Copenhagen
Carbon Neutral
by 2025

COPENHAGEN CLIMATE ADAPTATION PLAN

MILJØ METROPOLEN

CONTENTS

INTRODUCTION
CLIMATE CHALLENGES FOR COPENHAGEN

The earth's climate has been in a state of constant change throughout the ages, to which humans, animals and plants have had to adapt. This adaptation has consisted either in abandoning habitats or protecting oneself against climate change, for example by developing technology.

Today such great societal assets have been created, particularly in urban areas, that protection of these areas against climate threats can pay for itself even in cases where extensive investments are required. Copenhagen too will be affected by the global changes in the climate. It is therefore important for the city to be prepared for the climate of the future.

With this climate adaptation plan we will outline the challenges the city faces in the short and medium terms as a result of changes we expect in the future climate. We will also identify those solutions that, based on our present-day knowledge, appear to be most appropriate and reveal the opportunities climate change may also present to the city.

We do not yet know all the consequences climate change will have for Copenhagen, but we will continuously implement the measures required for Copenhagen to continue to be a safe and attractive city to live and spend time in.

The changes in the climate will happen over a long period of time. It nevertheless makes good sense to start work on climate adaptation now. Doing so provides a good opportunity to analyse challenges and proposed solutions and identify the optimum solutions and consequently avoid making wrong investments.

THE GLOBAL CLIMATE CHALLENGE

Researchers today are in no doubt that there is a connection between rising CO2 levels in the atmosphere as a result of human activity and rising temperatures on earth. The consequences and extent of changes in the climate are not yet fully understood. But one thing is clear: the greater the emissions and levels of greenhouse gases in the atmosphere, the greater the changes in the climate here on earth will be.

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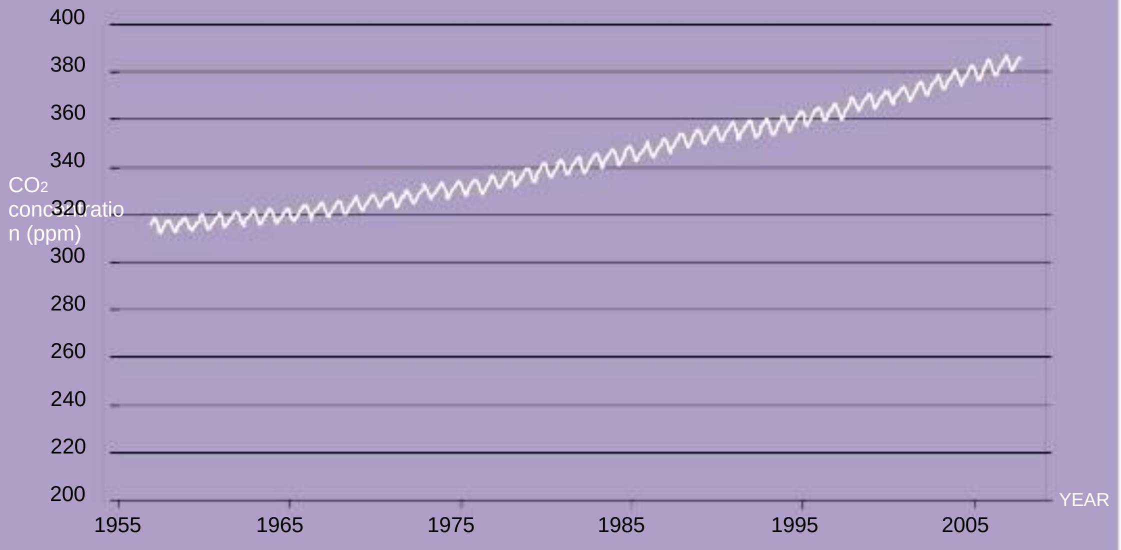

Figure 1: Change in the CO_2 concentration of the atmosphere
Source: Earth System Research Laboratory (ESRL), National Oceanic and Atmospheric Administration (NOAA).

GLOBAL ANNUAL MEAN TEMPERATURE FROM 1850 TO 2008

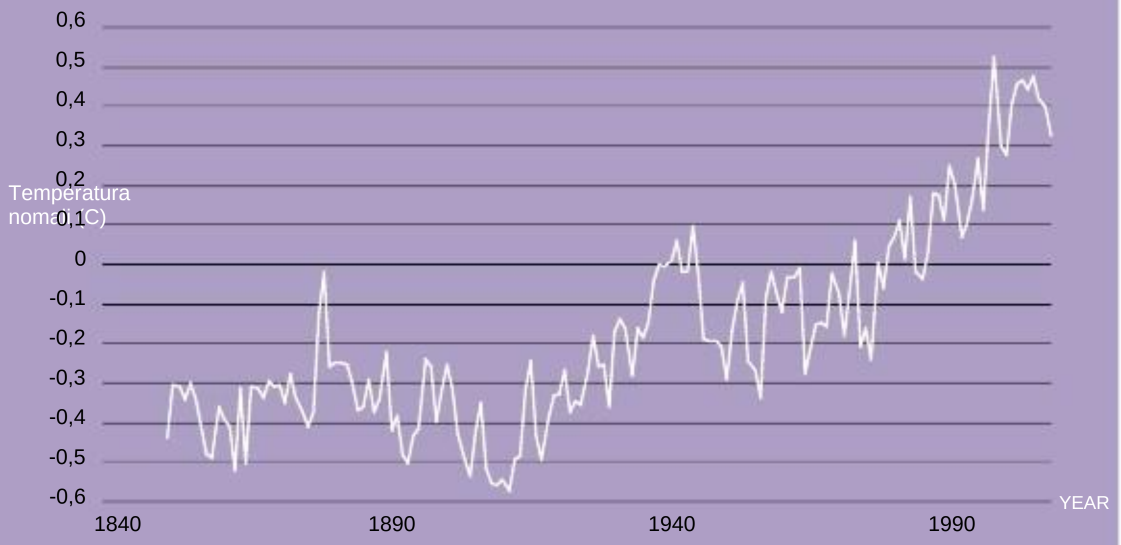

Figure 2: Change in global annual mean temperature
Source: Climatic Research Unit, University of East Anglia

It is difficult to make precise calculations of the future level of greenhouse gases in the atmosphere—and consequently the temperature rises and climate change of the future. This depends on a whole host of factors such as technological and economic development and, in particular, whether success is achieved in efforts to reduce greenhouse gas emissions.

THE CLIMATE OF THE FUTURE—SELECTION OF PROJECTIONS

The climate adaptation plan adopts a development scenario in line with the SRES A2 scenario of the UN's Intergovernmental Panel on Climate Change (IPCC). This development scenario is a projection of how the climate will change in the future. This scenario assumes that the global mean temperature will rise by around 3 degrees over the course of the 21st century. This projection includes the reporting that has taken place since COP15 on limiting emissions. In addition, the latest calculations and registrations of ice and snow melting show that substantially greater melting is taking place than has been assumed in earlier calculations. This means that the consequences of melting are correspondingly greater than previous calculations have assumed.

The Ministry of Climate and Energy has recommended that municipalities apply the IPCC's A1B scenario for planning in relation to climate change over the next 50 years. However, this recommendation came after the work on drawing up this plan had been carried out, where conditions for the calculation of future climate consequences had been chosen and calculation work had started.

The City of Copenhagen has used the IPCC's A2 scenario as a basis for assessing future climate impacts. It makes virtually no difference in relation to a timeframe of 50 years, as the two scenarios are almost identical within this period. It is not until timeframe of 100 years that there is a significant difference between the two scenarios. But as there is great uncertainty over the future development of the climate, no purpose is served by deciding in favour of one or other scenario. One should instead look at the direction in which development is moving, as the projections become better, and regularly update the need for climate adaptation measures in accordance with the new knowledge we acquire on the climate of the future. This plan therefore does not recommend investments being made now in relation to the long-term projections but instead recommends taking account of the need for climate-proofing in municipal planning so that urban development does make appropriate implementation of climate adaptation measures impossible.

In terms of measures in 50 years, the choice between A2 and A1B thus does not make any difference in relation to recommendations on action.

No one knows precisely how the world will develop technologically, in population terms, politically etc., or precisely how this will affect the climate, and whether this will be overlain by natural disasters etc. The figures and projections in this plan are thus chosen on the basis of best available knowledge on how the climate may perhaps develop and the consequences that will follow from this. The assessments have been essentially based on the IPCC's reports, the latest reports from the Danish Meteorological Institute (DMI) in connection with climate strategy for the Capital Region, the publications of the Water Pollution Committee of the Society of Danish Engineers and the high-water statistics of the Danish Coastal Authority etc.

The projections contained in the plan are not considered to the final. But they can be used to illustrate the consequences of the possible climate changes focused on in this plan. It is worth noting in this connection that even if success is achieved in making substantial reductions in global emissions of greenhouse gases, the quantity of greenhouse gases that has already been emitted will inevitably lead to changes in the earth's climate.

The predictions on the climate of the future will become steadily more precise as the climate models are developed. This will provide a better basis for assessing the necessary measures for climate adaptation. The next report from the UN's Intergovernmental Panel on Climate Change is expected in 2013.

The consequences that climate change may have in Copenhagen come gradually, but the pace of development of predicted to increase steadily, with the most substantial changes occurring after 2050.

Climate adaptation is undertaken in stages in relation to the latest knowledge on climate change and the tools for adaptation that are developed. Staged adaptation makes possible adaptation that, in addition to being based on the latest knowledge and technology, is also adapted to development in society with respect to consumption of resources and functionality.

The municipality's work on climate adaptation must therefore promote integrated planning of the city and its infrastructure to the benefit of the population and the environment.

IMPORTANT CONSIDERATIONS IN CLIMATE ADAPTATION MEASURES

To achieve successful adaptation of the city to the climate of the future, it is important that we consider a number of key factors:

FLEXIBLE ADAPTATION

It is pointless to plan in the very long term according to a particular scenario for future development in the climate. The City of Copenhagen will instead develop the city in relation to the main trends in the scenario and adapt the planning the whole time in relation to development in the recommendations emanating from the IPCC.

SYNERGY WITH OTHER PLANNING

Incorporating climate adaptation in those
sectors that are affected by climate change is therefore of crucial significance in utilising the strategy achieved by joint thinking on the action taken. Climate adaptation can be transformed into an asset for the city and help to secure growth in Copenhagen.

HIGH TECHNICAL LEVEL

Adapting the city to climate change is expensive. It is therefore important that the basis for decisions on investments and prioritisations is at a high technical level, so that wrong investments are not made. This situation applies to all types of analyses and studies, analyses of climatic threats, choices of solution models and economic analyses.

CLIMATE ADAPTATION RESULTS IN GREEN GROWTH

We have been working on climate adaptation in Copenhagen for many years. Our efforts have been focused on managing stormwater and the opportunities for recreational use and a better environment in Copenhagen's areas of water. The results have required the development of new methods to retain and treat stormwater.

COOPERATION NATIONALLY AND INTERNATIONALLY

Coordination with surrounding municipalities will take place through cooperation already established on wastewater planning and planning work in connection with the preparation of municipal water management plans.

At the regional level, the Capital Region has started work that illustrates the overall need for climate adaptation in the region. The City of Copenhagen has taken part in the monitoring group for this work and has used the region's work in the initial phase for its own work on climate adaptation.

In relation to the level of central government, knowledge sharing on climate adaptation takes place through cooperation with the Danish Energy Agency, which is the state coordinating unit for climate adaptation.

INFORMATION ON CLIMATE ADAPTATION

SCRIPT FOR CLIMATE ADAPTATION

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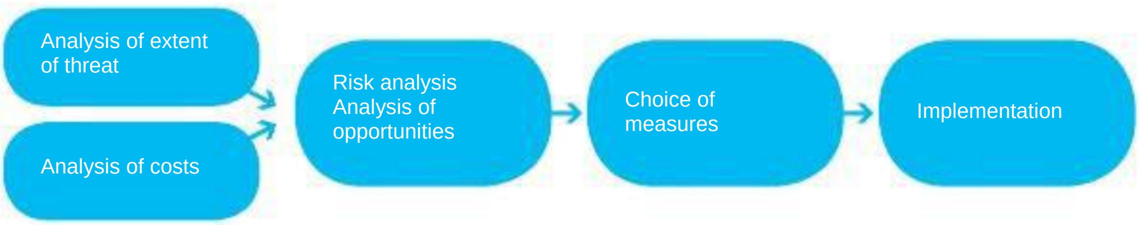
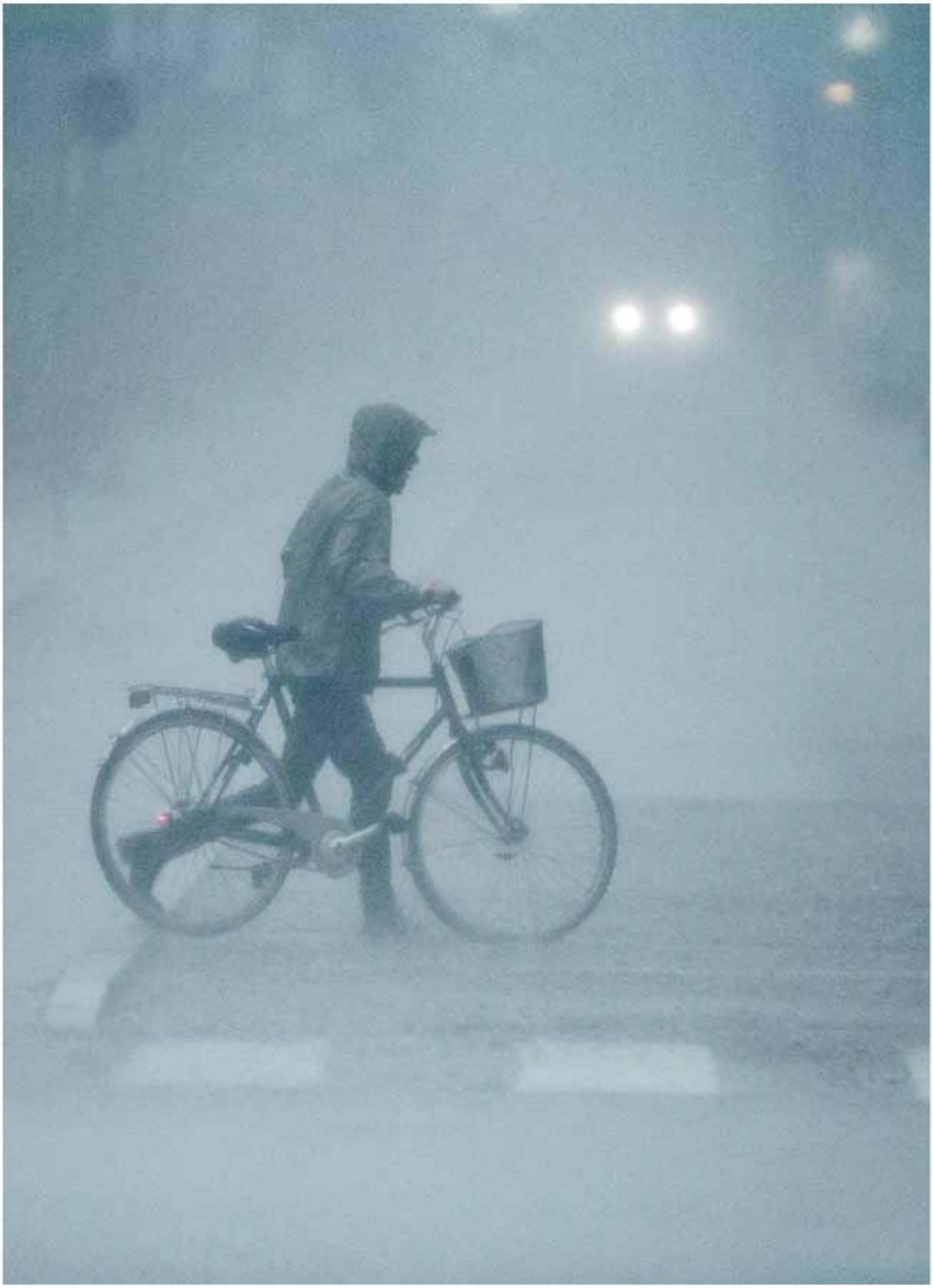
Climate adaptation is planned by continuously assessing the picture of risk and looking at the opportunities that are presented by the solutions. The aim is to achieve the greatest possible synergy with other plans and projects. The route to implementing the right solutions can be described by the following process:



By adopting this procedure, the City of Copenhagen will seek to ensure optimal adaptation to the climate of the future.



PRIMARY CHALLENGES RESULTING FROM CLIMATE CHANGE

MORE AND HEAVIER DOWNPOURS IN THE FUTURE

All the IPCC scenarios predict that there will be a change in the volume of rain and in the way in which it falls in the future. More precipitation will generally fall in a year, and it will fall in fewer rain events. The more extreme rain events are expected to result in increased flooding. The changes in the volume of annual precipitation are of no significance to the scale of flooding, but changes in distribution over the year will mean that the extreme events in the future are primarily expected to take place at the end of the summer.

PRECIPITATION OF THE FUTURE

The Danish Meteorological Institute (DMI) predicts that in climate scenario A2, which as mentioned assumes a rise in temperature of 2-3 degrees, there will be 25-55% more precipitation in the winter months in 2100, while precipitation in the summer months is expected to fall by 0-40%. At the same time, the precipitation will be more intense. The intensity of the heavy downpours is expected to rise by 20-50%—least for the frequent events and most for the very rare events. The changes are of great significance to how the rain will run off surfaces and for the load on sewer systems and watercourses.

The intensity of rain which statistically occurs once every 10 years will increase by around 30% by 2100 in climate scenario A2. This has the effect that the sewers in the future will have to cope with a volume of stormwater that in the maximum situation is around 30% greater than today, if the drainage system is to fulfil the same requirements and the same function as today.

The intensity of 100-year rain is expected to rise by around 40% by 2100 in climate scenario A2. This means that substantially greater surface runoff will occur in 2100 than we see today. The increase in intensity means that rain with a particular intensity will occur more frequently in the future. One-hour rain that today occurs once every 50 years, for example, will occur once every 10 years by 2110.

CHALLENGES DUE TO HEAVIER PRECIPITATION

Ved de store regnhændelser er der ikke plads i kloaksystemet. Derfor begynder regnvandet at løbe på overfladerne og søger mod de naturlige lave punkter i terrænet. Spørgsmålet er, hvor vandet løber hen, og hvor højt vandet vil stå i de laveste områder (typisk på vejene). Også vandløbene bliver kraftigt belastet i ekstreme situationer og vil brede sig ud over det nærmeste lavtliggende terræn. En kraftig og hurtig tilstrømning fra tæt befæstede overflader vil forstærke denne effekt.
There is no space in the sewer system in the large rain events. The stormwater therefore begins to flow on the surfaces and seeks the natural low points in the land. The question is where the water runs to and how high the water will be in the lowest areas (typically on roads). The watercourses are also heavily loaded in extreme situations and will overflow onto the nearest low-lying land. Heavy and rapid inflow from densely hardened surfaces will intensify this effect.

There are built-in “safety valves” in the sewer system that convey wastewater for which there is no space in the sewer to a watercourse, a lake or the harbour. A consequence of the increased intensity of rainfall is that the “safety valves” or overflow structures in the sewers will come into use more often. Even greater volumes of untreated wastewater will therefore be discharged into nature than happens today. This is not a sustainable development, as watercourses, lakes and the harbour are already suffering from a large load from discharges of this kind.

THE DIMENSIONS AND CAPACITY OF THE SEWERS

The daily management of stormwater from roads and roods in most of the city is the responsibility of the sewerage utility. This takes place in most of Copenhagen in pipes, to which both stormwater and household wastewater are conveyed. The pipes in many cases were built 150 years ago and are dimensioned on the basis of different criteria than apply today. The sewers as a whole have to meet the requirements of the present, that sewage may flow on the surface no more than once every ten years. In practice, this means that when heavy rain falls the sewers will be too small, and the sewage will therefore run off on the surface and seek lower points. The aim of the sewerage utility is to ensure that the discharge of wastewater from houses takes place safely from the ground floor. It is not a service objective for the sewerage utility to protect basements. These have to be protected on private initiative, for example by installing a backwater valve. The service objectives of the sewerage utility are laid down in the municipality’s wastewater plan, which is politically adopted by the City Council. The service objectives are based on historical assumptions, technical standards and economic considerations. Sewer systems normally have a life of between 50 and 100 years. It is therefore now already necessary to take account of climate change in 100 years

(*) Note: The standards are contained in the Committee’s publications 27, 28 and 29).

ASSUMPTIONS IN CALCULATIONS OF THE CONSEQUENCES OF TORRENTIAL RAIN

A mathematical runoff model known as MIKE URBAN is used to analyse existing conditions and project the impact of climate change on floods. This model can simulate flow in the sewer network and in watercourses as well as the spreading on the land of the water that the sewer network cannot accommodate. The model covers the sewer network throughout the catchment of the Lynettefælleskabet sewerage utility. It is ensured in this way that runoff from the neighbouring municipalities that flows through the City of Copenhagen is correctly included.

To ensure the best basis for making decisions, the results of the model are compared with operating experience and measures performed in recent years. This is done by carrying out what are known as sensitivity analyses, which test the model itself.
Sensitivity analyses have been carried out for the following parameters:

- Variation in rain over the catchment area
- Hydraulic parameters
- Simplification of the sewer network
- Rate of flow in the watercourses

All the sensitivity analyses are performed for the catchment area of the Damhusåen Treatment Plant. The results show that the model is robust in relation to changes in conditions and that calculations are made on the safe side with the following assumptions:

- That the rain is even distributed over the whole catchment area
- That calculations are only made for pipes more than 30-40 cm in diameter
- That a constantflow of rainwater in the watercourses is used based on measurements.

We have used the recommendations in Water Pollution Committee publication No 29 to project extreme rain. A number of climate factors are recommended here which are to be used in conjunction with the existing extreme rain events to project to 2060 and 2110.

The results of the calculations are presented as vulnerability maps showing the variation in water depth for the flooded areas.

The vulnerability maps are subject to some uncertainty—partly from the calculated water flows and partly from spreading on the surface. This makes the maps suitable for assessing the floods at district level but not at land register level.

We have used the model to perform a calculation of a number of scenarios, partly as a result of the planning of the runoff system by Copenhagen Energy and partly as a result of the assessment of the damage caused by the floods by the City of Copenhagen.

All the scenarios assume that the sea level will rise in the future.

OVERVIEW OF THE SCENARIOS USED:

Scenario	Repetition period	With climate measures	Damage calculation
2010	10	no	no
2010	20	no	yes
2010	100	no	yes
2060	10	no	no
2060	10	yes	no
2060	100	yes	no
2110	10	no	no
2110	10	yes	no
2110	20	no	yes
2110	100	no	yes
2110	100	yes	no

RESULTS OF THE SCENARIOS

THE SITUATION TODAY
Selected results of the model simulations for the existing sewer system with various rain events are shown in Figures 1 to 5. In the figures shown, flooding is defined as events where more than 3 cm of water is present on the land.

10-YEAR RAIN
Figure 1 shows 10-year rain today corresponding to the politically adopted service objective. Floods in this situation mean that the sewers are already too small today, or that more water will be conveyed to the watercourses than they can discharge. In this situation 48 hectares in the municipality are flooded.

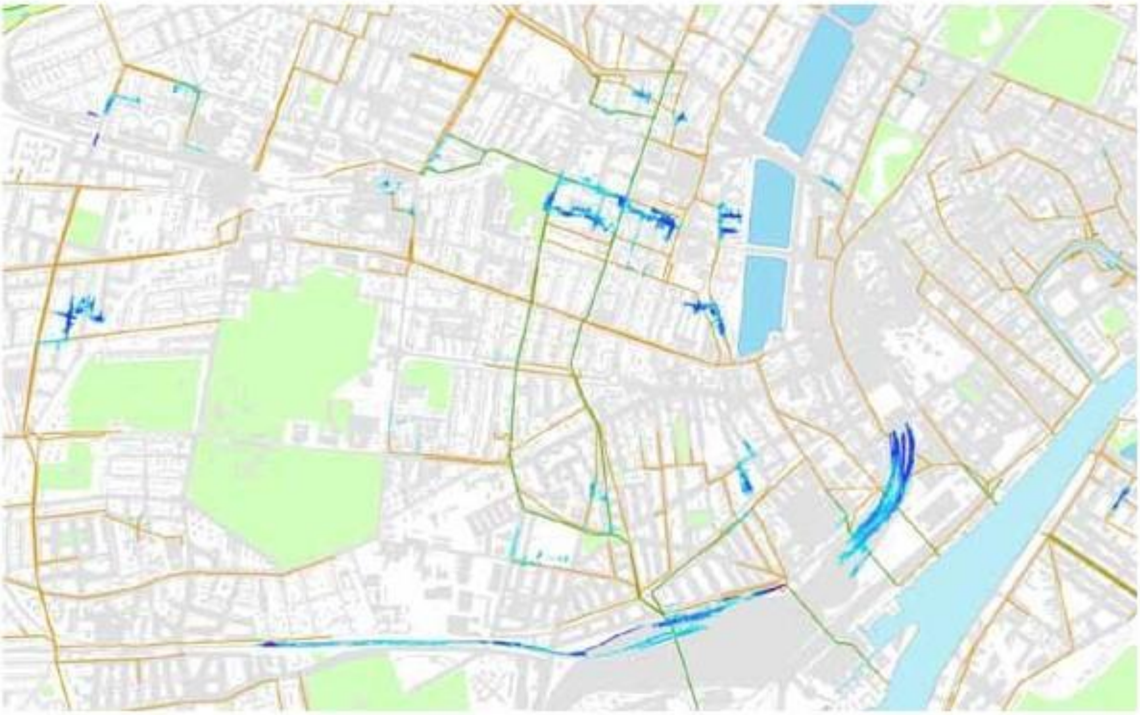


Figure 1. Floods in 10-year rain in 2010.

The simulation shows that there are substantial problems around Søborghusrenden, Harrestrup Å at Krogebjergparken and Damhus Å in Vigerslevparken. Problems in these areas are due to overloading of the watercourses and are consequently only indirectly related to the sewer.

The problems noted with bottlenecks in the sewers and the solution for these problems will be included in the municipality's wastewater planning.

20-YEAR RAIN

To assess which public assets are lost, we have carried out a calculation of floods in connection with a 20-year rain event. In this situation 230 hectares are flooded. The problem areas are the same as for the 10-year rain event, which means in connection with the watercourses.
The results are shown in Figure 2.

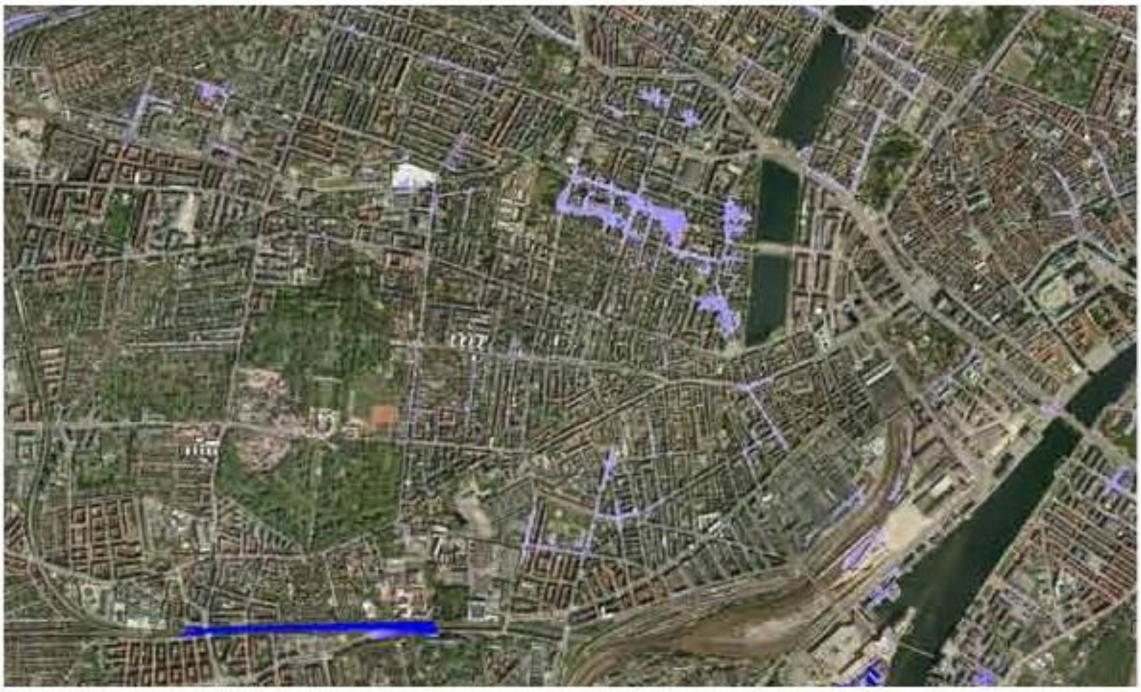


Figure 2. Floods in 20-year rain in 2010.

There are problems with damming-up at the following places:

- Around the Belvedere Canal i Sydhavnen
- On Enghave Brygge in Sydhavnen
- Teglholmen
- Pumpehusvej
- Valbyparken at the Damhusåen Sewage Treatment Plant.
- Skydebaneparken.
- Studsgaardsgade.
- Around the University Canal and the northern end of Ørestads Boulevard
- Tiøren on Amager Strand
- Kildeværldsgade

Experience of extreme rain events to date shows that the simulated flooding of the railway cutting at Central Station does not occur in reality. This may be due to the drainage conditions in reality being better than assumed in the model.

100-YEAR RAIN

Figure 3 shows floods as a consequence of a 100-year rain event in the present-day situation. The simulation largely corresponds to the flooding that occurred in Copenhagen on 14 August 2010.

Figure 3. Floods in a 100-year rain event in 2010.

In comparison with the simulation of the 20-year rain event, substantially more extensive and severe floods are now seen. The area flooded is now 595 hectares. The dark-blue shades on the map indicate that the water depth is more than one metre. There are now problems with the capacity of the sewer system almost throughout the city—which was expected as it is dimensioned to be able to cope with 10-year rain.

The problems around the watercourses are substantially worsened, resulting in flooding of large areas.

The principal new nodes for the floods in addition to those for the 10-year rain event are:

- Most of the older district on Amager
- The area around Strandvænget
- Along Grøndalsåen
- North of Valbyparken
- Lersøparken/Lersøpark Allé
- Lyngbyvej at Ryparken st.
- Bispebjerg
- Utterslev
- Individual streets in the city centre
- Vesterbro

THE SITUATION IN 2060

The results of the model simulations for 2060—as expected—show a degree of flooding between now and 2110. The most important result is that the area flooded for a 10-year rain event increases to 58 hectares if nothing is done. Another important result is that it is possible to minimise floods in a 100-year rain event by disconnecting a third of the stormwater from the sewer and establishing pumps in the runoffs from combined sewer overflows.

THE SITUATION IN 2110

No separate scenario has been produced for the 20-year rain event in 2110, as this corresponds to the 100-year rain event in 2010, see Figure 3. The probability of a flood of this magnitude changes from once every hundred years to once every twenty years.

Two simulations have been made of the 100-year rain event in a hundred years. In one, no form of climate adaptation has taken place, Figure 4, while it is assumed in the other that the sewer system is provided with pumps to lift the water out of the sewer, Figure 5. This becomes necessary due to a rising sea level. It is assumed at the same time that a third of the volume of water is disconnected from the sewer.

Figure 4. Floods in a 100-year rain event in 2110.

Figure 4 shows floods in connection with a 100-year rain event in a hundred years, if no form of climate adaptation is undertaken. There are now massive floods on 742 hectares of the city. It is necessary to make certain adaptations to the raised sea level, so that the sewer can deal with the water. Pumping of the wastewater from combined sewer overflows and stormwater runoff has to be established. Figure 5 shows the results of a simulation of the situation in a hundred years if the sewer is equipped with pumps and a third of stormwater is disconnected.

Figure 5 shows that the picture is largely unchanged from the simulation of a 100-year rain event in 2010, although the intensity of rain has risen by 40%. An area of 235 hectares is flooded, compared with 217 hectares in the 2010 scenario. The small difference is due to the establishment of pumps in the outlets and disconnection of 30% of stormwater from the sewer.

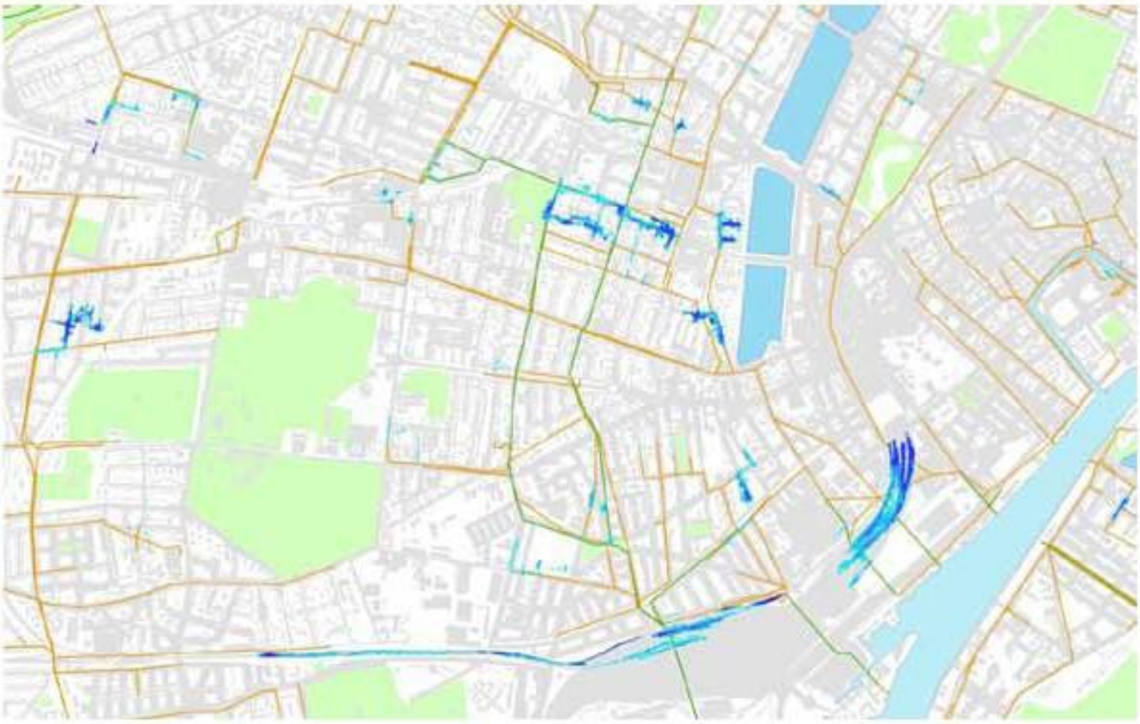


Figure 5. Floods in a 100-year rain event in 2110 with climate adaptation measures.

ECONOMIC CONSEQUENCES OF FLOODS

Analyses have been made of the economic consequences of selected flood scenarios. The total cost to society has been calculated in the analyses. Expenditure on loss of earnings, delays and expenditure on renovation of basements/ground floors and replacement of furniture, for example, are included. The real costs will fall substantially if basements are protected by backwater valves beforehand. The figures below are without any form of climate-proofing measures.

Scenario	Costs in DKK million	Remarks
2010 20-year rain event	2,039	
2010 100-year rain event	4,548	
2011 20-year rain event	4,548	Without climate adaptation
2011 100-year rain event	5,625	Without climate adaptation

HIGHER SEA LEVELS

When global temperatures rise, the temperatures in the oceans also rise. The warmed seawater expands, and this causes the water level to rise. The higher water level in the future may be significant in determining how serious storm surges that hit Copenhagen will be. A storm surge is a flood that is due to a high water level during stormy weather. Storm surges may result in temporarily high water levels in particular areas of Copenhagen. Copenhagen may consequently experience damage due to floods if the city is not properly prepared.

Copenhagen's location next to the sea has always given the city both commercial and recreational opportunities and advantages. On the other hand, the risk of a storm surge and consequently floods, which can cause great damage to the city, has also always been present. However, Copenhagen is relatively well protected through its location, although the risk will always exist. As a result of the city's development, a sharp rise has taken place over the course of time in the value and quantity of buildings and technical installations located in areas that are in danger of being affected by flooding. This means that the costs of damage in a flood are far greater today than they have been in previous storm-surge events.

CHALLENGES FOR COPENHAGEN AS A RESULT OF RISES IN SEA LEVEL

The future risk of floods in Copenhagen is closely related to the water level in the world's oceans. It is highly likely that rises in sea level will occur to some degree, partly due to the warming of the sea water. An attempt is therefore made in this climate adaptation plan to assess what rises in water level the future holds. This enables us to predict the risk of storm surges and associated damage, so that we can build protection against flooding from the sea into our thinking on the development of Copenhagen.

The sea around Copenhagen will rise by up to 1 metre over the next hundred years, according to a Danish Meteorological Institute assessment based on the latest calculations. The trend for rising water level is shown in Figure 1, which shows the water level measurements in Copenhagen Harbour in the past 60 years, stated as deviations from mean water level.

SEAWATER LEVEL IN THE HARBOR OF COPENHAGEN

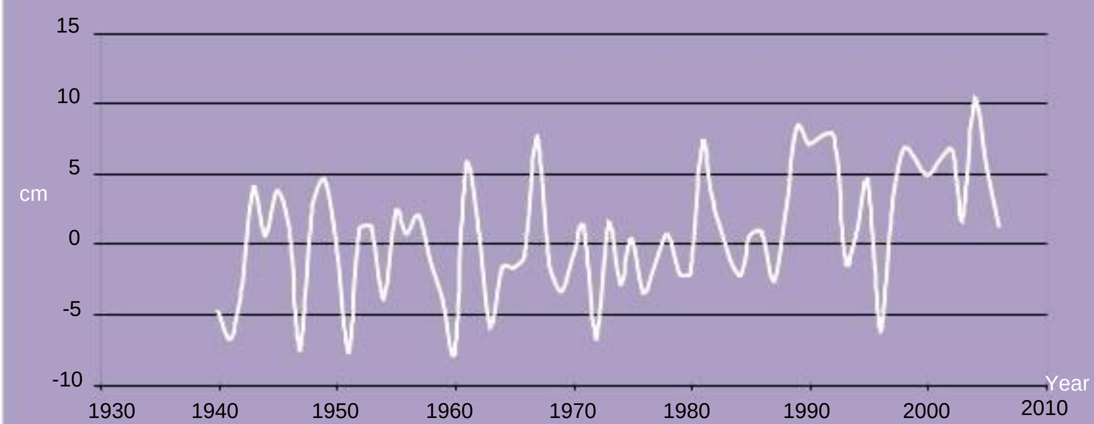


Figure 1: Observed water level in Copenhagen Harbour (deviation from mean water level).
Source: PSMSL, National Oceanography (psmsl.org)

No one knows how the world will develop technologically, in terms of population, politically etc., or how precisely the climate will respond to human activities. Neither, therefore, do we know precisely how great the rise in sea level will be.

Regardless of how great future rises in water level will be, there is always a risk of storm surges from the sea. There has therefore always been a risk of floods from the sea causing damage to Copenhagen. The probability of significant floods is not great at present, but the risk becomes greater if the sea level rises.

HOW IS THE RISK OF STORM SURGES ASSESSED?
Storm surges can lead to high waters and floods in Copenhagen. It can be seen in the table below that high waters in the future will reach a higher level above the sea surface more often, and can therefore potentially cause more serious floods. The surface of the sea is defined in this context on the basis of the standard known as DVR90. The studies are performed using a method of calculation that takes account of how the high water builds up and falls again and the way in which the water will flow over land.

Water level in relation to sea's surface (DVR90)	2010	2060	2110
20-year high waters	139 cm	180 cm	233 cm
50-year high waters	151 cm	194 cm	247 cm
100-year high waters	160 cm	205 cm	263 cm

The table above shows the expected development in high waters and water levels as a result of storm surges. The figure shows that high waters of an extent that at present occurs very rarely will occur far more frequently in the future. At present there are, for example, only high waters of 160 cm every 100 years. In 2060, high waters of 180 cm will occur every 20 years.

Figure 2 shows a projection of high waters and sea levels for the next 100 years. Although development is uncertain in the long term, there is a consensus in the scientific community that the present-day accumulation of greenhouse gases will have an impact on the earth's temperature conditions for several hundred years to come and therefore also on water levels in the oceans.

TREND IN HIGH WATERS

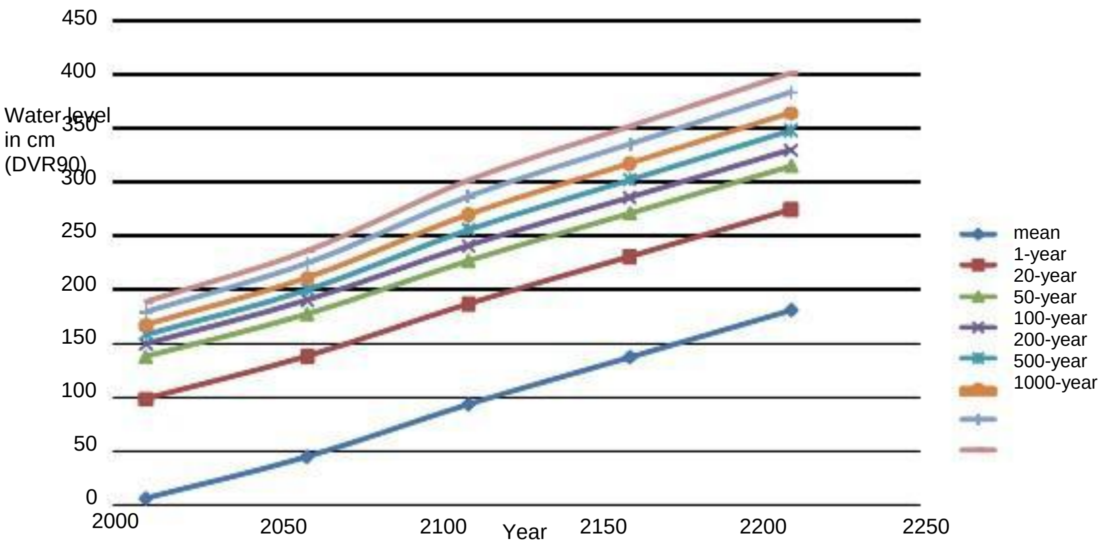


Figure 2: Trend in mean water level and resultant high waters over the next 100 years. Water level is stated in DVR90 in relation to present-day land points.

RISK ANALYSIS

The risk analysis is based on the method described in the section on strategy. The analysis shows that the probability of the city today being affected by a flood that causes unacceptable damage is not particularly great, but that the trend over the next 40-50 years is towards “high risk”, where the damage is unacceptable.

Figure 3 shows the trend in the risk of flooding from the sea and from rain. Until around 2050 the risk from rain is dominant, but afterwards the risk of flooding from the sea will dominate.

RISK OF FLOODING FROM RAIN AND SEA WATER

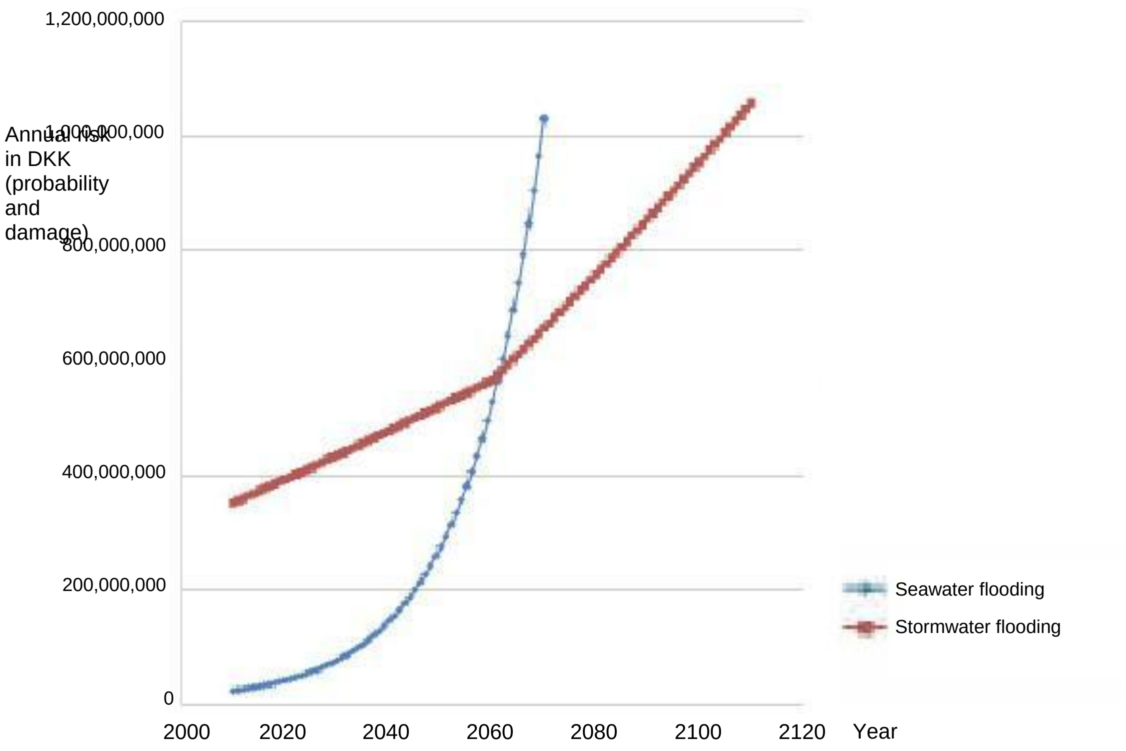
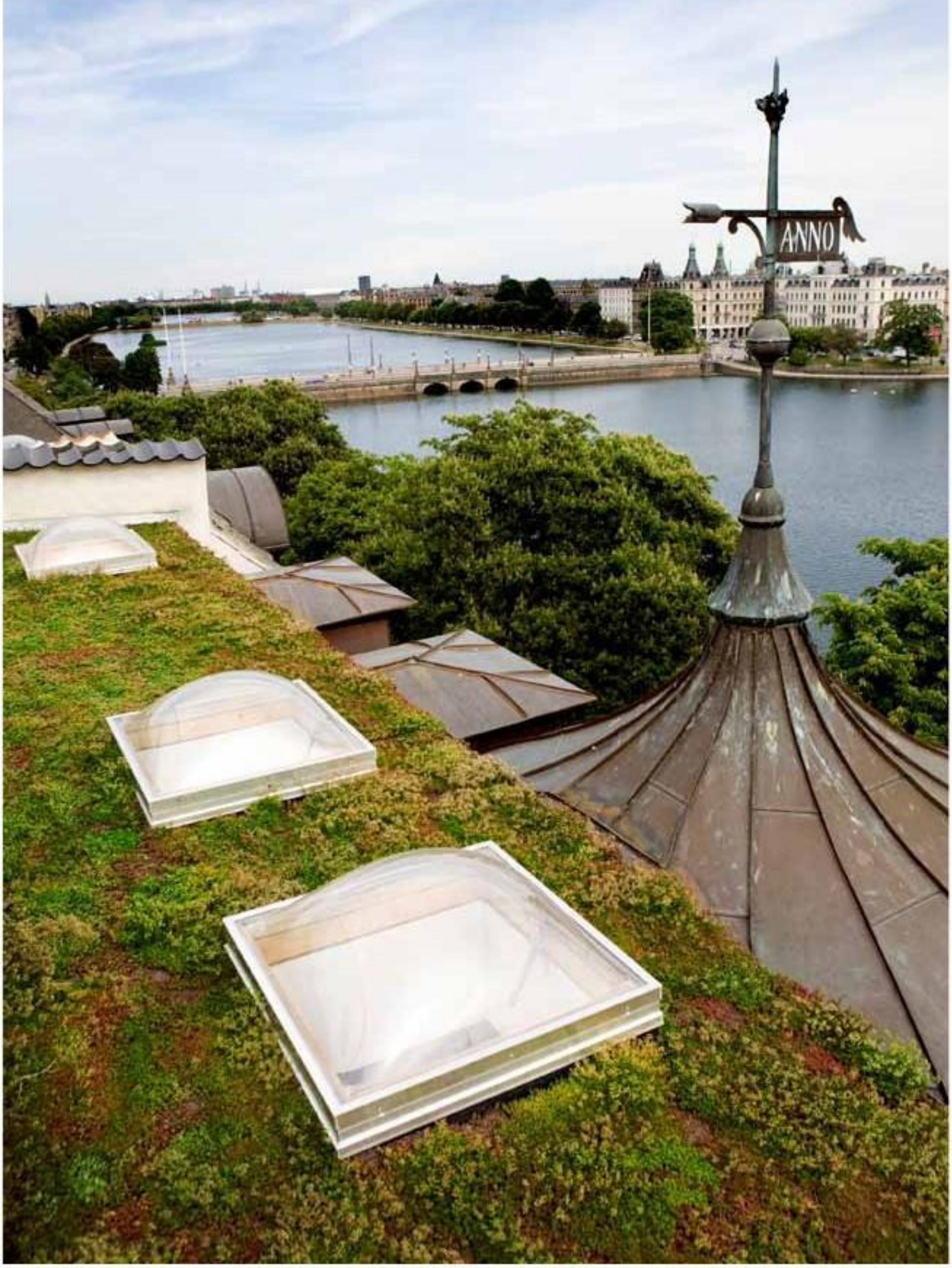


Figure 3: A risk area has been calculated for flooding from the sea. The index is calculated as the probability of an event times damage caused in the event. Table 3 shows the risk area as the number of million Danish kroner of damage that will occur in 10-year intervals.

Tme	Risk index	Combined assessment
2010-19	304	Low risk
2020-29	557	Medium risk
2030-39	1,039	Medium risk
2040-49	1,967	High risk
2050-59	3,770	High risk
2060-69	7,288	High risk
2070-79	14,157	High risk
2080-89	27,546	High risk
2090-99	53,504	High risk
2100-2109	103,414	High risk

Table 3: Risk index

As can be seen, the risk over the course of 30-40 years will be so significant that the damage in flooding from the sea is unacceptably great.


ANNO

OTHER CHALLENGES
HIGHER TEMPERATURES AND URBAN HEAT ISLANDS IN COPENHAGEN

The climate of the future poses new challenges for Copenhagen: temperature rises of two to three degrees, summers with longer periods of drought and a greater number of and more intense heat waves. A greater number of and more intense heat waves combined with the phenomenon of the urban heat island (UHI) in urban areas may lead to a lowering of the quality of life for the population of Copenhagen and may result in increased public expenditure on energy consumption and health.

If we continue along the path already pursued for instance by the climate plan and urban development projects and include consideration of long-term sustainable solutions in urban projects and promote solutions that work with cooling, shade effects, air circulation and balanced surface temperatures, we expected that Copenhagen will still have a pleasant urban climate in the future.

THE URBAN HEAT ISLAND EFFECT
A factor that has a bearing on the urban climate is the urban heat island effect.

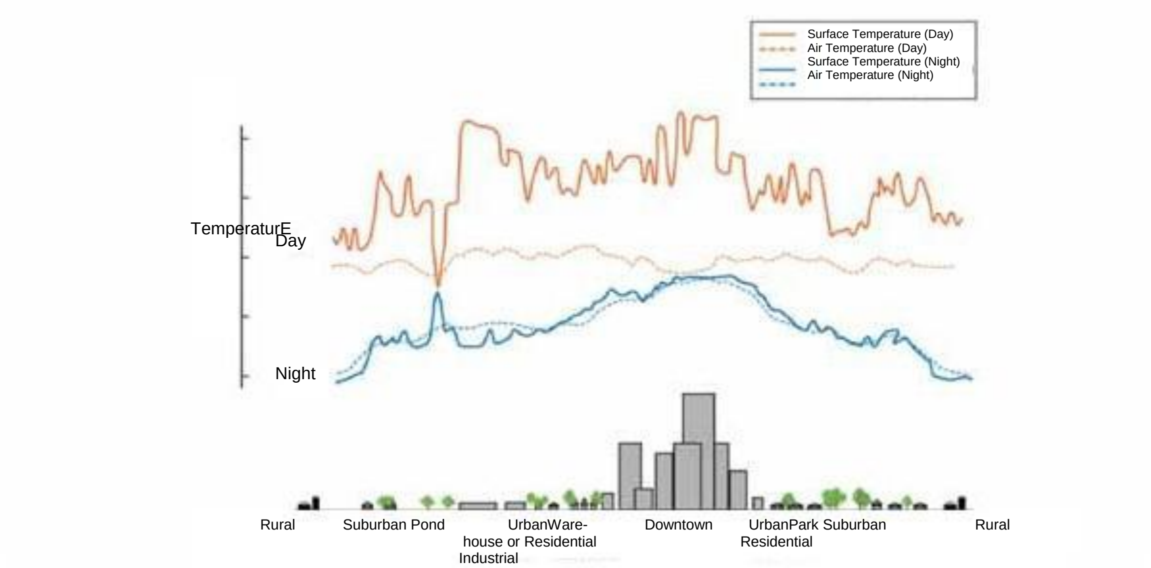


Figure 1: Surface temperature (solid curves) and air temperature (dashed curves) for different areas. The surface temperature around the 24-hour period fluctuates with the different surfaces (note, for example, the difference between pond and urban residential) and is highest in urban areas. The air temperature is relatively uniform over the whole 24-hour profile, while it falls at night outside the city, but remains high in the city (Source: www.epa.gov)

Urban heat islands describe the surface temperature of the city measured a few metres above the ground and reflect the fact that urban areas have higher air and surface temperatures than the surrounding countryside. The many hard and coated surfaces of the city and particulates and gases in the air retain the heat in the city. The heat of the city is, in brief, determined by:

- Solar radiation
- The heat generated by the city itself
- How much of the incoming heat and heat generated by the city itself can leave the city again by evaporation, air movement or radiation emission.

The urban heat island effect consists in the surface temperatures of cities rising when the sun is shining. The heat is stored and accumulated in buildings, roads, roofs etc. during the day and the heat is released again at night. The surface temperature of cities will therefore be higher around the clock than the surface temperatures of the surrounding countryside. Lack of water and vegetation means that the sun's energy does not evaporate and disappear again, but is stored as heat in the city. It is the combination of prolonged heat waves and the formation of "heat islands" that can make it difficult for humans and animals to maintain an ideal body temperature, particularly because the heat effect causes the city to cool down more slowly at night.

CHALLENGES FOR COPENHAVEN AS A CONSEQUENCE OF WARMER WEATHER IN THE FUTURE

The climate adaptation plan has made a study of the surface temperatures of the city and the formation of urban heat islands. The studies show that there are relatively wide fluctuations in surface temperatures in the city, but as the weather is today we do not consider that the urban heat island effect will cause major problems in the near future, simply because the weather in Copenhagen very rarely presents periods of prolonged heat waves where the temperature exceeds 25-28 degrees.

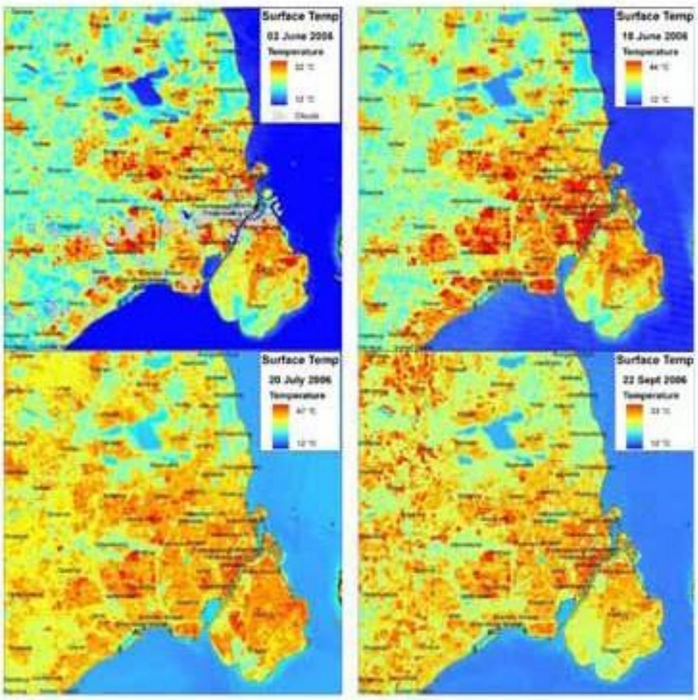


Figure 13: Map of surface temperatures in Copenhagen and surrounding area on four days in 2006, 2 June, 18 June, 20 July and 22 September. The maps were produced from the processing of Landsat data.

The climate plan has commissioned district maps on which surface temperatures in the heat wave of 2006 are recorded. It should be noted that the temperatures shown are surface temperatures and not air temperatures in the urban space, which are substantially lower.

The maps can be used as part of the preliminary studies in projects, local planning etc.

Districts and areas where particular attention needs to be paid to the formation of heat islands are: Vesterbro, parts of Sydhavnen, Amagerbro and Nørrebro/Bispebjerg and the inner city.

The expected temperature fluctuations in the future and the prospect of a greater number of and more intense heat waves may pose special challenges in cities, partly because of the urban heat island effect.

Figure 13 shows the surface area in the City of Copenhagen and surroundings for four selected days in the summer of 2006. It can be seen that there are wide regional variations with a clear trend towards higher surface temperatures in built-up areas, including inner Copenhagen. The coldest areas are water surfaces, followed by the larger areas of woodland. The hottest day of the summer, 20 July, resulted in surface temperatures of up to 47°C, while the surface temperature on the other three days was between 32°C and 44°C. The figure also shows that surface temperatures in Copenhagen differ very widely and depend on the surfaces of the urban landscape. Areas with dense and high building development, large covered areas and in periods of drought also large areas of grass are affected by heat. Open green residential areas and areas of green and blue are affected far less. Although vegetation can have a cooling effect, it is found that areas with groups of trees generally have a lower surface temperature than grass-dominated land in parks and sports grounds. The explanation is probably that the grass dries out more quickly because of a more superficial root system.

CLIMATE CHANGE AND GROUNDWATER

Future climate change may affect the groundwater. In Copenhagen we anticipate seeing rises in the level of groundwater right out at the coast, while there will be a minor fall in groundwater level in the rest of the municipality.

THE FUTURE GROUNDWATER LEVEL

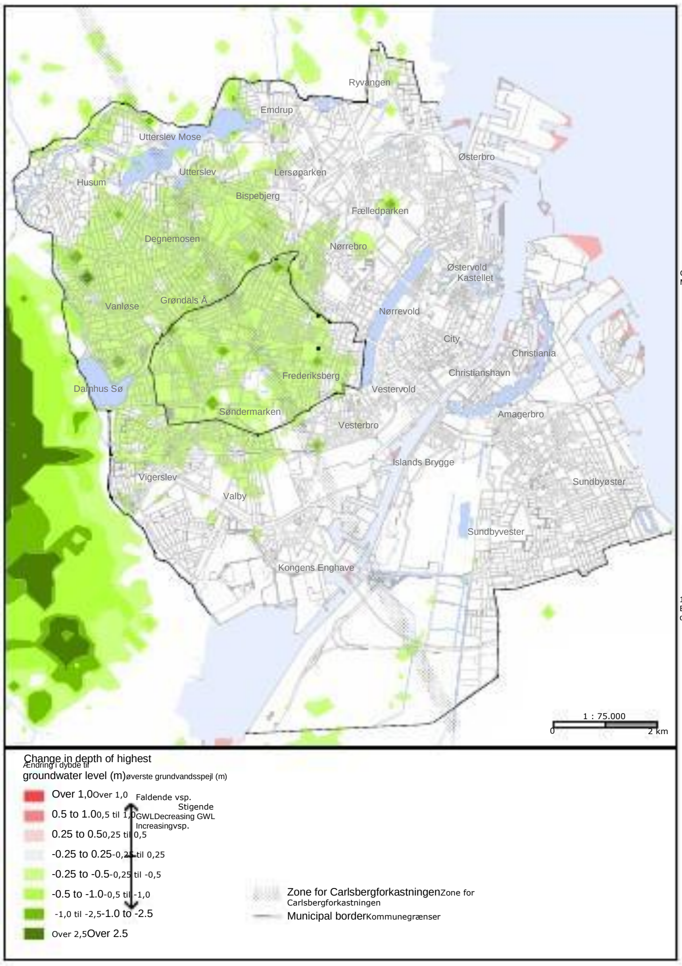
Climate change is expected to mean that less groundwater will be formed in the future. Partly because of the higher temperatures, a larger proportion of precipitation will evaporate before it can percolate into the ground. In addition, a larger proportion of the rain is expected to fall in the form of more intense downpours. The heavier the rain, the more water will flow away along the ground surface instead of percolating into the ground.

Along the coast, the groundwater level is to a great extent controlled by sea level, and the groundwater in a belt alongside the harbour and the coast will therefore rise in line with the rising sea level.

The climate adaptation plan has calculated the expected changes in groundwater level and the resultant depths down to the groundwater. The changes are calculated for a short term up to 2060 and a long term up to 2110.

The calculations show that the changes have not had a great impact in 2060. In 2110 there are substantial changes, particularly along the coast and the harbour front.

The map in Figure 1 shows the calculated groundwater changes in 2060 in the top level of groundwater. It can be seen that the changes are only small, both within the country and at the coast, where the rises in seawater level have not yet worked through. It is possible to read from the map for example that the greatest fall in the highest groundwater level in the City of Copenhagen—more precisely towards the north at Brønshøj and Bispebjerg—are calculated as being between 0.25 and 0.5 metres.

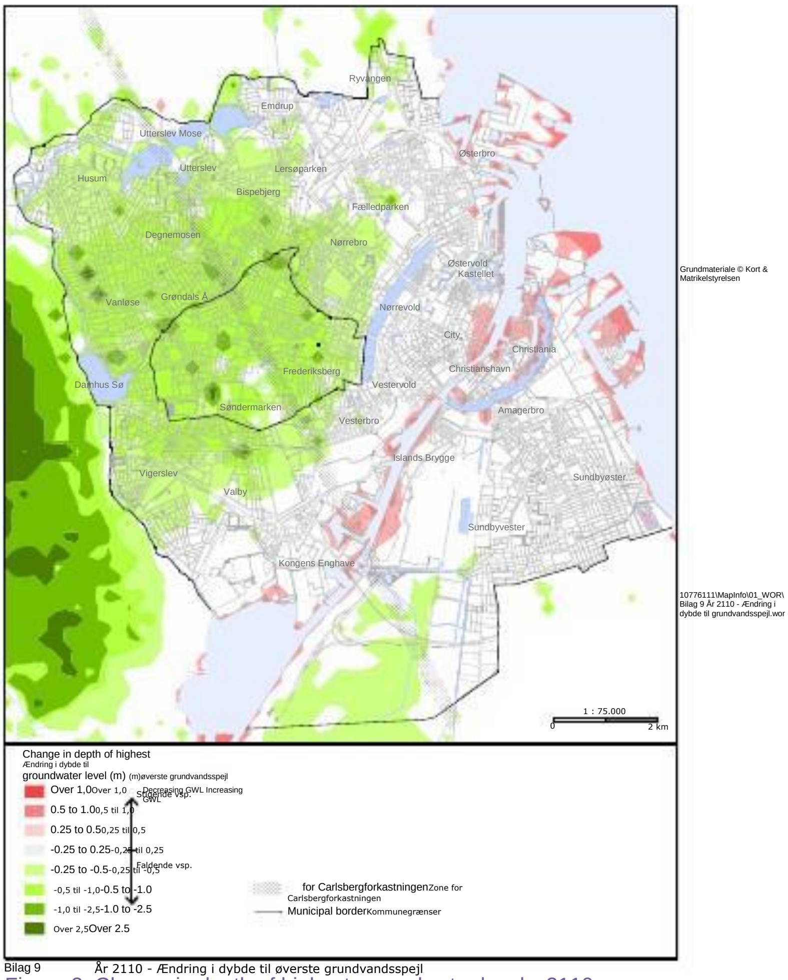


Bilag 8

Figure 1: År 2060 - Ændring i dybde til øverste grundvandsspejl level—2060Change in depth of highest groundwater

The map below shows the result of the calculated changes in the depth of the groundwater in 2110. Rises in the highest groundwater level of up to 0.5 metres are seen locally along the harbour front and the coast as a result of the rise in seawater level.

The lowering of the groundwater in Copenhagen will be up to 0.5 metres, as seen for example in Brønshøj, Vanløse and Bispebjerg. In the Municipality of Frederiksberg the groundwater level generally falls by between 0.5 and 1 metre.



Bilag 9 År 2110 - Ændring i dybde til øverste grundvandsspejl

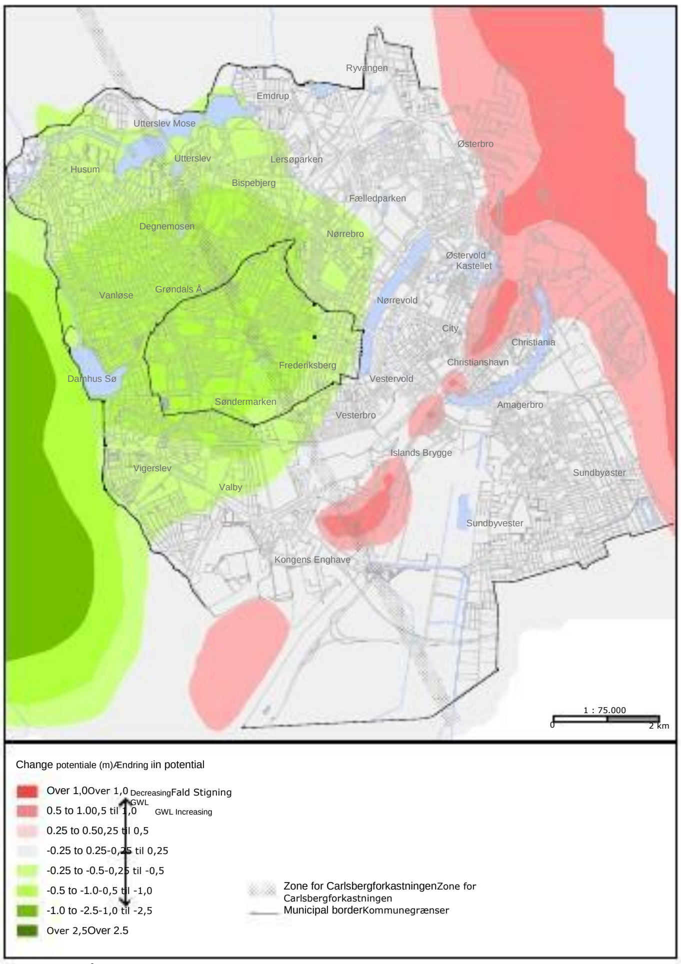
Figure 2: Change in depth of highest groundwater level—2110.

Many infiltration systems have been established on individual properties in recent years. Copenhagen Energy is speeding up this development by reimbursing connection payments, and this development is expected to continue.

As a greater proportion of the rainwater infiltrates through the surface, the contribution to groundwater formation will increase. It is uncertain how great a proportion of the infiltrating water ends up as groundwater. Greater groundwater formation will lead to a rise in groundwater level and will thus have the opposite effect to direct climate impacts.

The primary/deeper groundwater in Copenhagen is at a depth of around 10 to 20 metres in a continuous groundwater reservoir of limestone with fairly high penetrability. In some places there is a more impervious level of clay over the limestone. This situation has the effect that the pressure level in the limestone differs from the level of the highest groundwater, where an unsaturated zone is replaced by a saturated zone.

The map below in Figure 3 shows that the water pressure in the limestone rises out below the coast, while it falls within the municipality and in particular beneath Frederiksberg. The greatest fall in Copenhagen is seen to be up to 1 metre.



Grundmateriale © Kort & Matrikelstyrelsen

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Bilag 3 År 2110 - Ændring i potentiale i primært grundvandsmagasin

Figure 3: Change in the groundwater potential in the primary groundwater reservoir in limestone.

CHALLENGES AS A CONSEQUENCE OF GROUNDWATER CHANGES

When the groundwater rises it will result in increased pressure on foundations that are below the groundwater level. Draining of the soil will be reduced, and there may therefore be standing water in drains and around buildings above groundwater level for a prolonged time.

The groundwater can infiltrate through leaks in sewer and water supply pipes and district heating pipes. Pollutants in the soil can infiltrate into the pipes with the water.

Where the water level falls, leaking sewer pipes can go from receiving infiltrating groundwater to leaking sewage out into the surrounding layer of soil.

The publicly owned part of the supply network is in a good state of maintenance. On the other hand, the private service pipes from the individual property are in a mixed, and in some places poor, state of repair.

INDIRECT CONSEQUENCES OF CLIMATE CHANGE

Climate change will probably have some indirect consequences for a number of other areas, the most substantial of which is its significance for public health and biodiversity.

FUTURE CHALLENGES TO PUBLIC HEALTH

Climate change has a number of indirect consequences, which to a greater or lesser extent can affect the health and quality of life of the people of Copenhagen. The warmer and damper climate may lead to health problems if we are exposed to more sun and heat, and an extension to the pollen season will pose problems for allergy sufferers. Great volumes of rain may result in damper homes, and there will be an increased risk of infection from sewers, lakes, rivers and seas.

UV RADIATION AND HEAT STROKE

Hotter summers and milder winters may mean that we will spend more time outdoors in the future. We are consequently exposed to great amounts of ultraviolet radiation from the sun. In the summer, heat waves will cause more people to go to the parks or to harbour baths and beaches, where the sun's rays are particularly strong due to reflection from the water. This will mean a greater number of cases of sunburn and an increased risk of skin cancer. At the same time, the higher temperatures will pose a greater risk of dehydration and heat stroke, particularly for young children, the elderly and people with chronic diseases.

In some places, however, it may have a positive impact when we spend more time outdoors all year round. This might mean that the spread of respiratory infections diseases, for example, particularly for young children in day care.

DISEASES

A higher incidence of water-borne and food-borne diseases is one of the indirect consequences of climate change. Rising temperatures may signify greater spread of salmonella infections. Legionella bacteria, which live in freshwater in wet and damp environments, may also become more widespread. Infection takes place most commonly by inhalation of water vapour (aerosols) which is contaminated with legionella. As well as the water supply, infection may take place, for example, through cooling towers and air conditioning.

Existing environmental legislation in both Denmark and the EU is not just aimed at reducing greenhouse gas emissions, which cause climate change. It also aimed at improving air quality, because air pollution causes diseases in humans and results in environmental harm such as acidification and eutrophication.

DOWNPOURS AND DAMP NUISANCE

Very heavy downpours may lead to flooding of sewers, basements and seas. Sludge and residues following floods with sewage contain bacteria, algae and microorganisms that are harmful to health. There will therefore be an increased risk of infections in the gastrointestinal system and the respiratory organs.

A greater number of extreme downpours may also lead to greater damp damage to buildings and homes. Increased air humidity in buildings means more house dust mites and more cases of mould fungi. Some people experience discomfort such as headache and inability to concentrate when they spend time in a building affected by damp and mould. Some develop an allergy to the fungal spores and react with hay fever or asthma. And those who have asthma or hay fever may find that their symptoms worsen if they spend time in buildings with damp and fungal growth.

POLLEN ALLERGIES

The warmer climate is also significant for people with pollen allergies. The total quantity of pollen will rise, there will be more days with very high pollen counts and the pollen season will be extended. At the same time, the changed climate may result in better growing conditions for new pollen-bearing plants that have not previously been widespread. This has been the case, for example, for the highly allergenic common ragweed. This is of great significance to people with pollen allergies and makes it necessary for the municipality to take account of the pollen problem when planting trees and constructing recreational green spaces, which members of the public should be able to spend time in without suffering health consequences. At the same time, the public must be informed about prevention and control of ragweed, for example, on private land and in gardens.

The damper climate may result in more people having to live with respiratory problems and more people developing allergies. There may be more referrals to doctors, increased consumption of medication, more days of sick-leave and more days with reduced work capacity and quality of life.

AIR QUALITY AND HEALTH EFFECTS

Air pollution is a result of discharges to the air, spread in the air and chemical/physical conversions. The spread of the polluting substances in the atmosphere is determined by meteorological conditions, such as wind direction, temperature and wind speed.

The air pollution measured in Copenhagen comes predominantly from traffic, and up to around 90% is of traffic origin on very busy streets. Air pollution is governed by EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe. This Directive lays down limit values for the concentrations of a number of pollutants in the air.

Climate change also affects temperature and wind patterns. It is therefore necessary to assess whether air quality in Copenhagen is consequently becoming worse or better. The overall assessment is that it is difficult to make a clear statement about future air quality in Copenhagen. Air quality is affected by a number of factors, the principal ones being, on the one hand, emissions to the air, wind and temperature and, on the other, technological development and political decisions. Emissions, wind and temperature are described below and each assessed separately.

EMISSIONS

Existing environmental legislation in both Denmark and the EU is not just aimed at reducing greenhouse gas emissions, which cause climate change. It also aimed at improving air quality, because air pollution causes diseases in humans and results in environmental harm such as acidification and eutrophication.

The latest reports on air quality in Copenhagen suggest that air pollution from traffic is, in general, declining. Concentrations of certain pollutants such as lead and sulphur dioxide are far lower than previously, and the level of particulates in the air is below the limits. On the other hand, Copenhagen continues to exceed limit values for the level of nitrogen dioxide (NO2). Improved air quality is ensured politically and legally by tightening the Euro standards. The requirements relating to emissions are being constantly tightened, next time with the introduction of the Euro 6 standard in 2011.

WIND

The levels of air pollution do not depend just on the structure of the major city and emissions from cars and other sources but also on meteorological conditions. Copenhagen is also affected by the transporting of air pollution from areas outside Denmark and the EU. Together with changes in wind conditions as a result of climate change, this is also of significance to future air quality in Copenhagen.

In periods of hot summer days there are already known examples of polluted air from southern Europe being carried up to Copenhagen and affecting children and people with asthma, pollen allergy and other respiratory conditions in particular.

Climate change also affects wind directions. However, the expected changes in wind conditions over Zealand are generally marginal and subject to greater uncertainty than is the case, for example, for temperature and precipitation. Calculations performed by DMI overall suggest that average wind speeds will decrease by a few per cent in the spring and autumn, while they will increase slightly or be unchanged in the winter and in the summer, This general trend is mainly not seen until after 2050.

Changes in extreme winds (gales and storms) are more marked than the changes in average winds. The greatest changes are expected in the winter with an increase in extreme winds of up to 10% for a 10-year event in 2100. The strength of extreme winds in the spring and autumn follows the same trend as average wind and declines by around 5%. The same trend in extreme winds is observed from 2050, where they are, however, less marked.

Based on the current level of knowledge, our assessment is that the changes only affect air quality marginally. There is therefore no reason for Copenhagen to independently monitor or initiate projects on changes in wind conditions and their significance to people’s general well-being or consequences for buildings and other assets in the city.

TEMPERATURE

New Danish and international research shows that a warmer climate may increase air pollution, as both chemical reactions and emissions depend on temperature. The gradual rise in temperature will consequently result in more air pollution. The effect of the efforts made to date to counter air pollution is therefore at risk of being reduced as a consequence of climate change.

In the ground-level part of the atmosphere it is ozone in particular that is harmful to the respiratory tract, particularly among people who have respiratory conditions beforehand. The scientific assessment is that the warmer climate globally will result in substantially more episodes of critical levels, particularly in the cities. The IPCC’s A2 scenario, on which this climate adaptation plan is based, for example, gives 30 per cent more of the ‘bad days’ when air quality is so poor that the population has to be warned.

It is difficult to say in the long term whether air quality will become better or worse, as a great deal has happened politically and technologically in relation to air quality in recent years. Examples of this are the Environmental Zone around Copenhagen, efforts to secure political backing for a congestion charging zone around the city, particulate filters, technological innovation and new types of fuels and cars (for example the initiative in Copenhagen to encourage electric and hydrogen-powered cars).

Overall, it is therefore difficult to assess in the long term which factors will result in either a worsening or improvement in air quality.

BIODIVERSITY

More precipitation, higher temperatures with a greater number of and more intense heat waves and rises in sea level will increase the pressure on Copenhagen's biodiversity. Some plant and animal species that are not native to Denmark will become more widespread and be invasive, a situation we are familiar with through the example of hogweed. Others will become part of the city's nature. The increased quantities of rain increase the risk of the sewer system overflowing. This may mean that the city's rivers, lakes and coastal waters are polluted and that biological balance may be disturbed.

SIGNIFICANCE OF CLIMATE CHANGE FOR THE BUILDINGS AND ROADS OF COPENHAGEN

Climate change may come to mean that the buildings and roads of Copenhagen are more at risk of a number of types of damage. Buildings are vulnerable to changes in the climate, which may lead to water penetration, more storm, snow and subsidence damage, poorer indoor climate and a shorter life for building structures. The consequences of damage to buildings range from loss of life and health to expenditure on repairs and increased operating costs or loss of value. Roads and tunnels are vulnerable to floods and a rising groundwater level, and drainage of roads is important to avoid damage to roads, surroundings buildings and installations.

CLIMATE CHANGE AND BUILDINGS—CHALLENGES

A number of the challenges that we expect as a consequence of climate change, for example major changes in the level of groundwater and a general rise in sea level, are not expected to pose any major risk to the city's buildings and roads in the short term. But over the course of the next 100 years these changes too will gradually bring an increased risk of extensive damage and loss of value if action is not taken at the right time.

HEAVY RAIN AND CLOUDBURSTS

When it rains heavily, the public sewer system can become overloaded, so that the sewage may run "backwards" in the sewer pipes and be forced up through the floor drain in the basement.

Extreme precipitation determines the dimensions of wastewater systems. If the capacity of the drain is exceeded, there is a risk of flooding. This may result in water damage at various places in the building and water-filled basements. Torrential rain may also cause more basement floods as a result of more wastewater on the surface.

During heavy rain many roads will act as "drainage channels", where the water is transported to the sewer through street gullies. If street gullies or service pipes are defective or blocked, they cannot remove the water and therefore cannot protect against floods. In the same way, there is a risk of damage to the road bed if the water cannot be removed quickly enough.

In Roads of the Future 2010—2029, which is concerned with a status of operation and maintenance in the area of roads in the City of Copenhagen, the condition of the municipality's street gullies and service pipes is assessed such that 17% are in urgent need of renovation, 49% have a limited life and should be renovated in the near future and only 34% of all gullies and service pipes have an acceptable remaining life.

STRONG WIND

The most important challenges in the short term are that more powerful storms will pose a safety risk in the proportion of existing buildings that do not meet the requirements on safety in the building regulations.

Depending among other things on the location, height and roof slope of the buildings, very severe storms may result in minor or major damage—particularly on roofs. The damage entails expenditure on repair, and consequential damage is often seen on the underlying structure and on storage goods and belongings. But there is also a substantial risk to people who are in or next to the buildings when roof tiles or roofing sheets fly through the air, and damage often occurs to other buildings, parked cars etc.

A large proportion of the knowledge and experience that exists on climate adaptation of buildings is already available today in the form of reports, guidelines, booklets etc. In addition there are a range of Internet portals containing relevant information.

Today, Copenhagen is supplied with a sewer network, the purpose of which is to ensure that wastewater can be safely removed from houses from the ground-floor level. On the other hand, protecting basements is not a service objective for the sewer system. Basements must therefore be protected on private initiative, for example by installing backwater values.

The service level in connection with the city's sewer system is laid down in the municipal wastewater plan and has been politically adopted by the City Council.

LEGISLATION AND PLANNING

The climate adaptation of Copenhagen requires broad cooperation. In some cases the municipality itself has to carry out climate adaptation actions, but in many areas it can induce others to adapt through its administration of laws and plans. The municipality's options for planning and control of development are governed by a number of laws etc. This section presents an overview of the applicable rules and how they can be used to prevent and deal with the various challenges posed by climate change.

THE PLANNING ACT

The Planning Act contains the most important instruments for steering long-term development and adapting it to the local conditions, including climate development. But the planning only works prospectively and not on existing buildings and areas. The municipal plan establishes the combined regulation of expansion with homes, jobs, transport, service provision, recreational spaces and so on.

In addition, the Municipal Plan contains binding guidelines for the municipality's administration on a number of topics laid down in the Planning Act. It can also contain objectives for other topics, which indicate the desired development and point the way for the municipality's own actions.

The frameworks for development and land use in the Municipal Plan are created among other things through local plans. The local plan is legally binding on the individual landowner. Local plans cannot, however, regulate everything. The Planning Act indicates what conditions a local plan can regulate. In addition, the provisions in a local plan may have a basis in planning, which means that it has to fall within the aims of the Planning Act and the urban planning tradition. Nor does a local plan entail an obligation to act. This means, among other things, that we have limited opportunities to influence the existing urban areas unless there is a need for changes that are subject to local planning requirements. But even if there are restrictions, the local plan can go a long way towards ensuring that climate adaptation is taken into account in the development of the city.

THE BUILDING ACT

Part of the purpose of the Building Act is to ensure that buildings are safe and healthy, and that they can withstand external effects. It is possible for us in the municipality to lay down requirements regarding new buildings and renovations of existing buildings, requirements that will also ensure the optimal function, operation and maintenance of the buildings in the climate of the future. Buildings have to be protected against floods and moisture in the structures, and they have to be able to withstand strong winds. In addition, they have to have a good indoor climate with adequate ventilation. These are predominantly functional requirements, which means that the client can choose the methods that are best suited, provided they fulfil the requirements in practical use.

OTHER LEGISLATION

A number of circumstances of significance to adaptation to climate change are governed by special legislation. This applies for instance to the drainage of water (wastewater and stormwater), protection against coastal erosion and floods and rescue preparedness and legislation on listed buildings.

We will review below the key challenges posed by climate change. For each challenge a review will be made of how the applicable legislation can be used as a tool to improve Copenhagen in relation to climate change. Each section of the review will relate to the legislation in connection with the Municipal Plan, the local plans, building permits and other legislation.

MANAGEMENT OF MORE STORMWATER

The primary challenge with increased quantities of rain will be that there will be periods of floods in buildings and urban areas, both entirely locally in low-lying areas and as a result of overloading of watercourses and the pipe network.

MUNICIPAL PLANNING

The municipal plan is primarily concerned with designating areas for urban development. If areas are judged to be particularly at risk in torrential rain due to terrain etc., they can be kept clear of building and designated for purposes where there is no vulnerability to rain. Requirements can also be set for building development to be protected against flooding (this is typically implemented in local plans). The municipal plan can reserve areas for technical facilities, for example collecting and retarding basins for stormwater. The municipal plan can regulate how watercourses, lakes and seas are to be used. It will be possible to stipulate here, for example, that piped watercourses can be opened, or that lakes are made larger, so that they can take stormwater from adjacent areas. Despite the municipal plan stipulating this, it does not entail a duty to act. It means that the municipal plan opens up the possibility of use of the areas, but that the plan does not make this use compulsory. In connection with planning of building work, ‘expansion agreements’ can be entered into with land owners, which can contribute for example to increasing the capacity for local drainage. An expansion agreement expands the options contained in the municipal plan but also contains specific, mutually obliging agreements between the planning authority and the landowner. The municipal plan will be able to designate the areas in the municipality where permission can be given for local infiltration of stormwater.

LOCAL PLANNING

In the local planning, the City of Copenhagen has the option of requiring that construction and open spaces are designed in such a way as to make sustainable urban drainage systems (SUDS) possible. The aim of sustainable urban drainage systems is to relieve the load on the sewer system and reduce the risk of floods and water damage. It may entail green roofs that can delay the stormwater in reaching the sewer, permeable coatings and green spaces that contribute to the stormwater infiltrating instead of being conducted to the sewer system. It may also relate to systems for the collection of stormwater from roofs, so that the water can be used for flushing toilets and washing clothes. The planning basis for SUDS solutions may be a combination of aesthetic considerations, recreational considerations and the desire to reduce the risk of floods due to stormwater.

Local planning can also contribute to putting into practice large combined plans for the removal of water flowing on the surface. The planning reasoning for this is the desire to reduce the risk of flooding.

BUILDING PERMITS

To ensure dry construction, the City of Copenhagen can set requirements in its building permits for documentary evidence that new and renovated buildings are protected against moisture. Buildings are to be constructed so that water and moisture from rain, snow, surface water, air humidity etc. does not lead to damage or inconvenience in use, for example impaired durability and poor health conditions.

In connection with new construction, facilities must therefore be created that carry roof water, which is drained down to the ground surface, away from buildings. It must also be ensured that water from the surface does not penetrate into buildings. The building regulations today already contain requirements on how facilities that drain stormwater away from buildings are to be designed. The requirements that the City of Copenhagen lays down for these facilities are based on an assessment of the volume and intensity of rain. It will therefore also be possible for the requirements to be adjusted, so that they are in line with the volumes of rain we expect in the future.

OTHER REGULATION

The City of Copenhagen's wastewater plan is drawn up pursuant to the Environmental Protection Act. The wastewater plan can plan for the division of stormwater and wastewater and for facilities that can retain water in the event of heavy rain (e.g. basins above and below the ground), and options for infiltration of stormwater can be identified. The municipality is required by the Act to revise the wastewater plan when changes take place in the conditions on which the plan is based. It is ensured in this way that the wastewater plan is continuously adapted to the development in the climate.

The law on rules of payment for wastewater treatment plants provides for the possibility of landowners who themselves manage stormwater and do not drain it to the sewer can be reimbursed up to 40% of the 'connection charge'. This applies to both new and existing construction. The regular payments for drainage normally follow the registered water consumption and are therefore not directly related to whether the stormwater is disconnected. A reduction can also be given in the price of drained water from the use of stormwater for flushing toilets and for washing clothes, and groundwater that is pumped up and drained away to keep a building dry normally does not attract a charge.

RISING GROUNDWATER

MUNICIPAL PLANNING

The level of groundwater is expected to rise at the coasts as a result of the rising sea level. Areas particularly at risk can be kept free of building development on the basis of the municipal plan. It will, however, be more relevant to require new construction to have to take place on elevated terrain so that it is protected against penetrating water.

LOCAL PLANNING

To avoid the groundwater penetrating into buildings, it may be relevant to raise the land at certain places. This can be done in connection with local planning on the basis of specific assessment in each case, see also the section on "Higher level of water in the seas", where the recommended elevation of the terrain is described.

At other places further from the coast we do not expect changes to occur in the level of groundwater making regulation in local plans necessary. If it is assessed locally that the level of groundwater will fall and have adverse consequences for building foundations, this can be countered for example by infiltration of stormwater. Infiltration of stormwater can be carried out through local planning after a practical assessment of the local options.

BUILDING PERMITS

The building regulations require buildings to be constructed so that moisture is not drawn up from underground. In new construction, the building can be protected by choice of materials and execution against penetrating water and upward force of groundwater. Existing building can be adapted to a changed groundwater level, which may otherwise result in building damage and health problems.

OTHER REGULATION

The Water Supply Act stipulates that pumping for the purpose of lowering groundwater requires a permit. Permanent pumping-up of water to keep buildings stable and dry may be regarded as a last resort, but in some cases may be necessary to protect valuable buildings

FLOODS FROM THE SEA

Floods form the sea and from watercourses and lakes that burst their banks due to rain will become more common. This can be taken into account in new building development, while existing buildings must be protected in time.

MUNICIPAL PLANNING

In the municipal plan, areas particularly at risk can be exempted from building and be allocated to purposes that tolerate flooding (e.g. a number of areas alongside watercourses already laid out as parks). Construction can be made conditional on the land being adapted to the risk of flooding. The municipal plan can reserve areas for technical facilities. These include facilities that protect against flooding (dikes, locks etc.), so that it is ensured that there is space for these facilities when it becomes appropriate to establish them.

LOCAL PLANNING

To counteract damage due to storm surges, the municipality has an option in connection with local planning to ensure that new building work is done on higher ground. In addition, the municipality can regulate with the local planning where the building development is to be located and exempt areas particularly at risk from building development, see also the section “Higher water level in the seas”, where a description is given of the recommended elevation of terrain.

BUILDING PERMITS

The requirements in the building regulations on the protection of buildings against precipitation and penetrating moisture is sufficient security against minor floods, but not in the event of large floods and storm surges. Large volumes of water will lead to moisture damage and possible pressure effects which the buildings cannot be claimed to be designed to withstand.

OTHER REGULATION

In the law on the assessment and control of the risk of flooding from watercourses and lakes, rules are set forth for overall state designation of areas at risk. This designation will take place during the course of 2011. Municipalities containing areas at risk must draw up risk control plans by 2015. Afterwards this planning will also govern the content of the municipal plan concerning floods from watercourses and lakes.

The law on storm surges regulates the possibility of compensation in the event of storm surges and flooding from watercourses and lakes. Compensation is possible in the case of events that statistically occur more rarely than every 20 years, and is paid to meet a number of losses not covered by normal insurance. The law is therefore crucial to the choice of level of insurance against floods, as more frequently occurring events do not trigger payment to the landowner, and part of the aim is to provide incentives to prevent and limit damage.

PROTECTION OF THE COASTS

Higher sea level and severe storms can lead to erosion of the coast, a situation familiar in other parts of Denmark. Copenhagen is not, however, particularly at risk. There are no natural coasts there, as the municipality's coastline is created by filling-in, harbour construction, beach facilities etc., which do not require groynes, breakwaters and similar coastal protection facilities.

MUNICIPAL PLANNING

The Planning Act contains provisions to the effect that facilities on land that necessitate the construction of coastal protection are only permitted to be planned in very special cases. The coastal areas are generally planned in such a way that they are robust in relation to the effect of the sea or, like the artificial beaches, in a natural equilibrium.

LOCAL PLANNING

The design of the coast (quay facilities, collections of stones etc.) can be established in local plans in urban development along the waterfront, so that it is ensured that the coast is robust and can withstand higher water levels and more powerful waves.

BUILDING PERMITS

The stability of buildings must be satisfactory, but the Building Act does not contain particular provisions on threats from coastal erosion.

OTHER REGULATION

Actual coastal protection against erosion is only relevant to a limited extent in Copenhagen. Such facilities are covered by the Coastal Protection Act, which stipulates that landowners can apply for permits to undertake coastal protection or that the municipality if necessary can require coastal protection to be carried out. The Act also regulates the financing of the facilities. The principal rule here is that the landowners who benefit from a facility have to finance it, which also applies to public authorities.

RISING TEMPERATURES AND MORE HEATWAVES

Rising temperatures in the long term will lead to more heat waves, which affect people's well-being, and the need for cooling of buildings will become greater.

MUNICIPAL PLANNING

The municipal plan can be used to counteract warming of the city. This can be done by considering the need for cooling in the arrangement of developed areas and open spaces, for instance at areas of water and green spaces. Buildings with canals as in Sydhavnen, for example, are well protected against local warming. The requirement in the municipal plan for open spaces etc. ensures access to green courtyards, promenades at the waterfront and so on, where the temperatures will be lower. The designation of spaces for leisure purposes and nature protection ensures a high proportion of undeveloped spaces in the city, which counteracts warming. The municipal plan can reserve land for technical facilities for cooling, for instance pipes for district cooling.

LOCAL PLANNING

The local plans can set requirements for new construction to be designed with trees in the open spaces and with a location for actual construction that ensures shade and counteracts warming. This must, however, be weighed against the desire for good daylight indoors and sun on open spaces outdoors, as days of heat waves will be an exception in relation to cool periods. Local plans can also set aside spaces for facilities for cooling, for example with groundwater or seawater.

BUILDING PERMITS
The building regulations set requirements for satisfactory light conditions with the aim of getting daylight into buildings. At the same time, the regulations require good temperature conditions to be ensured in the orientation of the building, sun screening etc., including in the summer.

OTHER REGULATION
In the Municipal District Cooling Act, the municipality has been given the option to extend an environmentally friendly solution to the cooling of buildings, so that there is an alternative to local, electrically powered cooling.

Legislation on the working environment cannot be used directly to set requirements in relation to the situation with naturally occurring heat. The municipality's responsibility for particularly vulnerable groups (the sick, the elderly, children) in municipal institutions and for its employees may, however, lead to an obligation to protect buildings against long-term high levels of heat.

PROLONGED PERIODS OF DROUGHT

In the long term periods of drought, particularly in the summer months, may develop into a problem for the city's green spaces.

MUNICIPAL PLANNING
The City of Copenhagen can if necessary adopt provisions through the municipal plan on technical facilities, including facilities for the collection of rainwater for use in watering green spaces, cleaning road surfaces etc. Guidelines on the prevention of critically low water flow can also be established as part of the provisions on the use of watercourses and lakes.

LOCAL PLANNING
It will be possible for the load on the drinking water supply to be reduced as a result of the use of rainwater for flushing toilets and washing clothes being required in local plans. The collection of rainwater that can be used to water open spaces, green roofs etc. in dry periods cannot be regulated in local planning. The City of Copenhagen alone will be able to recommend collecting rainwater, for example in construction where the law does not provide for the possibility of using rainwater for flushing toilets and washing clothes.

PLANNING PERMISSIONS
Drought generally does not constitute a threat to buildings. The construction law holds sufficient legal requirement to ensure that the level of fire safety will also be satisfactory in long periods of heat and drought.

OTHER REGULATION
Prolonged periods of drought can pose a threat to some of the city's listed green spaces. Under the terms of the Nature Protection Act it can be ensured in care plans that these spaces can collect rainwater and convey it to wetlands and plants in the event of drought. The combination of drought and heat waves can increase the risk of fire. In this connection, the municipality can prohibit the use of open fires in parks and similar places.

STRONGER WINDS

Stronger winds and more actual storms are expected as part of climate change, but Copenhagen is one of the parts of the country where the wind rarely poses a serious problem.

MUNICIPAL PLANNING

The municipal plan cannot regulate the prevention of problems as a result of strong winds.

LOCAL PLANNING

Account can be taken of the effect of wind in preparing development plans, so that outdoor open spaces are ensured shelter from the wind.

BUILDING PERMITS

The building regulations require buildings to be dimensioned so that they can withstand effects that normally occur from wind. The guidelines on what is understood as normal can be adapted to stronger wind in the future, so that the buildings continue to be protected against damage. Buildings are also to be constructed so that wind does not lead to unnecessarily great heat loss.