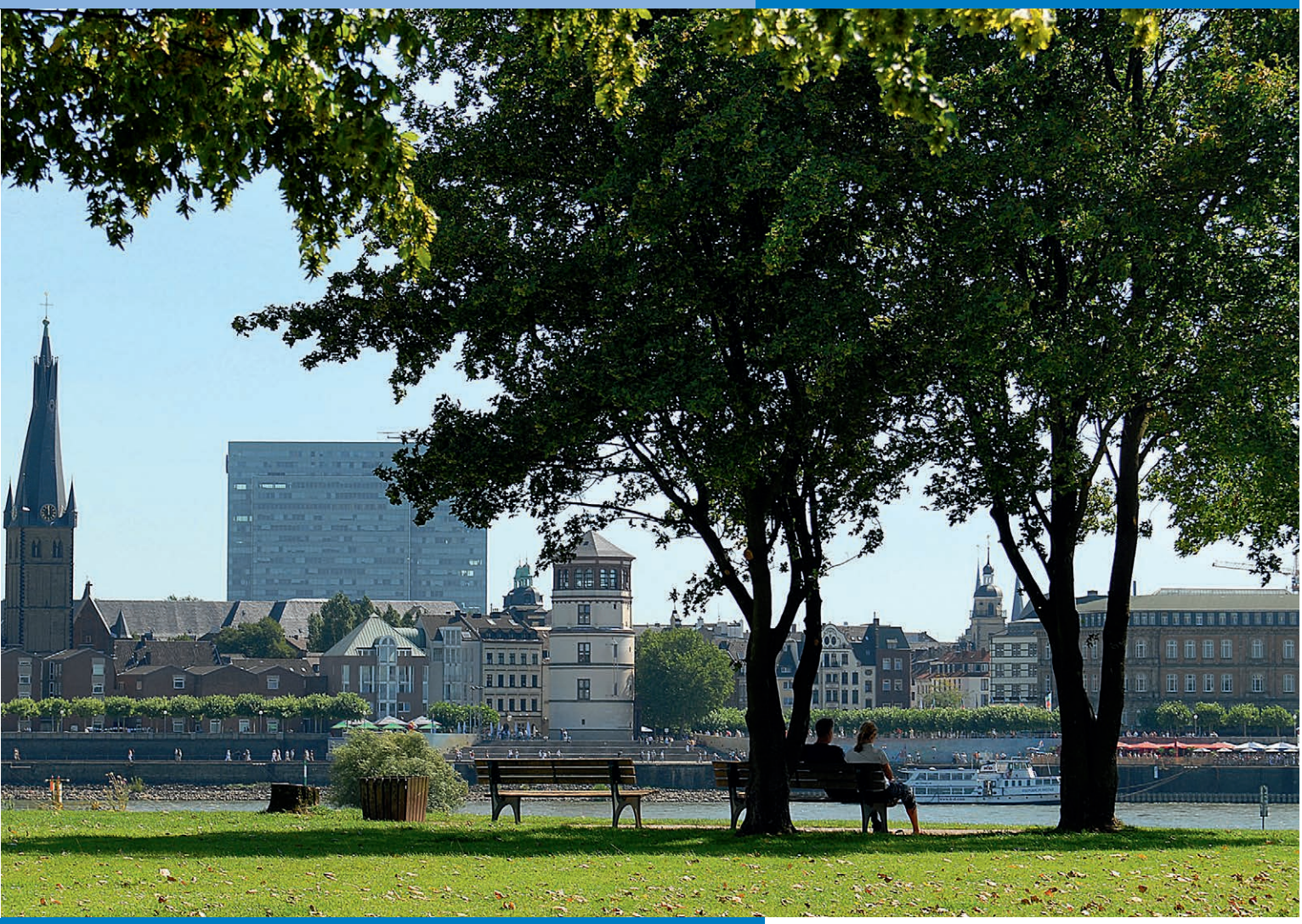
Landeshauptstadt
Düsseldorf

KAKDUS Climate Change Adaptation Concept for Düsseldorf

Summary



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NATIONALE
KLIMASCHUTZ
INITIATIVE

by resolution of the German Federal Parliament

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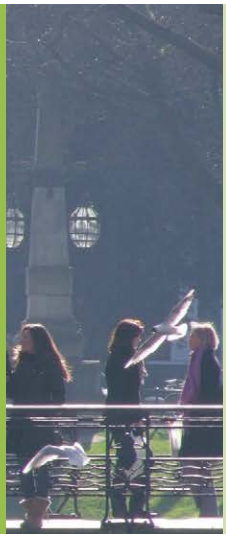
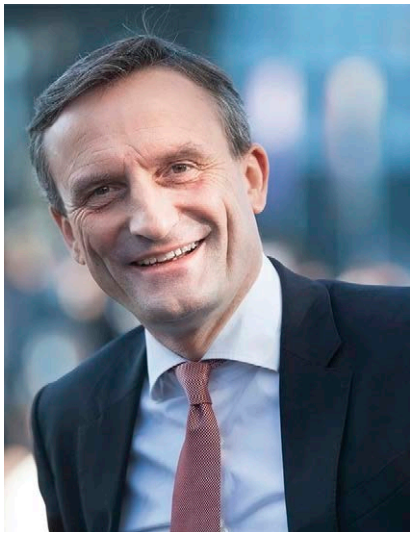


Preface



The effects of climate change are already being felt in Düsseldorf, the capital city of the federal state of North Rhine-Westphalia. Temperatures are on the increase, extreme weather events are occurring more frequently and some nights are so "tropical" that the good citizens of the city are losing sleep. The city is becoming increasingly vulnerable to the consequences of climate change. The state capital Düsseldorf takes this challenge very seriously indeed and plans to adapt the city so that it can deal more effectively with the emerging changes. This climate change adaptation concept represents a first step towards confronting climate change in a structured and strategic manner. Joint action on the part of civil society and the municipal administration is an important facet of this process. Both the City and its citizens are called upon to contribute to the necessary adaptation. This may involve improving the protection of more vulnerable population groups, such as children and senior citizens, within the city or enabling the population to be more self-reliant. Working together is the only way to succeed in creating a city that remains a viable place in which to live and work, even in the face of increasingly extreme weather.

As part of global warming, Düsseldorf's mean air temperature has already risen by approximately 1°C per annum compared with the decade from 1970 to 1980. The number of summer days, i.e. days on which the maximum temperature exceeds 25°C, has also increased. In addition, we are experiencing a greater number of "tropical" nights, on which the air temperature fails to drop below 20°C. And this trend is set to continue, according to projections made for Düsseldorf by Germany's National Meteorological Service. Against this backdrop, the high quality of life enjoyed in the city is at risk. To mitigate this process, we need to adapt to changing climatic conditions. And this climate change adaptation concept for the state capital Düsseldorf provides us with a starting point. The 15 "key measures" it describes in detail support the aim of allowing citizens to continue to live and enjoy a high standard of living in Düsseldorf. You can help the city too – for example, by planting a roof garden or by watering the tree grate nearest to your home during hot spells.

Thomas Geisel, Lord Mayor

Helga Stulgies, Deputy Mayor and Environment Officer

Introduction

Motivation and starting point

The effects of climate change are already being felt in Düsseldorf today. The city must adapt in preparation for the more intense hot spells, longer periods of drought and more frequent extreme weather events (e.g. heavy rainfall) that are coming our way in future. Early and ongoing adaptation to changing climatic conditions therefore represents an important element of avoiding climate risks for the state capital Düsseldorf.

Climate protection and **climate change adaptation** go hand in hand in this process. Ongoing environmental protection efforts seek to limit the extent of climate change going forward. Meanwhile, climate change adaptation will enable us to respond as flexibly as possible to any future climate changes that may occur.

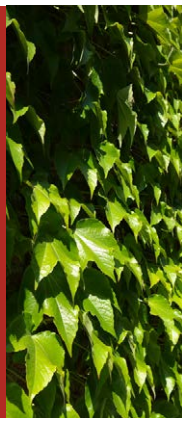
In 2015, the Committee for Environmental Protection therefore tasked the administration with creating a climate change adaptation concept for the state capital Düsseldorf. The goal was to develop strategies and measures to deal with the effects of climate change. These aim to increase the city's resilience to and ability to withstand the effects of climate change and to improve the responsiveness of Düsseldorf and its citizens. It is hoped that, by giving full consideration to climate change early on, it will be possible to maintain and develop Düsseldorf's high quality of life, its attractiveness as a location for business and investment, its competitiveness and good working conditions in the long term.

"Climate protection"

Climate protection refers to activities that aim to reduce the human impact on climate and thereby prevent further climate change. These measures seek, first and foremost, to reduce the consumption of fossil fuels and the emission of greenhouse gases.

"Climate change adaptation"

Strategies and measures for climate change adaptation seek to avert or at least mitigate the inevitably negative consequences of climate change. At the same time, these measures also aim to exploit the potential resulting from climate change.



Process and stakeholders

In order to achieve the specified objectives, a comprehensive and flexible concept is required, which establishes climate change adaptation as an ongoing process for the municipal administration. As a first step, an interdepartmental Climate Change Adaptation project group was set up to pave the way for and support the process of creating this concept. The project group comprises around 30 representatives of various departments within Düsseldorf's municipal administration, as well as various owner-operated municipal enterprises:

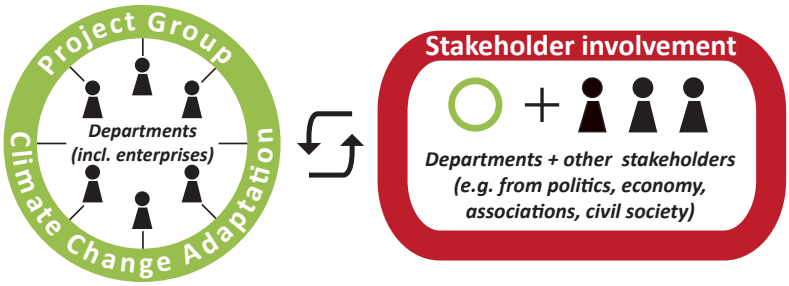
- Office for Building Management
- Statistics and Elections Office
- Office for Traffic Management
- Department of Environmental Protection and Public Buildings
- Düsseldorf Tourismus GmbH
- Fire brigade, rescue services, Civil Protection
- Parks, Cemeteries and Forestry Office
- Health authority
- Netzgesellschaft Düsseldorf mbH
- Neuss-Düsseldorfer Häfen GmbH & Co. KG
- Sports Office
- Municipal Drainage Department
- City Planning Office
- Stadtwerke Düsseldorf AG (water)
- Environment Agency

From March 2016 to March 2017, the municipal administration of Düsseldorf collaborated with the expert consultants GEO-NET (Hanover), MUST (Cologne) and PECHER (Erkrath) to develop the **C**limate Change Adaptation **C**oncept for the state capital **Düs**seldorf (**K**lima**a**npassungs**k**onzept für die Landeshauptstadt **Düs**seldorf, or "KAKDUS" for short).

The members of the interdepartmental Climate Change Adaptation project group assisted the expert consultants with their impact analyses, as well as with the development of adaptation strategies and measures. They brought the results of discussions from the process back to their individual departments on a regular basis in order to lay the groundwork for the necessary coordination that will be involved.

A broader set of stakeholders, including specialist circles within the general public and policy-makers, were involved in developing the concept at an inaugural event, a one-day workshop for stakeholders, a closing event and several newsletters.

Creation of the concept was funded as part of the National Climate Protection Initiative of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).



Action areas for adaptation

Climate change has many effects on the environment, buildings and communal infrastructures, the economy and urban society. The first step in formulating KAKDUS was to establish the municipal areas of activity in which special challenges are presented by long-term changes in the climate and the expected increase in extreme weather events.

The German Adaptation Strategy (Deutsche Anpassungsstrategie, DAS), adopted by the Federal Government in 2008, served as a basis for selecting the relevant areas of activity for Düsseldorf. The strategy identifies the individual and cross-cutting areas of activity that are of central importance at federal level. These were adapted to the municipal context for KAKDUS. Ultimately KAKDUS identified a total of eleven individual areas of activity and three cross-cutting areas of activity:

Individual areas of activity:

- Water management
- Health
- Agriculture and forestry
- Soils
- Biodiversity, nature conservation and species protection
- Green areas and open spaces
- Construction and real estate
- Traffic and mobility
- Energy
- Tourism and leisure
- Port and trade

Cross-cutting areas of activity:

- Urban and landscape planning
- Disaster control and civil protection
- Education and research

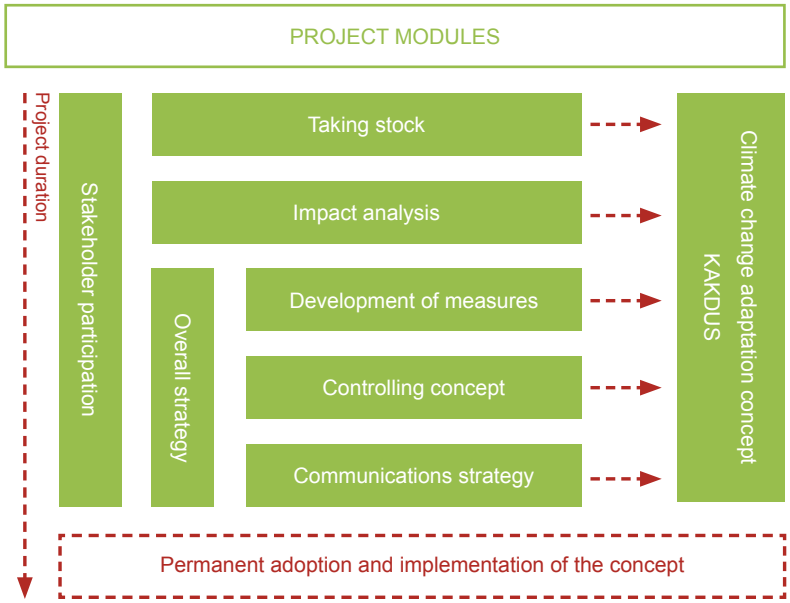
The individual areas of activity (e.g. Health) are impacted directly by the effects of climate change. In the three cross-cutting areas, climate change leads indirectly to a higher-level need for provisioning and action to adapt to climate change (e.g. urban and landscape planning).

Steps

Düsseldorf had previously taken a number of important steps on the journey towards creating a city adapted to climate change. Therefore, development of the concept (see chart on the right) began by taking stock of the actions that are already under way to support the process of local climate change adaptation. These need to be continued, interconnected and developed further. In addition, the existing basic research, data and models as well as previous experience of climate change and climate change impacts were evaluated.

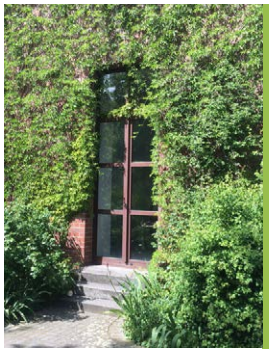
The next step was to conduct a comprehensive geographical and functional impact analysis. This analysis served to identify the effects of climate change on different geographical areas within the city and the consequences of these for the various municipal areas of activity and to evaluate these in terms of relevance (see page 10 et seq.).

Based on the impact analysis, the expert consultants worked closely with the individual offices of the municipal administration to identify objectives that the state capital's adaptation process should strive to attain in future (see page 22 et seq.). They collaborated with a large number of specialists, e.g. during a one-day workshop, to compile a set of measures that inherently lend themselves to the achievement of the stated objectives. This produced a catalogue of measures comprising approaches that have the potential to ensure the future sustainability of the municipal administration's ability to fulfil its duties even in the face of changing climatic conditions and which are to be pursued on a short-, medium- and long-term basis. As a next step, key measures were selected from the large number of measures proposed. These key measures are regarded as most likely to be particularly beneficial to the implementation of the adaptation concept.



An accompanying controlling concept was also developed to enable the future progress of the adaptation process to be documented in a structured manner. This will focus in particular on the implementation status of the key measures and their contribution towards achieving the objectives of adaptation. At the same time, the systematic recording of climate changes and their region-specific effects is to be extended.

The communications strategy developed towards the end of the KAKDUS project demonstrates, on the one hand, how the content of the climate change adaptation concept can be shared with the population and with other relevant stakeholders. On the other, it shows how a broad consensus and active collaboration can be achieved for the purpose of implementing the measures.



Existing measures for climate change adaptation in Düsseldorf (a selection)

- → Fostering of roof greening and insulation measures (since 2012)
- → City-wide groundwater model for mapping future groundwater formation
- → Improvement of flood prevention
- → Development of a flood protection concept
- → Damage and risk analysis for the drinking water supply
- → Operation of two weather stations (since 2008/2012)
- → Phenological garden (since 2008)
- → Species monitoring (since 2008)

Climate change

and its effects on Düsseldorf

Weather and climate in flux

The state capital Düsseldorf has been grappling with the analysis and assessment of the situation regarding the city's climate for quite some time now. A climate analysis was undertaken back in 1995, which was updated and extended significantly in 2012. Furthermore, changes in the climate are recorded by means of two City-owned weather stations, a weather station operated by the German Meteorological Service, a phenological garden and a programme of species monitoring, whereby a selection of climate-sensitive animals and plant species are closely observed.

These analyses indicate that the consequences of climate change are also detectable in Düsseldorf (e.g. heat stress, heavy rain, drought) and that strategies must increasingly be developed in order to deal with these changes.

As part of KAKDUS, the German Meteorological Service compiled a detailed report on the current climate, as well as climate changes that have occurred to date in Düsseldorf and those predicted to occur in future. The statements outlined on the following pages are based largely on the results of this report by the German Meteorological Service, which can be consulted for a more in-depth discussion. The evolution of the current climate is mapped by analysing the measurements recorded at the measuring station at the airport.

Based on the findings of climate research, the impact assessment underlying the current climate change adaptation concept presupposes the changes in climate summarised in the table (see below). KAKDUS took account of gradual changes and the increase in the number of extreme weather events. For the three climate parameters

- temperature increase and heat
- heavy precipitation
- shifting precipitation patterns and drought

geographical as well as comprehensive functional impact analyses were conducted, and the results of these are briefly discussed on the following pages also.

"Weather & climate"

The term "weather" refers to atmospheric conditions that are actually experienced in a particular place at a particular point in time. These include sunshine, cloud cover, rain, wind, heat and cold.

The term "climate" refers to the weather statistics available for a specific location. These statistics are recorded for periods of time that are sufficiently long for statistical conclusions to be drawn. In meteorology, this is normally 30 years or more.

Expected changes in climate		
	Rising temperatures and heat	– Increased average annual temperatures – More summer days (Tmax > 25°C) and tropical nights (Tmin ≥ 20°C) – Longer and more frequent hot spells
	Heavy precipitation	– Increased proportion of heavy precipitation compared with total precipitation
	Shifting precipitation patterns and drought	– Drier summers, damper winters – Longer and more frequent drought during summer

Rising temperatures and heat

What changes can we expect climate change to bring?

Climate changes and its effects are already being felt in Düsseldorf today. Over the last 50 years, the mean air temperature in the state capital has risen by around 1 °C (see chart below). The most significant rise in temperature has occurred in the last 25 years.

In recent decades, the number of summer days and hot days has risen, with maximum daily temperatures of ≥ 25 °C or more and 30 °C or more respectively. The number of sunshine hours has also risen considerably.

Meanwhile, the number of "ice days" – days on which the maximum daily temperature dips below 0 °C – has been declining. On the other hand, the number of "frost days", on which the minimum temperature drops to below 0 °C, has increased slightly.

The results of calculations based on regional climate models indicate that there will be a further temperature increase in the region of 0.8 to 1.7 °C by 2050. By the end of this century, we can expect a rise of between 1.5 and 4.3 °C, depending on which scenario you choose.

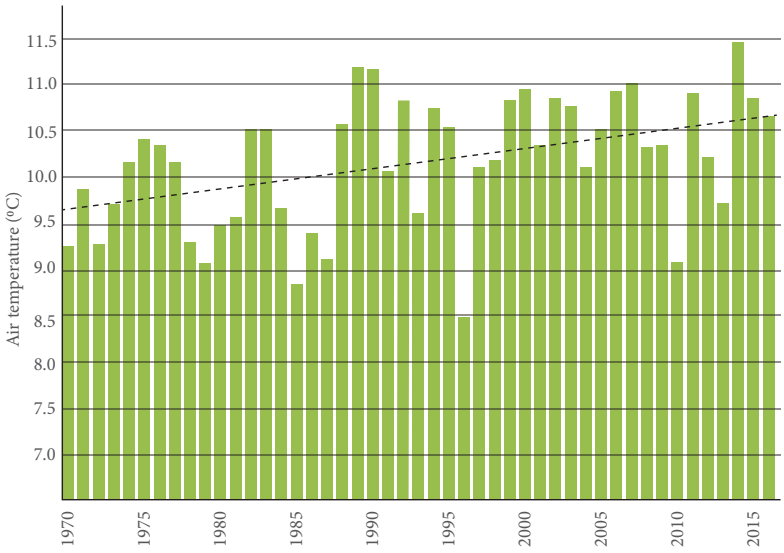
The increase in the number of hot days (with highest daily temperatures ≥ 30 °C) will be particularly noticeable, and the effect will also be amplified in a large, heavily built-up city like Düsseldorf. At present, an average of 8 to 9 hot days occur each year.

"Heatwave"

In Europe, the term "heatwave" is generally employed if the maximum daily temperature exceeds 30 °C for several consecutive days.

In the scenario that mostly closely corresponds to actual trends at present, 40 hot days per year could be the norm by the end of the century. And, even if calculations are based on a very optimistic scenario, it is still expected that the average number of hot days per year will, in future, be in the region of 20, as was the case in the hot summer of 2003
(see chart on page 13, bottom).

It is also expected that there will be a clear increase in the number of "tropical" nights, on which the temperature does not drop below 20 °C. Tropical nights in particular impact the human body, as it is usually impossible to have a restful night's sleep with temperatures as high as this. At present, Düsseldorf experiences an aver-



Time series of annual average temperatures measured at the weather station based in Düsseldorf airport 1970–2016 (source: German Meteorological Service 2017)

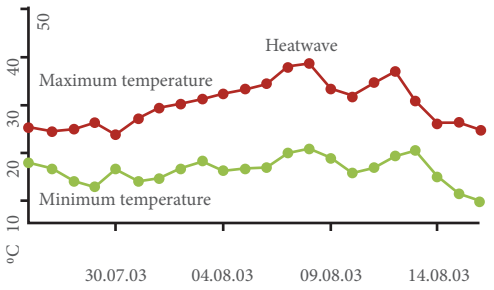
Hot summer of 2003

METEOROLOGICAL DATA:

- → Heatwave lasting more than 10 days
- → A very hot, dry summer
- → 664 hours of sunshine from June to August
- → Highest temperature measured in Düsseldorf on 8 August: 38.5 °C (highest value since 1969)
- → Hottest night: 24.7 °C

EFFECTS:

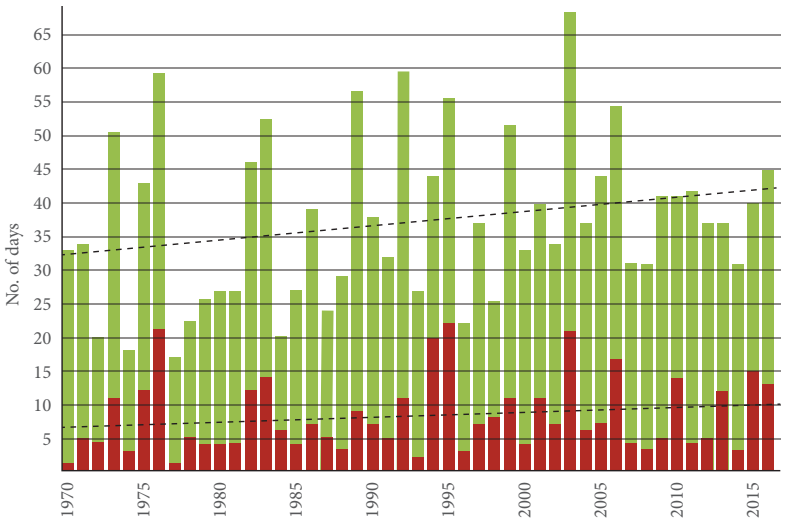
- → The water level of the Rhine dropped to a record low of approx. 74 cm in Düsseldorf.
- → Passenger transport services on the Rhine were suspended, while cargo vessels were only permitted to carry a third of their normal load.
- → Throughout Germany, around 7,000 people died as a direct or indirect result of the heat, with the elderly and those rendered vulnerable by illness being at particular risk.
- → There was a sudden rise in the number of burials taking place in Düsseldorf, despite a general downward trend.



age of 0.9 tropical nights annually. 13.3 tropical nights per year are projected for the end of the century (2071-2100). And, by the middle of the century (2041-2070), the models predict that we will be experiencing 5.3 tropical nights per year. The values specified here are based on the results from the measuring station located at Düsseldorf airport, i.e. away from the city centre.

Period	Highest temperature
9 to 13 August 1997	32.4 °C
30 July to 4 August 1999	31.3 °C
2 to 12 August 2003	38.5 °C
17 to 27 July 2006	36.3 °C
8 to 14 July 2010	36.0 °C
1 to 7 July 2015	36.0 °C
24 to 28 August 2016	33.5 °C
12 to 15 September 2016	32.6 °C

Hot spells of at least five consecutive days with highest daily temperatures of 30 °C and more between 1990 and 2016, as measured at Düsseldorf airport (source: German Meteorological Service 2017)



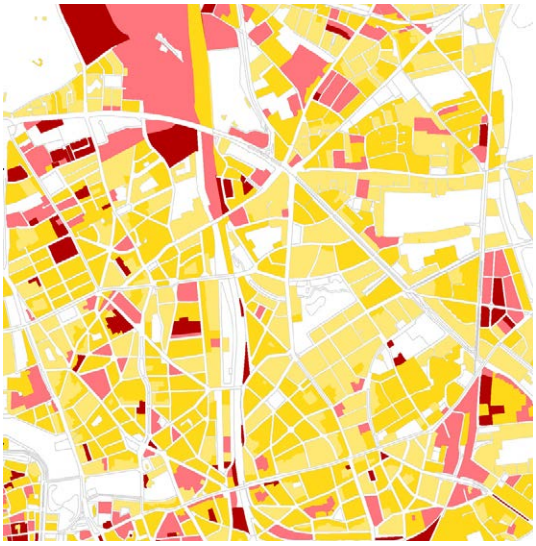
Number of summer days and hot days as measured at Düsseldorf airport 1970–2016 (source: German Meteorological Service 2017)

Which areas will be impacted most?

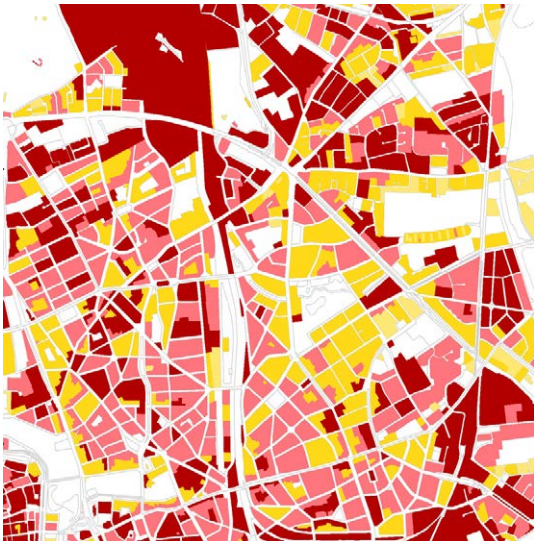
The relatively sharp rise in the number of hot days and tropical nights will be experienced very differently in different areas within the city of Düsseldorf. The projected values tend to be higher for areas in the city centre. The thermal impact on districts on the edge of Düsseldorf will be considerably less than for areas close to the centre. The reason for this is that the centre is more densely built-up with larger buildings, and the proportion of sealed surfaces is therefore significantly higher. Essentially, the models predict that areas that are particularly warm at present become all the warmer in future.

Compared with developed areas, thermal stress is much lower in green spaces and unsealed open areas. This underlines the importance of such areas for the city climate.

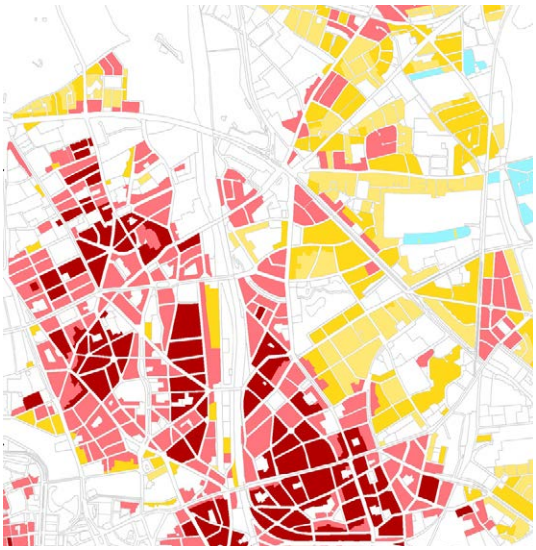
By way of example, the map sections (see below) illustrate the human bioclimatic stress due to heat during the day and at night for a selected area of Düsseldorf. These show, on the right, a clear increase in thermal stress in future (2041–2070) compared with the reference period on the left (1971–2000).



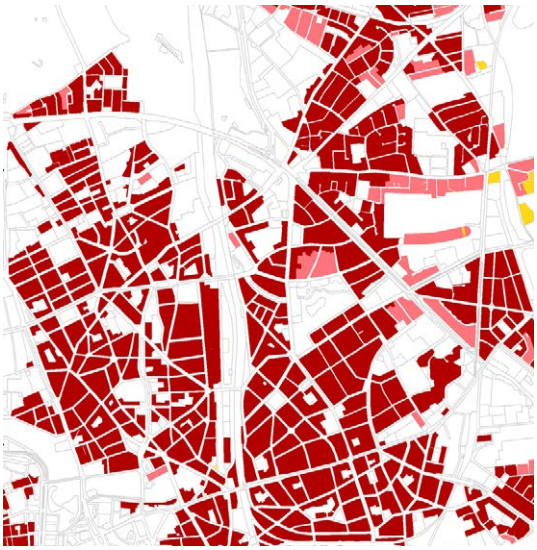
Thermal conditions during the day (currently)



Thermal conditions during the day (in future: 2041–2070)



Thermal conditions at night (currently)



Thermal conditions at night (in future: 2041–2070)

Thermal conditions during the day/at night

- Very comfortable
- Comfortable
- Less comfortable
- Uncomfortable
- Very uncomfortable

What are the potential consequences of these changes in climate?

The gradual increase in temperature impacts, above all, the components of the urban ecosystem (soils, water, flora, fauna) and their interdependencies. In the long-term, we must assume that there will be lasting changes that will affect, for example, the composition and distribution of species, growing seasons and the physiochemical water status.

The increased frequency of hot days and tropical nights leads to increased human bioclimatic stress levels among the population as a result of thermal stress. The investigations undertaken as part of KAKDUS have demonstrated that the proportion of residential areas with good or very good human-bioclimatic conditions could drop significantly in future as a result of increasing thermal stress. This places increased demands on the health service, in particular when it comes to dealing with heatwaves. However, other spheres of activity, such as the construction sector and city planning, are also faced with the challenge of counteracting overheating and avoiding damage caused by heat and solar irradiation.

Possible effects of rising temperatures

- → Rising energy requirements for the cooling of buildings, equipment and vehicles
- → Wear and tear on green spaces and sports fields due to increased solar irradiation and intensive use
- → Increased material wear and damage to transport routes due to heat and fluctuating temperatures
- → Thermal damage to goods (storage and transport) and to technical equipment
- → Heating-up of traffic areas and open spaces due to increased solar irradiation
- → Increased odour emissions due to decomposition processes in the sewage system
- → Warming and impairment of the physiochemical status and quality of bodies of water
- → Shifting species diversity/spread of invasive animal and plant species
- → Increasing and earlier pest infestations following mild winters
- → Damage (e.g. protein coagulation) to heat-stressed vegetation
- → Damage to/loss of soil functions due to increased soil temperature
- → Growing demand on resources for waste disposal, green waste, monitoring, sewer flushing and irrigation
- → Increasing physical strain and risk of accident due to heat stress and decreasing ability to concentrate
- → Establishment of new and spread of existing pathogenic agents and disease carriers
- → Sudden and increased demand on health and funeral services during heatwaves

Heavy precipitation

What changes can we expect?

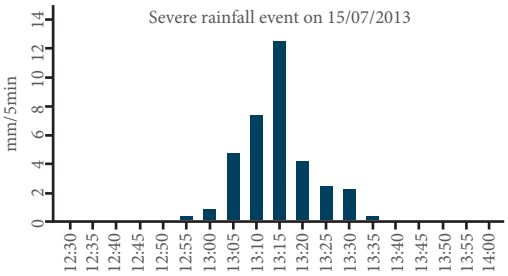
It is much more difficult to make assumptions about changes in precipitation than it is in relation to changing thermal conditions because precipitation is subject to much greater and more localised fluctuations. For Düsseldorf, one question that is particularly relevant in this context is whether more frequent and more intense precipitation will occur in future because past experience has shown that such events are associated with significant potential for damage and risks to safety.

From 1971 to 2000, Düsseldorf experienced an average of around 20 days per year on which precipitation levels reached 10 mm or more. The number of days such as these has increased slightly since 1970. They have occurred most frequently during the summer months and are usually caused by convective weather conditions, whereby warm and less dense air rises and colder and therefore denser air falls. Convective precipitation is often also associated with severe storm fronts. By 2050, it is expected that we will see a further increase of up to 20% in the number of days per year with precipitation levels reaching or exceeding 10 mm. By the end of the century, it is even predicted that there will be an increase of up to 50% in this figure, which would correspond to approximately 20 days per year.

"Heavy rain"

Heavy rain is the term used to describe short, high-intensity incidences of heavy precipitation.
Heavy rainfall events mostly occur during the summer months, are usually very localised and therefore only affect individual districts or locations.

Between 1971 and 2000, there were 3 to 4 days annually on which precipitation levels reached 20 mm or more. By the end of this century, this figure could rise to around 7 days per year. However, these predictions of future developments in relation to heavy precipitation are (at this point) associated with a large degree of uncertainty. Reasons for this include the present resolution of current climate models and the fact that convective events, on which heavy precipitation is based, cannot be modelled directly.



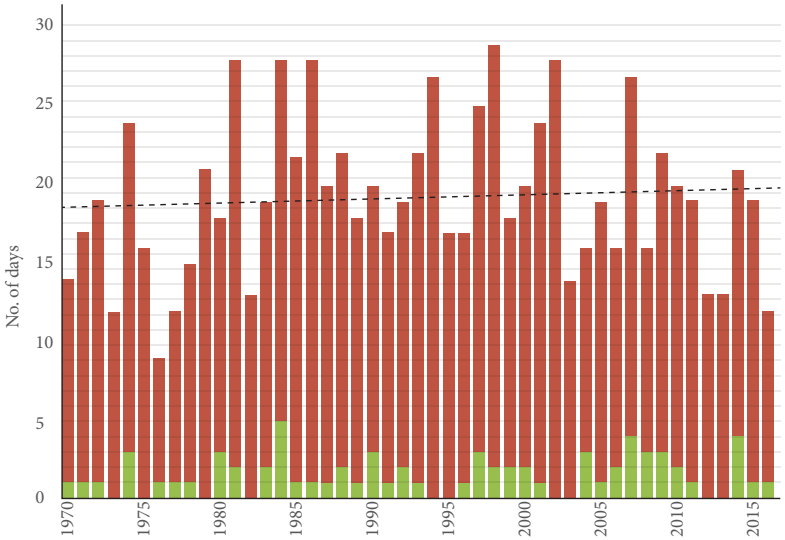
Heavy precipitation, 25 July 2013

METEOROLOGICAL DATA:

- → Severe weather with heavy rain and thunderstorms
- → Between 15 and 25 mm of heavy rainfall fell per hour.
- → In the district of Flingern, the volume of rain that fell in just 45 minutes was equivalent to almost 50% of the total rainfall for the month of July that had been recorded for many years.

EFFECTS:

- → Many rainwater gullies (road drains) became congested, leading to backflow from the sewage system, and many basements (including at the university hospital), streets and underpasses were under water.
- → Around 200 fire brigade call-outs
- → Massive restrictions on local public traffic, as well as road and air traffic



No. of days with precipitation levels ≥ 10 mm and ≥ 25 mm, as measured at the weather station at Düsseldorf airport 1970–2016 (source: German Meteorological Service 2017)

Days with precipitation ≥ 10 mm

Days with precipitation ≥ 25 mm

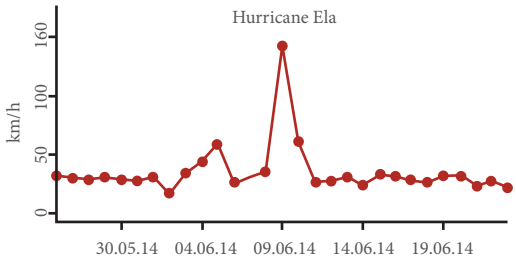
Thunderstorm, 9 June 2014

METEOROLOGICAL DATA:

- → Storm fronts with very heavy squalls, rain and hail
- → Gusts reaching a maximum of up to 140 km/h
- → Wind force 11 to 12
- → Localised rainfall of 40 l/m²

EFFECTS:

- → 3 fatalities, more than 10 people injured
- → 22,500 city trees and around 2,000 trees in cemeteries were severely damaged
- → Huge damage to the Rheinpark park in Golzheim and the Hofgarten park in central Düsseldorf
- → Houses lost their roofs, chimneys were destroyed and serious damage was done to cars
- → The Rheinbahn public transport network suffered damage of around 1.3 million euros
- → 1,200 fire-fighters and 330 soldiers were deployed
- → Total damage in the region of 64 million euros



Which areas will be impacted most?

As part of KAKDUS, a rainfall impact map was created to pinpoint the risks of flooding in the event of heavy rain in the city. The map also enables rough estimates to be made as to any risks of damage that may arise as a result.

This impact map provides information about the potential extent and depth of flooding due to heavy rain and the resulting surface outflows. The flood depths were calculated using a digital terrain model and on the basis of a simulated precipitation event which, in statistical terms, occurs once every 50 years.

The results of the simulated water levels show a relatively even distribution of areas affected by flooding within the city of Düsseldorf. This is in line with expectations due to the region's flat morphology. Significantly raised water levels of 30 cm or more are concentrated in natural channels in the higher-lying areas in the east of the metropolitan area (Gerresheim, Ludenberg, Hubbelrath), as well as along the south-western border of the Unterbach district. In the higher-density areas of the city centre, raised water levels are largely concentrated around underpasses and tunnels in the vicinity of railway and road embankments. Flood hotspots also occur around silted-up oxbow lakes in large sections of the eastern bank of the Rhine.

The water levels shown on the impact map provide an indication of the risk of flooding but, due to the simplifications required, do not provide a basis for planning specific flood prevention measures. The primary goals of running simulations as part of KAKDUS were to pinpoint hotspots for flooding across all districts of the city and to identify priorities for more detailed analysis. The analyses are not yet sufficiently detailed to enable the formulation of specific measures.

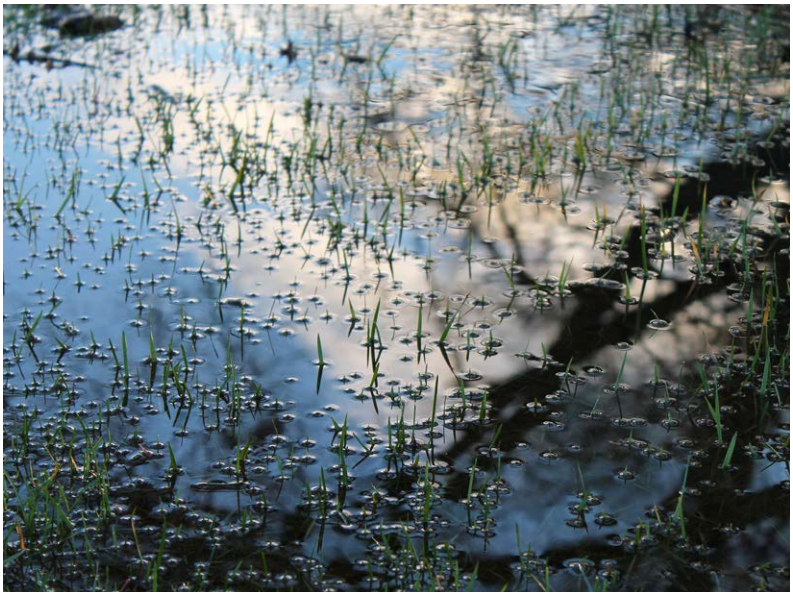
Flooding after heavy rain (T=50a) maximum water level (m)

- Low < 0.10 m
- Medium 0.10-0.30 m
- High 0.30–0.50 m
- Very high > 0.50 m

Precipitation according to KOSTRA-German Meteorological Service 2000
- Event: statistically once every 50 years (T=50a)
- Duration: 60 minutes (D= 60 min)
- Volume of rainfall: 43.3 l/m“ (h_N = 43.3 mm)

What are the potential consequences of these changes in climate?

The increased frequency and intensity of heavy precipitation that are predicted present a challenge for the state capital Düsseldorf, primarily due to the growing risk of flooding that is associated with these changes. In contrast to river-based flooding events, the risk of damage to property and personal injury caused by flooding due to heavy precipitation is expected to rise for the entire metropolitan region. This leads to growing requirements for structural and technical preventive measures to be taken by the construction sector and private property owners. Critical spots for flooding also include supply facilities and networks, as well as underground car parks, transport links and the traffic management systems that are so crucial for managing traffic flow in Düsseldorf. This could lead to interruptions of energy supply and communication channels, as well as massive traffic disruptions. In terms of city drainage and cleaning, an increase in heavy precipitation is associated, for example, with a rise in monitoring, clean-up and repair costs. Particularly in the summer months, convective heavy precipitation events may occur in conjunction with storm-related squalls, resulting in additional risks.



Possible effects of increasing heavy precipitation

- → Congestion of the sewage network as a result of storm water exceeding the established thresholds
- → Flooding and damage to public/private buildings and property
- → Damage to and failure of vehicles and traffic management systems due to flooding or undermining
- → Outage of supply facilities and networks (energy/water/heat/telecommunications)
- → Damage to and failure of commercial and industrial facilities due to flood damage
- → Damage to buildings and structures due to storm-related squalls
- → Loss of and damage to equipment or assets due to flooding, hale or trees being blown down
- → Increased demand on resources and increased strain on municipal drainage and cleaning
- → Damage to and loss of soil functions through erosion and entry of contaminants
- → Damage to and loss of city trees and woodland due to wind load during storm-related squalls
- → Personal injury due to water entering buildings or deep pooling
- → Increased demand on resources and increased strain on rescue services and fire brigade
- → Personal injury caused by falling trees (especially dead wood) during storm-related squalls

Shifting precipitation patterns and drought

What changes can we expect with climate change?

There is no clearly discernible trend in the general patterns of changing precipitation in Düsseldorf over the past 50 years. If we look at mean annual precipitation, we find that the western portion of the city is drier than the eastern part, with approximately 800 mm of precipitation on average per year, as against 950 mm.

At the present time, a clear picture of changes in precipitation has not yet emerged from the available climate projections. However, the results gleaned from models used to date indicate that we will not see a significant change in annual precipitation levels by the middle of the century. By the end of the century, however, we can expect to see a rise in annual rainfall levels, as well as an increase in winter precipitation.

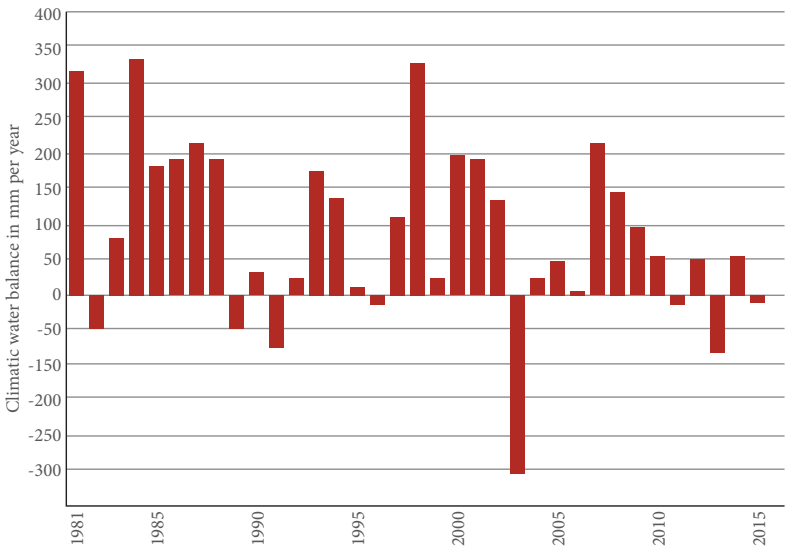
Even if there is only a slight increase in precipitation, there may be longer and/or more pronounced periods of drought during the summer. Due to rising temperatures, the natural water supply has been on the decline for a number of years now, despite increasing annual precipitation levels. Since 1981, the linear trend of the climatic water balance has shown a clear decrease, despite the annual water balance being subject to strong fluctuations (see chart below).

"Drought"

There is no one clear definition of the term "drought". In general, it is characterised by a lack of water or moisture, which can occur during periods of low rainfall and/or warm to hot temperatures. The climatic water balance, representing the difference between precipitation and evaporation, serves as an indicator for drought.

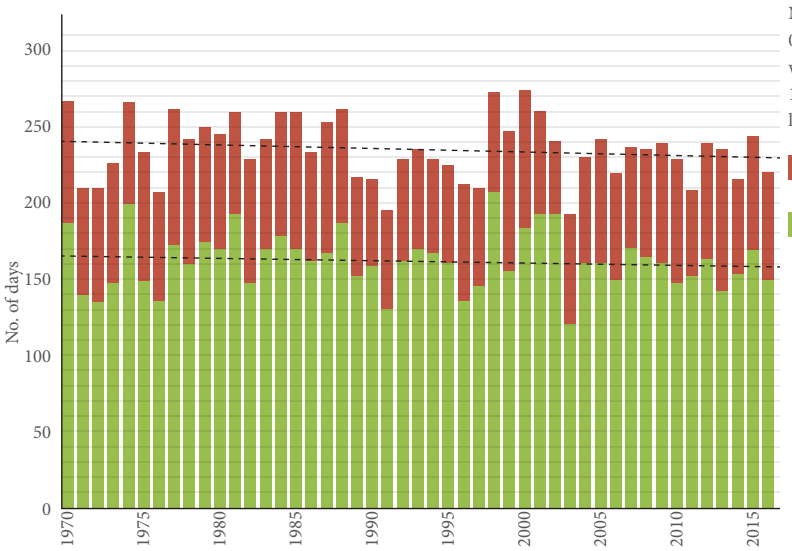
Another indicator of more frequently occurring periods of drought is the fact that the number of days with low precipitation levels is decreasing (see chart on p. 21), while days with insignificant precipitation or with heavy precipitation in excess of 10 mm are occurring more frequently. This means that the number of days of rainfall is declining, while the volume of rainfall per event is simultaneously on the rise.

The climate models do not (at this point) yield any results for the climatic water balance. However, it can be assumed that further warming will contribute to intensification of potential evaporation.



Annual total climatic water balance measured at the weather station based in Düsseldorf airport 1981-2015 (source: German Meteorological Service 2017)

Climatic water balance



No. of days with precipitation levels ≥ 0.1 mm and ≥ 1 mm, as measured at the weather station at Düsseldorf airport 1970–2016 (source: German Meteorological Service 2017)

What are the potential consequences of these changes in climate?

A large number of effects are associated with the predicted general shift in precipitation patterns whereby more precipitation is set to occur during the winter season (October to March), as well as the expected increase in the occurrence and duration of drought. The costs of maintaining green areas and costs for agriculture and forestry increase, for example because plants become more vulnerable to parasites and disease. Declining groundwater levels (even temporarily) reduce the soil's cooling capacity. More frequent freeze-thaw cycling causes damage to the transport infrastructure. Material damage due to damp also represents an increasing problem for buildings and sewage systems. For example, concrete corrosion on buildings due to groundwater fluctuations can be very costly, and may even cause them to become unstable. Longer and more frequent periods of drought, in conjunction with the overall significant reduction in water consumption, would lead to costly damage to the sewage network due to corrosion and additional (cost-intensive) cleaning and maintenance requirements in that network.

Which areas will be impacted most?

Development of the concept did not include an analysis of which parts of the city will be particularly affected by shifting precipitation patterns and drought in future. However, one of the key measures of KAKDUS involves updating ground water modelling based on the latest climate calculations and determining how this will affect ground water changes in future (see page 27).

Possible effects of shifting precipitation patterns

- → Damage to buildings and infrastructure due to changes in soil and groundwater levels
- → Problems with sedimentation, corrosion and foul odours in the sewage system during periods of drought
- → Damage to roads due to frequent cycling between days of freezing and days of thawing
- → Declining water quality due to lengthy periods of drought and low water levels
- → Damage to and loss of green spaces and trees due to drought stress and waterlogging
- → Pest infestations and fungal diseases affecting trees due to increased moisture
- → Shifting species diversity/spread of invasive species
- → Increased requirements for watering, monitoring and care of green spaces and city trees
- → Impaired status and quality of water bodies and of aquatic flora and fauna
- → Altered soil functions due to changed soil water content and erosion
- → Establishment of new and spread of existing pathogenic agents and disease carriers

Objectives and measures

for adapting to the consequences of climate change

Objectives

The state capital Düsseldorf aims to increase its resilience to the identified effects of changes to the climate by implementing strategies for climate change adaptation. It is hoped that, by giving full consideration to climate change early on, the city's high quality of life, attractiveness as a location for business and investment, its competitiveness and the good working conditions it offers can be maintained and, if possible, enhanced in the long term.

Some climatic effects are intensified by the high level of building density in the city. Buildings and streets store heat and the low proportion of green spaces and open areas means that the cooling effect of soils and plants is also reduced, as is the ability to soak up precipitation locally. This results in the formation of heat islands and an increase in aboveground run-off of heavy precipitation. At the same time, the very large number of people living and working in the densely built-up areas of the city must be protected. Therefore, the adaptation of the city centre to climate change must be effected in accordance with the guiding principle of "dual inner development" used in city planning (see Side Note on page 24). In order to promote urban density while simultaneously ensuring adequate green spaces, this city planning strategy seeks to reconcile the use of existing spatial reserves within the city centre for development with ecological objectives, such as roof and courtyard gardens and façade planting.

Catalogue of objectives

OBJECTIVES FOR THE "PEOPLE" SPHERE OF ACTIVITY

- → Maintain and improve thermal comfort and protection of the population from extreme human-biometeorological stress (heat stress)
- → Avoid personal injury during extreme weather events
- → Prevent or mitigate the establishment of pathogenic agents due to increased temperature and humidity

OBJECTIVES FOR THE "ENVIRONMENT" SPHERE OF ACTIVITY

- → Increase the resilience and protection of trees and other plants in the face of extreme weather events and climate-induced diseases
- → Mitigate the infiltration and dispersal of invasive animal and plant species
- → Maintain soil functions and soil diversity in the face of changing temperature and precipitation conditions
- → Guarantee a high quality and quantity of (drinking) water as well as good water status under changing climatic conditions.

OBJECTIVES FOR THE "BUILDINGS AND INFRASTRUCTURE" SPHERE OF ACTIVITY

- → Preserve or improve climate comfort in buildings and vehicles in the public transport network in an energy-efficient manner
- → Prevent or reduce the heating-up of exposed urban spaces
- → Reduce the risk of flooding during extreme heavy rainfall events
- → Increase the protection of buildings, equipment and assets against damage caused by extreme weather events
- → Protect transport infrastructure against weather-related damage and safeguard the flow of traffic during and after extreme weather events
- → Guarantee the functional reliability of the supply and disposal infrastructure when extreme weather events occur

OVERARCHING OBJECTIVES

- → Continue and reinforce interdepartmental and inter-city collaboration on climate change adaptation
- → Raise awareness of issues relating to climate change adaptation among politicians, companies and the general public
- → Establish comprehensive climate change monitoring

In order to formulate appropriate strategies and measures for adapting Düsseldorf to climate change, the goals defined as part of climate-adapted city planning were specified in more detail and broken down into differentiated sub -goals in consultation with the interdepartmental KAKDUS project group.

Based on the effects of climate change on Düsseldorf that were classified as particularly relevant in the impact analysis, the adaptation objectives were compiled in a catalogue under the headings "People", "Environment" and "City Buildings and Infrastructure". Furthermore, strategic objectives were formulated, which focus on the framework conditions that are essential to a successful implementation of climate change adaptation in Düsseldorf.

SIDE NOTE – the guiding principle of "dual inner development"

The population of Düsseldorf has been growing almost continuously for the past 15 years, and further growth is expected in future. This results in a high degree of pressure to build, which should be dealt with, first and foremost, by implementing measures for developing the inner city because further utilisation of the outer portions of the city for development is associated with many undesirable effects (loss of ecological functions, increasing traffic congestion, the need for new infrastructure etc.). The guiding principal of "inner development before outer development" has therefore been applied to state planning for many years. The question thus arises as to how the growing building intensity arising from this can be reconciled with the apparently conflicting requirements of climate change adaptation.

In densely built-up areas of the city, green areas are especially important and must be protected. Urban green spaces act as fresh air corridors for air pollution regulation and temperature regulation. They mitigate extreme heat and dampen the effects of heavy rain events. By providing a habitat for flora and fauna, they support biological species diversity.

In order to promote urban density while simultaneously ensuring adequate green spaces, the city planning strategy of "dual inner development" seeks to reconcile the use of existing spatial reserves within the city centre for development with ecological objectives. This approach is both ecologically essential and economically beneficial, as it safeguards the qualities of an attractive residential location in the long term and allows the standard of living to be raised. The strategy of dual inner development envisages, on the one hand, the retroactive densification of the city's housing stock by closing the gaps between buildings and developing brownfield sites and transforming existing buildings and extending them, e.g. by adding more floors. At the same time, the strategy seeks to increase the volume of green spaces by systematically planting roof and courtyard gardens and façades. Efforts are made to upgrade existing green spaces by increasing their ecological quality and their range of uses. The strategy also aims to improve links between green spaces. Last but not least, the high value attached to city-centre green spaces is reflected by efforts to ensure that, as far as possible, green spaces are not reduced in size and are even extended as part of planning.

The climate change adaptation concept for the state capital Düsseldorf and the measures it enshrines are capable of supporting the guiding principle of dual inner development in a strategic way.

Measures for adaptation

Identifying measures

In the next step, measures were assigned to each of the objectives that had been formulated as described above. The KAKDUS project group and other relevant stakeholders from political and administrative sphere as well as the public were involved in brainstorming ideas for possible measures.

The KAKDUS catalogue of measures contains a non-exhaustive summary overview of a large number of measures that are relevant to achieving the objectives. In the individual measures lists, each of which is specific to a particular objective, existing activities and instruments already in use by the state capital are itemised, together with measures that are currently at the planning stage. This makes it possible to identify starting points for further measures, detect possible synergies and any coordination that may be necessary between the measures, as well as to recognise potential new alliances.

Due to the size of the municipal administration in Düsseldorf and the wide range of departments affected and already involved, this overall perspective is extremely important. Furthermore, compiling a list of ongoing and planned measures facilitates the identification of areas where further action may be required.

For the measures that can be implemented in future, complementary measures deemed useful by experts or stakeholders in the process are accordingly specified, together with options for intensifying, continuing, updating and realigning existing measures.

Key measures

From the many ideas and proposals for measures that were gathered as part of KAKDUS, 15 clusters of thematically related measures were chosen – these are referred to as key measures. These are regarded as being particularly likely to facilitate the implementation of the adaptation concept and, for reasons of urgency or to provide a beacon for change, should be implemented as soon as possible once development of the concept is completed. They also include measures that are already under way and are to be continued for the purpose of climate change adaptation.

The key measures were selected in close consultation with the KAKDUS project group. Corresponding proposals from previous events, the findings of administration-internal brainstorming and other feedback received from the individual departments were also included in the selection.

For each key measure, a measure specification was formulated in close collaboration with the relevant departments in each case.

Overview of key measures

ANALYTICAL MEASURES

→ Further develop and flesh out the heavy rainfall impact map
→ Groundwater modelling based on current climate scenarios
→ Update and flesh out existing climate analysis
→ Compile a monitoring report for climate change

STRUCTURAL AND ECOLOGICAL MEASURES

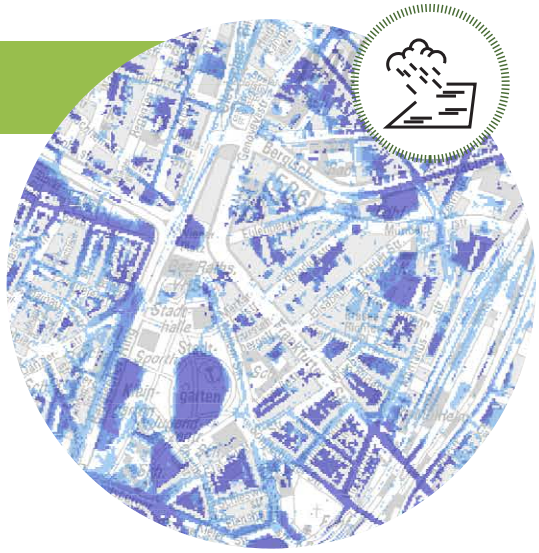
→ Develop the city forest in preparation for climate change
→ Intensify the planting of roof and courtyard gardens and façade
→ Düsseldorf's city trees concept
→ Concept for managing heavy rain events
→ Plan of action for preserving and improving the ground cooling capacity and the soil water regime
→ Protecting and preserving water bodies as part of the natural environment and as the basis for the drinking water supply
→ Action plan for shading and cooling heavily frequented public spaces

ORGANISATIONAL AND COMMUNICATIONS MEASURES

→ Recommended actions for taking account of climate change adaptation requirements in planning processes
→ Recognition for climate change-adapted construction
→ Information campaign on dealing with changes to the climate and on adaptation measures
→ Institutionalise climate change adaptation within Düsseldorf's municipal administration

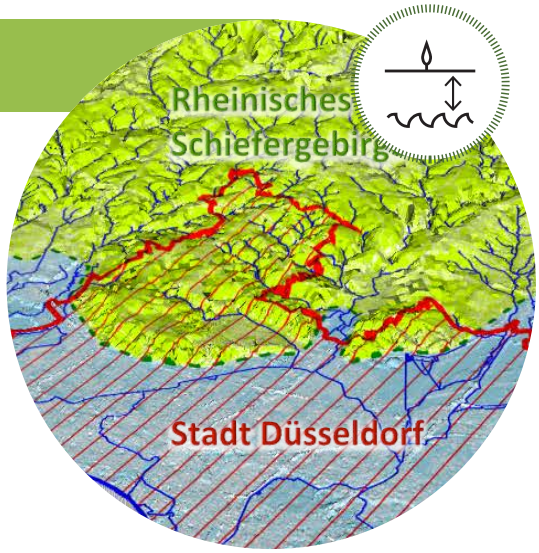
Further develop and flesh out the heavy rainfall impact map

The heavy rainfall impact map developed for the city as a whole as part of KAKDUS indicates which areas of the city are at risk of flooding. These new findings about the potential hazards across the entire city will allow the existing local and detailed flooding models used by the Municipal Drainage Department to be extended to include new areas. As part of outflow simulation, flooding from the sewage network due to waterlogged pipelines is taken into account as far as possible.



Groundwater modelling based on current climate scenarios

Future changes in groundwater levels in Düsseldorf should be determined on the basis of various regional climate models (i.e. a climate projection ensemble). This must take account of the factors of temperature, soil moisture and evaporation, which are highly sensitive to climate change. Modelling must also incorporate the interplay between the groundwater body and the Rhine. The goal of these analyses is to determine seasonal fluctuations in groundwater levels in the context of climate change. In relation to the changes in precipitation that are forecast for the long term, it is also necessary, for example, to identify built-up areas that will, in future, have high groundwater levels or significantly lower groundwater levels and therefore may be exposed to the risk of subsidence/waterlogging.



Update and flesh out existing climate analysis

The existing climate analysis for the state capital Düsseldorf, the central outcome of which is the urban planning map from 2012, should be supplemented with a detailed analysis of the urban climate's cold and fresh air balance, and its perspective should be updated in accordance with the latest modelling techniques. A greater level of detail will enable more qualified argumentation as well as a revaluation of the restrictions on building development in climatically significant areas that have been identified on the urban planning map on the basis of the existing climate analysis. This measure will ensure that climate change adaptation requirements are mapped more adequately and taken into account to a greater extent in city planning and urban development planning.

Compile a monitoring report for climate change

City-wide, integrated monitoring is to be set up to document the degree of local climate change experienced in Düsseldorf on an ongoing basis. As part of this process, the network of climate monitoring stations that are operated by various bodies is to be harmonised and, if necessary, expanded. In addition to gathering climate data, a key objective here is to systematically record any effects and damage caused by changes in climate. The key outcome of this measure is a regular monitoring report on climate change, which will enable the tracking of urban climate change and its local consequences in a way that enables comparisons to be made over time. The report will be based on a system of indicators that is yet to be developed and will actively involve the population of the city.

Develop the city forest in preparation for climate change

Development of the city forest in preparation for climate change primarily involves continuing to maintain the forest in a sustainable manner, with a greater focus on climate change considerations. These include the natural regeneration of the forest, risk distribution over a wide range of tree species, establishment of a balanced age structure, silvicultural development towards the creation of a climate-adaptive forest, the identification of observation plots for process conservation, as well as strategies to deal with increased recreational pressure due to climate change.

Intensify roof and courtyard gardens and façade planting

The planting of roof and courtyard gardens and of façades is to be extended. To this end, existing measures and incentives should be synchronised, continued, better promoted and, if necessary, intensified. To increase the proportion of roof and courtyard gardens and planted façades in new builds in the climate-sensitive areas identified as part of KAKDUS, recommendations (e.g. substrate thickness, etc.) are to be developed for mandatory urban land-use planning and for large building projects outside the framework of land-use plans.

Düsseldorf's city trees concept

Based on the existing "1,000 Trees" concept developed by Düsseldorf's Parks Office, an action plan is to be drawn up for dealing with city trees from the perspective of climate change adaptation. In addition to measures for increasing the number of trees in specific locations, e.g. to optimise natural sun-screening and evaporative cooling capacity, this action plan should, above all, include measures that will contribute to improving the resistance of urban parks to extreme weather events (heatwaves, drought, storms) and climate-induced diseases. The concept's long-term goal is to enhance tree health by systematically taking account of habitat demands, improving the properties of the habitat, selecting climate-resistant species and increasing species diversity.

The Düsseldorf Parks Office has developed a catalogue of criteria for habitat optimisation for the city's existing stock of trees and for selecting and creating new habitats for trees. This catalogue will serve as an important starting point for the new concept. For example, the catalogue sets out best-practice solutions for various habitats, which, going forward, should be implemented across the city, primarily in the areas identified by KAKDUS as being at particular risk of impact from climate change.

Concept for managing heavy rain events

The growing requirements for flood protection will, in future, demand that precipitation run-off is handled differently in Düsseldorf. The new approach will take account both of increased soil sealing due to new developments and retroactive densification and of changing precipitation patterns caused by climate change. In light of the new challenges, more "water-sensitive" urban design will be required in future, pursuing the primary objective of identifying local solutions for storing and draining storm water without causing damage. Therefore, the process of updating the waste water and storm water elimination concept should include developing an integrated approach for managing heavy rain events in Düsseldorf. In order to minimise damage due to extreme precipitation, it is necessary to identify the areas where rainwater can be retained with as little damage as possible when such extreme weather events occur. For this purpose, the concept must set out the options for temporary retention of rainwater in traffic areas and green spaces ("multifunctional land use") during very rare heavy rain events and describe the prerequisites for their implementation. Another component of the concept is to determine the additional water retention potential offered by floodplains in the city and the modification measures required to avail of this potential.

Plan of action for preserving and improving the ground cooling capacity and natural soil water regime

The sealing of surfaces, drainage, drawdown of the groundwater table and the entry of building waste have all diminished the climate regulation function of soils in Düsseldorf. A plan of action should therefore be drawn up with a view to preserving and, if necessary, improving the natural soil water regime and ground cooling capacity. The plan should initially focus on particularly effective soils that will have a beneficial effect if preserved. Furthermore, the action plan should include the formulation of measures to protect soils and which are also compatible with the construction and development pressure that is being experienced by the city. These measures could include, for example, the unsealing of sealed surfaces and measures to keep soils with particularly high evaporation rates bare.

Protect and preserve water bodies as part of the natural environment and as the basis for the drinking water supply

To protect and preserve bodies of water– in particular, bodies of water used for the production of drinking water – both the renaturation of the bodies of water and the decontamination of contaminated groundwater in the urban area should be continued as part of climate change adaptation. Building on the monitoring and recording of the effects of climate change on water management, a water supply concept should also be developed in accordance with Section 38 of the State Water Act for North Rhine-Westphalia with the aim of safeguarding local production of drinking water.

Recommended actions to take account of climate change adaptation issues in planning processes

Recommendations are to be formulated that will allow climate change adaptation to become an integral component of planning and decision-making processes in Düsseldorf that are geographically relevant or will have an impact on the urban climate. These should present new perspectives and facilitate a unified, coordinated approach to climate change adaptation both within the administration and when collaborating with external stakeholders. To this end, tangible suggestions should be presented as to how climate change adaptation requirements can be taken into account in real terms in planning and construction processes. However, implementation of the recommendations should not merely provide a rigid framework – instead, it should enable a flexible approach to dealing with the very wide range of planning conditions.

Action plan for shading and cooling heavily frequented public spaces

Unshaded, sealed surfaces with sparse vegetation heat up significantly, in particular in the densely built-up areas in the centre of Düsseldorf. Due to the heat islands effect, the quality of life decreases during hot spells in the height of summer. Night-time cooling is also reduced. In addition to the human-biometeorological stress for the population, the effects of heat and solar irradiation can also cause material damage, e.g. to the transport infrastructure, sports fields and green spaces. To enhance the climate comfort in public spaces and improve the durability of open spaces and surface materials, a plan of action should be developed to demonstrate how temporary or permanent measures can be used to achieve (additional) cooling.

Based on the geographical analyses of heat stress conducted as part of KAKDUS, the public spaces that are at particular risk of a high level of heat stress should now be identified. For selected street sections and city squares, individual cooling solutions should be developed and subjected to feasibility testing. These solutions could include, for example, temporary solar protection equipment or water atomiser systems in heavily frequented pedestrian zones.

Recognition for climate change-adapted construction

Certification for climate change-adapted buildings should be introduced for construction projects that meet specific standards in relation to protection against extreme weather events such as heat, heavy rain and storms. This should focus, above all, on projects and measures that are particularly innovative and go above and beyond what is normally considered to be state-of-the-art technology. This certification should act as an incentive for developers, property owners, architects, planners and tradespeople to tackle the issue of climate change-adapted construction and redevelopment. Public awareness of climate change adaptation requirements should also be promoted.

Information campaign on dealing with changes to the climate and on adaptation measures

Ongoing communication measures relating to climate change in Düsseldorf should be continued, intensified and coordinated. For this purpose, suitable structures and instruments are to be put in place so that the issue of climate change adaptation can occupy a permanent position within the political sphere, the municipal administration and among the public, as well as in the education and training courses on offer in Düsseldorf. As part of the information campaign, the necessity and significance of climate change adaptation for the quality of life in Düsseldorf are to be highlighted. It is also essential to raise awareness of the hazards and risks due to changes in the climate. The goal here is to motivate citizens and companies to take preventive measures against heavy rain or heat.

Institutionalise climate change adaptation within Düsseldorf's municipal administration

A coordinating body for climate change adaptation should be established with responsibility for interdepartmental coordination and organisation of the topic of climate change adaptation, as well as for the continuation and further development of the climate change adaptation project group set up in 2014. This body should also have a role to play as a platform for the sharing of information and experiences, and should take responsibility for monitoring the implementation of the climate change adaptation concept. It should also have the additional task of supporting the acquisition of funding for adaptation-related projects. Another equally important component of the work to be done by the coordinating body is networking to facilitate knowledge transfer and an exchange of experiences with other municipalities in the context of city partnerships and within the Climate Alliance.

Conclusion and outlook

What has already been achieved with KAKDUS?

The KAKDUS climate change adaptation concept has laid the foundations for long-term, interdepartmental consideration of the topic of climate change adaptation in the state capital Düsseldorf. The concept thus represents one of the first crucial steps forward on the path to a climate change-adapted city. The effects of climate change can only be counteracted in a timely and sustainable manner and the quality of life in Düsseldorf and the attractiveness of the city as a location for business and investment can only be safeguarded through the concerted, expert-led development of viable strategies and solutions.

New findings and instruments

As part of the concept development process, knowledge was generated in relation to which climate changes are relevant to the adaptation of Düsseldorf and which are not, taking account of the latest climate change scenarios. In addition, more precise data was gathered in relation to the degree to which the climate has already changed to date and the scale of the changes that can be expected in Düsseldorf in future. To this end, a scientifically based study was conducted for the first time, in close collaboration with local stakeholders, to analyse the ways in which the individual spheres of activity within the city are affected by the consequences of climate change. This study thus provides a basis for developing targets and measures. Furthermore, maps were created for the entire city, indicating, for the first time, the hazards posed by flooding due to heavy rainfall and showing the locations where heat stress occurs today and where it will occur in future.

The new findings and instruments provide the state capital Düsseldorf with tangible work and planning tools for estimating and taking account of the current and future effects of climate change.

Success factors

The KAKDUS climate change adaptation concept defines key measures that are to be set in motion by the relevant bodies in the coming years. One central prerequisite for the successful implementation of these measures is the long-term and permanent establishment of climate change adaptation management as part of the city's municipal administration (see page 33).

A successful implementation of the adaptation concept also requires that the topic of climate change adaptation will be taken into consideration as a matter of course and at an early stage within all planning processes in the state capital Düsseldorf. For this to happen, the employees of all relevant departments must be made aware of the issues and as broad a consensus as possible must be reached. Involving the stakeholders in the creation of KAKDUS via the interdepartmen-

tal climate change adaptation project group has established some of the essential groundwork in this regard. The dedicated cooperation of this group has meant that some key points of the concept, in particular objectives and measures, could be agreed between the various departments involved while the project was still ongoing. The climate change adaptation project group should not be dissolved at this point – rather, it should continue to support the implementation of KAKDUS going forward. The experience gained over three years of the project group working together will facilitate the implementation of measures and advance their acceptance.

The practical implementation of KAKDUS will also be simplified by virtue of the fact that the key measures have identified a manageable number of solutions for adaptation. With each of these key measures, activities that are already ongoing can be built upon, so that fewer initial hurdles are to be expected during the implementation phase. Furthermore, the task of implementing the key measures is shared among a large number of departments. This division of responsibilities will facilitate implementation and will also promote acceptance of the issue of climate change adjustment throughout the entire municipal administration.

Where do we go from here?

The next step must now be to implement the key measures. During this step, the implementation of cost-effective measures must be ensured in each case in line with the individual departmental budgets, and the precise form these measures take must be continually reviewed in terms of efficiency and efficacy.

Controlling

Appropriate controlling is essential to enable oversight of the implementation and effectiveness of the measures devised for climate change adaptation. The controlling concept that was developed as part of KAKDUS comprises both continuous monitoring of climate change and evaluation of the key measures. The findings from these two components will feed into a controlling report, which will be repeated and updated at regular intervals.

Regular evaluation of the adaptation concept will serve the purpose of verifying it on an ongoing basis and determining whether and to what extent the stated objectives, as well as the processes and measures developed by KAKDUS, have been achieved and whether and to what degree they may need to be supplemented. An evalua-

tion report carried out at regular intervals will review whether the general conditions and basic information on which the concept is based have changed and whether the concept needs to be updated. An update may be required, for example, if the regulatory framework changes, if there are new findings in the field of climate change or in relation to the local effects of climate change arising from measurements and modelling, or if the formal and informal planning instruments are reoriented.

Evaluation of the concept will also involve checking whether its objectives need to be revised due to new findings and changes in the underlying conditions. First and foremost, the evaluation should seek to record the milestones achieved in implementing the concept and highlight any remaining obstacles to progress. The focus of the evaluation will be on the key measures. It is intended that the evaluation report will document the degree to which the measures have been implemented and the extent to which the stated objectives have been successfully achieved.

Communication

Climate change adaptation also presents a challenge from the point of view of communication due to the wide range of stakeholders involved. Informing the public and raising their awareness around this issue will be essential to the success of the climate change adaptation concept. Therefore, a communications strategy was formulated as part of KAKDUS, which is intended to make the results and objectives of the climate change adaptation concept accessible to the general public. The aim is to raise awareness in political and commercial spheres, as well as among the public and other stakeholders, of the need for action arising from the changes in climate both for the state capital Düsseldorf and for each individual member of society in the city.

The communications strategy seeks to disseminate the newly gained knowledge about climate change and its consequences for Düsseldorf, to promote acceptance of climate change adaptation, to consolidate the objectives and strategies that have been developed for the concept, and to initiate collaboration with the local population and any other relevant stakeholders in the sustainable adaptation of the state capital Düsseldorf.

Literature

German Meteorological Service (Deutscher Wetterdienst, DWD), Department of Climate and Environmental Consulting [2017]
Klima und Klimaentwicklung bis Ende des Jahrhunderts, basierend auf Klimaprojektionen für Düsseldorf ("Climate and Climate Change to the End of the Century, Based on Climate Projections for Düsseldorf") Essen.

Image sources

German Meteorological Service (Deutscher Wetterdienst, DWD), Essen Regional Climate Office
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