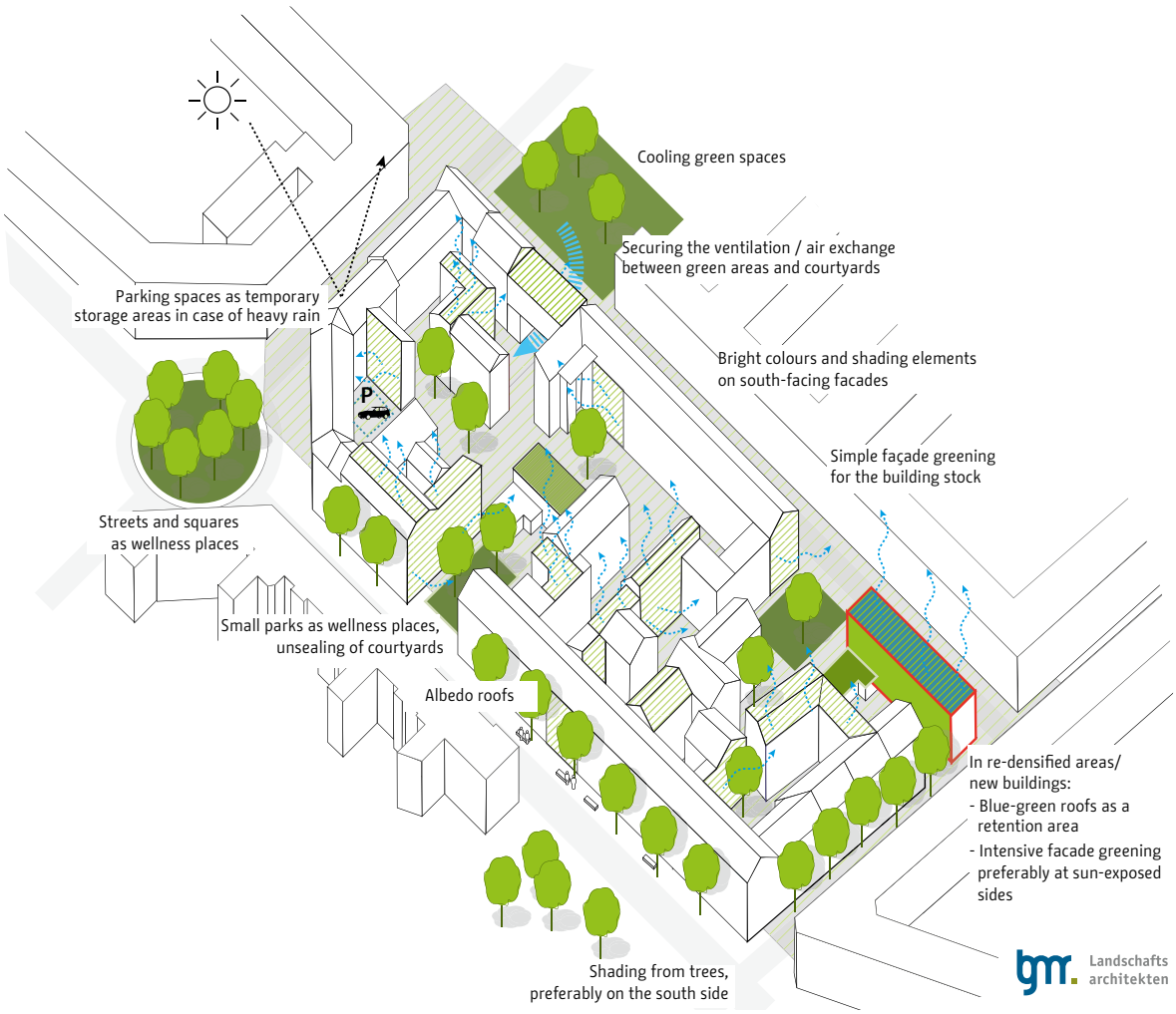
Thereby the built urban surface is increasing the health risks of its inhabitants due to the expected higher temperatures, especially in summer. Intermittent dry periods set the urban parks under stress. And the increase in heavy rain events will lead to more flooding in highly sealed urban space - road sections and basement are under water, underground shafts are in danger, the sewers are overstretched.

Although Berlin has experienced such events repeatedly in recent years, they are only the foretaste of what has to be expected in the long run. At the same time Berlin is growing – most recently by about 40,000 people per year, partly due to global migration processes. The construction of new residential buildings has a high priority, and in addition to homes, job opportunities, schools etc. need to be built.

The 'compact city of short distances' is still the paradigm of urban development. It additionally offers many advantages for the goals of climate protection. When it comes to climate adaptation, however, the urban fabric needs to be more open and requires de-densification.

This is a charged relationship, but not necessarily an irresolvable contradiction. Because with good planning we may well have both: more housing and simultaneously more cli-

Fig. 12: Adaptation potential in the compressed perimeter block development.

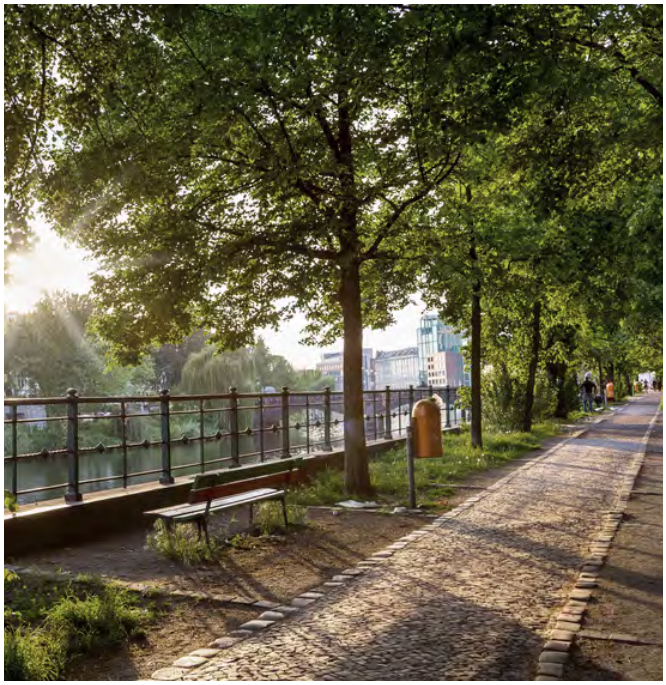


matic relief in the city. The two can go together if we not only consider the urban green surface area, but also its density and its multiple functions. If strategically important green areas are upgraded and retrofitted for climate change, Berlin can well benefit from the cooling and evaporation of its green areas – even without an increase of them.

The superior goal of all these measures is to rebuild and re-qualify the city surface in such a way that even a growing Berlin can maintain its quality of life in the face of climate change. If strategic green and open spaces are protected, if a systematic roof and facade greening is implemented, if the remaining urban green is revalued, if sealed areas become permeable for precipitation, if green comfort zones are built into the urban quarters, then Berlin can grow in a climate-adapted manner. A new handling of water in the city (see box 'sponge city' on page 17) complements these physical measures.

Measures

- Protecting climatic relief areas
- Creation of qualified green and open spaces, systematic strategy of roof and facade greening
- Increasing the resilience of urban green
- Climatic decoupling of new construction projects
- Climatic qualification of city surface
- Climate adaptation strategies at the neighbourhood level
- Pilot projects on climate adaptation
- Climate-proofing of existing planning instruments
- Provide cooled rooms during heat
- Limitation of conventional air conditioners
- Better information for tenants and owners
- Public debate on storm water management



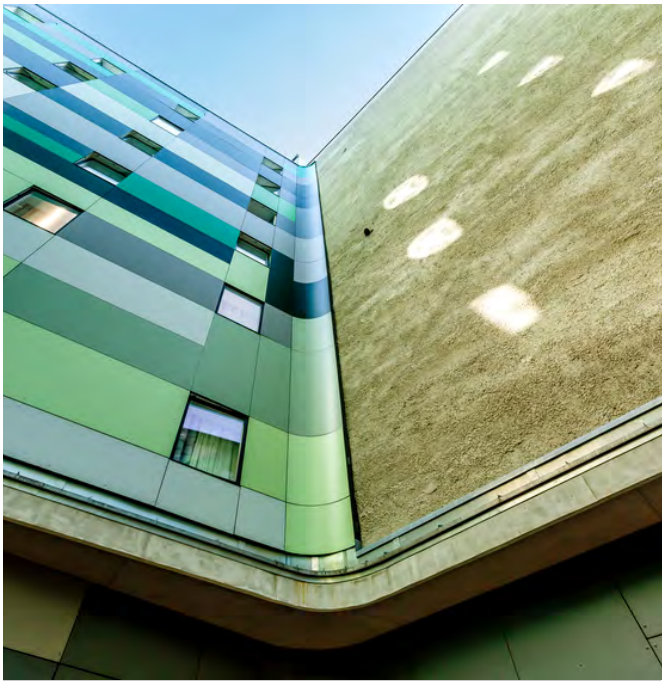


Fig. 13, 14: Shadowed public spaces in the urban centre, heat protection inoptimized facades

Action Area Water Supply and Distribution

Each year approximately 522 million m^3 rain water is falling onto the city region of Berlin. About 321 million m^3 of this volume seeps away, 142 million m^3 seep away into the ground, and almost 70 million m^3 are discharged via the sewage system. According to the AFOK scenarios two trends are particularly noteworthy: first, the annual precipitation will increase until 2050 by about 3 to 10 percent, and until 2100 by about 8 to 18 percent, particularly during winter. Secondly, under climate change we can expect an increase in heavy rain events, between about 14 and 40 percent by 2050, and about 22 to 80 percent by 2100. This results in a number of risks.

A well-known problem is posed by the combined sewer system, discharging rainwater along with waste water in a single sewer system. For historical reasons it can be found mainly in the inner city of Berlin. When heavy rainfall occurs, the combined sewer system is overloaded and discharges rainwater together with untreated sewage flows directly into the surface waters. The Senate and the Berlin water works (Berliner Wasserbetriebe, BWB) have been investing heavily in measures to increase the underground storage volume. But as climate change might lead to an increase in heavy rain events, it will pose a clear risk of counteracting or even eliminating the improvements reached by the investment of the recent years.

In the future, hotter summers may be associated with longer dry periods. This reduces the water flow through the sewage system, causing unpleasant odors. In addition, the water levels and the flow rate of river Spree can be reduced. Simultaneously, these weather conditions will lead to an increased water demand in the city.

Right in this field of action, a significant need for adaptation is given, if damages are to be avoided and cost burdens should be reduced. Through a combination of different measures Berlin's water supply and distribution can be made climate-proof. In this context it is very helpful that in recent years the BWB have been initiating a number of research and development projects, addressing exactly these future challenges.

The measures are intended to increase the decentralized rainwater infiltration, to prepare the surface of the city for temporary flooding and controlled drainage and to treat only the inevitable remaining amount of water in the classical sewage system. The free supply of drinking water in the public space has to be expanded rapidly. Water in the city needs to become more accessible and should also be designed in aesthetic attractive ways.

Measures

- Decoupling of rainwater management from centralised systems
- Flood-fit design of surfaces
- Adapting infrastructures to heavy rain events
- Adapting infrastructures to drought and heat
- (Drinking) water quality protection
- Increasing climatic effectiveness of water bodies
- Expansion of the drinking fountain network
- Creation of bathing facilities and swimming pools
- Water sensitive climate adaptation as public issue
- Information for vulnerable urban areas
- Exploration of climate change effects on water balance

Fig. 15: Combined sewers. Fig. 16: In order to combat the fish die-offs the aeration vessel is supplying surface water with oxygen.

Fig. 17: Rendering Flussbad Berlin/Friedrichsgracht with plant/gravel filter.

'Sponge city' Berlin

The measures in the areas of urban development and water must complement each other and achieve a synergistic effect, which is referred to here as 'sponge city' principle. Berlin needs to become a sponge city, so that it can deal with the risks of climate change well. What does that mean more concretely?

- The permeability of the city surface for rain water must be increased to reduce the runoff and to relieve the sewer. De-sealing and trough-trench systems are important here.
- Defined road sections, park areas or city courts need to buffer the expected precipitation peaks in a decentralised manner in order to protect sensitive buildings and infrastructure against urban flooding and relieve the sewers.
- At the same time the evaporation rate must be increased significantly. The evaporation process consumes energy, thereby contributing to the cooling of the urban climate especially in the warmer months.
- More small oases and wellness places in the Berlin districts are needed. In addition to their climatic and hydrologic functions, they also enhance the amenity of public spaces.
- A redesign of responsibilities and cost absorption is necessary and calls for improved coordination and communication with the urban society.

If Berlin is transformed according to these sponge city principles, it could increase its resilience; namely with regard to the two major effects of climate change - more heat and more heavy rainfall events. They could be significantly improved. The increase of costs for public infrastructure could be dampened, maybe even reduced, and the quality of lives and sojourning in the city can be enhanced.

Action Area Environment and Nature

Berlin is a green city. Almost 44 percent of the city is covered by forest, water, parks or sports grounds, allotments or agriculture - in Paris there are only 23 percent, in New York 27 percent. This 'green' Berlin has positive effects on the urban climate and is home to many animal and plant species. In addition, it offers various leisure and recreational opportunities.

Climate change will burden the soils. Dry periods will lead to hardening and compaction; heavy rains can promote soil erosion. Berlin's 76 peatlands occupy only 0.8 percent of the city area, but they do have important ecological functions with respect to water storage and the generation of cool air. Longer dry periods imperil their functions. Berlin's diverse water landscape is popular with nature lovers, bathers, anglers and boat athletes alike. Rising temperatures and the conditional sewage overflows due to heavy rains will negatively affect the water quality. Berlin forests are not only recreational areas. They also sequester CO_2, store (drinking) water, filter pollutants and cool the city. Hotter and partly drier summers put the trees under drought stress. Expected milder winters will increase the risk of pest infestation. The urban greenery, such as parks, gardens, street trees etc. does also cool the city and ensures lower surface runoff. But also the urban greenery can be put under stress in hot and dry summers and will require more care. Already today, attentive nature enthusiasts can observe how the growing periods of many trees, shrubs and crops have changed. Also fish, amphibians or birds show altered patterns of behaviour.

The impacts of climate change on biodiversity are difficult to assess. Worldwide and in Germany deforestation and agriculture are still the most important drivers of biodiversity loss. Future climate change will lead to a shift of habitats, thus setting individual species under pressure. The corresponding trends must be strictly observed and explored further. More than 100 areas of nature and landscape protection must be monitored in their spatial context and need to be connected so that endangered species can migrate better.

Only about 2 percent of the Berlin land area (1,985 ha) is dedicated to agriculture - mostly for grain cultivation, permanent pasture or for growing fruit. The farms should be protected against damage caused by extreme events. Agricultural lands should be preserved, not least for their service to provide fresh and cold air.

The proposed measures are intended to better protect the sensitive parts of the green infrastructure of Berlin (for example, by securing and increasing the forest conversion programme). Berlin's nature has to become more resilient to climate change (for example by planting more (native) species resistant to stress). The urban biodiversity of Berlin can be better protected by linking-up of nature protection areas and by an intensified use of the existing instrument of eco-accounts.

Fig. 18: The Berlin Tiergarten - resort, 'green lung' and cooling factor in the inner city.

Measures

- Precautionary soil protection
- Upgrading of the existing soil monitoring
- Protection and restoration of the Berlin peatlands
- Expansion of the Berlin peatland monitoring
- Backup, maintenance and development of the Berlin Forests
- Environmental monitoring of forests
- Climate resilient and locally adapted plantations
- Establishment of area pools / eco-accounts
- Review of existing protected areas
- Security and maintenance of Berlin's cultural landscape
- Increase of the urban green volume
- Campaign on climate adaptation in allotments

Action Area Energy Supply and Solid Waste Management

Fig. 19: Power Station Klingenberg in Berlin-Rummelsburg.

Fig. 20: Adaptation measures for employees working mainly outside reduce their vulnerability.

Climate change will in the longer term reduce the heating demand due to milder winters, while hotter summers on the other hand will lead to an increased demand for cooling of buildings. In the interests of Berlin's climate neutrality target, the additional cooling of buildings should be realized primarily through passive measures (for example, by shading, ventilation, use of evaporative cooling), and by using renewable energy. Trigeneration (combined cooling, heat and power, CCHP) with an increasing share of renewable fuels is an option that fits well to Berlin's current energy structure.

Throughout Germany the aboveground power grid is considered vulnerable to extreme weather events – there is a small but non-negligible risk of blackouts. In Berlin, most of the electricity network is underground. But even here the climate change can be dangerous – for example by so-called 'summer frost', that is line interruptions by subsidence of the soil due to prolonged dry periods. Transformer stations can fail at temperatures above 35 °C. Due to technical improvements in the cooling of conventional power plants the thermal load on river Spree have been reduced in recent years. Increasing water temperatures due to climate change do thus not pose a significant risk in Berlin, other than in most other water cooled power plants in Germany. Grid upgrading, the roll-out of power storage, emergency planning and the improved coordination of task forces will make Berlin's power grid less prone to climate change damages.

The city's waste management will be affected in two ways by climate change. Firstly, rising summer temperatures can affect the entire waste cycle. Odors will aggravate, and compost bins offer improved growth conditions for bacteria and other micro-organisms. Secondly, more heat events will impede on productivity and health of employees, especially outdoors (waste collection, street cleaning, recycling centers, composting plants).

The adaptation strategy in the waste sector has to identify and improve sensitive process steps. For example, while abbreviated collection cycles for the compost bin are no issue today, this needs to be reconsidered in the future. Already today the occupational safety and health of outdoor employees needs more attention, e.g. via lighter workwear or more cooling boxes for waste truck teams. In the medium term, the shifting of working hours to cooler times of the day needs to be considered.

Measures

- Promoting energy-efficient cooling systems
- Take precautions for power supply disturbances
- Planning of energy systems under changed environmental conditions
- Optimization of energy infrastructure, focus: networks
- Optimization of energy infrastructure, focus: storage
- Assurance of waste collection during heat events and improved health protection for staff members
- Boost efforts to avoid waste

Action Area Industry, Services and Financial Sector

Berlin's economy includes more than 170,000 firms, mostly small and medium enterprises, and has about 1.3 million employees. The focus of value creation lies with the service and trade sectors and likewise important are the construction and manufacturing industries. Climate change affects the economy in three ways. Firstly, extreme events can damage buildings and facilities. Secondly, there are adverse effects on the economic processes (from logistics to the water and energy supply to disposal). Thirdly, climate change can also impair the productivity of the work force. Estimates of the value losses due to heat waves range from 0.03 to 2.8 percent of the current gross national product - depending upon the intensity and duration of the event. Looking at the Berlin gross domestic product of 2015, this would mean losses in the range of 37 million € to 3.5 billion € per year.

First of all, the economy has to recognize these dangers and provide enterprise-specific risk assessments. In particular, small and medium enterprises (SMEs) need support for this step. Moderated round tables to exchange experiences are therefore a first step for them. Certain industries (e.g. the construction industry) need reliable and user-friendly weather forecasts. Via the chambers, associations and the insurance industry, the creation of operational adaptation strategies should be encouraged and supported financially for SMEs.

Summer heat protection in commercial buildings should be expanded in order to protect the employees. Climate-friendly cooling options should be preferred. In the long run, we have to rethink working and opening hours, which requires the cooperation of management and trade unions. Last but not least, the development of adaptation solutions is also an opportunity for the Berlin economy.

Measures

- Provision of reliable weather forecasts
- Training for damage prevention due to weather extremes
- Round tables for exchange of experience
- Adaptation of government aid for construction and of implementation deadlines
- Design of corporation-specific climate adaptation concepts
- Design of sector-specific climate adaptation concepts
- Transition to flexible working and office hours
- Improved heat protection during summer
- Improved risk prevention for outdoor construction works

Fig. 21: Employees working outside (e.g. construction workers) are particularly vulnerable to the effects of climate change.

Action Area Traffic

The expected changes in climate will affect both the traffic and the transport infrastructure.
AFOK research shows that the number of road accidents increase with temperature. The main reason for this effect is that warmer weather leads to higher use of bicycles in the urban traffic. As a consequence, under climate change conditions we will have to improve the traffic safety especially of bicycles. Cars are less sensitive to heat stress, but more to moisture on the streets.
Pedestrians are sensitive to heat and moisture alike. As both heat and heavy rainfall events will increase in the future, the security and comfort of pedestrian traffic in Berlin has to be improved i.e. by building crossovers and putting in place shady design in public traffic space, drinking fountains or arcaded sidewalks. These will also promote public transport, as every travel with busses and trains starts and ends with a walk. Particularly exposed stations and waiting areas need climatic optimization, for example by roofing or shading.

Fig. 22: Heavy rainfall is flooding streets impeding traffic.

Already today, Berlin road surfaces suffer from heat stress. On motorways, dangerous faults are forming on very hot days (so-called 'blow-ups'), the dark tar covers of city streets soften up. New road constructions and road repairs need a shift towards heat resistant surface materials. They should simultaneously cushion the effect of rain and reflect the solar radiation better. As part of the 'sponge city' strategy the Berlin road space must be also redesigned so that it can discharge rainwater peaks. For monitoring a special task force 'transport infrastructure check' is needed.

Measures

- Application of adapted road covers
- Adaptation of the road drainage to more heavy rains
- Reduction of traffic-related NO_x emissions
- Ensuring an environmentally friendly composition of the mode of transport
- Improve the safety of cyclists
- Improve cooling in public transport
- Maintain safety for pedestrians
- Introduce Task Force transport infrastructure check

Climate change as 'Smog-Amplifier'

Climate change is associated with increased solar radiation. This leads to an augmented production of ground level ozone from the originating substances NO_2, CO and volatile organic compounds (VOC). More than 80 percent of these substances are a by-product of internal combustion engines. Especially susceptible to elevated ozone levels are high-risk groups such as young children or people with chronic respiratory diseases. Even without the additional production of chemical precursors climate change in Berlin will lead to increased ozone pollution. If we do want to keep the ozone concentration at the current level, the motorized individual traffic must be reduced. This is not only a climate protection requirement, but also needed for an improved climate change adaptation – a clear example of synergies between both pillars of climate policy.

Action Area Tourism, Culture, Sports

With almost 12 million arrivals and 28.7 million overnight stays Berlin is the top tourism destination in Germany. Accordingly, the tourism industry is an important economic sector. Berlin has Germany's largest and most versatile cultural programme, and many people from all over the world visit the city for exactly that reason. Sport offers in Berlin are equally overwhelming. About 600,000 people belong to one of more than 2,300 sports clubs.

Many activities in tourism, culture and sports are held outdoors. They are therefore sensitive to changes in climatic conditions. On the other hand, climate change also offers clear opportunities for Berlin. The tourist season is likely to expand, and the hotel and restaurant industry could benefit, for example by offering attractive outdoor deals, especially if care is taken for shading. Many outdoor areas can be longer used for sporting activities.

But there are also discernible risks. Tourists are increasingly exposed to sun and heat. They need easy-to-understand information and warning systems for prevention. In order to assess and manage the risks and opportunities of climate change for the Berlin tourism industry a coordinated strategy is needed along with a modified marketing concept. At cultural and sports events a free supply of drinking water must be ensured. Here we also need to think about the relocation of opening and event times. Finally, the outdoor facilities will be exposed to more drought and heavy rainfall events. Improved maintenance concepts and the drainage must be adjusted to the new conditions, too.

Fig.: 23: People looking to relax on the banks of the Spree.

Measures

- Adaptation of offers in the cultural and sports area
- Free supply of drinking water
- Refreshment facilities at events
- Marketing concept: climate adjusted city tourism
- Inclusion of tourists into civil defense and early warning
- Improved drainage of sports fields

Fig. 24: Basketball court in Schöneberg

Fig. 25: 'Drinkmen' – Mobile water supply on the Carnival of Cultures.

Action Area Education

Education is another important sector which has been assessed by AFOK – for mainly two reasons. Firstly, the educational sector is itself vulnerable to the impacts of climate change. Secondly, the education sector plays a key role for the future perception of and coping with climate change.

Measures

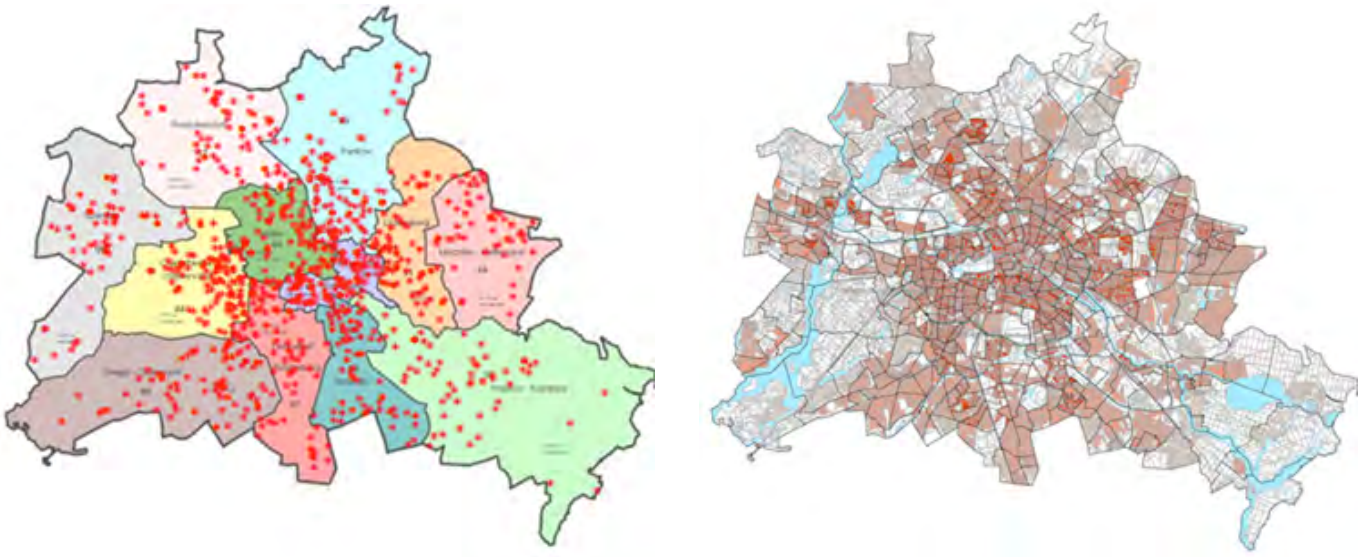
- Toughening-up of school buildings
- Promotion of school gardens
- Adaptation of the (pre-) school organisation
- Schools as places of exchange of experience
- Integration of climate adaptation in educational programmes
- Climate adaptation as part of BEK networks and continuation schemes
- Anchoring of climate adaptation in the curriculum
- Climate education in adult education centres
- Promoting education campaigns with partners

The more than 2,100 institutions of early childhood education and care are attended by almost 150,000 children. Berlin's about 800 schools were attended by some 300,000 pupils during school year 2015/16. Due to their urge to move as well as inadequate hydration children are particularly susceptible to heat stress. The spatial distribution of day-care centeres and schools follows the population distribution, so that the majority of these institutions in Berlin are located in areas with already elevated temperatures (urban heat island effect).

In order to adjust the Berlin educational sector to climate change, first the buildings must be improved: summer heat insulation, shading and natural cooling areas have to be provided. The outdoor areas of the schools must offer sufficient protection too. This can easily be combined with the establishment of learning and experience venues.

The organization of the (pre-) school education must be made sufficiently flexible in the face of more heat events, e.g. with respect to the time-off scheme due to excessive heat, especially during sports hours. We also need more heat adapted food and drink offers, as well as an adaptation of rules for ahead-of-schedule school finishing times. Schools can serve as multipliers and partners for climate adaptation measures in the neighborhood. Finally, the issues of climate change, mitigation and adaptation should become more systematically contents of the curriculum. Here, collaboration between AFOK and the education measures proposed by the Berlin Energy and Climate Protection Programme (BEK) is helpful.

Fig. 26, 27: High coverage between the spatial location of schools in the city (left figure, red dots) and the boosted thermal stress in certain parts of Berlin (see dark gray colored areas in the picture to the right).



4. Making Adaptation Happen

Implementation

Taking the AFOK, the STEP Climate/ StEP Climate KONKRET, and the updated planning reference map Berlin disposes of excellent planning and strategy bases to transform the German capital into a climate-proof, resilient city. This transformation can be realised and the implementation costs are well below the damages avoided. Climate adaptation is therefore necessary also from an economic perspective.

Berlin's green and blue infrastructure is a great asset for this endeavor and its ecosystem services are very often provided at low or no costs. This nature capital needs to be qualified and strengthened. In part, it can serve as a complement, if not substitute for the city's grey infrastructure.

The Berlin Energy Transition Act, adopted and issued in spring 2016, provides a sound legal basis for adaptation to climate change as well.

Now the measured proposed by AFOK need to be discussed publicly and enacted consequently. The necessary funds need to be provided in a timely manner, the cooperation between Senate und districts has to be expanded while the relevant economic stakeholders and the society have to be won over to get involved.

Monitoring

Climate change will become more noticeable in the next years. Exactly how the climate is changing and what climate change impacts will occur in Berlin must be continuously observed. AFOK proposes a monitoring system together with sets of indicators for all action areas. They are informed by the widely known monitoring system of the OECD, differentiating between 'state', 'impact' and 'response' indicators.

In addition to the observation of the urban climate, monitoring is particularly needed when it comes to public health effects, the various impacts on ecosystems and the urban infrastructure. Climate and climate impact monitoring in Berlin can be build in many parts upon existing or already planned monitoring activities.

Finally, the monitoring of the actions taken by the political and administrative system as well as by privates is needed. It is an extra task then to also monitor the physical effects of these measures, requiring all types of indicators and expert evaluation on top.

Such a monitoring system is important in order to be able to make adaptation to climate change itself adaptable and enable flexible responses.

Communication

Climate change in itself is a well-known issue, but most people still do associate it more with climate protection (mitigation) than with adaptation.

But mitigation and adaptation belong together - not only in Berlin. This needs to be communicated more intensely. It is essential to inform the urban community about upcoming risks and to underline that action is needed – and especially how the individual can do something.

Nationwide comparative studies show that the perception of heat related health risks is much lower in Berlin than elsewhere – despite the fact that Germany's capital belongs to the most vulnerable regions of the whole country.

Adaptation communication must not only help to resolve this lacking risk awareness. Communication is also needed when it comes to motivate people for improved self-protection and more help for others.

Unusual communication formats can be helpful here, e.g. via 'stumbling blocks' on localized climate risks in the public space, information on cool places in the city, or on adaptation competitions in the neighborhood.

5. Conclusion

Climate change is already a reality and will significantly worsen in the future. Berlin, with its highly-densified areas is particularly vulnerable to the expected increase in heat events, more frequent heavy rain periods and periodically occurring dry phases.
Particularly vulnerable are the elderly, infants and chronically ill people. Those working outdoors and tourists are in this risk group, too.
Here a heat early warning system and various preventive measures are needed. The rapid expansion of the public drinking fountain system is necessary. Berlin‘s economy has to take structural and organizational measures to maintain labour productivity at its current levels.

Protecting critical infrastructure

The urban infrastructure is endangered and must be protected. For several years now, the Berlin combined sewer system is upgraded through technical measures in order to reduce the environmental impacts of recurring rain water overflows. Climate change has the potential to undermine these investments by more heavy rain events. More surface storage capacities have to be created, complementing the subterranean storage facilities. Berlin’s city surface has to become more permeable via de-sealing and greening. This will also increase the surface water storage capacity, helping to cool the city during summer heat periods (‘sponge city’ principle).

The largely subterranean power grids of Berlin need a continuous climate check, as well as the traffic infrastructure. We need to adapt the traffic routing in such a way that the environmental alliance (pedestrians, bicycles, public transport) can continue to function well.
After all the urban nature – forests, parks, public green areas, allotments – need to be better protected against heat, drought and pest infestation.

Participation of all groups of the society is required!

Under the AFOK, more than 80 measures for all nine sectors under consideration were developed. If implemented, our city is well prepared for climate change. Many of them also have synergies with the Berlin Energy and Climate Programme (BEK), aiming at climate-neutral by 2050.
The Berlin Senate has to play a key role here along with the districts, since it has to decide and implement many of these measures. The Senate can assist in implementation, whereas the districts of Berlin should become role models for climate adaption. Adaptation should also become more anchored in the education system.
As with climate protection, the implementation of adaptation can only succeed if the business sector and the urban society are actively involved. After all it‘s also about their own well-being.

Glossary

Adaptability: ability of a system or actor to react to changing climatic and environmental conditions by system or changes in behaviour and thereby reduce the vulnerability. Adaptation to climate change can be done consciously/intentionally or unconsciously/spontaneous.

Biodiversity: Refers to the variety of life on three different levels: (1) within species (genetic diversity), (2) between species (species diversity) and (3) between the habitats of species (ecosystems diversity).

Dehydration: In Human medicine, dehydration refers to a lack of fluid in the human body. The sensation of thirst is already to interpret as a physical signal of a negative water balance.

Unsealing of areas: reversal of the sealied area, i.e. the air- and water-tight cover of the natural soil by man-made buildings.

Exposition: The exposition of a system (i.e. sector) in relation to climate change or a particular climate signal describes how strongly the sectors are subject to climate change.

Extinction: biological term for the dying out of a species.

Green (also: blue-green) Infrastructure: Strongly promoted by the European Union the concept of 'green infrastructure' aims at the strengthening and regenerating of existing natural capital. The nature-based ecosystem services – such as water retention, cooling, improve air quality, etc. – are in many cases able to complement or even to replace the performance of the conventional 'gray-brown infrastructure' (that is the built infrastructure). This is due to the fact, that the green infrastructure is often more durable, more cost effective and multifunctional.

Heat stress: Strain caused by the heat on a human, animal or plant organism with a negative impact on the metabolism, especially on the water balance (risk of dehydration).

Morbidity (also: disease recurrence): An epidemiological term for the disease rate related to a specific population.

Mortality (also: mortality rate): Demographic term for the number of deaths in a given period based on 1,000 individuals in a population.

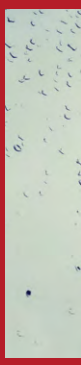
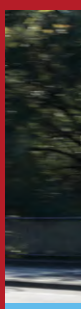
Ecosystem Services: Direct and indirect benefits, that individuals or societies obtain from functioning ecosystems.

Resilience: The ability of a social or ecological system to withstand external disturbances or shocks and to resume function after longer or shorter periods of time and maintaining its structure.

Summer Smog: Summer smog (also smog, ozone smog or L.A. smog) refers to the load on the ground-level air by a high concentration of ozone and photochemical oxidants.

Urban heat island effect: Refers to the higher average temperature in a city compared to surrounding areas, caused mainly by the higher heating of the building and the lower air circulation in the city. It is influenced by the choice of a built-up surface, the evaporation and the air exchange.

Vulnerability: The lost susceptibility of a system and its exposure and sensitivity to climate change (which determines its potential damage) on one side, and the adaptability on the other side.

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