Sino-German Urbanisation Partnership

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

URBAN CLIMATE ADAPTATION IN GERMANY

KEYSTONE PAPER 6

Sino-German Urbanisation Partnership

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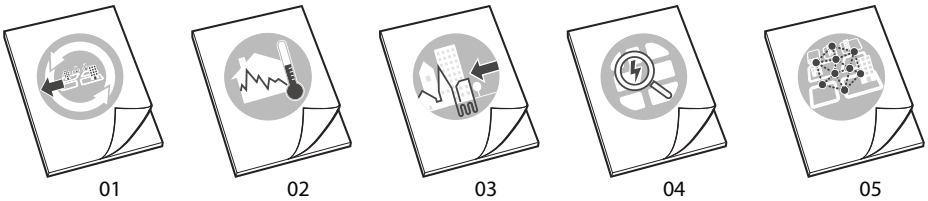
This document is part of ten keystone papers looking at current emerging topics in the building and city sector, focusing on energy efficiency and resilience. The keystone papers were developed within the framework of the Sino-German Urbanisation Partnership as a basis for the forthcoming working period and cover following topics:



01 Plus Energy Buildings and Districts

02 Energy Efficiency of Buildings and Districts in Urban Renewal

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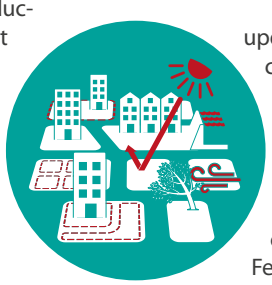
LIST OF ABBREVIATIONS

AFOK	Adapting to the Impacts of Climate Change in Berlin (Konzeptstudie zur Anpassung an die Folgen des Klimawandels in Berlin)
DAS	German Federal Strategy for Climate Adaptation (Deutsche Anpassungsstrategie an den Klimawandel)
DWD	German Weather Service (Deutscher Wetterdienst)
GIS	Geographic Information Systems
KIAK-RH	Climate Change Adaptation in the Hannover Region (Klimaanpassungskonzept für die Region Hannover 2018)
KLIMAKS	Climate Adaptation Concept Stuttgart (Klimaanpassungskonzept Stuttgart)
KlippS	Climate Planning Evaluation Stuttgart (Klimaplanungspass Stuttgart)
SteP Klima	Urban Development Plan for Climate (Stadtentwicklungsplan)

1. INTRODUCTION

Cities and towns have a significant role in mitigation of global carbon emissions, while at the same time, they are particularly at risk of the effects of a changing climate. Already today, climate change and its impacts are affecting Germany's urban areas, and they are increasingly recognised as a global and local challenge not only by politics, but also the German public. Increasing occurrence of hot and dry summers, or heavy precipitation events are affecting human health, the environment and biodiversity, forestry and agriculture, as well as public and private infrastructure. The increased frequency in the past years has also been raising public awareness. While cities and towns have large potential to minimise their carbon footprint, they also require targeted measures and urgent action to enhance their resilience towards the impacts of climate change. In order to identify potential vulnerabilities and identify measures according their urgency for action, climate risk assessments are a tool to define immediate priorities.[1] Overall, climate change is not only affecting the natural and built environment, but also human productivity and thus economic activity in the country. Drought periods are affecting farmers' harvest, also increasing their dependence on subsidies. Further, damages inflicted by natural hazards on buildings and public infrastructure have accounted for roughly 2.6 billion Euro insurance cost in 2018.[2]



To highlight the efforts of Germany to reduce impacts of climate change in urban areas, this Keystone Paper takes a closer look at three exemplary urban adaptation strategy frameworks of German cities, situated in different regions across the country: Berlin, Germany's capital in the North-East, Stuttgart in Baden-Württemberg the South-West, and Hannover, the centrally located capital of the Federal state of Lower-Saxony. All selected cases face similar, but different challenges, and in recent years, have developed strategic adaptation frameworks aligned to Federal policies (see below). In this Keystone Paper, those three overall adaptation frameworks are scrutinised, main priorities identified, and a specific project example in context of the respective strategy examined. Findings are aggregated and included in this paper's recommendations.

While climate mitigation can be assessed using few quantifiable indicators such as CO2 emissions, the progress made in terms of climate adaptation is more complex to evaluate. Adaptation measures intervene in multiple sectors with various scales and timeframes and do not necessarily translate into quantitative data. In many cases, climate adaptation strategies will only prove effective in the long term, when the impact of climate change has amplified. Urban climate adaptation frameworks thus often develop their own monitoring systems based on qualitative indicators to evaluate outcomes and progress..

1.1 GERMANY'S FRAMEWORKS FOR CLIMATE ADAPTATION

Already in 2008, Germany's Federal government issued the German Strategy for Adaptation to Climate Change (DAS) as main strategic adaptation framework, to enhance climate resilience in Germany. DAS is continuously monitored and adapted. This has led to several updates since. DAS defines 15 main fields of action, to be considered for all Federal strategies and departments focusing on climate adaptation:

- Human health
- Construction industry
- Water balance, water management, coastal and marine protection
- Soils
- Biological diversity
- Agriculture
- Forestry
- Fishery
- Energy sector
- Finance and insurance sector
- Traffic and transport infrastructure
- Industry and commerce
- Tourism

Cross-sectoral action areas considered by DAS are spatial, regional and urban development planning, as well as civil protection and disaster control. As a comprehensive framework, DAS includes strategies on Federal level, including risk assessments, acknowledging regional disparities throughout the country, and Germany's international responsibility.

An important factor in Germany's adaptation strategy is the focus on the regional and local level. German states retain important legislative and executive authority over their territory. To strengthen the cooperation between the federal government (Bund) and the states (Länder), a federal exchange on climate change adaptation (Bund-Länder Austausch zur Anpassung an den Klimawandel) was initiated to complement the ongoing work of the biannual joint federal and regional ministerial committees (Bund-Länder-Gremien).[3] While a close exchange is sought with state governments, responsibilities for implementation of individual measures mostly are with municipal administrative bodies.[4] It has been shown that since adoption of DAS in 2009, more than 90 % of Germany's with a population above 100.000 have addressed the challenge of climate change adaptation either with creation of strategies and dedicated plans, or indirect measures integrated in sector policies.[5] To support development of adaptation strategies, the Federal government and agencies provide tools and guidelines for creation of comprehensive frameworks. Further details on Germany's climate adaptation policy framework and tools can be found in Keystone Paper #4: Climate Risk Management in Cities.

1 For more details on Germany's climate adaptation policy framework, climate risk assessment, and climate insurance, see *Keystone Paper #4: Climate Risk Management in Cities*.
2 Umweltbundesamt (2019): Monitoringbericht 2019 zur Deutschen Anpassungsstrategie an den Klimawandel. Source: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/monitoringbericht_2019_bf.pdf
3 Bundesregierung (2009): Deutsche Anpassungsstrategie an den Klimawandel. Source: https://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/das_gesamt_bf.pdf
4 Bundesregierung (2009): Deutsche Anpassungsstrategie an den Klimawandel.
5 Kind, Christian, Sartison, Katharina (2017): Wie deutsche Großstädte sich an den Klimawandel anpassen. Source: https://www.umweltbundesamt.de/themen/wie-deutsche-grossstaedte-sich-an-den-klimawandel

1.2 CURRENT ACTION AND CLIMATE EMERGENCY

In 2019, more than 40 municipalities across the country have declared "Climate Emergency", acknowledging that previous efforts to mitigate and adapt to climate change have not been going far enough, and additional, effective and urgent measures are to be developed and implemented.[6] This form of emergency declaration occurred first in context of the global Fridays-for-Future movement, and has been adopted from states, municipalities, businesses, and other stakeholders since, to highlight the great urgency to act. Declaring Climate Emergency does not induce any binding measures or compliance to a climate adaptation strategy. The aim is to send a strong message to both the state and the public, and to designate climate change as a foremost priority for the municipality. Most municipalities that declared Climate Emergency however also agreed on a strong common climate mitigation target by aiming for carbon-neutrality in 2030.[7]

While the case studies presented in this Keystone Paper, except for Berlin, have not declared Climate Emergency yet, they have all developed ongoing adaptation strategies, with some individual components dating back to the 1990s or 2000s or before. Several issues, such as urban heat island effect in densely populated urban areas, or flood events in cities located at riverbanks have been present since decades. Nonetheless, their increased occurrence and aggravated effects in recent years are considered to correlate with the rapidly changing climate.

6 Umweltbundesamt (2020): Deutsche Kommunen rufen den Klimanotstand aus. Source: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/anpassung-an-den-klimawandel/anpassung-auf-kommunaler-ebene/deutsche-kommunen-rufen-den-klimanotstand-aus#

7 Klima Bündnis (n.d.): Klima-Bündnis - Klimanotstand. Klimabuendnis.de. Source: https://www.klimabuendnis.org/kommunen/klimanotstand.html

2. CASE STUDIES FOR URBAN CLIMATE ADAPTATION IN GERMANY

Figure 1: Berlin Tiergarten (© Erik, https://www.flickr.com/photos/77784613@N02/18825956980)

2.1 BERLIN

Berlin is Germany's capital city and with a population of 3.7 million in 2019, the most populous city in the country. With around 892 square kilometres area, it is also the largest municipality. Since 2010, Berlin's population rose by around 9% although it started stagnating in recent years. [8] Berlin has become an increasingly attractive hub with an economy growing at a highly dynamic rate: between 2008 and 2018, the gross domestic product rose by an annual average of 2.3 %, compared with 1.3 % nationwide.[9] Berlin is considered one of the greenest cities in Germany, with approximately 42 % of the city's territory covered by forests, water bodies, parks or sports grounds, or farmland, offering a broad range for recreational spaces, biodiversity and good preconditions for integration of climate adaptation measures. Nonetheless, Berlin has been identified by the German Strategy for Adaptation to Climate Change as being particularly sensitive to climate change.

Challenges

Berlin's urban infrastructure is increasingly being affected by adverse impacts of climate change. In Berlin's region, the average annual temperature already rose by one degree Celsius between the beginning and end of the 20th century.[10] Over the last few years, the number of tropical nights has increased in Berlin, especially in the city centre. A study by the German Weather Service (DWD) and the Senate Department for Urban Development shows that thermal stress is increasing in Berlin, particularly in those areas, already affected by thermal stress today.[11] Despite Berlin's location at the banks of two rivers the Spree and Havel river has not resulted in major floods recently, increasing weather extremes are likely to require measures for flood prevention in the future. Climate projections for the Berlin-Brandenburg area predict a further increase in climate-related damages by 2050.

According to Berlin's Senate Department for Urban Development, projections based on climate models for Berlin estimate following trends: [12]

- Until 2050, annual average temperatures to increase by a total of 2.5 degrees Celsius
- Longer summers, with an increase of hot days and tropical nights
- Days with frost will decline
- Heat waves will occur more frequently, will be more intense and longer than before
- Annual precipitation average will decline
- Rainfall events are expected to shift from summer to winter months, resulting in drier summers and wetter winters
- In general, extreme weather events such as heat waves or heavy rainfalls events will occur more frequent

8 Amt für Statistik Berlin-Brandenburg (2019): Bevölkerung. Source: https://www.statistik-berlin-brandenburg.de/grundlagen/Bevoelkerung.asp?Ptyp=50&Sageb=120&creg=BBB&anzwer=0
9 Amt für Statistik Berlin-Brandenburg (2019): Wirtschaftsleistung im 1. Halbjahr 2019. Source: https://www.statistik-berlin-brandenburg.de/pms/2019/19-09-24.pdf
10 Cubasch, Ulrich & Kadow, Christopher. (2011). Global Climate Change and Aspects of Regional Climate Change in the Berlin-Brandenburg Region. Erde. 142.
11 DWD (2010): Umweltatlas Berlin - Klimawandel und Wärmebelastung der Zukunft. Source: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/i412.htm
12 Senatsverwaltung für Stadtentwicklung (Ed.) (2011): Stadtentwicklungsplan Klima. Urbane Lebensqualität im Klimawandel sichern. Kulturbuch-Verlag, Berlin. Source: https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/download/klima/step_klima_broschuere.pdf

Effects of climate change affect not only the city's ecosystems and infrastructure, but also its citizens. It has been estimated that climate impacts in Berlin could result in damages worth a total of around up to 10 billion EUR by 2050. Scenarios project a 0.07% to 0.14% loss on Berlin's gross added value due to lower productivity among workers and office staff during heatwaves.[13] With demographics pointing towards an ageing society and the elderly being particularly vulnerable to weather extremes, more citizens are becoming increasingly susceptible to effects of climate change. Ongoing population increase and growing economic activity in Berlin, is closely linked with rising construction activity for residential, office buildings other forms of infrastructure. As the population has grown around 1 % annually in the past decade, so has the number of completed residential units. While in 2011, the number of completed housing units was around 0.2 % per year, in 2018 the number of finished units increased to 0.9 % per year.[14] Despite population increase stagnating slightly below 1 % in 2019[15] and fewer new construction permits issued in recent years, Berlin still requires targeted strategies to provide a future-proof urban infrastructure that can cater to a larger population in the context of climate change.

Strategic Framework

Climate adaptation is increasingly becoming a central priority in policy making and spatial planning in Berlin. Rather than address it as an individual discipline, the municipality is incrementally integrating climate adaption across all related administrative departments. For the development and implementation of strategies and projects on local level, a multi-disciplinary approach links several stakeholders, including district administrations, the city's Senate, the private sector, including developers, investors and property owners, as well as civil society.[16]

Berlin's climate adaptation strategy builds upon three interlinked strategy documents. In 2009, Berlin's Senate issued the first report on the consequences of climate change, which was followed by the Urban Development Plan for Climate (StEP Klima) in 2011 and updated in 2016 to StEP Klima KONKRET. The StEP Klima/ StEP Klima KONKRET is the guiding document for spatial planning addressing a changing climate, containing dedicated recommendations and strategies for Berlin. Overall, StEP Klima forms an instrument of strategic planning, aiming to future proof quality of life in the city. StEP Klima identified following main fields of action: bioclimatic stress, green and open spaces, quality of water bodies and heavy rainfall, complemented by overarching climate mitigation aspects. Since 2016, the Environmental Atlas, a spatial analysis tool, complements the StEP Klima with providing geo-spatial information on climate related impacts such as heat stress, and potentials including cold-air corridors or night cooling.[17]

The Berlin Energy- and Climate-Protection Programme 2030 (BEK 2030), launched in 2018, draws on several feasibility studies and a wide discussion which incolved the administration, the general public, as well as local businesses and stakeholders through online participation, surveys and events. BEK 2030 is presented as an integrated strategy covering up both climate mitigation and climate adaptation measures.[18] The study Adapting to the Impacts of Climate Change in Berlin (AFOK) was developed in 2016 and adopted in 2018 as part of BEK 2030. Based on current global and regional climate scenarios, AFOK analyses potential climate impacts likely to affect Berlin in the near future (i.e. by 2050) and in the distant future (i.e. by 2100) . It identifies main climate vulnerabilities and outlines sectoral approaches and concrete strategies for 9 fields of action (see Table 1). AFOK does not set targeted objectives for each sector, it provides however a framework of indicators based on the trusted PSR monitoring-system used by the OECD.[19] Strategies of AFOK were integrated into BEK 2030, which is currently implemented to enhance the resilience of both urban infrastructure (e.g. sewerage, green spaces, mobility) and quality of life in a changing climate.[20] Implementation of measures under BEK 2030 is currently funded with 94 million Euro for the 2018 – 2021 period.

Solutions and Measures for Adaptation

Based on its climate vulnerabilities analysis, AFOK defines specific climate adaption measures for each field of action. BEK 2030 draws on the same categories and describes in further details the implementation of the adaptation measures. Table 1 summarises the fields of action outlined in BEK 2030 as well as a selection of strategic measures. BEK 2030 does not define detailed quantitative targets for each adaptation measure as the aim is to avoid completely or to mitigate as much as possible the potential damage caused by climate change.[21] Monitoring is ensured using the overarching framework provided by AFOK (see Table 2).

Overall responsibility and steering of implementation of BEK 2030 is with Berlin's Senate Department for Environment, Transport and Climate Protection. Responsibility for implementation of individual

13 Reusswig, Fritz, Becker, Carlo, et al. (2016): Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept. Hauptbericht. Source: http://www.pik-potsdam.de/~luedeke/xWS1718/Berlin_AFOK_Endbericht.pdf
14 Amt für Statistik Berlin Brandenburg (2019): Bautätigkeit und Wohnungen in Berlin und Brandenburg. Source: https://www.statistik-berlin-brandenburg.de/BasisZeitreiheGrafik/Zeit-Gebaeude_Wohnen.asp?Ptyp=400&Sageb=31000&creg=BBB&anzwer=8
15 Amt für Statistik Berlin Brandenburg (2019): Geringster Bevölkerungswachstum seit 2011 in Berlin. Source: https://www.statistik-berlin-brandenburg.de/pms/2020/20-01-16a.pdf
16 Senatsverwaltung für Stadtentwicklung und Umwelt (Ed.) (2016): Klimaanpassung in der Wachsenden Stadt. Stadtentwicklungsplan Klima KONKRET. Source: https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/download/klima/step_klima_konkret.pdf
17 Senatsverwaltung für Stadtentwicklung und Wohnen (2016): Klimamodell Berlin. Source: https://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/kb410.htm
18 Senatsverwaltung für Umwelt, Verkehr und Klimaschutz (n.d.): Berlin Energy And Climate Protection Programme 2030. Berlin.de. Source: <https://www.berlin.de/sen/uvk/en/climate-protection/berlin-energy-and-climate-protection-programme-2030-bek-2030/> [Accessed 18 June 2020].
19 Linster, M. (2003): OECD Environmental Indicators. Development, Measurement and Use. Reference Paper. OECD, Paris. Source: http://www.oecd.org/environment/indicators-modelling-outlooks/24993546.pdf
20 Reusswig, F. (Ed.) et al. (2016): Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept Zusammenfassung. Potsdam, Berlin. Source: https://www.berlin.de/senuvk/klimaschutz/klimawandel/download/afok_summary.pdf
21 Reusswig, F. (Ed.) et al. (2016): Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept Zusammenfassung. Potsdam, Berlin.

measures is passed on to individual departments within the city's administrative body, such as the Senate Department for Health, Care and Equality regarding actions focusing on health-related impacts of climate change, or the Senate Department for Urban Development and Housing, responsible for measures related to spatial planning and avoidance of heat-islands throughout the city. While individual departments are responsible for successful implementation, they collaborate with district administration, or relevant public and private entities (e.g. Berlin Waterworks, Berlin Public Transport, etc.).

The design and implementation of the individual measures depends in many cases on the involvement of other public sector bodies, such as e.g. Berlin Waterworks, or the city's public transport company BVG. Other stakeholders relevant for implementation are stakeholders of civil society, associations and private companies.

In 2017, the Climate Action Council (Klimaschutzrat) was introduced as an advisory board for implementation of BEK 2030, consisting of stakeholders from civil society, research and economy. The board aims to consult between the city's citizens and administration, and to raise broad public awareness on the issue of climate action.

To monitor progress of BEK 2030, the Berlin Senate provides an annual report on implementation of measures, including timeframes and milestones, as well as cost-plans to the House of Representatives, Berlin's state parliament. Main responsibility for reporting is with the Senate Department for Environment, Transport and Climate Protection, supported by progress reports provided from other Senate Departments with responsibility for individual measures.

Progress Monitoring and Indicators

For monitoring of implementation of BEK 2030, AFOK provides follows an approach based on three pillars:

I) implementation,
II) monitoring, and
III) communication.

Concerning implementation, measures from AFOK have been included in BEK 2030 (see above) and are subject of public funding and political decision making on city and district level. Concrete projects currently in development include e.g. climate adaptation for public transport, widespread implementation of public drinking water dispensers, or decentralised rainwater management ("1000-green-roofs-programme").[22]

For monitoring purposes, AFOK sets a unique framework for all action areas, based on three indicators: state, impact, and response. "State" indicators include e.g. climate and atmosphere parameters, "impact" focuses on e.g. climatic impacts on the environment and "response" addresses e.g. successes of adaptation measures regarding climate change and its consequences. Monitoring includes evaluation of the urban climate, health parameters of the Berlin's citizens, effects on the environment and the urban infrastructure.[23] Suggestions and indicators of AFOK were integrated in the BEK monitoring concept diBEK, which provides publicly available information on current projects.[24]

On communication, AFOK clarifies that for the public, differentiation between climate mitigation and adaptation is key, and understanding of interrelations between both fields. Further, it helps to raise awareness of individuals to climate change, and to motivate taking measures by oneself.

Berlin's strategies on climate adaptation focus primarily on adaptation to climate change, however, are closely interlinked to the city's programmes for climate mitigation. Overall, Berlin has adopted an approach based on three pillars:

I) increasing energy efficiency,
II) reducing energy consumption, and
III) implementation of renewable energy systems.

Such measures have already been implemented for several years - in the legal and organisational field, through cooperation and engagement of different stakeholders, through large scale building renovations, as well as education and awareness raising.

Integration of mitigation measures into the climate adaptation strategy framework is key for the achievement of sustainable results. AFOK and STeP Klima, for example, encourage of energy-efficient construction and refurbishments, expansion of utilisation of renewable energy production, preservation of natural greenhouse gas reservoirs, as well as climate sensitive urban and transport development.[25]

22 Abgeordnetenhaus Berlin (2018): Bericht zur Umsetzung des Berliner Energie- und Klimaschutzprgramms (BEK 2039) – Berichtsjahr 2018. Source: https://www.parlament-berlin.de/ados/18/IIIPlen/vorgang/d18-1710.pdf
23 Reusswig, F. (Ed.) et al. (2016): Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept Zusammenfassung. Potsdam, Berlin. Source: https://www.berlin.de/senuvk/klimaschutz/klimawandel/de/anpassungskonzept_berlin/index.shtml
24 Senatsverwaltung für Umwelt, Verkehr und Klimaschutz (2020): digital Monitoring- and Information System of the Berlin Energy and Climate Protection Programme. Source: https://dibek.berlin.de/?lang=en#caption_c1
25 Senatsverwaltung für Stadtentwicklung (Ed.) (2011): Stadtentwicklungsplan Klima. Urbane Lebensqualität im Klimawandel sichern. Kulturbuch-Verlag, Berlin. Source: https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/download/klima/step_klima_broschuere.pdf

Field of Action	Measures (selection)	Main Responsible Entity
Health and Civil Protection	• Development of early warning systems • Development of a hospital programme for climate adaptation • Research of climate related health risks • Climate adaptation in public transport	• Senate Department for Health, Care and Equality • Senate Department for Environment, Transport and Climate Protection
Buildings, Urban Development, Green and Public Space	• Protecting climatic relief areas • Creation of qualified green and open spaces, implementation of a systematic strategy of roof and facade greening • Making existing planning instruments suitable for climate change • Climatic decoupling of new building projects	• Senate Department for Environment, Transport and Climate Protection • Senate Department for Urban Development and Housing • District administration
Water Supply and Distribution	• Design of surfaces suitable for flooding • Adaptation of the infrastructure to heavy rainfall events • Adaptation of the infrastructure to dryness and heat • Securing (drinking) water quality	• Senate Department for Urban Development and Housing • Senate Department for Environment, Transport and Climate Protection
Environment and Nature	• Precautionary soil protection • Protection and regeneration of the Berlin moor sites • Climate resilient and site-adapted plantations • Environmental monitoring of forests	• Senate Department for Environment, Transport and Climate Protection
Energy Supply and Solid Waste Management	• Promoting energy-efficient cooling systems • Design of energy systems under changed environmental conditions • Optimization of energy infrastructure, focus: networks and storage • Efforts to avoid waste	• Senate Department for Environment, Transport and Climate Protection
Industry, Services and Financial Sector	• Provision of reliable weather forecast • Round tables for knowledge transfer • Improved heat protection during summer • Improved risk prevention for outdoor activities	• Senate Department for Environment, Transport and Climate Protection
Traffic	• Adaptation of road drainage to heavy rainfall • Reduction of traffic-related NOx emissions • Improvement of cycling safety • Regulation and improvement of cooling in public transport	• Senate Department for Environment, Transport and Climate Protection
Tourism, Culture, Sports	• Free supply of drinking water • Marketing concept: climate adjusted city tourism • Improved drainage of sports fields • Refreshment facilities at events	• N/A
Education	• Integration of climate adaptation in educational programmes • Promoting education campaigns with partners • Refurbishing school buildings for climate change • Using schools as places of knowledge transfer	• Senate Department for Education, Youth and Family • Senate Department for Urban Development and Housing • District administration

Table 1 Fields of Action and Measures defined in BEK 2030

	Indicator Type		
	State	Impact	Response
Description	Set of 14 indicators including regular assessment of climate (temperature, precipitation, wind), within a framework of long-term measurements split-up into small-scale areas on district level.	Set of 43 indicators including measurements or assessments of weather effects and parameters in the individual fields of action. If necessary, empirical studies are recommended in comparative timeframes. Indicators are allocated to thematic focal areas.	Set of 93 indicators including measurements or assessments of the achievement of the objectives of the respective measure. Response indicators include two groups: • process indicators, reflecting status of implementation of the measure, excluding actual impacts • result indicators, signifying actual impact of the respective measure
Selected Example Indicator	• hot days (above 30°C, annual) • cold days (below 0°C, annual) • snow (precipitation on days below 1°C, annual)) • heavy rain fall days (rainfall above 10/20mm, annual) • consecutive dry days (longest phase with precipitation < 1mm, annual)	**Human Health and Civil Protection, e.g.:** • mortality as a result of cardiovascular diseases • incidence of algaes in waterbodies • Buildings, Urban Development, Green and Public Space: • soil sealing factor • condition of trees • climatic stress in urban districts • Tourism, Culture, Sports, e.g.: • no. of cancelled events due to extreme weather events • no. of tourists in Berlin • Environment and nature, e.g.: • forest fires • cartography of biotopes • Industry, Services and Financial Sector, e.g.: • no. of weather-related production losses in economy • interior temperature in public buildings • Traffic, e.g.: • traffic incidents with two-wheelers • air quality: heat-impact on ozone-concentration • Water Supply and Distribution, e.g.: • local flood events • groundwater level / groundwater temperature • Energy Supply and Solid Waste Management, e.g.: • potential energy demand for cooling • no. of power cuts • Education, e.g.: • No. of lessons, adapted to weather conditions, in schools • No. and type of health-impairments in schools	**Human Health and Civil Protection, e.g.** • increase / decrease of climatic relief areas • implementation of pilot projects regarding climate adaptation **Buildings, Urban Development, Green and Public Space, e.g.:** • density of drinking fountains • no. of heat related cases in hospitals **Tourism, Culture, Sports, e.g.:** • outdoor sports areas with drainage systems • beginning / ending times of cultural events **Environment and nature, e.g.:** • transformed areas according to Berlin's mixed forest programme • seales / unsealed areas **Industry, Services and Financial Sector, e.g.:** • No. of sector-specific adaptation concepts • No. of implemented projects in enhancement of thermal insulation **Traffic, e.g.:** • Maintenance of weather-induced road damages • Share bicycle-traffic / pedestrian-traffic **Water Supply and Distribution, e.g.:** • Capacity of sewer system • Water runoff volume of reconstructed / newly built areas **Energy Supply and Solid Waste Management, e.g.:** • No. of subsidised pilot projects • Implemented projects of solar energy storage **Education, e.g.:** • Integration of climate adaptation in education • Implementation of water drinking fountains in schools

Table 2 Selection of State, Impact and Response Indicators as recommended in AFOK

Outcomes and Progress

The Berlin Senate provides bi-annual monitoring reports on implementation of projects carried out under BEK 2030.[26] The report outlines progress and outcomes in the individual target areas and projects implemented through the strategy. It includes overall metrics on carbon mitigated in Berlin, status of selected projects, and integration of other strategies, that are indirectly related to the climate agenda. Individual small- and large-scale projects targeting climate adaptation include, for example: [27]

- climate adaptation for public transportation, including increase of shadings on bus and tram stops and seating possibilities for the elderly,
- decentralised rainwater management, to reduce stress on the city's sewer system in case of heavy rainfall events, integrating concepts in development plans, and enhancing rainwater storage through promotion of green roofs,
- implementation of drinking fountains, to widen the network of drinking fountains in public spaces to be used free of charge all over the city,
- forest restructuring, aiming to carefully transform Berlin's vulnerable pine forests towards more robust mixed forests, enhancing water balance, as more precipitation can reach forest soil with deciduous trees.[28]

Due to the large consultation process carried out already during development of adaptation measures in AFOK, a large share of the around 80 individual measures are well-received by implementation agencies and other involved parties in Berlin. The comprehensive planning measures and interlinkages between the individual actors thus can rely on a profound foundation, which benefits the ongoing implementation processes. Apart from the regular monitoring reports, transparency is increased for the public which can follow the implementation on diBEK, a dedicated online platform. While diBEK already tracks the progression of each specific climate mitigation measure, it currently only outlines the first climate adaptation measures until 2021.[29]

EXEMPLARY PROJECT

1000 Green Roofs Programme (1000 Grüne-Dächer-Programm - GründachPLUS)

Green roofs are an important aspect in Berlin's strategy of decentralised rainwater harvesting. Green roofs retain rainwater, mitigate the effects of extreme weather events such as heavy rainfall, provide cooling through evaporation and contribute to improved air quality. In addition, green roofs serve as additional recreational areas for citizens and as habitat for insects, birds and plants. Today, only about 3 % of all roofs in Berlin are currently green. Across the city, there are around 18.000 roofs that have potential for greening.

The 1000 Green Roofs Programme or GründachPLUS was initiated in 2019 as part of BEK 2030 to increase the share of green roofs on existing buildings. The aim is to provides public funding for green roof projects meeting specific criteria in Berlin. The Programme consists of a 'regular' scheme, subsidising 75 % of project cost up to 60 000 Euro for a minimum of 100 m^2 rooftop area, and the 'Green Roof LAB' scheme, subsidising up to 100 % for innovative, experimental, or participatory flagship-projects.

The 'regular' funding focuses on urban areas with a high density of existing buildings, with particularly few open spaces, high climatic stress, air pollution and a special need for rainwater retention to relieve the local sewage system. Owners can apply for subsidy of initial greening of existing roofs on residential, office and commercial buildings, including underground car park roofs, with a minimum size of 100 m^2 vegetation area. Extensive and intensive green roofs as well as retention roofs are supported.

The subsidy programme is administered by the Senate Department for Environment, Transport and Climate Protection and is funded up to about 3,5 million Euro by the Investitionsbank Berlin (IBB), the development Bank of the state of Berlin. Initial consultation on feasibility of prospective projects is provided by the Berlin Rain Water Agency (Berliner Regenwasseragentur).*

* Investitionsbank Berlin (2019): GründachPLUS - Berlins Förderprogramm für mehr Dachbegrünung. Source: https://www.gruendachplus.de/

26 Senatsverwaltung für Umwelt, Verkehr und Klimaschutz (2019): Bericht zur Umsetzung des Berliner Energie- und Klimaschutzprogramms (BEK 2030). Berichtsjahr 2018. Source: https://www.berlin.de/senuvk/klimaschutz/bek_berlin/download/BEK_Monitoringbericht_2018.pdf
27 Senatsverwaltung für Umwelt, Verkehr und Klimaschutz (2019): Bericht zur Umsetzung des Berliner Energie- und Klimaschutzprogramms (BEK 2030). Berichtsjahr 2018. Source: https://www.berlin.de/senuvk/klimaschutz/bek_berlin/download/BEK_Monitoringbericht_2018.pdf
28 Berlin Stadtportal (2019): Mischwaldprogramm. Source: https://www.berlin.de/forsten/waldwirtschaft/mischwaldprogramm/
29 Digital Monitoring- and Information System of the Berlin Energy and Climate Protection Programme: Source: https://dibek.berlin.de/?lang=en

2.2 STUTTGART

Figure 2: City of Stuttgart with surrounding hills (Source: pixabay)

Stuttgart is the capital of the federal state of Baden-Württemberg, with a population of around 615 000 in 2019 and part of the greater metropolitan region Stuttgart, with a population of around 5.4 million. [30] Stuttgart is well-known for its high-tech and automotive-industry, thanks to which the region is considered as one of the strongest economies across country.

The city is located in the Neckar river basin in the South-West of Germany, shielded by steep hill slopes, and characterised through several valleys crossing through the city. Overall, the city has a large share of green areas, with vineyards located within the city's boundaries, and more then 50 % of the total urban area being green and recreational spaces, agricultural land, or other forms of vegetation.[31] Due to its location, Stuttgart is characterised by a mild, temperate climate, and hot summers. It is one of the warmest regions in Germany.

Challenges

Stuttgart's location in the Neckar basin, lack of fresh air corridors, and the industrial activity in its surrounding areas have made the city vulnerable to poor air quality and prone to urban heat islands during summer months. Low wind speeds in the region in general, and construction development on the hillslopes in recent years, further prevents fresh air from moving through the city, affecting air quality and urban climate.[32] Stuttgart's urban heat island effect is a well-known phenomenon and regularly monitored since the 1980s. Assessments already carried out since then, include analysis of cold air corridors, wind patterns, and air pollution concentrations and have been integrated in urban development plans and zoning regulations back since.[33] Nonetheless, climate projections for Stuttgart for 2071 - 2100 project a 2 °C increase of mean annual temperature. The number of days with heat stress are projected to increase significantly and, consequently, a higher percentage of people are likely to be exposed to the risks associated. While today, around 6 % of Stuttgart's area is experiencing heat stress (temperatures > 30 °C) more than 30 days a year, by 2071, more than 57 of the city's area are projected to be affected.[34] With increasing occurrence of extended heat periods, more temperature-related illnesses and deaths are projected to follow. For the state of Baden-Württemberg, it has been shown that number of heat related fatalities correlate with extreme heat periods in the 2000s. Compared to up to 1 400 heat-related fatalities in 'moderate' summers, the "hottest summer of the century" in 2003, led to around 2 700 deaths.

30 Landeshauptstadt Stuttgart (2020): Lage und Größe der Landeshauptstadt Stuttgart. Source: https://statistik.stuttgart.de/statistiken/tabellen/7552/jb7552.php
31 Landeshauptstadt Stuttgart (2020): Flächennutzung. Source: https://statistik.stuttgart.de/statistiken/tabellen/2425/jb2425.php
32 Landeshauptstadt Stuttgart (2020): Das Klima von Stuttgart. Source: https://www.stadtklima-stuttgart.de/index.php?klima_klimainstuttgart
33 Landeshauptstadt Stuttgart, Amt für Umweltschutz, Abt. Stadtklimatologie (2020): Die städtische Wärmeinsel in Stuttgart. Source: https://www.stadtklima-stuttgart.de/index.php?klima_waermeinsel_stuttgart
34 Verband Region Stuttgart (Ed.) (2008): Klimaatlas Region Stuttgart. Verband Region Stuttgart. Source: http://www.stadtklima-stuttgart.de/index.php?klima_klimaatlas_region

Also the extreme summers of 2006, 2015 and 2018 resulted in around 2 000 fatalities.[35]

Apart from impacts on human wellbeing and biodiversity, effects of climate change are likely to impact the global, and local economy. With Baden-Württemberg, and especially the region around Stuttgart being an industrial hub, projections show that direct impacts of climate change could result in a reduction of gross domestic product (GDP) of up to -25 %, compared to a reduction of 2 % on German average.[36]

Strategic Framework

The challenges described above are not a recent occurrence. Urban climatology in Stuttgart dates back to 1938, when the city council started with analyses on the city's climatic conditions, to investigate interlinkages of urban development and climate. Findings on urban climate and integrating them into planning was recognised as an important health factor for the city's citizens. Since then, the city operates a Urban Climatology department, which advises other municipal departments and urban stakeholders on climate adaptation measures.[37]

Main foundation of climate adaptation plans is the **Climate Atlas Stuttgart Region (Klimaatlas Region Stuttgart)**, published in 2008, and is still in use since as guiding document. It includes spatial analysis maps for the city of Stuttgart and municipalities of the surrounding region, depicting wind patterns, cold air corridors, air pollution concentration, and other information relevant to consider in new and rehabilitation developments. The Climate Atlas does not aim to provide an integrated adaptation strategy, but overall objectives are the enhancement of open and green spaces throughout the region, provision of additional green infrastructure, and improvement of air corridors through the city. For the latter, e.g. spaces are defined, where new construction should be avoided. Further recommendations are given, where additional construction within the city should be averted, to preserve open spaces and areas for cold air production.[38]

Concepts and actions targeting climate adaptation are clustered in the **Climate Adaptation Concept Stuttgart** (KLIMAKS), issued in 2012 by the Department for Environmental Protection and adopted by the city council. KLIMAKS builds upon the Federal strategy, DAS, and includes concrete overarching strategies, broken down into concrete measures, to be implemented in the city of Stuttgart. A dedicated task force accompanies implementation of the measures or can initiate enhancement of strategies. Both in the development of KLIMAKS, as well as in the task force, are interdisciplinary stakeholders, from internal city administration, and external actors from e.g. water, energy and transportation providers. KLIMAKS includes main priorities, iterative finance, and implementation timelines.

Other instruments focusing on spatial components are the **Climate Planning Evaluation Stuttgart** (KlippS – Klimaplanungspass Stuttgart)[39], providing guidance in climate related issues in concrete spatial decision-making, including requirements of the building code and urban land use planning, and the **Climate Handbook for Urban Development** (Städtebauliche Klimafibel)[40] issued by the state Ministry of Baden-Wuerttemberg, a technical document for supporting zoning and planning within the state, against the backdrop of the Germany's Federal Building Law with its requirements concerning climatic conditions in urban development.

Solutions and Measures for Adaptation

Individual measures for climate adaptation are described in KLIMAKS, and clustered according to sectors as recommended by DAS. Thematic focus and individual measures are shown in Table 3 below. Individual measures are then prioritised, depending on urgency to act, based on a standardised procedure. Prioritisation is based on recent climate projections for Stuttgart, and a risk assessment.

Individual measures are not implemented all at one, but clustered regarding their risk, and their effectivity of risk mitigation. Prioritisation is based on projected impacts and risks of climate change in Stuttgart.[41]

Considered of highest importance in Stuttgart are those measures with a focus on urban heat islands, and climatic optimisation of urban development plans, including fresh air corridors and cold air production areas, as well as measures related to water management and flood prevention.

In addition to the dedicated measures of KLIMAKS, additional spatial considerations shown in the Climate Atlas are continuously incorporated in Stuttgart's urban development policy, such as legally binding land use plans and regulatory frameworks. A module for geographic information systems (GIS) was developed, to allow further visualisation and simulation of air flows

35 Brachat-Schwarz, Werner; Winkelmann, Ulrike (2017): Führt der Klimawandel zu einem Anstieg der "Hitzetoten"? Source: https://www.destatis.de/GPStatistik/receive/BWMonografie_monografie_00000664;jsessionid=E9243B3AC69A7D36DFD2DA33081506F9

36 Beestermöller, Robert, Fahl, Ulrich (2015): Energie- und gesamtwirtschaftliche Effekte des Klimawandels in Baden-Württemberg. Source: https://fachdokumente.lubw.baden-wuerttemberg.de/servlet/is/119659/U83-W03-N19.pdf?command=downloadContent&filename=U83-W03-N19.pdf

37 Landeshauptstadt Stuttgart, Amt für Umweltschutz, Abt. Stadtklimatologie (2020): Eighty two years of Urban Climatology in Stuttgart. Source: https://www.stadtklima-stuttgart.de/index.php?service_contakt_about_us

38 Verband Region Stuttgart (Ed.) (2008): Klimaatlas Region Stuttgart. Verband Region Stuttgart. Source: http://www.stadtklima-stuttgart.de/index.php?klima_klimaatlas_region

39 H. Mayer, H. Lee, et al. (2015): KlippS – Klimaplanungspass Stuttgart. Source: https://www.stadtklima-stuttgart.de/stadtklima_filestorage/download/KlippS-Klimaplanungspass-Stuttgart.pdf

40 Ministry of Economy, Work and Housing of Baden-Württemberg (2015): Städtebauliche Klimafibel Online. Hinweise für die Bauleitplanung. Source: http://www.staedtebauliche-klimafibel.de/?p=0

41 Prioritisation is based on a standardised methodology published by the Federal Environment Agency. Criteria for analysis of adaptation measures are: effectivity, flexibility, resilience, feasibility, financial feasibility, positive synergies, and sustainability. Source: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse/3-massnahmen/34-wie-koennen-sie-massnahmen-analysieren

Stuttgart's KLIMAKS primarily focuses on adaptation measures, overall, synergies with climate mitigation are sought. For example, enhancement of green infrastructure, including provision of new and protection of existing green spaces, not only benefits cold air production, but at the same time, creates and preserves carbon sinks. Another important factor, especially regarding green infrastructure, are positive side-effects for recreational use of citizens.

Progress Monitoring and Indicators

Stuttgart's climate adaptation framework does not include a holistic monitoring system or any indicators of progress. However, KLIMAKS uses a standardised procedure to evaluate the importance of its climate adaptation measures. Each measure is awarded an effectiveness score, calculated by assessing the type of climate risk and the risk reduction potential of the measure. Other factors such as feasibility and side effects are also taken into account. The measures are subsequently ranked into four categories of priority:[42]

- Urgent
- A ("take action directly")
- B ("observe and take action")
- C ("observe and take no-regret action")

For all measures, potential impact is assessed, with regard to individual risks. The calculated effectivity is the sum of the individual effects on the risks. Furthermore, the measures are assessed, for example, with regard to financial feasibility, synergies, or resilience. [43] Responsibility for implementation lies with individual administrative authorities, in collaboration with public agencies or service providers.On a strategic level, the achievement of measures by order of priority serves as an indication of progress. Technical norms specific to each adaptation measure ensure the quality of their individual implementation.

Outcomes and Progress

Since rollout of KLIMAKS in 2012, several measures outlined in the strategy have already been implemented or are currently in development. As Stuttgart's *Urban Climatology* department has been analysing climate-related factors already since several decades, and integrating dedicated measures gradually into the city's development plans, a number of measures highlighted in KLIMAKS were considered a logical progression of them, with low barriers for implementation.[44] Already existing master plans, in which measures of KLIMAKS have been integrated and effectively implemented since, are for example:

- Masterplan "Halbhöhenlagen", to preserve existing and create new green fresh air corridors on hills surrounding the city, with the main concept dating back to 2008[45]
- Masterplan "Talgrund Stuttgart-West", a development strategy focusing on densification within inner city limits under consideration of factors for climate-adaptation, reducing soil-sealing and enhancing green spaces[46]

Such masterplans are considered a robust contribution to climate adaptation with a focus on sustainable, and balanced inner-city-development, clearly defined by urban development boundaries, with a main focus on strategic preservation of retention and cold-air production areas.

Other individual projects with top-priority, as highlighted in KLIMAKS and since under implementation are (selection):[47]

- Air-conditioning implemented in all public transport in Stuttgart and the surrounding region
- Reinforcement of flood dams at Neckar river, to prepare for severe flooding
- Greening of several tram tracks throughout the city
- Extension of the green roof programme, take potential of underutilised flat roofs

A 2019 evaluation of KLIMAKS found that especially those measures have been implemented or are on track, which are well integrated with ongoing operations or that were already indirectly planned through strategies not directly targeting climate adaptation. According to the study, identifying synergies with existing frameworks, strategies or measures, and to integrate dedicated climate-related actions, is key to increase likelihood for implementation. On the other hand, not surprisingly, implementation of those measures requiring additional staff or financial resources was lagging behind.[48]

For updating the first adaptation strategy towards a KLIMAKS 2.0, several recommendations are given: [49]

- Clearly define responsible departments and stakeholders for project implementation,

42 Landeshauptstadt Stuttgart, Amt für Umweltschutz, Abt. Stadtklimatologie (2013): Klimawandel – Anpassungskonzept Stuttgart KLIMAKS. Source: https://www.stadtklima-stuttgart.de/stadtklima_filestorage/download/kliks/KLIMAKS-Broschuere-2013.pdf
43 Landeshauptstadt Stuttgart, Amt für Umweltschutz, Abt. Stadtklimatologie (2013): Klimawandel – Anpassungskonzept Stuttgart KLIMAKS. Source: https://www.stadtklima-stuttgart.de/stadtklima_filestorage/download/kliks/KLIMAKS-Broschuere-2013.pdf
44 Reuter, Ulrich, Kapp, Rainer (2019): Studie zur Umsetzung von kommunalen Klimawandel-Anpassungsmaßnahmen in der Stadt Stuttgart. Source: http://fachdokumente.lubw.baden-wuerttemberg.de/servlet/is/128361/U82-W03-N23.pdf?command=downloadContent&filename=U82-W03-N23.pdf&FIS=91063
45 Landeshauptstadt Stuttgart, Referat Städtebau und Umwelt (2008): Rahmenplan Halbhöhenlagen. Source: https://www.stadtklima-stuttgart.de/stadtklima_filestorage/download/Rahmenplan-Halbhoehenlagen-2008.pdf
46 Thimme, Kathrin (2013): Der rote Faden ist grün. Stuttgarter Zeitung. Source: https://www.stuttgarter-zeitung.de/inhalt.s-west-rahmenplan-talgrund-der-rote-faden-ist-gruen.6e90c4d9-233b-46e9-8272-886d3ccf7795.html
47 Lessat, Jürgen (2019): Hallo Hexenkessel. Kontext. Source: https://www.kontextwochenzeitung.de/politik/438/hallo-hexenkessel-6131.html
48 Reuter, Ulrich, Kapp, Rainer (2019): Studie zur Umsetzung von kommunalen Klimawandel-Anpassungsmaßnahmen in der Stadt Stuttgart.
49 Reuter, Ulrich, Kapp, Rainer (2019): Studie zur Umsetzung von kommunalen Klimawandel-Anpassungsmaßnahmen in der Stadt Stuttgart.

Sectors	Selected measures and responsible public stakeholder
Human Health	Monitoring "Urban Heat Islands" (Department for Environmental Protection) • Alignment of healthcare towards climate change (State of Baden-Württemberg) • Increased protection for outdoor workers and indoor working spaces (individual employers, monitored by Department for Environmental Protection) • Enhanced cooling of food transport (Department for human ressources) • Development of a monitoring system of climate-related diseases (Department for Healthcare) • Information of the population/training in health care (Department for Healthcare)
Construction Sector	• Thermal insulation for buildings (summer) (Department for Real Estate and Housing, Building Construction Authority, Department for Environmental Protection) • Temperature simulations (Building Construction Authority • Precautions against heavy percipitation events, strong winds, hail events, wet winters, snow loads (Public Works Department, Department for Urban Planning and Urban Renewal, Building Construction Authority)
Water Management	• Enhancement of road drainage systems (Public Works Department) • Ground water management (Department for Environmental Protection) • Restoration of streams (Public Works Department, Department of Environmental Protection) • Determination of flooding areas within the city (Fire Department, Public Works Department, Department for Environmental Protection) • Dam safety checks (Waterways and Shipping Administration) • Rain water treatment (Public Works Department, Department for Environmental Protection) • Adaptation of flood water reservoirs (Public Works Department, Cemetery and Forest Department, Department for Environmental Protection) • Precipitation water charge (Public Works Department) • Securing the supply of drinking water to Stuttgart (Local and state water supply agencies)
Soil	• Prevention of soil erosion due to heavy precipitation (Department for Agriculture, Department for Environmental Protection) • Implementation of soil protection strategies according to soil protection concept (Department for Environmental Protection, Department for Urban Planning and Urban Renewal)
Biodiversity	• Creation of networks of biotopes (Department for Urban Planning and Urban Renewal, Department for Environmental Protection)
Agriculture	• Cultivation measures (production / cultivation consultancy) (Department for Agriculture) • Adaptation of technical equipment for extreme weather events (Department for Agriculture)
Forestry	• Restructuring of forestry (mixed forests) (Cemetery and Forest Department, Department for Environmental Protection)
Transport	• Enhancement of winter road maintenance (grit, resources), including cycle roads (Waste Department) • Enhancement of drainage of trams, implementation of green tram tracks (Tramway Stuttgart Ltd.) • Implementation of shadings etc. at public transport stops (Tramway Stuttgart Ltd.) • Air condition of public transport (N/A) • Implementation of city-wide mobility concept 2030 (Department for Urban Planning and Urban Renewal, Public Works Department, Department for Environmental Protection)
Tourism	• Extension of season of outdoor pool operation (Local Pool Operation Agency)
Planning	• Consideration of climatic factors in planning (Department for Urban Planning and Urban Renewal, Department for Environmental Protection) • Enhancement and extension of existing plans and development models (Department for Urban Planning and Urban Renewal, Department for Environmental Protection) • Density concept for quality proof of urban design and urban ecology (Department for Urban Planning and Urban Renewal, Department for Environmental Protection) • Integration of KlippS (Department for Urban Planning and Urban Renewal, Department for Environmental Protection) • City-wide tree concept (Department for Urban Planning and Urban Renewal, Cemetery and Forest Department) • Green roof concept (Department for Urban Planning and Urban Renewal) • Climate assessment for critical infrastructure (Department for Urban Planning and Urban Renewal, Department for Environmental Protection)

Table 3 Fields of Action and Measures defined in KLIMAKS

- Specify "champions" focusing on climate issues and implementation in respective departments and city-owned companies,
- Regular meetings of stakeholder groups involved in implementation,
- Implement monitoring mechanism for climate adaptation and annual, periodic progress reports,
- Further prioritisation of individual measures, to avoid trade-offs

Above all, successful implementation of an adaptation strategy requires a sound political mandate, a resolution by the municipal council, consequent flow of information between relevant departments, and generation of regular status updates, to be able to channel funding into the right direction, if required. Regarding finance, for upcoming periods of KLIMAKS, a separate budget for adaptation measures was recommended, to be able to act more independently and initiate, for example, information campaign or monitoring studies Stuttgart's most important fresh air corridors are located between already developed districts, Möhrigen and Vaihingen, the areas of Heumaden and Sillenbuch, in the district of Bad Canstatt between Espan and Kreutelstein, and in the district of Untertürkheim next to the Dietbach valley (see Figure 2-3). Stuttgart's plans on climate adaptation, especially the city's Climate Atlas, promote those corridors, to preserve large- and small-scale green belts for fresh air changes.

Unterer Grund area in the district of Stuttgart-Vaihingen is one of the main air corridors providing the inner city districts with fresh and cool air during night time generated through the existing thermal mountain-valley ventilation systems. The southwest-northwest oriented Nesenbach valley in Unterer Grund directs wind from this direction, which is the city's most common, with a frequency of 20% during daytime, and 40% during night-time.

Construction activity in Unterer Grund in the early 2000s was close to jeopardise the city's efforts in preserving this particular air corridor. However, early involvement of Stuttgart's climatology department allowed for changes in the planned structure, also comprising of smoke-tests carried out on-site. Following the recommendations of the climatology department, the project got restructured to cluster planned buildings at the centre of the site. Thereby, urban density could be increased, while large stretches of vacant green space, North and South of the site, were preserved to allow continuous cold air flow in the area.

The case of Unterer Grund exemplifies the role of a city's own climate institution and proactive, forward-looking planning in decision making processes for construction sites, balancing both interest of investors and the city itself. While the changes in zoning led to trade-offs for the original development plans, they ensure long-term preservation of the respective cold air corridor with particular importance for the urban climate and air quality.[50]

50 State Capital Suttgart, Office of Urban Planning and the Environment (2010): Climate change – challenge facing urban climatology.

EXEMPLARY PROJECT

Preserving Fresh Air Corridors in Stuttgart

A central pillar of Stuttgart's ongoing adaptation strategies are preservation and enhancement of fresh air corridors. Due to the city's geographic located in basin surrounded by valleys, such corridors, which are mostly respresented through natural meadow valleys and green belts, are a key factor for the urban air quality and thermal comfort, especially during the summer months. To preserve them over long term, it is important to avoid construction activity in relevant areas over long term by setting the right directions through the land use and zoning plan. The city's own department for urban climatology stressed that the future impacts of climate change will exceed the already existing struggles with air quality and urban heat islands.* For Stuttgart's urban planning, it is therefore crucial to balance between urban densification and inner city development, and preservation of the city's 'green lungs'.

Stuttgart's most important fresh air corridors are located between already developed districts, Möhrigen and Vaihingen, the areas of Heumaden and Sillenbuch, in the district of Bad Canstatt between Espan and Kreutelstein, and in the district of Untertürkheim next to the Dietbach valley. Stuttgart's plans on climate adaptation, especially the city's Climate Atlas, promote those corridors, to preserve large- and small-scale green belts for fresh air changes.

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The case of Unterer-Grund exemplifies the role of a city's own climate institution and proactive, forward-looking planning in decision making processes for construction sites, balancing both interest of investors and the city itself. While the changes in zoning led to trade-offs for the original development plans, they ensure long-term preservation of the respective cold air corridor with particular importance for the urban climate and air quality.

Figure 3: Cold air downflow along the ventilation axis left free of buildings at Unterer Grund, Stuttgart-Vaihingen. (Source: author. Imagery: Google, 2020.)

* State Capital Stuttgart, Office of Urban Planning and the Environment (2010): Climate change – challenge facing urban climatology.

2.3 HANNOVER

Figure 4: View on Hannover Center © H. Helmlechner, https://commons.wikimedia.org/wiki/File:Hannover_Blick_Neues_Rathaus_01.jpg

Hannover is the capital of the federal state of Lower Saxony with a population of around 530 000. Located in central Germany at the confluence of the rivers Leine and the Ihme, the city is a major crossing point for railways and highways, connecting European main-lines from East to West, and North to South. Through the Mittelland canal, the city is also a hub for inland water transport.

Challenges

A long-term analysis for the region of Hannover over the past 60 years showed an increase of yearly average temperatures, an increase of hot days, and duration of heat waves. While an overall increase heavy rainfall events was not yet reported for the past, several individual, localised extreme weather events in the region showed that there is a large potential for devastation on infrastructure, resulting in health impacts and financial cost.[51]

In the future, such adverse impacts related to climate change are likely to occur more frequently. According to studies focusing on climate change in the region of Hannover, following changes are to be expected:[52]

- considerable increase in the number of hot days and tropical nights: increase from around 6-10 hot days today, up to 16 hot days in the period 2071 - 2099
- increase in occurrence of intense heat waves and impacts of heat stress on human health, with longer lasting heat periods, beginning in spring compared to summer months today
- changes in precipitation patterns; increasing precipitation in winter months by 6 - 19 % in 2017 - 2099, decline of climatic water balance in summer months, and overall increase of annual rainfall volume by 13 %
- increase in extreme weather events including more frequent heavy rain and the risk of flooding: increase of days with rainfalls between > 20 mm per day and < 50 mm / per day from around 3 days today up to 4 - 6 days in 2071 - 2100
- longer and more frequent periods of summer droughts, with potential impacts on waterbodies, forestry and agriculture [53]

51 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

52 Schmidt, D. (Ed.) (2019): The City under Climate Change - The Adaptation Strategy for the City of Hanover. In: Urban Resilience, Governance and Climate Change. Coping with the consequences of climate change in Hanover, Germany. Hannover: Institutionelles Repositorium der Leibniz Universität Hannover. Source: https://doi.org/10.15488/6748

53 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

The **Concept for Climate Change Adaptation in the Hannover Region (KIAK-RH)** from 2018, based on guiding principles of DAS, identified six themes that should be considered in risk analysis for climate change impacts in the city of Hannover and surrounding regions:

I) human health,

II) water,

III) soil,

IV) biodiversity,

V) construction, and

VI) transport.

Based on those action areas, an impact analysis was conducted, with resulting thematic maps aiming to investigate and localise regional climate-related risks for potential impacts. [54]

Those areas with a dense built up structure and lack of green spaces, are especially prone to climate change impacts, and require focus regarding adaptation measures. In densely built-up areas, e.g. in Hannover's district Vahrenwald, an increase of very hot days from today's average of 8.7 up to 19.1 in 2090 - 2099, and a rise of tropical nights from an average of 1.2 today up to 9.2 in the same time period has been projected. [55] Resulting heat stress will especially influence vulnerable parts of society, such as the elderly and children, presenting challenges for the city in provision of adequate infrastructure. Demographic trends towards an ageing society, and with more citizens moving to Hannover's city centre due to better service infrastructure compared to the surrounding regions, the number of people affected is likely to increase in the future. This requires focus on adequate infrastructure, such as hospitals, climate-resilient enhancement of retirement homes, and childcare facilities.[56]

Strategic Framework

While the most recent strategy for climate adaptation is embedded within a broader, regional context, the municipality published an **Adaptation Strategy and Action Programme** with defined measures for the period of 2012 to 2016, highlighting on global and local climate data and projections for Hannover. The strategy identified three main focal areas: [57]

- Overheating of the urban fabric, resulting in heatwaves and tropical nights
- Change in precipitation, with increase of heavy rainfalls, and risk of flooding
- Longer dry periods in summer months

For the period between 2012 to 2016, the Adaptation Strategy for Hannover identified eight fields of action, which were selected according to their urgency:

- Flood protection, aiming to reduce impacts from overflows of river flooding:
  - construction of new and enhancement of existing dams and dikes across the city
  - introduction of a flood protection office, for investigation of past flood events, optimisation of existing strategies and systems and information of the public including early warning systems
  - renaturation of waterbodies, including deconstruction of human-made regulatory interventions and recreation of natural retention and water catchment areas
- Rainwater management and handling of heavy rain events:
  - measures in urban development planning including determination of rainwater seepage, implementation of temporary water storage areas, rainwater retention basins, and additional substitute areas through green roofs
  - additional synergies through utilisation of rainwater as greywater, unsealing of spaces, renaturation of waterbodies
- Preventive soil and groundwater protection, to preserve essential soil functions:
  - protection of semi-natural soils and vegetation, in respect to climate-effective functions
  - continuous brownfield remediation, enhancement of existing soils
  - unsealing of spaces, and regeneration of contaminated sites
  - avoiding freshwater use for irrigation purposes, focusing on greywater use
- Roof greening, to increase micro-climate:
  - subsidy programme for implementation of green roofs and facades on existing buildings
- Climate-adapted vegetation, aiming to focus replanting on resilient species:
  - Analysis of areas with heat-stress across the city, and selection of appropriate, climate resilient, trees
  - Improvement of existing tree grates by enlargement, deepening and exchange of substrate, to improve water storage capacities of trees

54 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover.
55 State Capital Hannover (2016): Adaptation Strategy and Action Programme 2012 – 2016. Living with Climate Change – Hannover Adapts.
56 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover.
57 State Capital Hannover (2016): Adaptation Strategy and Action Programme 2012 – 2016. Living with Climate Change – Hannover Adapts. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Hannover-im-Klimawandel

- Climate-adapted urban planning and climate-adapted construction, with consideration in individual projects:
    - For buildings, consideration of measures targeting solar protection, building insulation, passive cooling, façade design, greening of roofs and facades, and building orientation
    - For urban design, enhancement of retention areas and planting of trees for shading, mixed-use and compact urban design to preserve open spaces
- analysis map for climate adaptation, to support decision-making in urban planning through:
    - Cold air corridors, climate comfort islands, areas with climate-stress, locations for sensitive uses, areas with particularly high population-density, floodplains
- Public relations and educational activities:
    - Publication of flyers and brochures
    - Lectures on climate change and adaptation through educational facilities

To implement dedicated measures and especially 'quick-wins' under these focal areas, the municipal council of Hannover provided a total funding of around 1 Million Euro for the period of 2012 - 2016. Not all measures were implemented through this funding, as separate budget is provided for e.g. flood protection, where dedicated measures for extending dikes and expansion of cross sections of rivers where supported with 30 million Euro, or improvements of the road network.

While the Hannover adaptation strategy focuses on the city itself, KIAK-RH from 2018, follows a more regional approach. The KIAK-RH concept's core elements are guided by a spatial-functional impact analysis of expected regional impacts of climate change, both including the city of Hannover and surrounding municipalities. The overall strategy is then broken down into individual key measures. During the development process of the adaptation concept, it was considered essential to secure an early involvement of all stakeholders and provide a transparent flow of information, in order to guarantee efficient implementation. Actors playing a role in the implementation, such as public administrations, climate research institutes, local businesses and community organisations, decision makers and disseminators were invited over one year to several roundtables, committees and events to develop the concept collectively.[58]

Based on the analysis, targets were clustered under following fields of action: Human Health, Environment and Construction and Transport as well as Overarching Targets. Targets have been defined under the overarching paradigm of the strategy, to maintain a high-level quality of life in the city, and, to enhance the quality of life through multi-functional adaptation measures. Another guiding objective of the adaptation concept is to strengthen the interdisciplinary cooperation and knowledge transfer between the region and the municipalities.

Solutions and Measures for Adaptation

Hannover's Adaptation Strategy defines a number of individual key measures, of which several have been implemented during the 2012 – 2016 period, clustered under the eight thematic fields of action described above. In general, the Adaptation Strategy does not only include newly developed measures, but also measures that have already been integrated in city planning since several years, dating back to the 1990s or 2000s.

Strategic fields of action outline a clear direction and challenges to address, followed by individual measures, guidelines or financial aspects to consider. In some cases, measures are supported through subsidy programmes, not directly linked with the adaptation strategy. For example, expansion of retention areas, including roof greening, is supported by funding of the city's own roof and façade greening programme. Other measures are integrated within more holistic action or development plans, such as rainwater management and handling of heavy rain events, which is primarily addressed through urban development planning, including installation of rainwater retention basis or integration of technical rainwater storages, or renaturation of flowing waters. A key pillar therefore form information campaigns for involved stakeholders and the public, to enhance sensitivity to the topic of a changing climate.

The regional strategy, KIAK-RH, formulates key measures with the ambition of integrating them as efficiently as possible into existing planning departments or linking them to existing processes. Considering the spatial-functional impacts and objectives of KIAK-RH outlined in the previous chapter, the adaptation concept for Hannover identifies 14 key measures for climate adaptation and four fields of action, as outlined in Table 4 below. [59]

The fields of action of KIAK-RH align with the thematic clusters as outlined in DAS, the federal adaptation strategy. Spatial maps, risk assessments and individual measures focus on both Hannover and other municipalities in the region, include a detailed description of the individual measure, targets, clearly defined stakeholders, cost, potential pilot projects, and reference programmes.

Although climate adaptation is a separate field of activity and independent of climate mitigation, in the adaptation strategy for Hannover climate mitigation activities and projects in the region of Hannover, which are already being implemented and also serve as a starting point for adaptation measures are identified.

58 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

59 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

Field of Action	Key Measures for Climate Adaptation
Human Health	• Creation of a heat action plan • Ensure drinking water supply, even during long periods of drought and heat • Update the regional climate analysis
Construction and Transport	• Implementation of a pilot project for climate-adapted building and open space design • Elaboration of an integrated concept for traffic management during flood events in the region • Development of an action strategy plan for traffic safety in the S-Bahn network during extreme weather events • Climate sensitive public transport
Environment	• Management of groundwater-related applications with regard to changing requirements • Strengthening and intensification of measures for nature-based climate adaptation • Monitoring invasive species and developing strategies to combat them • Providing an expert foundation for precautionary soil protection measures
Consolidation and Communication	• Institutionalization of climate adaptation within the regional administration • Development of an information platform on climate change • Implementation of a municipal pilot project for climate adaptation

Table 4: Fields of Action and Key Measures of the regional adaptation strategy KIAK-RH

These include the following climate mitigation activities:

- E.coSport: Support programme for energy-efficient renovation of sports facilities with environmental consulting
- Climate protection framework programme: Reduction of CO_2 emissions by 40% by 2020
- Climate Protection Region Board for optimisation of structures relevant to climate mitigation
- Hannover Master Plan: Climate Neutral Region Hannover by 2050 [60]

Progress Monitoring and Indicators

A crucial aspect of KIAK-RH is the integration of a permanent controlling system as a central element for successful implementation of the concept over long-term. KIAK-RH suggests a system divided into a monitoring module and an evaluation module and to summarise the findings in an annual progress report. The monitoring module includes following indicators, with annual, seasonal and monthly assessments:

- Average temperature, including min. and max. temperatures, hot days and tropical nights, duration of heat periods
- Precipitation patterns, including seasonal changes, quantity, and occurrence and duration of dry periods
- Heavy rainfalls, including max. daily precipitation, occurrence of heavy rainfalls (> 50 mm per day)
- Heavy storms, changes in wind speed, max. annual wind velocity, average daily wind velocity

Findings and patterns should be highlighted and reviewed in context of long-term trends.

The evaluation module addresses progress of the adaptation strategy regarding status of implementation and achieved impact. The evaluation is based on following components:

- Implementation monitoring: interviews with relevant stakeholders from implementing institutions or public administration departments, addressing status of project implementation
- Impact monitoring: quantitative (e.g. through models or measurements) or qualitative assessments (e.g. expert interviews), investigating effect of implemented measures
- Success monitoring: evaluation of success through qualitative indicators developed for each measure.[61]

The evaluation highlights success of already implemented measures, and proposes adjustments, if necessary. For measures still in process, prevailing challenges are pointed out and recommendations for improvements are given.

60 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

61 Region Hannover (Ed.) (2018): Klimaanpassungskonzept für die Region Hannover. Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Die-Region-Hannover-im-Klimawandel/Klimaanpassungskonzept-für-die-Region-Hannover-2018-KIAK-RH

KIAK-RH forms a cornerstone of Hannover's Masterplan City and Region Hannover | 100% for Local Climate Action, which aims for a carbon-neutral city and region until 2050. Targets mostly include aspects on mitigation of greenhouse-gases, however includes components such as KIAK-RH, with a focus on adaptation.[62] Other strategic instruments in Hannover include the city's Climate Analysis Map, giving a broad overview on green and open spaces and their cold air flow volume, as well as those areas that are prone to the heat island effect.[63]

Outcomes and Progress

Several projects for climate adaptation in Hannover have been implemented in recent years, with some of them outlined in the Adaptation Strategy, while others were integrated in already developed programmes.

Hannover-Bothfeld, Herzkamp – Development of a Climate-Adapted Residential District

EXEMPLARY PROJECT

The "Herzkamp" project is a new urban development of a residential district with around 300 housing units on former agricultural land. The development is considered a pilot project under Hannover's climate adaptation strategy to integrate learnings into a "Hannover-Model" to be used for sustainable and climate resilient developments of new and existing neighbourhoods and districts.

"Herzkamp" is developed in close cooperation between the City of Hannover and the private developer Grundlach. City and private developer both shared work packages in the planning process, for the city steering project management, process development, location and structures, climate, energy and mobility as well as educational aspects, with Gundlach focusing on buildings and architecture, soil and rainwater management, and open spaces and vegetation. Further, the project is monitored by a private research firm, partly funded by Germany's Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety to investigate impacts of adaptation measures, and used as a reference project for local and regional cooperation.

For the project area of approx. 9,2 hectares, more then ten measures target climate adaptation were addressed, including, for example:

- Cold air corridors, through early consideration in urban design
- Roadside trees, with focus on dryness- and heat-resistant local species
- Rain water concept, integrating decentralised runoff basins on private properties to collect rainwater from buildings, and roadside rainwater basins for rainwater from public areas; during heavy rainfall, water is cascaded into the adjacent green corridors
- Neighbourhood plaza, with water features for cooling, trees for shading, reed-basins for evaporation and high-albedo surfaces
- Extensive green roofs, on all buildings on the site,
- Climate adapted buildings, with light-coloured facades, smaller window areas, and solar shading
- Underground waste dumpsters, to reduce odours during hot days

In addition, measures for climate mitigation are equally targeted, through highly energy efficient buildings (KfW 40 Efficiency Standard), a CHP plant in combination with solar thermal, access to public transport and carsharing, as well as chargers for e-mobility.

62 Landeshauptstadt Hannover (2020): Klimaneutrale Region 2050 – Das Masterplan-Projekt. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimaschutzregion-Hannover/Masterplan-100-f%C3%BCr-den-Klimaschutz/Das-Masterplan-Projekt

63 Landeshauptstadt Hannover (2017): Klimaanalyse für die Landeshauptstadt Hannover. Source: https://www.hannover.de/Leben-in-der-Region-Hannover/Umwelt-Nachhaltigkeit/Klimaschutz-Energie/Klimawandel-und-anpassung/Klimaanalyse-f%C3%BCr-die-Landeshauptstadt-Hannover

Implemented measures under the city's "Programme for the Minimization of Impacts of Global Warming" are:

- Rainwater management / soil protection, with a success in unsealing around 4000 m^2 of bus lanes, and unsealing of street verges and planting of trees, as well as renovation of existing tree locations, creation of retention spaces, and installation of groundwater measuring stations

- Roof greening, launching of a roof and façade greening project, providing funds for around 10 000 m^2 roof greening and 20 projects for façade greening, with focus on institutional and educational buildings

- Climate modelling for several urban districts, and integration into urban development planning,

- Continuing research for climate-adapted urban development, including vulnerability analysis

- Public relations work, including leaflets and brochures for the public, as well as series of lectures and information campaigns,

- Environmental education, in school classes to sensitise pupils towards the topic.

Currently, a review for measures included in the regional KIAK-RH strategy have not been issued yet, however, an annual review including monitoring and evaluation on implementation is to be produced.

3. RECOMMENDATIONS AND OUTLOOK

3.1 RECOMMENDATIONS

From the cases of Berlin, Stuttgart and Hannover a number of cross-cutting recommendations are derived for guidance in both development of urban climate adaptation strategies and measures. The recommendations are explained in detail below:

Significance of the municipal level for climate adaptation

For a streamlined approach in Federal adaptation strategies such as DAS, it is key to integrate and consult with the municipal level for development and implementation of the framework. Municipalities are the key stakeholder in implementation of concrete strategies and measures, with their fundamental responsibilities on infrastructure supply, including water and wastewater management, energy, transportation infrastructure, or flood protection. Such essential components of urban infrastructure, usually are established, administered and maintained by local authorities. This increases flexibility of cities and towns in driving forward adaptation strategies and aligning existing infrastructure with requirements in a changing climate. In addition, action at municipal level allows for a great variety of collective decision-making processes to address with accuracy the needs of local stakeholders and communities. Municipalities can integrate citizens in stakeholder processes when deploying strategies and consult them in planning and development of localised measures. Building local capacity to respond to impacts of climate change requires organisational, process-oriented, and technical skills as an essential prerequisite for successful implementation of adaptation strategies.

Comparability through structured strategies

In Germany, the Federal strategy DAS is the guiding document for development of municipal adaptation strategies. Although the local strategies presented in this document evolved through different processes – especially regarding stakeholder consultation and development timeframes - underlying structures, thematic focus and processes for implementation follow a similar approach. Focal areas outlined in DAS, can be found as well in the local strategies. This allows for high-level comparability between different strategies, despite their variations regarding geographic and climatic particularities. This also enables streamlined approaches in deployment of subsidy programmes, which for example, are issued by Federal agencies since 2011 for adaptation projects, with varying focal areas. This allows initiation of projects aligning with Federal funding priorities.

Understanding climate adaptation as a cross-sectoral challenge

For cities and regions, climate adaptation is a cross-sectoral challenge that requires close cooperation and exchange between individual public and private stakeholders. In many cases, dedicated adaptations measures on the ground call for involvement of already existing specialist departments in urban administration (e.g. in case of flood protection). Such departments already fulfil a role in mitigating risks of natural hazards, which are likely to get

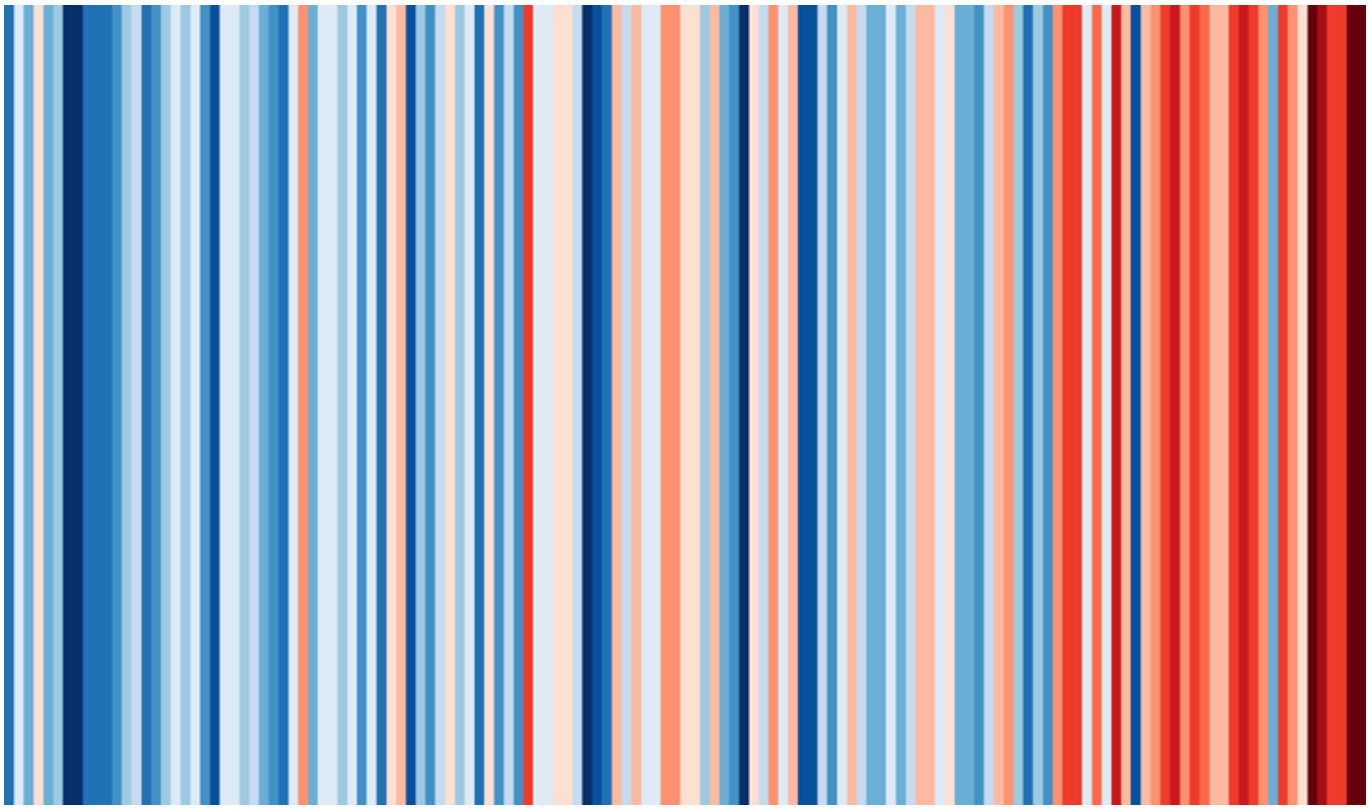

Figure 5: Visualisation of average annual temperature change between 1881 - 2019 in Germany © Ed Hawkins, https://showyourstripes.info/

aggravated through a changing climate. A comprehensive climate strategy holds the strings together between individual administrative departments and other stakeholders, articulates common adaptation goals, builds networks and ensures regular and transparent communication to avoid trade-offs. The challenge of embedding an integrated approach towards climate adaptation in already existing structures could be overcome through dedicated cross-departmental working groups in public administration or permanent coordinating and organisational structures. Further, to ensure ownership of individual measures within an adaptation strategy, the responsibilities for their implementation have to be clearly determined and communicated among the different municipal departments.

Sound monitoring and reporting mechanisms

A comprehensive monitoring and reporting mechanism is crucial to ensure long-term success of an urban adaptation strategy. This includes periodic monitoring and review of ongoing climate impacts as well as the performance and effectiveness of adaptation strategies allows for detailed assessment, continuation, alignment or rejection of targets and measures. To consider the specific local requirements of an adaptation strategy, dedicated indicators are required, to be assessed in regular intervals (e.g. annual or biannual). As shown in the case of Berlin, developing a set of state, impact and response indicators allows to track and assess a wide range of climate related impacts and effects of measures. Findings of regular monitoring allow for consideration in adjustments in targets, as well as planning, including finance, time schedules, and personnel to the situation on the ground.

3.2 OUTLOOK

The past summers with prolonged heat periods and dry winters have increased the focus of the German public and political attention on climate adaptation. While global relevance of climate mitigation is unchanged, the importance of climate adaptation has experienced a continuous rise of attention, with the notion that many effects of the changing climate can no longer be avoided.

Against this background, Germany's municipal administrations and local political bodies are required to further consider their vulnerabilities to the consequences of climate change. Addressing adaptation strategies already at an early stage, helps to avoid high cost in the future. Climate-proofing of construction projects, that would be carried out anyway, in many cases allow for negligible additional costs when adaptation measures are included. Urban development projects considering climate adaptation, hence can evolve in multifunctional infrastructures with favourable effects for the urban environment. Construction projects considering well considered green and open spaces, not only benefit from enhanced micro-climates, but also have positive effects for recreational purposes, and urban beautification. Those positive side-effects are well-established, and recently established Federal urban development subsidies especially take green infrastructures into account.[64] Climate adaptation can therefore be considered as an opportunity rather than a nuisance, as most adaptation projects are not monofunctional, but include additional functions for the urban environment and its citizens. Future-oriented and sustainable urban development increases quality of life, enhances well being of citizens, and thus contributes to a positive image of respective cities and towns.

64 For more information on Germany's Federal urban development subsidy programmes, see Keystone Paper #3: Transformative City.

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Sino-German Urbanisation Partnership

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