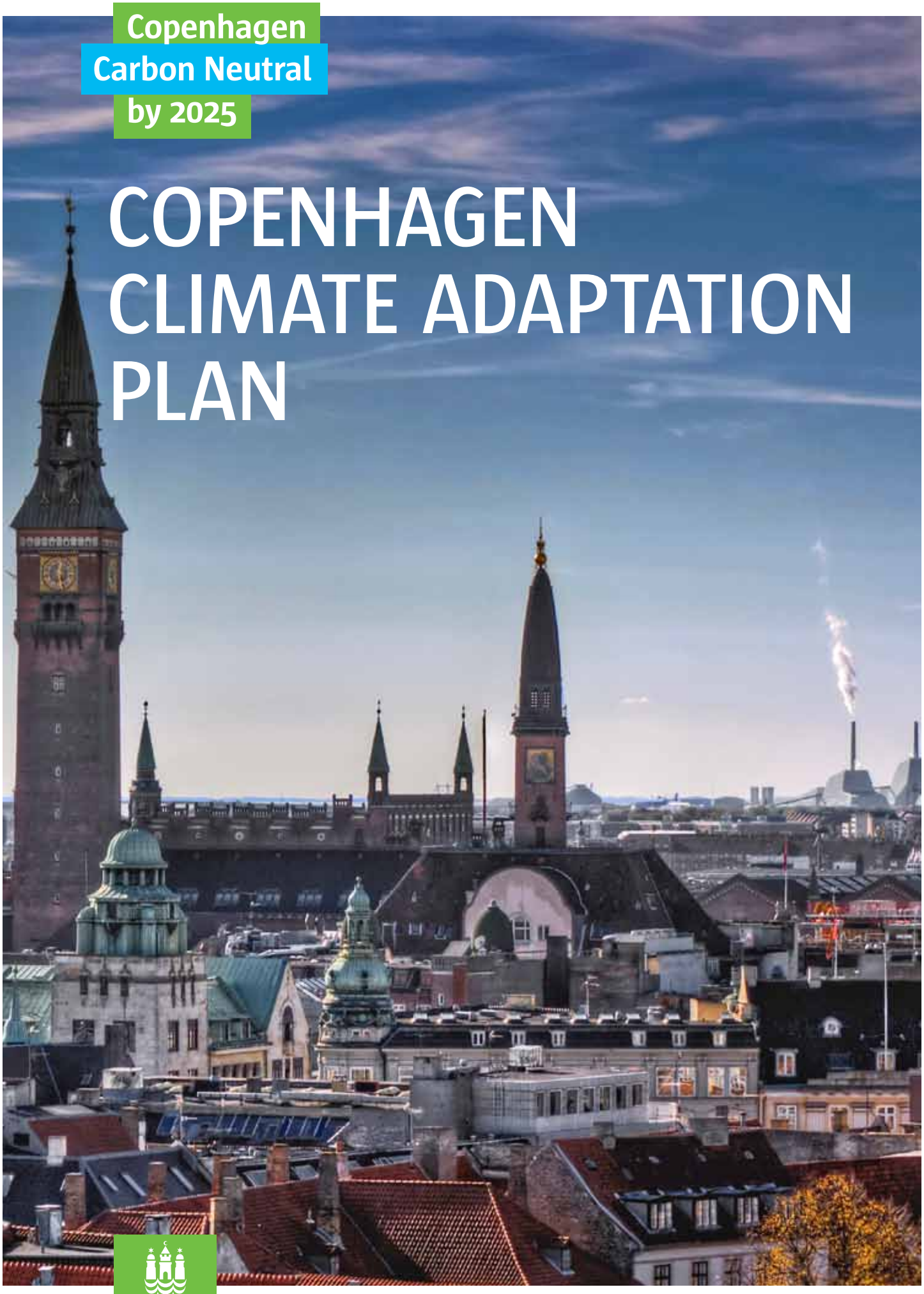
Copenhagen
Carbon Neutral
by 2025

COPENHAGEN CLIMATE ADAPTATION PLAN



MILJØ
METROPOLEN

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INTRODUCTION
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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 CO_2 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.

CO2 CONCENTRATION IN THE ATMOSPHERE (MEASURED AT MAUNA LOA OBS.)

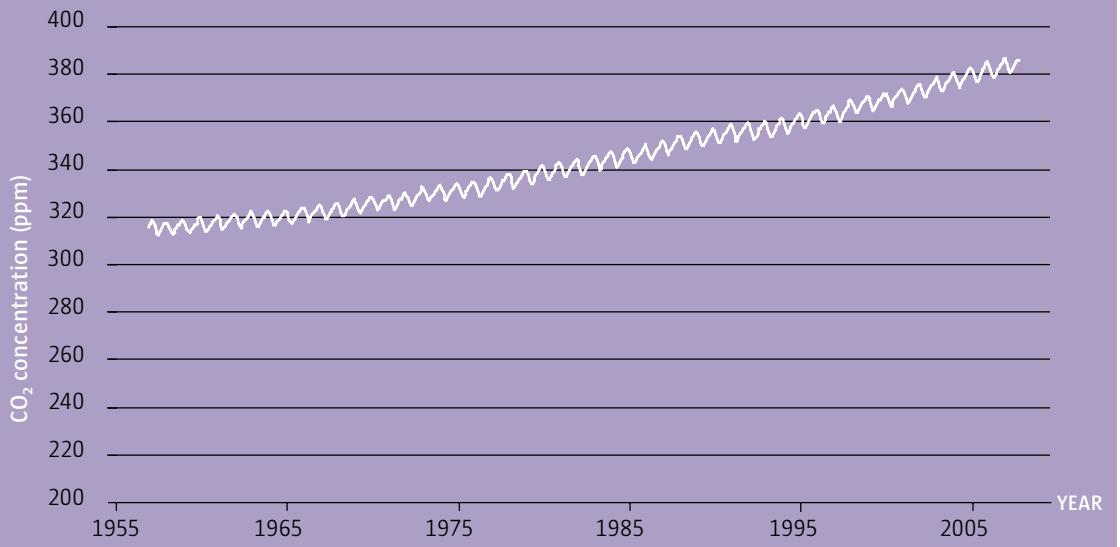


Figure 1: Change in the CO_2 concentration of the atmosphere
Source: Earth System Research Laboratory (ESRL), National Oceanic and Atmospheric Administration (NOAA).

GLOBAL ANNUAL MEAN TEMPERATURE FROM 1850 TO 2008

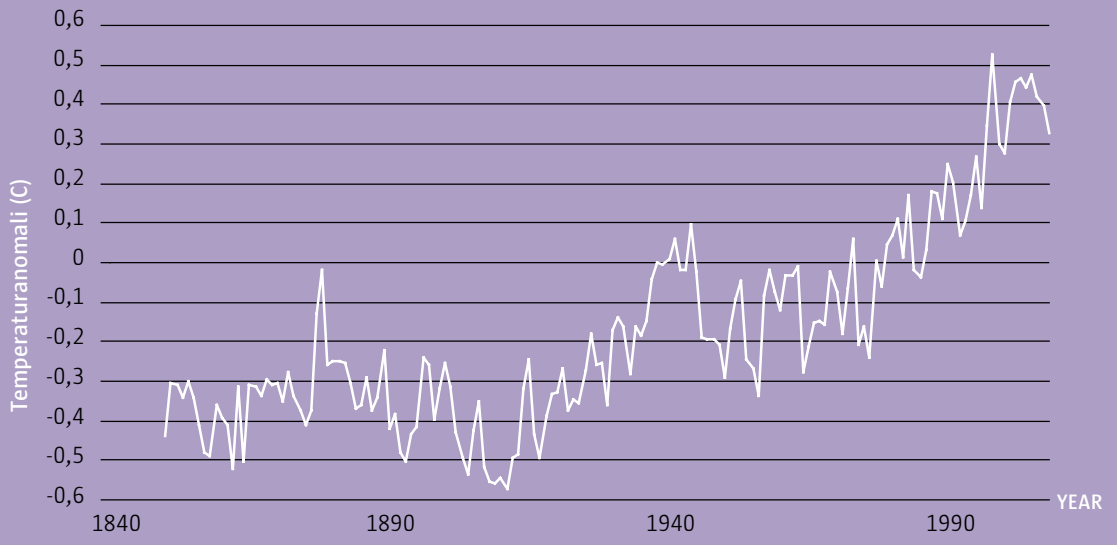


Figure 2: Change in global annual mean temperature
Source: Climatic Research Unit, University of East Anglia

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. An example is integrated development of green spaces to reduce heating, manage stormwater and at the same time increase recreational facilities.

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

Climate adaptation is closely linked to the long-term planning of urban development, the area of nature and the environment, wastewater, groundwater etc. 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.

AN ATTRACTIVE, CLIMATE-ADAPTED CITY

In Copenhagen we will focus on climate adaptation measures also representing an asset in themselves, regardless of the extent of the expected climate change. In this connection we will work in particular on the use of blue and green elements in the urban space, which will make Copenhagen an even more attractive city.

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. The need for a climate-adapted city makes further demands on the development of strategies and methods for climate adaptation. Climate adaptation must therefore be part of the green growth strategy for Copenhagen by attracting both national and international projects and investors for the development and production of systems for climate adaptation. The municipality will ensure that part of the investment in climate adaptation is recouped in the form of growth.

COOPERATION NATIONALLY AND INTERNATIONALLY

Knowledge of the effects of climate change and possible measures that can remediate the effects is constantly being developed both nationally and internationally. It is therefore important that there is a focus on knowledge sharing in connection with work on climate adaptation. We will actively take part in knowledge sharing, at both national and international levels. This knowledge sharing also applies to the local cooperation with the public, users of green and blue spaces, municipalities and the Region, where coordination and knowledge of planning in the neighbouring areas is crucially important to successful climate adaptation.

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

Climate change will to some extent affect all people and businesses in the city. It is therefore important that we provide clear information on how climate change will affect the city and how the challenges are being tackled so that Copenhagen will continue to be a secure city to live in.

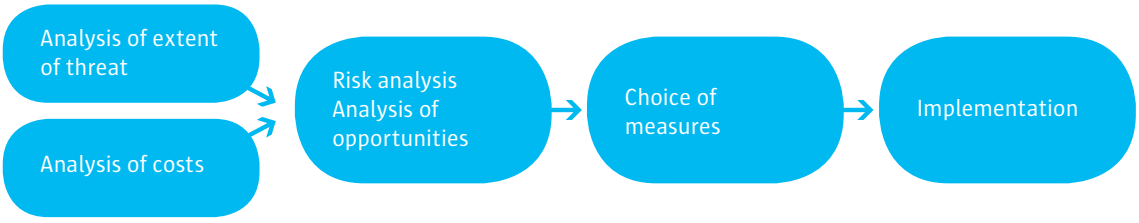
SCRIPT FOR CLIMATE ADAPTATION

The initial work on climate adaptation was done with the drafting of the City of Copenhagen Climate Plan in 2009, where the principal challenges were identified and five initiatives were identified as essential to continued work on climate-adapting Copenhagen:

1. Development of methods to discharge during heavy downpours
2. Establishment of green solutions to reduce the risk of flooding
3. Increased use of passive cooling of buildings
4. Protection against flooding from the sea
5. Preparation of a combined climate adaptation strategy

Initiative 5 has been implemented with the implementation of this plan. The other initiatives are an integral part of the combined plan.

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.

STRATEGY

STRATEGY FOR CLIMATE ADAPTATION IN THE CITY OF COPENHAGEN

The City of Copenhagen has been working on adaptation to climate change for many years, for example through the municipality's wastewater plans. These adaptations have been based on development in the climate that has already occurred. The accelerating trend in climate change has, however, made it possible to draw up a strategy based on projections for the climate of the future.

The IPCC works continuously on describing the most likely scenarios for development in the global climate based on best available knowledge. The IPCC's projections for the development of the climate are relatively certain for the next 30 to 40 years, but after this period there is great uncertainty on how the climate will develop. It is therefore pointless to plan in the very long term according to a particular scenario for future development in the climate. The planning has to reflect the uncertainties of the projections.

However, all the projects show the same trends. We can therefore mark out the direction of the necessary measures we must implement with a high degree of certainty. The principal challenge will be to implement the measures at the right time and in the correct sequence. We will ensure this by preparing a flexible strategy that meets uncertainties by incorporating new knowledge and technology as and when they emerge.

PURPOSE OF THE STRATEGY

The purpose of a strategy for climate adaptation in Copenhagen is to ensure:

- due care, at the right time
- that wrong investments are not made
- that investments are recouped as an element in the development of green growth
- greatest possible synergy with other planning
- flexibility in relation to changes in the projections for the climate of the future
- that climate adaptation measures at the same represent quality in themselves for the city's people and businesses
- that the adaptation takes place on the basis of analyses at a high technical level
- that overall control of the climate adaptation of the city takes place

PROCESS

The action plan for the municipality's climate adaptation must be regularly revised. It must be so in order to incorporate the large volume of new knowledge generated in the area of climate, and to clarify the effort made by the municipality in relation to the city's population and the world at large. The rate of updates to the action plan must be regularly adapted to the pace of change in climate projections and technical development in the area. It is judged in principle that the action plan should initially be updated every four years.

THE CLIMATE ADAPTATION PLAN

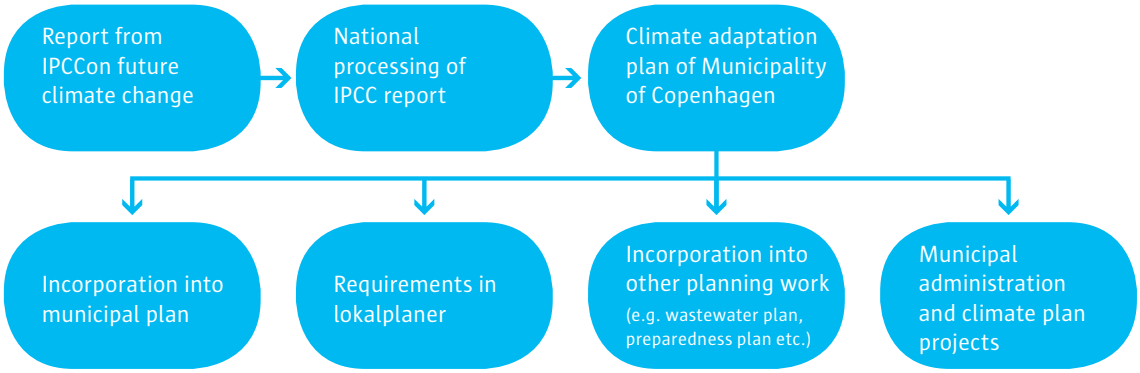


Figure 1: Process of climate adaptation in City of Copenhagen

The results of climate adaptation planning are to be continuously incorporated into all forms of other planning, including municipal plan, local plans, emergency preparedness plans and a number of the sector plans. These plans are each separately to contain sections showing that climate adaptation concerns have been considered in the planning, from the overall concern in the municipal plan to the more specific projects in the sector plans.

STRATEGY

It is not possible—either technically or economically—to protect Copenhagen completely against climate-induced accidents. However, a whole series of measures can be taken that either prevent the accident, reduce its scale or reduce vulnerability to it. The trick is choosing the right ones.

There is very wide diversity in the assets that will be lost—for example in a flood—from unique cultural buildings to warehouses. This diversity should be taken into account in prioritising the effort, so that the greatest public assets are given high priority. Potential personal injuries are not included in the loss, as these are very difficult to value. Public assets are protected by utilising a risk-based prioritisation of the effort. Risk in this context is understood as meaning the probability of an event happening times the costs of the event.

COST / PROBABILITY	Low	Medium	High
Likely	Risk can be tolerated	Risk can be tolerated	Moderate risk
Likely	Risk can be tolerated	Moderate risk	Risk cannot be tolerated
Very likely	Moderate risk	Risk cannot be tolerated	Risk cannot be tolerated

To allow the calculation or risk to be used to prioritise action, it has to be normalised, so that different threats can be compared. This is done by calculating the combined public risk on a ten-year basis over a hundred-year period. This is compared with a simple assessment criteria divided into levels, as shown in the table below.

Ten-year risk in DDK million	0 - 500	501 - 1500	> 1500
Assessment criterion	Low risk	Medium risk	High risk

THE THREE LEVELS OF ADAPTATION

If the risk assessment shows that the risk is so high that it cannot be tolerated, the strategy of the City of Copenhagen is to choose actions that first of all prevent an climate-induced accident from happening. If this cannot be done—for either technical or economic reasons—actions that reduce the scale of the accident will be preferred. The lowest priority goes to measures that are only capable of making it easier and/or cheaper to clear up after the accident.

LEVEL 1

The aim is to reduce the likelihood of the event happening, preferably to completely prevent it. At this level is the establishment of dikes, building higher above sea level, local adaptation of sewer capacity, local management of stormwater etc. If measures can be implemented effectively at this level, measures at levels 2 and 3 will not be taken.

LEVEL 2

The aim is to reduce the scale of the event. At this level are warning systems for rain, the establishment of watertight basements, sandbags, adaptation of public spaces so that they can store rainwater etc. If measures at this level can be taken effectively, measures at level 3 will not be applied.

LEVEL 3

The aim is to reduce vulnerability to the event by taking measures that make it easier and cheaper to clear up after an event. At this level are extensive utilisation of basements, emergency preparedness with pumps etc.

DIFFERENT GEOGRAPHICAL LEVELS

The three levels of adaptation entail widely differing solution models, depending on how large a geographical area the action has to cover. Based on the above, a diagram can be drawn up on which the various measures that are applicable can be seen, both in relation to action level and the geographical levels that extend from regional level to local building level.

	Level 1	Level 2	Level 3
Geography/Measure	Reduce likelihood	Reduce scale	Reduce vulnerability
Region	Delay of quantities of rain in catchment, pumping of water to sea	Delaying of volumes of rain in catchment, pumping of water to sea	
Municipality	Dikes, raised building elevations, increased sewer capacity, pumping of water to sea	Emergency preparedness Warning Securing of infrastructure	Information, moving of vulnerable functions to safe places
District	Dikes, "plan B", raised building elevation/ threshold	"Plan B" securing of infrastructure	Moving of vulnerable functions to safe places
Street	Control of stormwater runoff, raised building elevation/threshold, local management of stormwater	Control of stormwater runoff, raised building elevation/threshold, sandbag	Moving of vulnerable functions to safe places
Building	Backwater valve, raised building elevation/ threshold	Sandbags	Moving of vulnerable functions to safe places

FLEXIBLE SOLUTIONS

When a method is to be chosen for adaptation, it is important to ensure that the choice of method does not preclude further measures that might become necessary later on. Flexibility is necessary to be able to carry out continuous adaptation.

SECONDARY GAINS AND SYNERGY

A key element in the climate adaptation strategy of the City of Copenhagen is that in our choice of solutions we will emphasise that the solutions must also help to improve quality of life for the people of Copenhagen here and now, at the same time as being effective and economically justifiable.

When methods are chosen for adaptation, we therefore emphasise the greatest possible number of secondary gains and the greatest possible synergy with other planning being achieved. Examples of desired secondary gains are:

- More recreational opportunities
- New jobs
- Improved local environment with more green elements

The risk analysis in all cases therefore has to be supplemented by a feasibility analysis, where the emphasis has to be on highlighting which solutions create the greatest possible gain for the people of Copenhagen.

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. With good planning, it is possible carry out activities that can direct some of the floods to places where they cause least damage, for example parks, sports grounds and open spaces. This can be done with

permanent devices such as bumps, embankments, ditches and raised/lowered kerbs or as emergency preparedness, where a calculation is made beforehand of where sandbags or similar items should be located to limit damage.

To enable the consequences of the changed pattern of rainfall to be assessed it is examined—using advanced hydraulic models—where in the city the stormwater will flow on the surface and where the water will accumulate. The description of the models can be found on sections on the assumptions underlying the calculations.

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. Basins in the system will therefore have to be expanded, so that they retain the wastewater until there is space in the pipes, so that the wastewater can be conveyed to the treatment plant for treatment. Basin capacity is already established—for a number of overflow structures—or is planned to be established over the next few years with a view to improving water quality in watercourses and lakes and the possibility of bathing in the harbour.

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. When the heavy downpours become more frequent in the future, it will be necessary to expand the sewers or reduce the volume of wastewater conveyed to the sewers. This needs to be done to continue to meet the sewer utility's service objective of sewage flowing on the surface no more than once every ten years. Standards have been drawn up in Denmark for dimensioning sewers for the weather of the future by the Water Pollution Committee under the Society of Danish Engineers (IDA)*

The new standard for dimensional design is used in establishing new sewer systems in the City of Copenhagen.

(*) 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 constant flow 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.

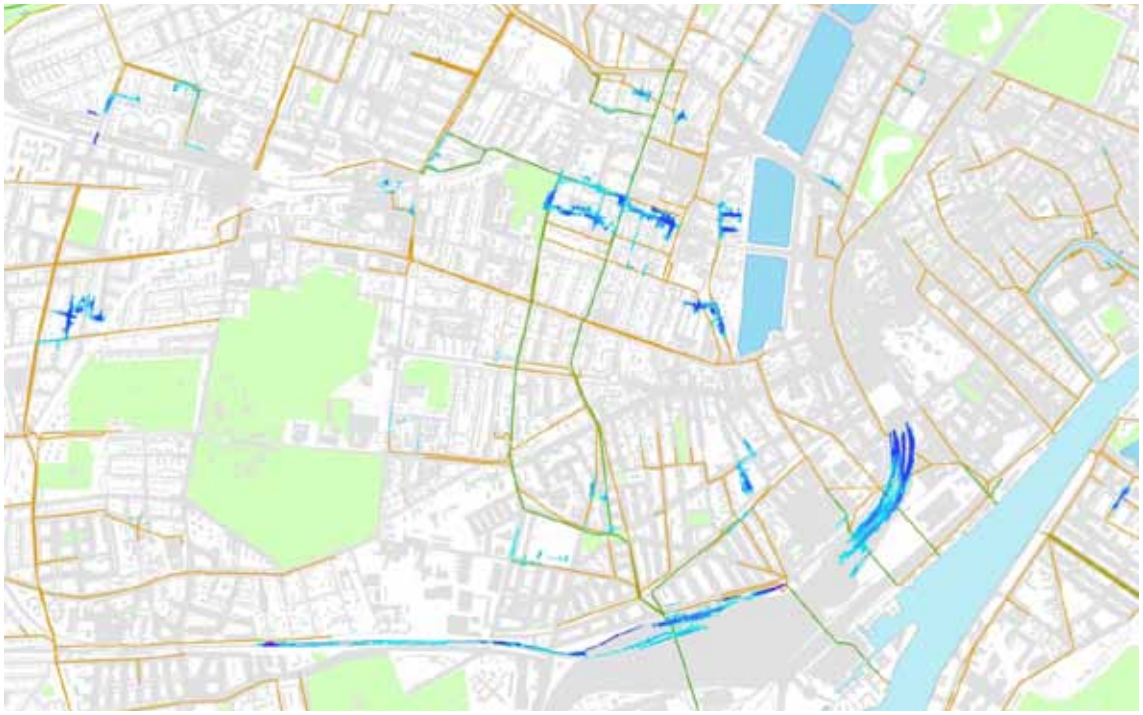


Figure 1. Floods in 10-year rain in 2010.

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
- Kildevældsgade

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.

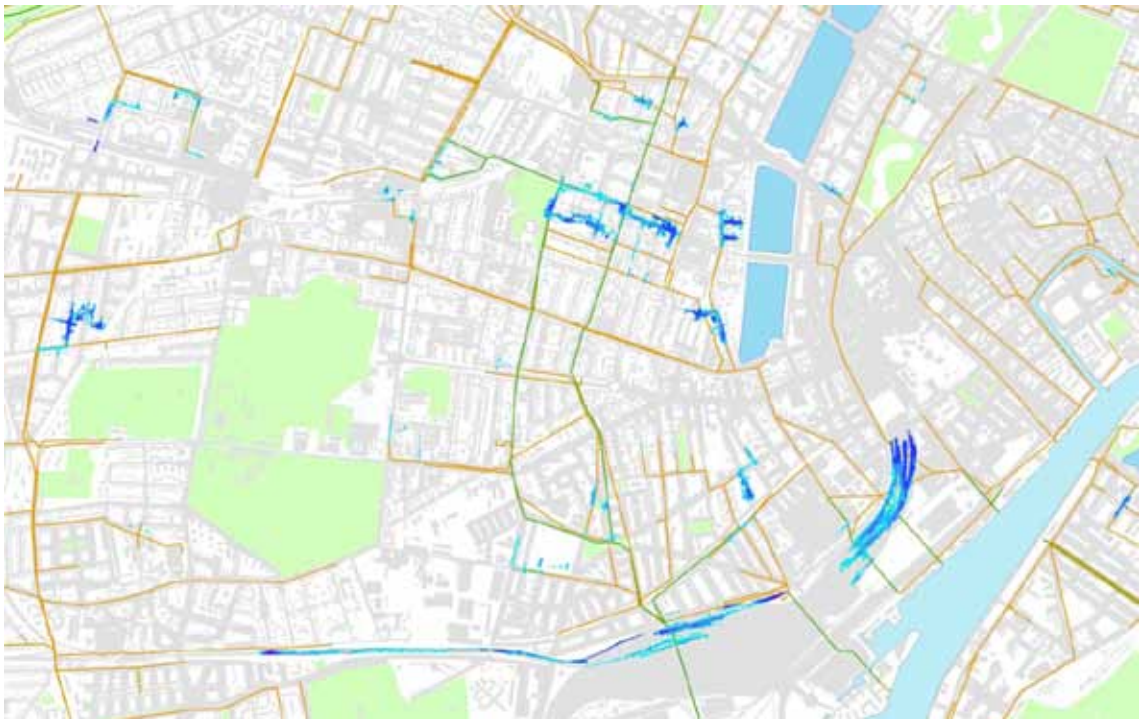


Figure 5. Floods in a 100-year rain event in 2110 with climate adaptation measures.

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

As can be seen from the table, there are very great costs in connection with extreme rain events. It is therefore economically attractive to plan interventions that reduce the risk of floods.

Economic calculations of the following scenarios have been performed for climate adaptation as a background to the assessment of the individual measures:

1. **Retained level of service for sewer**
   - Measures are taken on the sewer system so that the currently intended level of service can be maintained until 2110

   >> Costs of damage are compared with the baseline situation today.
2. **Retained level of service for sewer plus backwater valves**
   - Measures are taken on the sewer system, so that the currently intended level of service can be maintained until 2110, and
   - Backwater valves are installed in all basements

   >> Costs of damage are compared with the baseline situation today.
3. **Retained level of service for sewer plus backwater valves plus service adaptation**
   - Measures are taken on the sewer system, so that the currently intended level of service can be maintained until 2110, and
   - Backwater valves are installed in all basements
   - Surface adaptations are made (redirecting of water)

   >> Costs of damage are compared with the baseline situation today.
4. **Only backwater valves plus surface adaptation**
   - No measures are taken on the sewer system, so that the currently intended level of service can be maintained until 2110 and
   - Backwater valves are installed in all basements

   >> Costs of damage are compared with the baseline situation today.
5. **Sustainable Urban Drainage System (SUDS) plus backwater valves plus surface adaptation**
   - Inflow to the sewers is reduced by 30% with separation and SUDS solutions
   - Backwater valves are installed in all basements
   - Surface adaptations are made (redirecting of water)

   >> Costs of damage are compared with the baseline situation today.

THE RESULTS ARE SHOWN IN THE TABLE BELOW:

(Amount in million DDK)	Scenario 1 sewer	Scenario 2 sewer backwater valves	Scenario 3 sewer backwater valves surfaces	Scenario 4 backwater valves surfaces	Scenario 5 SUDS backwater valves surfaces
Costs of damage in baseline	15,552	15,552	15,552	15,552	15,552
Costs of damage after measures	5,458	2,471	1,785	4,316	1,785
Saving	10,094	13,081	13,767	11,236	13,767
Measures	10,372	11,108	13,374	3,001	6,268
Net saving	-278	1,973	394	8,235	7,499

The calculations show that unilateral climate adaptation in expansion of the sewers produces a negative societal gain. This means that the city and its population do not achievea reduction in damage that corresponds to the high investment. See Scenario 1.

Both regulating inflow to the sewers and expanding the sewers and merely "curing" the symptoms can be omitted entirely. This produces a high gain, because the costs are low (see Scenario 4). On the other hand, this has the drawback that the population will find that the sewers attain a declining level of service and there is an unacceptable increase in discharge via combined sewer overflows during rain.

Finally, in Scenario 5 inflow to the sewers can be regulated with the previously discussed SUDS solutions. In this way the inflow to the sewers and therefore the need for expansion are increased, while the level of service is not reduced.

The conclusion is that Scenario 5 in societal terms offers the best combination of intervention, where the level of service is reduced to the greatest extent, while the costs are held down, and a large surplus is created for society.

ASSESSMENT OF RESULTS

RISK ASSESSMENT

The strategy of the climate adaptation plan—see separate section—provides the following results when used on the results for stormwater.

The combined risk of floods from rain is shown in Figure 6.

RISK OF FLOODING FROM STORMWATER AND SEA-WATER

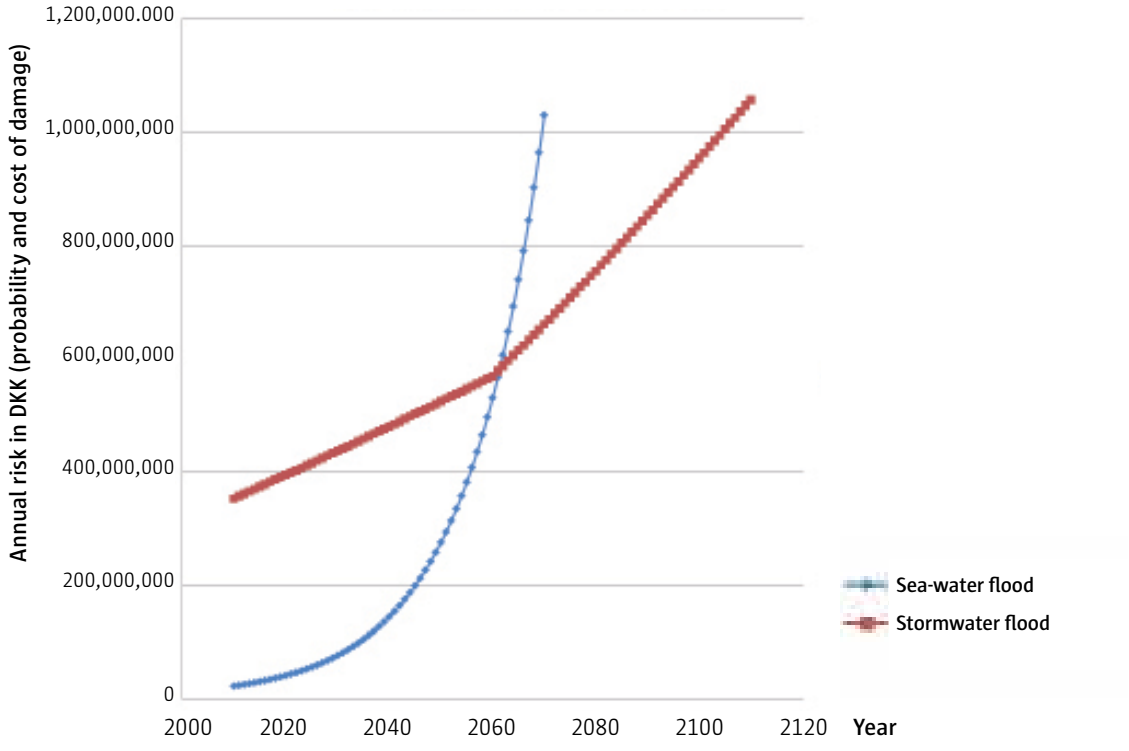


Figure 6.Risk of flooding from rain and seawater

It can be seen in the analysis of the combined risk of flooding that the stormwater is the dominant factor for the next 50 years from today. The risk of economic costs of damage is already DKK 350 million a year in 2010. In 2060 the risk has grown to DKK 570 million a year, and in 2110 the risk is DKK 1,050 million a year. We judge the risk today already to be so great that it is unacceptable. Under the strategy of the climate adaptation plan, the choice of instruments is to be made based on a prioritisation of the effect these instruments have. Instruments that limit the probability of the damage occurring are given top priority. Then come instruments that reduce the scale of the damage, and last come instruments that reduce vulnerability to the damage. In view of this situation, it makes good sense to initiate measures that can limit floods from rain today.

Based on data from Figure 6, a risk index can be added together for ten-year periods over the next 100 years. The index can be compared with a corresponding index for rise in sea level.

Period	Risk index	Combined assessment
2010-2019	3,725	High risk
2020-2029	4,144	High risk
2030-2039	4,573	High risk
2040-2049	5,010	High risk
2050-2059	5,454	High risk
2060-2069	6,104	High risk
2070-2079	7,030	High risk
2080-2089	7,993	High risk
2090-2099	8,987	High risk
2100-2109	10,005	High risk

As can be seen above, the risk of flooding from stormwater is already judged to be unacceptably high today. On that basis is recommended that a number of projects that are aimed at reducing the risk of flooding should be quickly implemented.

The risk of damage depends on the assets in the areas affected by flooding and can be assessed on the basis of land use. To assess the risk in the areas that may be subject to flooding, a calculation has been made of vulnerability based on the costs associated with damage in the event of extreme rain. On this basis a map has been produced showing the risk in DKK totalled over 100 years within areas of 1 hectare in the whole City of Copenhagen. This map will be included in the prioritisation of the effort in Plan B solutions

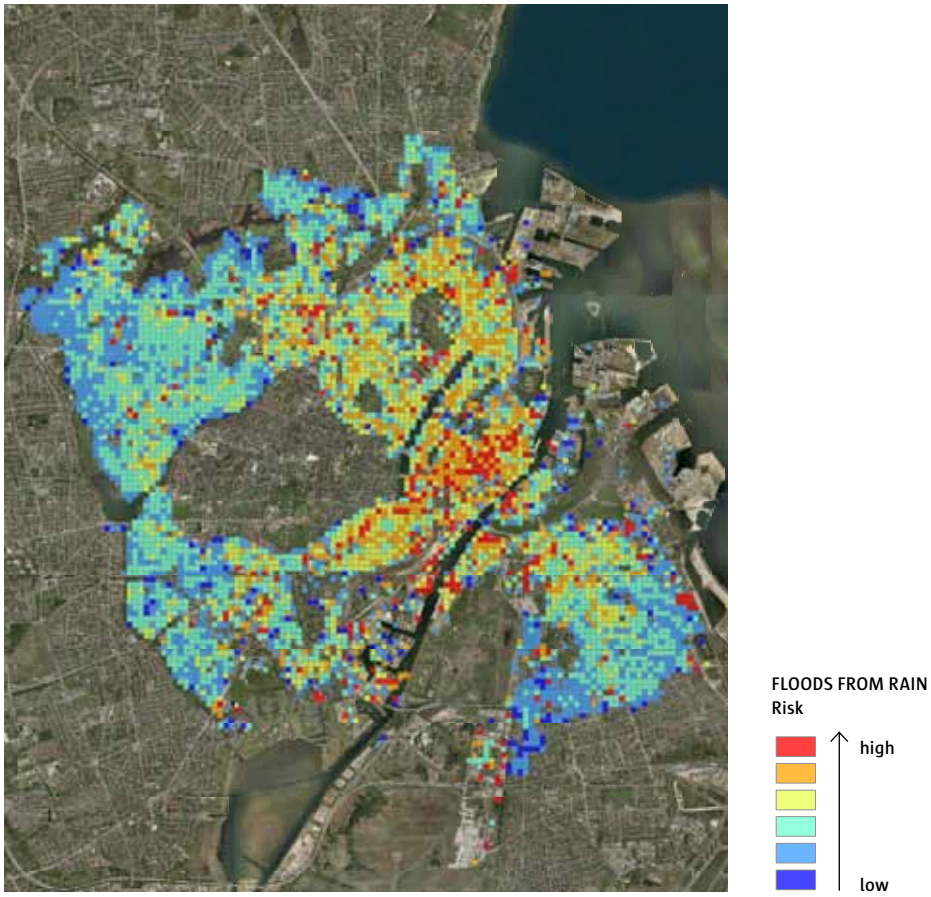


Figure 7. Risk of floods in the event of extreme rain

MEASURES

The calculations show that there are problems with watercourses bursting their banks during extreme rain events. Floods like these are due to very large quantities of rain being conveyed to the watercourses in the catchment area. This is typically stormwater that collects from roofs and roads and is conveyed to the watercourse without substantial delay. The result is that the watercourse bursts its banks, perhaps not at the point of discharge but further down the watercourse, where further quantities of stormwater are received. With a future rise in mean sea level of up to 1 metre in 2110, the ability of watercourses to discharge the water will be greatly reduced.

The solution to this problem has to be found in cooperation with the other municipalities in the catchment area, as the discharges occur here and in the City of Copenhagen, while the flooding only takes place in the City of Copenhagen.

When the quantity of stormwater exceeds the capacity of the sewer, water will flow on the surface. The water will seek low points. To protect public assets, work can be undertaken on two parallel tracks to reduce the scale.

1. Disconnection of stormwater from the sewer by separation or SUDS
2. Methods to convey surplus stormwater to where it causes no or little damage, “Plan B”.

DISCONNECTION OF STORMWATER FROM THE SEWER BY SEPARATION OR SUDS

SUDS consists of a number of different elements, all of which serve the purpose of managing stormwater locally. These may be elements that delay/store the water, that treat the water either before discharge to bodies of surface water or percolation of the stormwater. The elements are often "green" and low-technology and will therefore be able to contribute to a greener city, for example in the form of rain gardens, green ditches, lakes and canals. If the rainwater is disconnected from the sewer, the load will fall accordingly. As stormwater during heavy rain makes up most of the water in the sewer, disconnection can have a great effect. The wastewater is roughly distributed one-third household wastewater (black wastewater), one-third stormwater from roads and one-third stormwater from roofs and hardened surfaces in general.

METHODS FOR CONVEYING STORMWATER TO WHERE IT CAUSES LITTLE OR NO DAMAGE, "PLAN B"

Plan B is a term used for various methods used to direct stormwater on the surface. The aim of the methods is to convey the stormwater to where it causes least—or no—damage. This may, for example, involve kerbs, gutters and so on. If Plan B is to be seriously relevant, it is important that no mixing of stormwater and wastewater takes place, as this can cause hygiene problems. This is best and most cheaply ensured by separating the water before it is directed to where it does not cause damage. This may involve combining low technology with various technical solutions, such as when a road has to be crossed, or if there are substantial depressions in the roads.

Areas have to be designated for Plan B taking account of the many different interests there are in the city.

As mentioned previously, protecting basements is not part of the service objective of the City of Copenhagen. The Municipality will not therefore carry out measures to protect buildings against water in basements. This is a form of protection that has to be provided through private initiative.

If problems with flooding in basements have been noted, it may be advantageous to install a backwater valve. A backwater valve is cheap to buy and produces great savings. An information campaign on backwater valves targeted at the public and businesses is recommended.

Copenhagen Energy must ensure that places where the sewer does not meet the service objective are remediated. The detailed studies will take place in connection with the preparation of a new wastewater plan.

It will be most appropriate for Plan B to be implemented in the utility company, as this is where expertise on dimensional design, establishment and future operation etc. exists. However, Plan B is not contained in the service objectives the Municipality has set for the supply company. The implementation of Plan B therefore cannot be directly financed through tariff funds. Consideration can therefore be given to revising the service objectives at the time of the next wastewater treatment plan.

	Level 1	Level 2	Level 3
Measure Geography	Reduce probability	Mindske omfanget	Reduce vulnerability
Region	Establishment of retarding basins on separate rain runoffs in catchment area of Harrestrup Å and Søborghusrenden	Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets	Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets
Municipality	Disconnection of stormwater using SUDS Establishments of pumps on runoffs	Disconnection of stormwater using SUDS Planning	Planning
District	Decoupling of rainwater using SUDS [Sustainable Urban Drain System]. Plan B-solutions on central squares/sport facilities/parks	Decoupling of rainwater using SUDS. Emergency Management, sandbags etc.	Moving electrical cabinets for light regulation, pumping stations etc. from low-lying points
Street	Plan B solutions separation of stormwater from sewer	Disconnection of stormwater using SUDS Preparedness, sandbags etc.	Moving electrical cabinets for light regulation, pumping stations etc. from low-lying points
Building	Disconnection of stormwater from sewer	Backwater valves, sealed basements, Preparedness, sandbags etc.	Move vulnerable functions away from basement level (service rooms, electrical panels etc.)

PLANNING MEASURES

- New sewer systems already have to be dimensionally designed today so that they cope with the new volumes of rain and consequently meet the service objective. The dimensional design base has to be incorporated into all relevant municipal plans.
- Separation of common sewer in SUDS solutions is to be promoted and implemented.

PROJECTS AND RECOMMENDATIONS

THE CLIMATE ADAPTATION PLAN PROPOSES IMPLEMENTATION OF THE FOLLOWING PROJECTS:

No	Project	Aim of the project
1	Reduction in the hydraulic load on watercourses	Restriction of the hydraulic load from separate rain runoffs
2	Passing on knowledge to the public and businesses on options for climate-proofing	Information to the public/businesses on private measures for climate-proofing
3	Planning and implementation of Plan B measures in City of Copenhagen	Control of water on surfaces/ roads during extreme rain events
4	Opening of watercourses in pipes	Bringing about greater hydraulic capacity in watercourses
5	Disconnection of stormwater from sewer	Restriction of volume of water in sewer
6	Quantification of the effect of different SUDS measures	Improvement of the planning base for the wastewater treatment plan
7	Coordinated wastewater planning in the whole catchment area of the Lynettefællesskabet sewage treatment plant	Ensuring of optimum transport, storage and treatment of wastewater in the catchment area

The climate adaptation plan recommends the following

No	Recommendation
1	Separation of wastewater using SUDS is incorporated into the wastewater plan. Specific work should be done to look at where wastewater can be disconnected from the sewer
2	Establishment of pumps in runoffs as consequence of rises in sea level is incorporated into the wastewater plan
3	Plan B is incorporated into future urban planning
4	Integrate SUDS into future urban planning
5	A climate-adapted dimensional design base for new sewers is incorporated into municipal plans
6	Work is done on the introduction of differential billing for stormwater and wastewater at the Lynettefællesskabet sewage treatment plant as an incentive for disconnecting stormwater in the catchment municipalities

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.

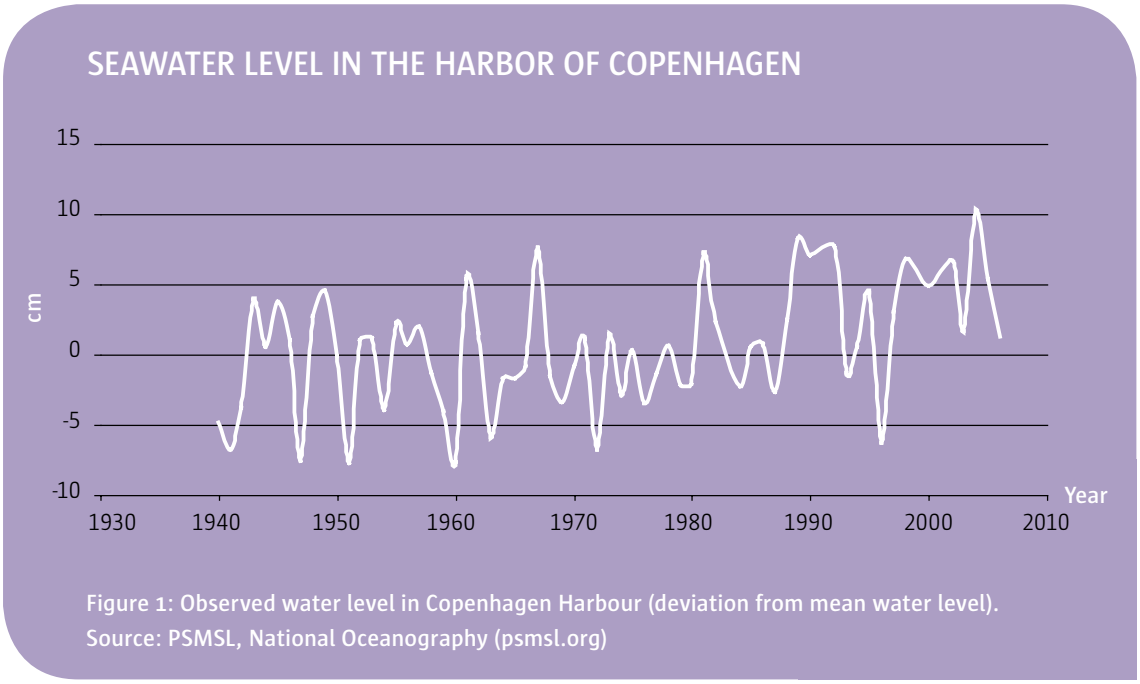


Figure 1: Observed water level in Copenhagen Harbour (deviation from mean water level).
Source: PSMSL, National Oceanography (psmsl.org)

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

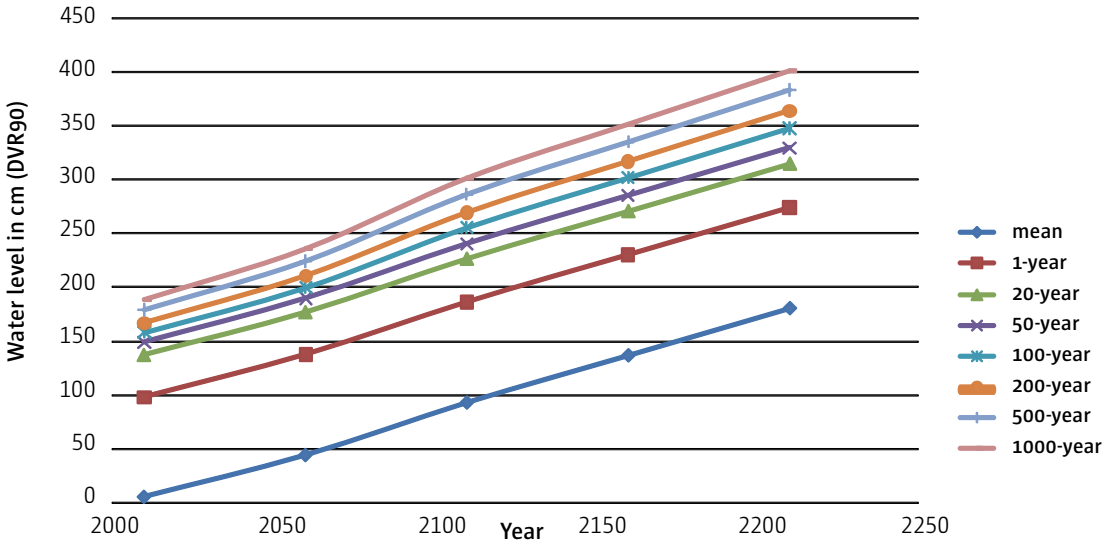


Figure 2: Trend in mean water level and resultant high waters over the next 100 years. Water level is stated in DVR90 in relation to present-day land points.

Protection against high waters has a long time perspective, while it can also entail heavy costs. Careful consideration is therefore needs to be given to what resources are to be used to guard against high waters. The scenarios for future water levels and storm surges presented here are therefore examples to be used in assessing what time perspective we work with when need to establish protection against high waters and the floods that future storm surges may bring with them.

ASSESSMENT OF NEED FOR DEFENCE MEASURES

The assessment of the need for protection against floods is based on the following factors:

- How great is the risk of flooding?
- Can implementation of the proposed solution happen quickly enough in relation to the anticipated climate change?
- Is the technology it is proposed should be used sufficiently documented?
- Is the proposal sustainable economically and environmentally?
- How can the proposal be incorporated into other plans (municipal plan, local plans, wastewater plan, water plan etc.)
- What elements can the proposal contribute in relation to urban life and recreational areas?

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

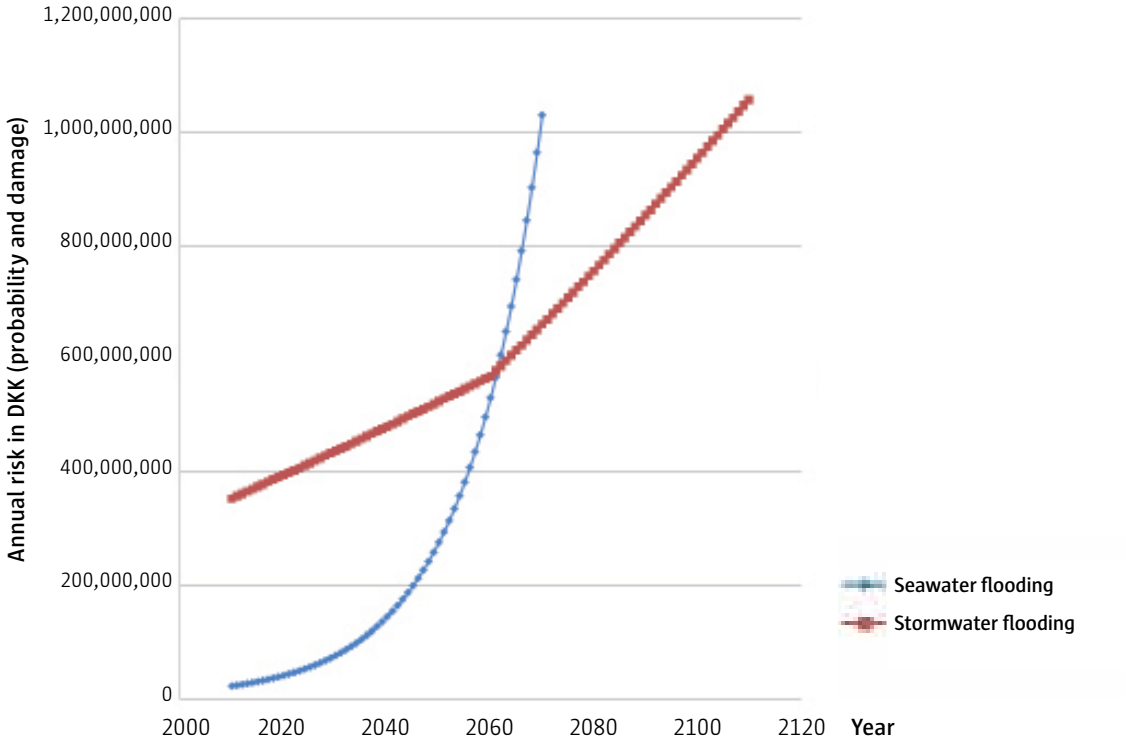


Figure 3: A risk area has been calculated for flooding from the sea. The index is calculated as the probability of an event times damage caused in the event. Table 3 shows the risk area as the number of million Danish kroner of damage that will occur in 10-year intervals.

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.

The risk of damage depends on the assets in the areas affected by flooding and can be assessed on the basis of land use. To assess the risk in those areas that may be subject to flooding, a calculation has been made of vulnerability based on the costs associated with damage at high waters.

It is judged on this basis that there is a need to draw up proposals for solutions to protect the city against flooding from the sea in the long term. It is important to be aware in this connection that coming up with the optimum solutions will be a protracted process, and that it will cheapest by far to establish the protection over a longer period, where sections can be protected in connection with other construction projects. The economic circumstances concerning the establishment of measures with long timeframes will be described more closely in the section on financing.

DAMAGE IN FLOODS CAUSED BY STORM SURGES

To assess possible costs in storm surges, the climate adaptation plan has made calculations of a number of possible situations with high waters. A description is given of the extent of the floods to which high water levels can lead, in order to obtain an overview of where will be affected by floods. Calculations are carried out by using a detailed model of the city, where the floods are described as the technology today permits.

The consequences of high waters that statistically occur at intervals of 1 to 300 years have been looked at. A calculation has been made, for each of the high-water events, of how they will affect the city today, in 50 years and 100 years based on the expected rise in water level.

To assess the extent of damage, we compare the flood calculations performed with City of Copenhagen data on how the areas will be used, for example which buildings are located in the areas concerned. The results of the flood calculations are illustrated by maps showing how different levels of high waters affect Copenhagen. It is possible to see on the maps the maximum extent of the flooding, when high the water is reached, and the maximum depths of water in the flooded areas.

Figure 4 shows a map of the extent of a high water in Inner Copenhagen that reaches 226 cm above the surface of the sea.

Figure 4: Maximum extent of a high water of 226 cm (DVR90). A high water level of this kind will statistically occur every 20 years in 2110.

In Table 4 it is possible to see examples of how high a level a high water has to reach before it begins to be critical for selected buildings and installations in Copenhagen.

These calculations of which areas of Copenhagen will be affected by flooding in different situations are used to assess the socioeconomic costs of the floods. The socioeconomic costs in different situations with floods are calculated on the basis of the activities, installations, infrastructure etc. affected by the event.

High water DVR90	Frequency	Year	Cost Total DKK million
137 cm	16 years	2010	0
158 cm	85 years	2010	465
200 cm	73 years	2060	1,576
226 cm	11 years	2110	4,647
255 cm	70 years	2110	9,287
285 cm	300 years	2110	13,583

Table 4: Socioeconomic costs in flood situations.

The costs in future storm-surge events will be so great that is of interest to look at the options for and costs of protecting the city against such events. If no form of protection facility is established, the combined costs of damage over the next 100 years will total DKK 15-20 billion at current prices.

The costs of protecting Copenhagen up to a high water 255 cm above the normal water level (DVR90) are estimated at DKK 2.3 billion in construction costs.

Protection over the next 5 years and later re-investments, operation and maintenance over the same 100-year period will accordingly amount to around DKK 4 billion at current prices. It will therefore be economically appropriate, with the anticipated extent of climate change, to establish defensive measures rather than taking no action.

Saving from measure	19,908
Costs of measure	3,997
Net saving	15,911

Table 5: Net present-day value of costs of damage and possible measures in DKK billion calculated on the basis of a statistical frequency of damage.

The calculated net gain reflects the sum of the damage that will occur to buildings, infrastructure and lost earnings etc. that is avoided by protecting against flooding.

As can be seen from Table 4, even a flood of 158 cm, which statistically occurs once every 85 years, will mean significant socioeconomic losses. The economic assessments make it possible to weigh up which situations with high waters it can pay to protect the city against in purely socioeconomic terms, based on what the various forms of protection will cost society. In addition, the

assessment should include whether irreparable damage occurs to the cultural heritage in the various situations with high waters. If so, it is not the economic damage alone that is to be included in the basis on which decisions are made for protection against flooding.

Over time there will be several valuable buildings and other assets in the areas that may be affected by flooding, and the costs a flood may entail therefore rise. We have chosen to assess the extent of damage caused by floods from the sea both in relation to today and in the future. The assessment of future damage includes areas threatened by floods having become more valuable by that time as a consequence of urban development (more metro, more technical installations), and there being a risk of more frequent floods, among other things because we anticipate higher sea levels.

MEASURES

	Level 1	Level 2	Level 3
Measure Geography	Reduce probability	Reduce scale	Reduce vulnerability
Region	Establishment of dikes	Establishment of warning system for high waters	Protection of vulnerable infrastructure, metro, S-trains, tunnels
Municipality	Establishment of dikes	Planning, warning	Planning, preparedness
District	Raised building elevation, dikes	Preparedness, sandbags etc.	Moving of vulnerable functions and installations
Street	Raised building elevation, dikes	Preparedness, sandbags etc.	Moving of vulnerable functions and installations
Building	Raised building elevation	Backwater valves, sealed basements, preparedness, sandbags etc.	Moving of vulnerable functions and installations

It will be logical to intervene first where it is cheap to take preventive measures, for example in low-lying areas where the establishment of small dikes can protect the hinterland. However, there are no particular areas that can be protected and consequently prevent flooding of larger areas behind them, as the water will come in across a broad front along the coastline.

Areas at threat of flooding in the city can be protected by establishing raised edges along the whole inner part of Copenhagen Harbour and along the periphery of the coast. However, this will be undesirable for architectural reasons and because it will reduce the opportunities to exploit the development opportunities and recreational potential offered by the harbour.

Instead, there is an option to establish a barrier at Nordhavnen and Kalveboderne and to raise the rest of the coastline out towards Øresund (The Sound). The barriers would be established so that they protect the city against storm-surge events, but without disrupting harbour operation at the same time.

In areas outside a barrier, protection against flooding can be provided by local protection of buildings and installations or by changing the use of these areas.

Figure 5 shows the areas where there is a need to carry out measures that can protect the areas behind against flooding. The map shows the heights above sea level the various sections have to be raised by to protect against a given high water.

Figure 5: Areas where there is a need for local protection to guard against high waters.

The rise in the water level of the sea that increases the risk of unacceptable damage and therefore makes establishment of a barrier cost-effective takes place slowly. We therefore only expected a substantial increase in risk in 30-40 years.

However, there is always a risk of damage to buildings and technical installations in flooding or penetration of groundwater. In areas close to the coast there will be an increasing problem as the level of groundwater in areas closed to the coast follows the risk in sea level. It therefore makes sense to protect new building in certain areas against flooding and penetrating groundwater, as it is far cheaper to provide protection at the time of establishment than subsequently.

The climate adaptation plan therefore proposes that new construction and new building in areas that are at risk of flooding from the sea and rising groundwater levels should be protected. This protection should be based on a specific assessment of the use of buildings and installations in relation to the consequences flooding will have.

The solution may be higher building elevations, i.e. building work should be undertaken on land that is raised in relation to the sea surface, changed use of the ground floor, protection of the building or protection around the building. Alternatively flooding may be occasionally tolerated, because the damage is limited. This applies, for example, to parks, nature areas, sports fields, promenades etc.
In areas that will end up outside the protection line for high waters there is a particular need to assess the options for protection. Areas such as Prøvestenen and Nordhavnen can be mentioned in this connection.

The areas can be classified according to use and how well they tolerate flooding, and on this basis the design elevation can be established. The table below shows a proposal for land use, and how well various types of land tolerate flooding.

Areal type	Frequency of flooding, years	Design elevation (DVR90)
Type 1: Areas that tolerate frequent flooding: coastal parks, promenades	5-10	0-233
Type 2: Areas with limited damage: sports facilities, roads	20	233
Type 3: Areas that can tolerate some flooding: marinas, roads	50	247
Type 4: Houses	100	263
Type 5: Areas that do not tolerate flooding: Metro	10,000	333

THE OVERALL PROJECTS FOR PROTECTION AGAINST HIGH WATERS

Large parts of West Amager are below sea level and are protected to the west and south by a dike along the coast. To protect the low-lying parts of South and West Amager against future high waters, work to raise the dike along this part of Amager began in 2009.

Better protection to the south is necessary, as the most powerful storm-surge events come from the south, and the water level during a storm surge is substantially higher along the south coast of Amager than in its northern parts.

When work on raising the dike has been completed, the areas protected by the dike will be protected up to a height of 5.9 m. This means that the dike can withstand a high water that only occurs once every 10,000 years, which is the basis of dimensional design for the shore facilities of the Øresund Link.

An expected rise in seawater level of 0.5 metres over the course of the next 100 years is used in the basis of dimensional design. The dimensional design has been based on assessments of the future sea level that were available in 2007, when the project was outlined.

Based on the forecasts for the future sea level on which this plan is based, the selected elevation should be adopted as a minimum, and the options for a future further raising of the dike should be considered at the same time. Vital parts of the city that are threatened by storm surges from the south will be protected with the establishment of the dike.

In Nordhavn a barrier out towards the Øresund (The Sound) can be established as a dam with gates in Kronløbet and Lynetteløbet that are closed when there is a risk of high waters that may cause damage to areas close to the harbour.

Figure 6: Two proposals for routing of barriers towards Øresund in Nordhavnen.

In the south, protection can be provided by establishing barrier south of Kalveboderne in the form of a movable gate.

Figure 7: Establishment of barrier south of Kalveboderne.

It is the City Council that, under the Coastal Protection Act, takes decisions on the establishment of coastal protection. Under this Act, plot owners who benefit from the coastal protection have to contribute to its financing.

If the Municipality decides that the coastal protection should have different purposes than protection against flooding, the Municipality has to fund the costs of establishing these purposes. As far as possible, attempts will be made to utilise the coastal protection for recreational purposes. However, by far the greater part of the funding will go on building technical facilities that will not serve any purpose other than protection against high waters.

There is therefore a need to investigate the sharing of funding/responsibility in connection with the establishment of protection against storm surges.

The decision to establish protection against flooding has to be taken in cooperation with the adjoining municipalities and central government, as the protection of Copenhagen as the capital city is also of national interest.

PROJECTS AND RECOMMENDATIONS

As a basis for being able to make a decision on protecting Copenhagen against storm surges in connection with the planned revision of this plan in 2015, the Climate Adaptation Plan proposes that the following projects be implemented:

No	Project	Purpose
1	Surveying of the coastline	Establishment of the need for protective measures
2	Choice of instruments	Identification of optimal measures and decision on establishment
3	Financing model and timetable	Investigation of sharing of costs for barrier and timeframe for establishment

The Climate Adaptation Plan recommends as follows:

No	Recommendation
1	In connection with local plans and construction projects it should be assessed in each specific case whether there is a need for climate-proofing in relation to future changes in sea and groundwater levels.

In the short term it is recommended that a specific assessment be made, in connection with new establishments, of the need for climate-proofing in relation to future rises in sea level. The basis for this assessment will be a decision on how the city is protected in the long term against storm surges from the sea. It is therefore crucial that work on making this decision is promoted as much as possible.


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.

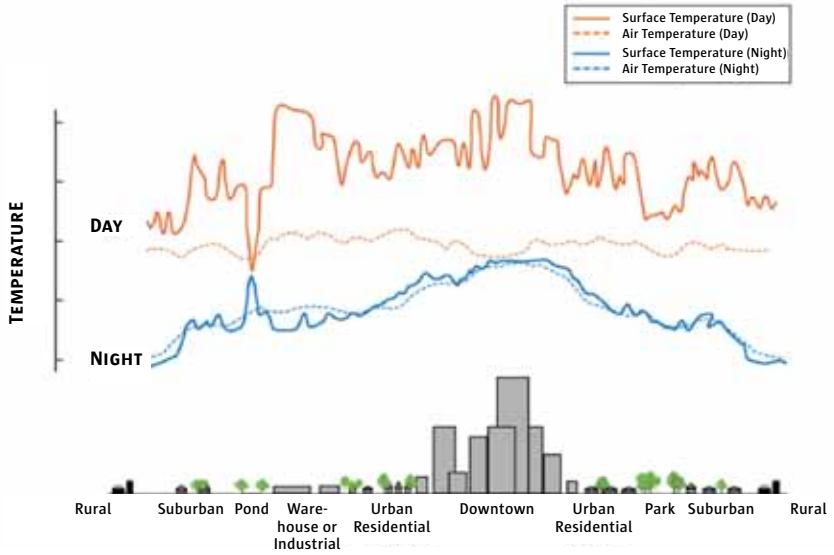


Figure 1: Surface temperature (solid curves) and air temperature (dashed curves) for different areas. The surface temperature around the 24-hour period fluctuates with the different surfaces (note, for example, the difference between pond and urban residential) and is highest in urban areas. The air 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.

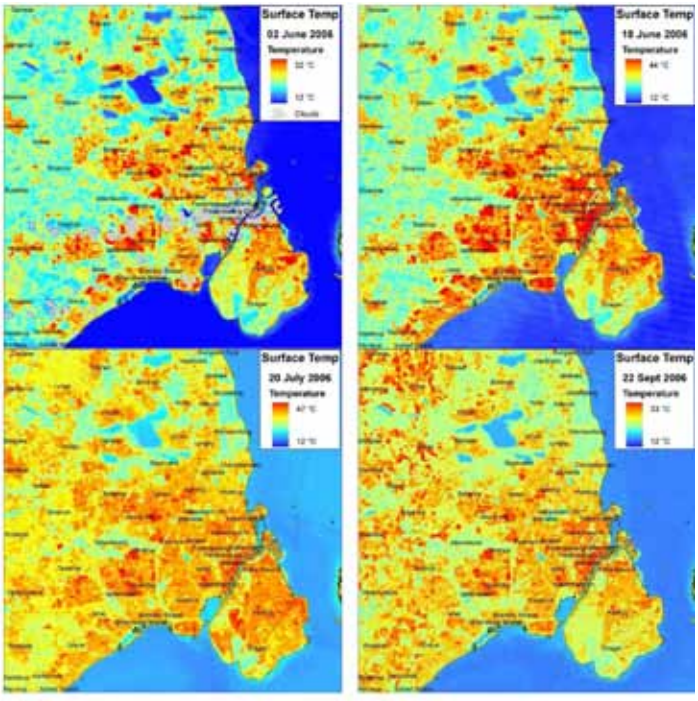


Figure 13: Map of surface temperatures in Copenhagen and surrounding area on four days in 2006, 2 June, 18 June, 20 July and 22 September. The maps were produced from the processing of Landsat data.

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. The climate adaptation plan therefore recommends that the urban climate is borne in mind when the city is developed and modernised, and that the city's green structures are used to prevent "heat islands" and the formation of high surface temperatures in the city.

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.

PREVENTION OF HOTTER SUMMERS IN THE FUTURE

When the city's physical frameworks are modernised and developed, we will have to prevent the heat effects of the future and take account of factors such as air temperature, sun and thermal radiation, air humidity and wind speed, which are of significance in creating a pleasant urban climate.

Copenhagen's green structure is emphasised as a major preventive instrument, as green initiatives can have a broad a multifaceted impact. Experience in other countries and research projects emphasise using the green structure of the city preventively. A number of different model calculations have been made for instance in New York, Toronto and Manchester indicating that greening of the city's surfaces is an effective way of lowering the city's surface temperatures and contributes to reducing the urban heat island effect. Japanese studies also, for example, indicate that the greatest mitigating effect on the urban heat island effect is achieved by creating a network of evenly distributed green spaces with a significant proportion of tree cover.

The green solution options are associated with the use of water, shade, air circulation and considerations on balanced surface temperatures and can be incorporated into the existing planning and are a possible way of preparing the existing city for the weather of the future. Copenhagen's urban development projects, for example in Ørestaden and the development work on Nordhavnen, where building, traffic management and landscape are planned jointly and where the use of water for canals etc. enables green sustainable considerations to be combined with the creation of recreational and landscape assets.

MEASURES

Urban heat island effect and high surface temperatures	Level 1 Reduce probability	Level 2 Reduce scale	Level 3 Reduce vulnerability
Regional			
Municipality	Establishment of green, continuous structures, preserve and add to the existing green structure and include SUDS solutions in thinking	Planlægning Promote district cooling of buildings	Planning
District/neighbourhood	Establishment of green, continuous structures, establish stormwater basins etc., plant trees, preserve and add to the green structure	Planning. Incorporate green solutions into private and public initiatives	Planning. Incorporate green solutions into private and public initiatives
Street	Establishment of green, continuous structures, establish green walls and other green elements, rain gardens etc.	Planning. Incorporate green solutions into private and public initiatives	Planning. Incorporate green solutions into private and public initiatives
Building/Property	Establishment of green, continuous structures, establish stormwater ponds, rain gardens etc., green roofs and trees	Planning. Incorporate green solutions into private and public initiatives	Planning. Incorporate green solutions into private and public initiatives

PROJECTS AND RECOMMENDATIONS

The climate adaption plan proposes that the following projects are implemented:

No	Project	Purpose of project
1	Measurements of temperatures in the city	Monitor the urban heat effect using satellite data and supplement this with own measurements of the city's surface temperatures
2	A greener and bluer city—what is needed?	The City of Copenhagen in co-operation with research institutions will carry out studies on how green and blue the City of Copenhagen should be and how it should be done, if we are to be able to even out and balance the city's temperatures, to safeguard the city's everyday life during the hot summers and heat waves of the future

The climate adaptation plan recommends the following:

No	Recommendation
1	When the city is modified and modernised, account must be taken of the urban heat island effect, particularly in the heavily built-up areas in the city and in areas with very little green and with many hard surfaces. The quality of the city's planting and good conditions for growth must also be ensured.

The Copenhagen Climate Adaptation Plan has had the phenomenon of the urban heat island elucidated by Forest and Landscape at the Faculty of Life Sciences of the University of Copenhagen, the Danish Hydraulic Institute (DHI) and GRAS. The whole report can be downloaded from the website of the City of Copenhagen at www.kk.dk/klima.

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.

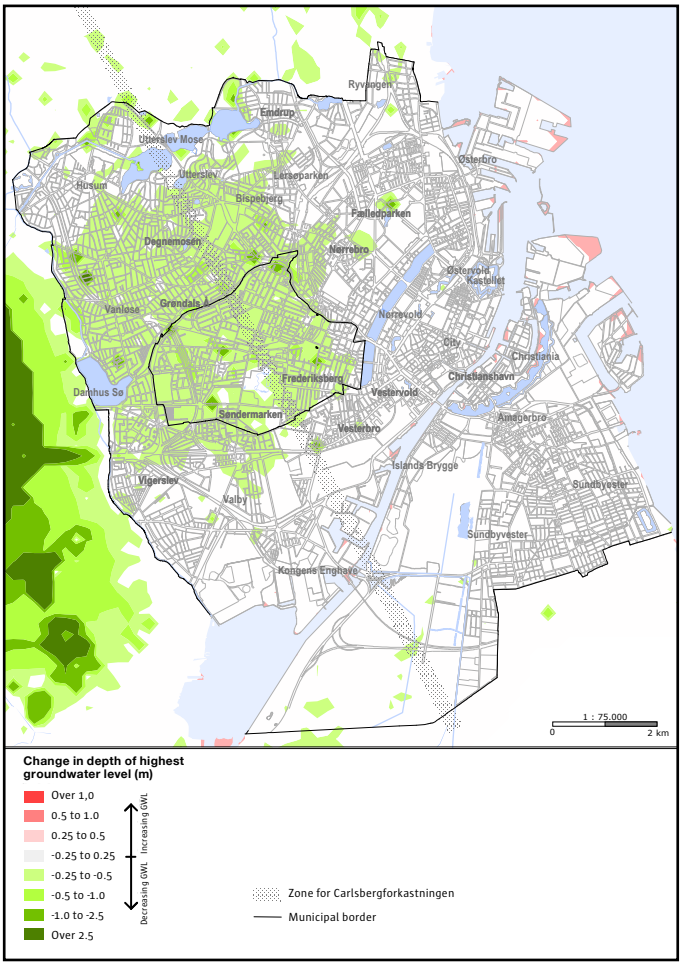


Figure 1: Change in depth of highest groundwater level—2060

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.

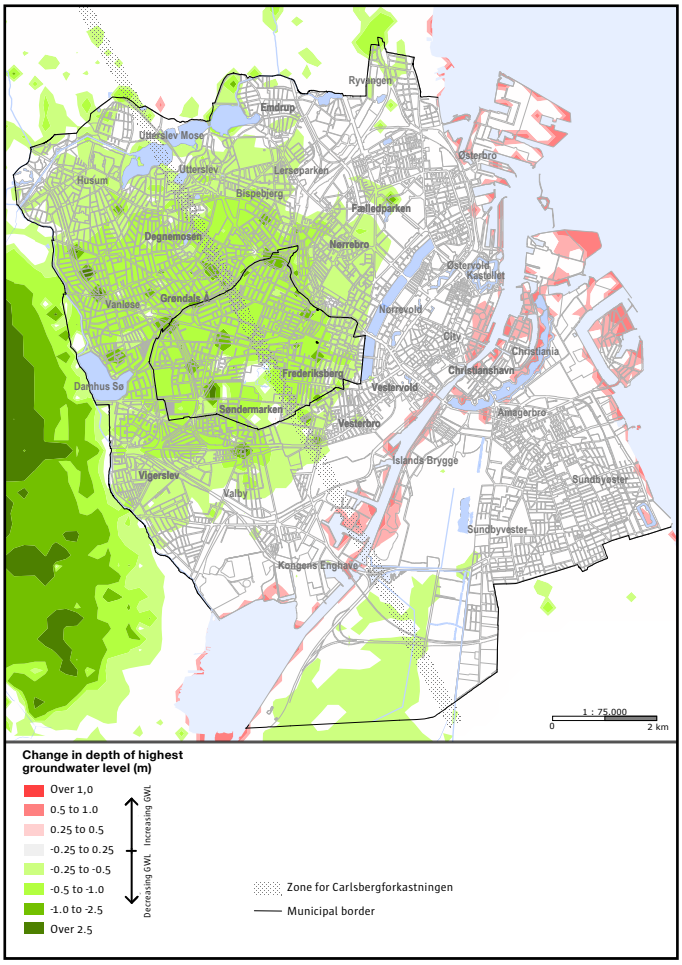


Figure 2: Change in depth of highest groundwater level—2110.

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.

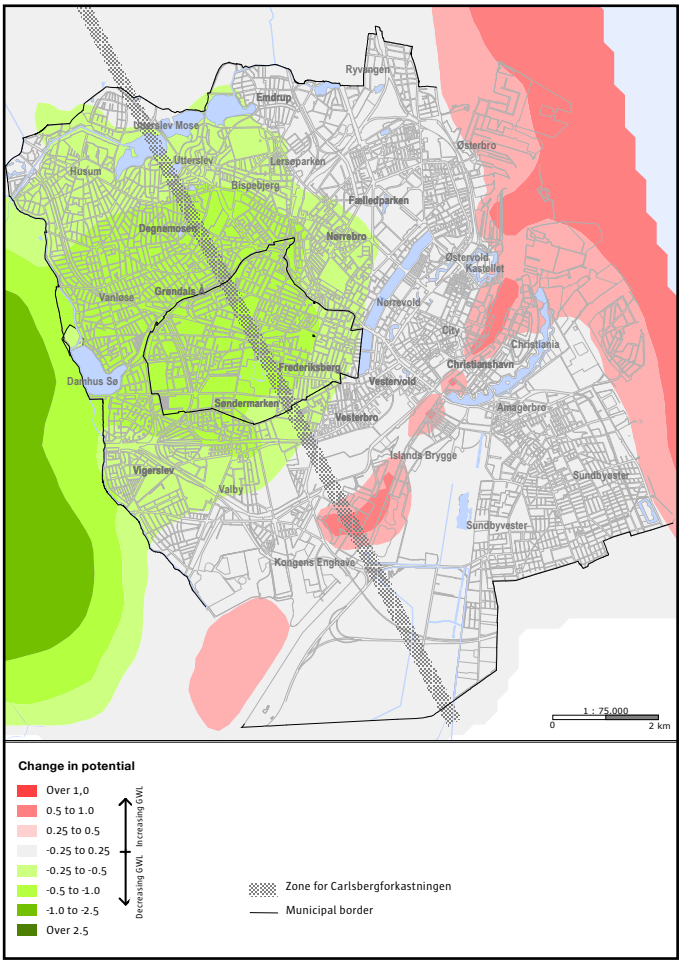


Figure 3: Change in the groundwater potential in the primary groundwater reservoir in limestone.

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.

MEASURES

INDIVIDUAL BUILDINGS

Sealing of basements and foundations. In new building, the City of Copenhagen requires buildings to be constructed in such a way that foundations and basements are sealed in relation to the existing groundwater level. By mapping future sea and groundwater levels it becomes possible to set requirements in relation to the future groundwater level.

Existing buildings can also be sealed in relation to increased groundwater pressure. It will be more costly than for new buildings.

Groundwater pumps: One solution may be to establish permanent pumping-away of groundwater, for example from a pump sump in the basement. This solution entails some sustainability problems, both in relation to energy consumption and based on a view of groundwater as a resource. Permanent pumping-away of groundwater is therefore not permitted in Copenhagen in new building projects. The Municipality may possibly be forced to revise this practice in the longer term if no acceptable alternatives are found for the individual landowner. Groundwater pumps are used to an extent that has not been mapped in detail in existing building work.

SEWER AND WATER PIPES

Sealing: An undesirable exchange of water or wastewater between sewer and water pipes and the layers of soil and groundwater reservoirs the pipes are located in can be counteracted by sealing and regular maintenance.

RESPONSIBILITY FOR PROTECTING BUILDINGS AND PIPE NETWORKS

Protecting building and private service pipes for sewers and water supply will be an individual matter for the landowner/building owner. It will be a public task to protect central and local government properties, including the municipal pipe network.

Raising of ground level: Account must be taken in the adoption of local plans of future groundwater, sea and high water levels. It will be possible for new urban districts in some cases to be constructed with a raised ground level. Requirements may consequently be set for the ground level to be raised in local plans close to the coast. The Municipality has already made use of this in two specific cases.

SPECIFIC RESPONSIBILITY FOR DRINKING WATER EXTRACTION

Water today is extracted from the groundwater in the limestone for the water supply of the Municipality of Frederiksberg. The possibility of extracting drinking water may perhaps be affected by climate change. One risk may be that the increased pressure from the coast combined decreasing formation of groundwater will reduce the fresh drinking water resource that can be pumped out. However, the Municipality's calculations only show small changes in the direction of flow in the limestone.

It is not, however, possible to rule out the possibility of local circumstances in the limestone such as cracks and channels leading to a larger volume of saltwater from the harbour flowing in and affecting the existing extraction of drinking water.

It is worth noting that the existing extraction keeps the water in the limestone reservoir artificially lowered. If it were to prove necessary to abandon the extraction of drinking water for the water supply company Frederiksberg Vandværk, it will entail rises in groundwater that far exceed the effects of climate change, and that may lead to problems with water in basements etc. further into Copenhagen.

This is an area that will be analysed more closely in the next version of the Climate Adaptation Plan.

The Climate Adaptation Plan proposes implementation of the following projects:

No.	Project	Purpose of project
1	Risk of infiltration to the drinking water resource	Mapping of the long-term options for drinking water extraction in the Municipalities of Frederiksberg and Copenhagen
2	Calculation of effects of increased infiltration of rainwater	Illustrating options and effects of local infiltration of rainwater
3	Options for making use of surplus soil for climate adaptation	Clarification of options for increased re-use of surplus soil for climate-proofing
4	Monitoring of groundwater level	Generation of knowledge on development in groundwater level

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.

The effect of the expected climate change on public health will, however, occur so gradually that it will be possible to adapt to them along the way. The City of Copenhagen will therefore monitor development and the consequences and assess the need, for example, for information material or preventive measures.

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.

It will become more important in the future for it to be possible to find shade in the city in playgrounds, at swimming pools and on sports groundss. To prevent and alleviate heat stroke, it will also become more important for there to be easy access to cool spaces, not just in municipal institutions such as schools, day-care centres and nursing homes but also, for example, in cinemas, shopping centres etc.

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 (NO_2). 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. It is recommended that developments in research in the area should be monitored.

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.

The climate adaptation plan has therefore commissioned studies of what the city can do to protect and enhance biodiversity in connection with climate change. Studies have been performed by COWI and have resulted in a report that recommends that the city should include consideration of preventive measures and initiatives for the city's biodiversity in connection with climate-related measures such as more green in the city and removal of stormwater.

Climate change will mean that habitats change as a result of heavier precipitation or periods of drought. The report states that Copenhagen's areas of nature are not sufficiently interlinked, and in several places appear to be like islands in the city where flora and fauna may find it difficult o move between the areas of nature and consequently maintain healthy populations. It is therefore recommended that dispersal corridors should be established between the areas of nature so that both animal and plant species can move when their habitats change. There should also be a focus on the plants we use having to be able to tolerate increased quantities of rainwater and prolonged humidity, and on the key need for natural environments not to be affected by wastewater from sewer systems.

If the city is generally made greener, this can have a positive impact on biodiversity. Two prerequisites for this to happen are that we spread the choice of species when we select species for street trees, parks and areas of nature and that we focus on creating habitats for animals and insects. We must avoid using plant species where there is a known risk of them being invasive over the course of time, and we must also focus on how plant species are spread and prevented. The more we spread the choice of plant species, the greater the likelihood of us avoiding whole areas/plant and animal populations being affected by diseases such as Dutch elm disease.

In the same way, utilisation of the rainwater in green spaces will increase biodiversity if it is used in the right contexts. In connection with the management of stormwater, it is desirable that selected green spaces are used for the temporary storage of water in relation to extreme downpours. This necessitates choosing plant species in park planning that can tolerate periods of flooding and making sure that the stormwater is separated from sewage.

In order to maintain and increase the diversity of urban nature, continued work must focus on creating links between the green and blue areas and on the choice of species suited to the changed living conditions. Emphasis must also be put on interdisciplinary cooperation and dialogue to promote health-oriented solutions with sensible consideration of the many interests associated with urban nature and use of the city's recreational areas.

Further information can be obtained from the report Strategy for Biodiversity, in the section on climate adaptation. This report has been produced by COWI A/S for the City of Copenhagen, Parks and Nature Department.

RECOMMENDATIONS ON THE INDIRECT CONSEQUENCES OF CLIMATE CHANGES

The Climate Adaption Plan recommends the following:

No.	Recommendation
1	In relation to public health, the City of Copenhagen will monitor the changes and the consequences of these and assess the need for preventive measures and information.
2	It is generally important to incorporate consideration of a warmer climate, e.g. in the form of heat waves, into other planning. This must be done by ensuring and creating access indoors and outdoors to cool spaces and shade in buildings, beneath trees, on playgrounds, in schools, day-care facilities, shopping centres, cinemas etc.
3	Specifically in relation to air pollution, the City will maintain the existing political and technical focus on improving air quality in the city.
4	Biodiversity must in general be taken into consideration in other climate-related measures, e.g. in the form of dispersal corridors, selection of plants that tolerate more moisture, periodic floods and use of increased quantities of rainwater to create greater biodiversity.

OPPORTUNITIES

The work on climate adaptation is obviously concerned primarily with safeguarding Copenhagen and its population against the inconveniences that future weather trends may present. But the work on climate-proofing Copenhagen is also concerned with seeing opportunities.

The work climate adaptation offers us a unique opportunity to develop Copenhagen to continue to be one of the world's best cities to live in. By choosing solutions that improve the city's physical environment and create attractive urban spaces in relation to residence, transport and experiences, we can use climate adaptation efforts to raise the quality of life of the people of Copenhagen. And by taking the lead in developing new methods to climate-proof a modern metropolis, we can create growth throughout the Capital Region, which will also help secure the economic foundation for the future of Copenhagen.

A GREENER COPENHAGEN IS A CLIMATE-PROOF COPENHAGEN

The Climate Adaptation Plan recommends that green spaces should contribute to clothing Copenhagen to cope with the weather of the future. A long-term, broad and focused effort to bring about a greener Copenhagen should be a preventive investment in a climate-proof Copenhagen with a high level of quality of life, health and satisfaction for the city's population. If the green element is incorporated now, we ensure that it will work in time.

A fundamental aspect of the Copenhagen climate adaptation plan is that a commitment is to be made to flexible adaptation that can develop gradually over the next several years. The work on climate adaptation is not just to focus on minimising the risk in future climate change but also ensure that all the opportunities for developing Copenhagen in a positive direction are utilised.

Flexible climate adaptation therefore requires cross-cutting solutions focused on facing up to more of the challenges posed by future climate change. At the same time, climate adaptation should help in creating a city in which the quality of life of the population is paramount. Every time we have to consider what measures need to be taken to avert a risk, we must also consider what opportunities it presents to develop the city to the benefit of its population. The green approach is emphasised here as a major preventive instrument, as green measures can have a broad and multifaceted impact.

The climate adaptation plan has commissioned a number of studies and analyses of rainwater, biodiversity and the urban heat island effect. The analyses and studies support the notion of Copenhagen's green structures being used as one of the tools for reducing and preventing stormwater floods and ensuring that we continue to have an agreeable climate and diverse urban nature.

The green solutions cannot stand alone but have to be combined with a number of other measures such as improvements in the city's sewer network. The green solutions can assist in keeping down expenditure on costly expansions of the sewer network, and above all are a way of working on climate-proofing in the existing densely populated city, where sewer renovation will be very difficult.

A GREENER COPENHAGEN—THE FRAMEWORKS FOR FUTURE WORK

A climate-proof and greener Copenhagen is a city with more trees, green roofs, green and blue spaces and a city that as well as being able to tolerate the weather of the future is also rich in nature experiences and options for outdoor activities. Parks, gardens, lakes and rivers are improved and joined together by green links and corridors. This can provide relief in the event of torrential rain, create more habitats for plants and animals and give the people of Copenhagen more experiences and opportunities to spend time in green spaces. Some of the city's rainwater is captured or stored in the green spaces, and in the case of cloudbursts some of these spaces are used as temporary collectors. The green structures in the city in this way can relieve the pressure on the city's sewer network. At the same time, attempts are made to minimise the damage by directing the stormwater to areas arranged to receive the water or areas where the harmful effects are reduced or are temporary.

Copenhagen's green structures comprise the city's green and blue spaces and consist of private gardens and courtyards, allotment gardens, public parks, nature areas, green sports grounds, lakes and rivers, churchyards and transport corridors.

The city's green structure has many life-giving functions and is essential for continued high quality of life in Copenhagen.

The potential of green spaces is to:

- reduce and prevent stormwater flooding by absorbing and retarding stormwater
- moderate and balance temperature
- create shade and air circulation, which assists in reducing the city's future energy consumption for the cooling of buildings
- remediate and reduce air and noise pollution
- prevent stress and create opportunities for recreation
- be a home for animals and plants

Copenhagen's main green features are historically formed by low-lying nature areas, the fortifications, the royal gardens and the commons, the coast, the harbour, lakes, rivers, bogs and meadows. Thanks to many years of sensible planning and urban renewal, Copenhagen is a green city. It therefore also makes sense to utilise and build on the city's green qualities in climate-adapting the city. In the existing city it is primarily a matter of improving the existing green and blue spaces and supplementing these by creating green continuous links between the city's green and blue spaces. Where the city is developed, it is important to bear green and blue solutions in mind from the outset. Climate adaptation in green and blue spaces is largely concerned with content and quality.

WHAT WE ARE DOING

The climate adaptation plan recommends starting work where it is appropriate to do so, where it is most needed, and where there is local backing. This will primarily be in areas where the city is being developed, modified and renewed. Where there is an increased risk of floods or other challenges as a result of climate change and on public properties and in public spaces (kindergartens, schools, homes for the elderly, cultural buildings, parks etc.).

Climate adaptation, with the aid of greening, is also to be developed into a tool in the City of Copenhagen, and it is therefore important to prioritise projects and measures that can provide the city with new knowledge and inspiration.

The future climate adaptation work involves considering stormwater collection and infiltration, biodiversity and prevention of urban heat islands and thinking about these together.

PRESERVING AND LOOKING AFTER EXISTING GREEN SPACES

Copenhagen has many valuable parks, nature areas and green facilities alongside institutions, areas of housing etc. Changes to the existing green spaces are to assist in climate-adapting the city and at the same emphasising the individual identity of the individual places. In addition to this, the green spaces must continue to offer the people of Copenhagen experiences and activities, for example more water in parks can endow these areas with new experiences. Most of the city's parks and nature areas are protected or listed for preservation, the purpose of which is to preserve and retain the existing condition of the area. The incorporation of climate adaptation measures will therefore as far as possible take account of cultural assets and will also require it to be possible to deviate from current provisions on protection etc.

SUPPLEMENTING WITH MORE GREEN AND BLUE SPACES IN THE CITY

Schoolyards, institutions, large car parks, courtyards, allotment gardens, road expropriations, gardens and residual areas are spaces and areas in the existing city that can be activated and contribute to the city being climate-adapted, at the same time as breathing new life into the courtyard, street or district.

Green roofs and walls are highly effective and do not take up space. They are therefore particularly beneficial in the densely populated areas of the city and in areas that feature hard surfaces. Broad-crowned trees provide shade and are particularly good at cooling the city. We therefore propose prioritising street trees and trees at schools and public institutions, common areas in housing estates, in parks and nature areas and, where there is space, along major roads and approach roads.

CREATING CONTINUOUS GREEN NETWORKS IN THE CITY

Green continuous networks in the city can contribute to climate adaptation and the collection of stormwater. These networks are significant to the city's nature and climate and can prevent urban heat islands. A green continuous network can consist of trees, green roofs and walls, gardens and green courtyards, green planting on roadsides etc. Each project in the city and every garden owner can contribute. Green continuous networks have to be borne in mind and included at several levels in the city; at an overarching level as green wedges, corridors etc. between the city's parks and nature areas. One of the options may be green continuous city spaces, which will be an investment in health and quality of life, where cyclists, pedestrians, rainwater and urban nature share space. The climate adaptation plan recommends the following overarching initiatives in the city:

MEASURES

A greener Copenhagen Urban scale	Level 1 Reduce probability	Level 2 Reduce scale	Level 3 Reduce vulnerability
Regional	Establish corridors/green network with link to green finger plan	Planning	Planning
Municipal	Establish green continuous networks, preserve and add to existing green structure	Planning	Planning
District	Establish green continuous networks, green roods, establish stormwater basins and similar	Planning and specific private and public initiatives	Planning and specific private and public initiatives
Neighbourhood/Street	Establish green continuous networks, establishment of stormwater basins, plant trees, preserve and add to existing green structure by establishing green walls and other green elements, water gardens etc.	Planning and specific private and public initiatives	Planning and specific private and public initiatives
Building/Property	Establish green continuous networks, establish stormwater basins, water gardens and similar, green roofs and walls, trees	Planning and specific private and public initiatives	Planning and specific private and public initiatives

PROJECTS AND RECOMMENDATIONS

The climate adaptation plan proposes that the following projects be implemented:

No.	Project	Projektets formål
1	A green and blue structural plan	Preparation of a plan for specific blue and green measures that coordinate efforts in relation to wastewater, recreation and other concerns
2	Sustainable watering systems	Development of a cost-effective and sustainable watering system where rainwater is collected for watering the city's street trees etc.
3	Planting strategy	Preparation of a climate-adapted planting strategy for parks and green spaces

The Climate Adaption Plan recommends the following:

No.	Recommendation
1	The municipality plan is to ensure a coherent green master structure in the municipality; where areas are ensured for capturing rainwater, for open flora and fauna corridors, and for conditions that contribute to an improvement of urban climate.
2	The municipality plan is to ensure coordination of climate adaption measures and of the green structures, where areas are ensured for green corridors and contribute to capturing rainwater, ensuring biological diversity and recreational values. In areas such as green wedges and corridors, the local planning should include requirements regarding capturing of rainwater, open corridors, etc., and other measures that contribute to improving urban climate.

A CLIMATE-PROOF COPENHAGEN IS A COPENHAGEN WITH GREEN GROWTH

The selection of actions must be focused on efforts to adapt Copenhagen to the climate being capable of contributing to the city's strategy for green growth and the ambitions to make it a shop window for green technologies and solutions. Over the next few years, climate adaptation will be high on the agenda in a large number of the world's cities, and in that way Copenhagen can benefit from taking the lead in developing green urban solutions.

The aspiration in adopting a perspective of green growth is to enable the investments to be made in partnerships with external investors. This can contribute towards the investments not simply being an expense for the city but also contributing to growth and employment and generating new knowledge and new occupations for the city.

The challenges posed by rising sea levels and increased levels of rainfall are a special opportunity for Copenhagen to think big, look for potential and monitor selected projects as demonstration projects for the city.

The climate adaptation plan contains great opportunities for the business development of the municipally owned utility company Copenhagen Energy, and it is important that this perspective is integrated into the implementation of the practical initiatives.

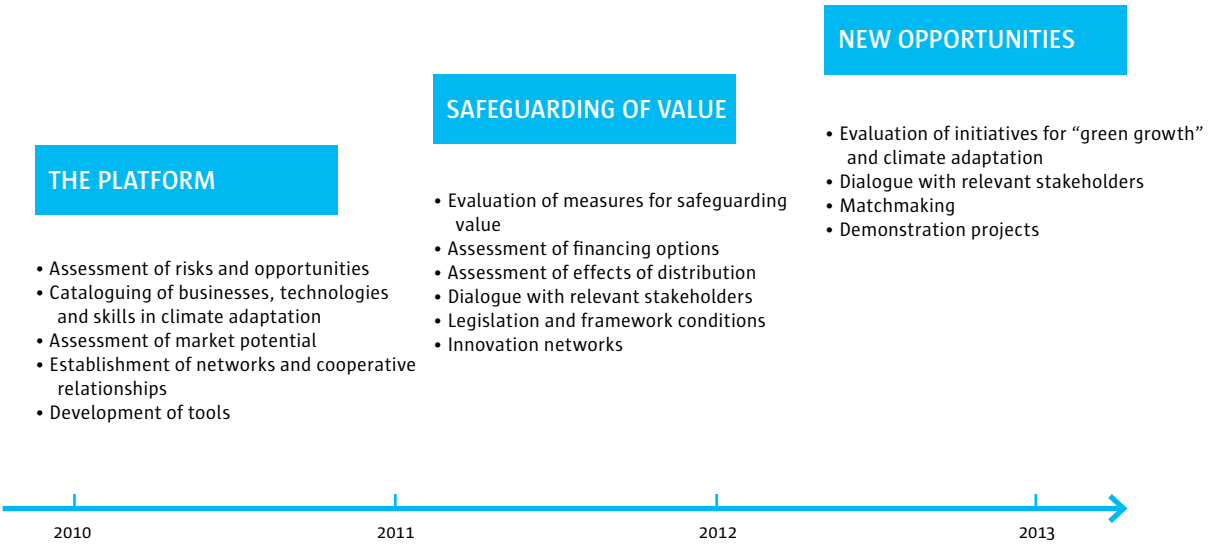
The aim of the climate adaptation plan is to protect the city, its citizens, the business community and the city's many assets. But the plan is also a development plan, focused on opportunities. The plan has to deal with great uncertainties over the expected climate change and establish flexible solution options, which take account of both timing and potential damage.

The future investments associated with the plan and the city are an incentive to look for new forms of funding, assess and examine ways of generating knowledge and jobs. The plan's strategy to ensure the greatest possible synergy, add new resources and cooperative relationships to the city and improve Copenhagen's quality of life also entails opportunities for cross-cutting cooperation and innovative thinking. All in all, it creates interesting opportunities to bring climate adaptation into Copenhagen's green growth strategy.

ADAPTIVE CAPACITY OF THE CITY OF COPENHAGEN
("ADAPTIVE CAPACITY")

Knowledge and skills	Networks and partnerships	Public regulation and planning	Funding

A number of possible platforms have been established for development and growth in connection with climate adaptation. The plan's potential lies in the opportunities to search for interdisciplinary knowledge, establish cooperation with the research and business communities on practical measures and selected demonstration projects, develop new technology, materials etc. The plan also creates an opportunity for interdisciplinary organisational and administrative development. The relatively large investments in climate adaptation measures can make Copenhagen attractive as a partner in cooperation and open up the possibility of positioning the city in the international market.



The knowledge gained from the climate adaptation in Copenhagen, the goals and the strategy, can be of use in most other places around the world, even though the challenges faced might be very different from those in Copenhagen. A focus on preventive initiatives such as a strategy for development and improvement with the keywords learning, knowledge, flexibility and quality can, if managed properly, contain potentials for the city in terms of growth..

THE WORK IS ORGANISED IN FIVE SELECTED "WORK STREAMS"

	DESCRIPTION	RECOMMENDATION
KNOWELDGE AND SKILLS	• R&D in "business-oriented climate adaptation" • Gathering ("best practice") and sharing of knowledge • Development of tools	• Build-up of knowledge concerning climate adaptation, innovation and growth • Cooperation and if appropriate integration with the Climate Adaptation portal
NETWORKS AND PARTNERSHIPS	• Expansion of the territory for work on climate adaptation in the City of Copenhagen • Expansion of the territory for work on climate adaptation in the City of Copenhagen • Links between scientific, technical and business-oriented networks (innovation)	• Increased dialogue and cooperation between Technical and Environmental Administration (TMF) and Economic Administration (ØF) on evaluation etc. • Cooperation with Copenhagen Cleantech Cluster and other networks • Coordination across the municipality
PUBLIC REGULATION AND PLANNING	• Assessment of opportunities and barriers in legislation through demonstration projects and dialogue with relevant authorities (central and local government)	• Dialogues with Coordination Forum for Climate Adaptation
FUNDING	• Assessment of alternative funding options • CBA and assessment of budget economic and distribution-related consequences	• Establishment of models for CBA and funding mechanisms • Establishment of business case for investments
MEASURES CONCERNING CLIMATE ADAPTATION	• Development and maintenance of catalogue of ideas • Development of practical projects and initiatives	• Evaluation of measures in relevant sectors • Special focus on insurance (claims, premiums and charges, regulation)

It is a matter of entering into various types of networks that have knowledge of the needs and opportunities of the international market and creating contact with research and business networks with the right knowledge and motivation.

It must be emphasised that the growth potential has to be searched for and borne in mind from the start, and priority must be give to interdisciplinary development/demonstration projects. Emphasis is also given to some of the networks the municipality is already engaged in, for example the "Water in Cities" cooperation, which is a Danish network between universities, public institutions and private enterprises. A number of similar networks could be established on topics such as:

- Protection against rising sea level and foods (backwater valves, dikes etc.)
- Protection of new urban areas (raising of harbour quay etc.)
- Sustainable urban drainage systems (SUDS)
- Green networks and urban design
- Adaptation of municipal buildings
- Incentives for prevention (grants for fascines etc.)

PROJECTS AND RECOMMENDATIONS

The climate adaptation plan proposes that the following projects be implemented:

No.	Project	Projektets formål
1	Interdisciplinary demonstration project for the city	An interdisciplinary demonstration project in the existing city—discussion and development of climate adaptation measures targeted at the existing city

The Climate Adaptation Plan recommends the following:

No.	Recommendation
1	It is recommended that climate adaptation of Copenhagen is included in Copenhagen's Green Growth Strategy

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.

The Climate Adaptation Plan therefore recommends that Copenhagen's building stock and roads over a period are protected against serious damage that may be a consequence of climate change.

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. It is important to ensure that the buildings meet applicable safety requirements. This can done for instance by inspection and, where appropriate, strengthening of weak building parts.

It may also be necessary for weakened trees that may damage buildings to be felled so that the number of cases of damage does not rise, even if cases of strong winds increase.

OPTIONS FOR CLIMATE ADAPTATION OF BUILDINGS AND ROADS IN COPENHAGEN

The options for direct climate adaptation depend to a great extent on whether new construction or existing buildings are concerned. It is often considerably more expensive to improve a building or a road than to carry out more climate-proof building work from the start. When planning new construction it is therefore often possible to advantageously build in options for upgrades that can then be decided upon at a later time, when the circumstances dictate.

It will be expensive for the individual citizen and municipality to adapt to climate change. The principal challenges include water that penetrates basements from the sewer during frequent downpours and extreme rain that causes floods resulting in damage. If no investment is made in defensive measures, such events will represent an increasing economic burden for the individual citizen and for the municipality.

On the other hand, measures that limit the extent of damage in extreme events will also be associated with substantial costs.

The heavy downpours and cloudbursts of recent years have highlighted the need to protect many of the city's existing buildings against penetrating water from the surface, both in basements and on the ground floor of buildings.

Responsibility for protection of the individual property at present rests with the owner of the building. If the property is privately owned, this means that the individual owner himself bears the economic burden and responsibility for the damage that occurs as a result of inadequate drainage, defective sewer systems at the property and failure of building structures.

On the other hand, protection of the municipality's own properties and the pipe network outside the private properties is a public task.

In addition, the municipality's tunnels and roads should be protected against future downpours. In the great downpour in August 2010, when several tunnels were flooded, the tunnel beneath Lyngbyvejen at Ryparken st., for example, subsequently had to be renovated at a cost of around DKK 450 000.

In connection with rises in groundwater, our old macadam roads should be looked at. The macadam roads were built in the late 19th and early 20th centuries, and they consist of stone and gravel. These roads are under-dimensioned, because of the later development in traffic. With the rise in groundwater, the roads will be further weakened, and operation is therefore associated with high costs. Around 40% of City of Copenhagen roads are still macadam. The roads in the critical areas should therefore be protected.

With the adoption of the Copenhagen Climate Plan, the focus has been put on the climate in connection with renovations of existing buildings and roads. The plan points out that economic resources can be used better by thinking about rebuilding and renovation work along with energy renovation and climate adaptation.

We therefore recommend that guidelines are formulated for the climate adaptation of the city and its buildings and roads to ensure that the necessary renovation work is done at the right time, so that the costs are minimised and the functions and continued operation of the buildings can be protected.

The City of Copenhagen will therefore, in cooperation with private and public enterprises and knowledge institutions draw up information material for building owners and tenants that provide readily accessible information on the challenges and opportunities that climate change signifies for the buildings of Copenhagen.

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.

It has to be assessed in connection with the determination of the future municipal level of service to what extent larger protection systems should be established for whole urban areas, large building complexes or areas particularly at risk in the city.

An assessment needs to be made of whether the desired level of service means that buildings in Copenhagen have to be protected against climate change or whether the consequences have to be entirely or partially accepted, and the individual building owner therefore has to take on the task of protecting his property.

If the level of service means that not all buildings are protected by joint defensive measures, the municipality will have to decide:

- Which buildings can be advantageously demolished, arranged for a different purpose or alternatively moved to a different location, where there is less risk of damage.
- Which buildings are so essential that floods for example cannot be accepted.
- Preparation of plans for the protection of buildings that are worthy of preservation and listed.
- Establishment of what aesthetic and functional qualities are desired for the city's existing building stock and for new construction.

The decisions that are taken will decide what defensive measures should be implemented and when they are to be implemented.

With the extensive and serious consequences that climate change may have for Copenhagen's buildings, and consequently for people and businesses in the municipality, it is important that correct and sustainable decisions are made.

If the decisions are to be made on a qualified basis, a thorough analysis and registration of the ability of the individual buildings to withstand climate change should therefore be implemented as quickly as possible. Buildings that are located in areas at risk and are of particular significance and value to society should be registered first. A general registration of all buildings should then be undertaken.

A building has to be a safe place to spend time in, including when critical situations arise in the form of extreme high waters due to storm surges, extreme downpours or severe storms. The measures taken should therefore be capable of coping with the scenarios that may arise both now and in years to come, as most existing buildings may be expected to also be in use for the next century.

What the best solutions are depends both on the arrangement, function and design of the individual building and the nature and height above sea level of the surrounding land. In addition, the capacity and safety of the sewer system and supply network are important factors in assessing which solutions are best suited to the individual building. Qualified specialists should therefore be used to assess which solutions should and can be selected to avoid serious problems as a result of changes in the climate.

PROJECTS AND RECOMMENDATIONS

The Climate Adaptation Plan proposes that the following projects be implemented:

No.	Project	Purpose of the project
1	Registration of the municipality's own properties	Registration of current condition and safety of buildings and roads in relation to climate change and preparation of an action plan, including analysis of needs for investment.
2	Information to citizens	Preparation of information material and information campaigns on options for climate-proofing.
3	Upgrading of qualifications/ training	Preparation of guidelines and syllabus/material for municipal employees with relevant contact with the public, with a view to ensuring fundamental knowledge on the significance of climate change and options for action by the public.

The Climate Adaptation Plan recommends the following:

No.	Recommendation
1	It is recommended that a general registration of at-risk districts, neighbourhoods, streets and buildings should take place.
2	That action plans should be drawn up for particular categories of buildings and roads.
3	That climate adaptation and energy renovation of the municipality's properties are included in the planning of all future renovation works and that the necessary economic resources are set aside for this.
4	That members of the public can obtain general and specific guidance and assistance at the municipality's service centres.

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 spac-

es 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.

EMERGENCY PREPAREDNESS

In cases of exceptional climatic events such as heavy rain or high waters there may be a risk of damage to buildings, houses and installations located in sensitive areas.

To optimise the effort in relation to that kind of damage, the knowledge brought about in connection with the preparation of the climate adaptation plan is incorporated into both the municipal action plan in the area and the risk-based dimensioning of fire and rescue preparedness in the municipality.

BACKGROUND

In relation to municipal preparedness it is the trend in the future pattern of precipitation with heavier rains and higher sea level that is of interest.

Increased intensity of rain will result in a greater risk of floods, which requires action by the emergency services. With the analyses carried out in connection with preparation of the climate adaptation plan, it is possible to identify areas where there is a risk of damage in the event of heavy rain and high waters and consequently take preventive action and urgent target remedial action.

ASSESSMENT

STORMWATER

In August 2010 parts of the City of Copenhagen were struck by a rain event that statistically occurs only once every 100 years. In relation to the tasks this event brought with it for the emergency services, there is judged to be a need to update emergency preparedness with respect to events of this scale.

- There is a need for equipment that can deal to a sufficient extent with polluted water, which will typically happen in overloading of the sewer system. It will be appropriate for closer cooperation to be established with the utility company Copenhagen Energy, which both has knowledge of the sewer system and has equipment at its disposal to deal with wastewater.
- There is a need for draw up a combined risk/threat assessment in the municipality, which covers prioritisation of objects to be protected and assessment of the need for equipment to provide protection.
- The warning of the event concerned did not work.

SEAWATER

With the analyses that have been made of high waters that can affect Copenhagen, it is possible to identify the areas where the high water will first penetrate. There is consequently a basis for establishing emergency preparedness for these areas, either in the form of defensive measures or warning, so that buildings and installations in the areas can be protected in time.

SOLUTIONS

With the analyses that have been made of high waters that can affect Copenhagen, it is possible to identify the areas where the high water will first penetrate. There is consequently a basis for establishing emergency preparedness for these areas, either in the form of defensive measures or warning, so that buildings and installations in the areas can be protected in time.

The Climate Adaptation Plan proposes the following projects:

No.	Project	Aim of project
1	Updating of action plan	Climate adaptation of action plan
2	Establishment of warning system for stormwater and high water	Optimisation of action in extreme events

The Climate Adaptation Plan recommends the following:

No.	Recommendation
1	Cooperation with Copenhagen Energy on management of wastewater and critical rain events

FINANCING

The financing of major climate adaptation measures requires investment over a longer period of time than is normally seen for municipal projects. In addition, the expenditure is not evenly distributed over time, as the implementation of major individual measures such as dikes and lock facilities has to be carried out over a relatively short period. In addition, there is substantial uncertainty with respect to development in the climate and consequently the extent of the future need for financing.

Most of the climate adaptation measures have to be financed and operated in a cooperation between several stakeholders, including central government, Copenhagen Energy, CPH City and Port Development and the Copenhagen Metro.

The challenge facing the municipality is therefore not just the level of expenditure but the distribution of this expenditure, as there will be very high expenditure in certain periods which cannot be directly kept within municipal budgets. This is illustrated in Figure 1.

PROFILE OF CAPITAL NEED FOR TIME AS A RESULT OF INVESTMENTS AND OPERATION

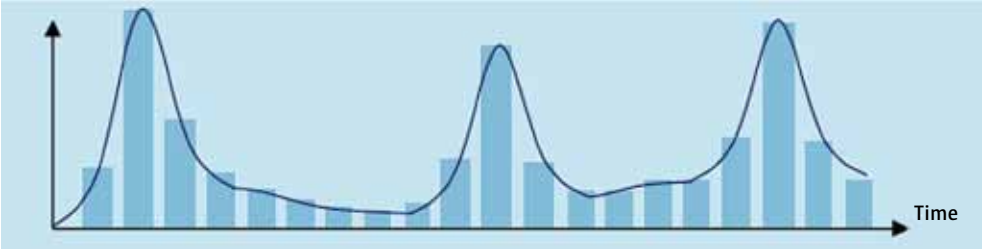


Figure 1. Illustration of costs over time. Source: Deloitte

Investment in the various projects should in principle be prioritised so that all the necessary projects are carried out without putting too great a burden on municipal budgets. It is therefore important that the municipality considers carefully the budget effects of starting or deferring the various measures, as this will for a period substantially reduce the economic room for manoeuvre and possibly defer the start of other investments.

There will also be a significant risk of projects initiated in a given year reducing both the economic and political opportunities for action in subsequent years. We are consequently in a situation where the actions of a municipal council go considerably further than has been customary.

In order to be able to make good long-term decisions, it is necessary for the municipality to have access to tools that enable it to establish necessary prioritisations and analyse the combined economic effects of various financing strategies, in both the short and long terms. The form of financing has to be chosen on the basis of available information on possible future climate change and the municipality's cost expectations.

A key challenge is that the uncertainty concerning the costs of damage expected to occur in the future, when the climate changes, will influence the prioritisation and scope of the necessary defensive measures. It underlines that the control tools the municipality needs must be able to cope with a large number of risks and uncertainties, and that it must be possible for them to be

expanded in relation to future scenarios. At the same time, there is significant uncertainty with respect to the size of the investments to be made and when it is best to make them. Uncertainties such as those must also be taken into account when the various defensive measures are planned.

ORGANISATION AND FINANCING

In order to face up to the adverse consequences of climate change there is a need for substantial investment in the City of Copenhagen over the next few years in defensive measures, and a rise in climate-related costs is to be expected. The financing options that the City of Copenhagen can apply are closely linked to the forms of organisation that can be applied in connection with implementation of the necessary defensive measures.

The municipal borrowing limits will determine the choice of organisation. Investments in climate adaptation are not at present eligible for loans. If the rules are changed so that investment in climate adaptation becomes eligible for loans, the municipality will be far more flexible in its choice of organisation. If the rules do not change, the municipality will be restricted to either saving up for the investments or bearing the investment in full in the individual budget years.

The municipality may have an interest in a form of climate fund, where savings are made based on different scenarios. The saving is to be used among other things to cover unexpected expenses due to extreme climate events, but at the same time ensure that the municipality has some equity to invest in defensive measures.

The organisation can take place in various forms of company. Advantages and drawbacks of the various forms of organisation are to be analysed more closely as the various projects are described better and approach the time of implementation.

MODEL

Uncertainty on climate change entails a substantial risk at present of incorrect investments. The defensive measure can be regarded as the purchase of an insurance policy, where the probability of the damage occurring is uncertain, the extent of the damage is unknown and the correct price of the insurance is uncertain. The major uncertainties make several ongoing analyses of the defensive measures relevant, among other things to clarify the optimum time of investment, level of investment, the size and frequency of the damage risks and who is actually to finance and manage the investments.

To optimise and assess advantages and drawbacks in different measures and forms of financing in relation to the development in the climate, there is a need to establish a model for decision support.

The model is also to be capable of providing the basis for establishing a basis for decision-making in subsequent considerations on change in payment circumstances, upgrading or amendment of projects and calculation of economic consequences of changes in the environmental scenarios.

The financial model also has to be capable of describing the economics of the envisaged projects, including for suppliers, operators and for relevant public authorities. Furthermore, the model is to be capable of being applied to describe economic consequences of alternative scenarios, changed estimates for the costs of implementation and changes to the annual and total operating costs. The Technical and Environmental Administration is taking part in a project entitled “RiskChange” under the Strategic Research Council, the purpose of which is to develop a decision support tool for climate ad-

aptation. The project is expected to bring about methods or models that will be capable of preparing a basis for decision-making for optimal investments in climate adaptation measures.

PROJECTS AND RECOMMENDATIONS

The Climate Adaptation Plan proposes that the following projects be implemented:

No.	Project	Aim of project
1	Financing model and timetable	Establish basis for decision-making for choice of form of financing for long-term climate adaptation measures
2	RiskChange	Basis for decision-taking for long-term investments in climate adaptation

The Climate Adaptation Plan recommends the following:

No.	Recommendation
1	An attempt is made to have the municipal borrowing limits changed so that investment in climate adaptation becomes eligible for loans

PROSPECTS FOR CLIMATE ADAPTATION IN COPENHAGEN

Even if success is achieved in reducing greenhouse gas emissions, we will experience climate change as a result of the volume already emitted. Climate change happens gradually, and the analyses in the Climate Adaptation Plan show that extensive measures will have to be taken over the next 30 years to adapt to climate change in Copenhagen.

In the short term there is a need for us to start immediately on action to prevent damage as a result of intensive rain such as the downpour that struck Copenhagen in August 2010. In the longer term, a rising sea level means that flooding from the sea will be a major threat to Copenhagen. Even though the threat is not great today, it is crucial to make decisions on how Copenhagen is to be protected against storm surges and the floods that can follow. The actions we choose are of great significance to the development of the city and already have to be incorporated into the development plans for the city now.

Climate change will also be significant to the temperature in the city in the longer term. It is anticipated that we will experience more intense and longer-lasting heat waves, which may affect public health and create a greater need for cooling. A number of other areas such as groundwater, air quality and biodiversity will also be affected. The challenges are as far as possible to be solved in such a way that something is supplied to the city, for example recreational provisions. At the same time, the solutions have to be formulated in such a way that the fit in with the city's architecture.

There is a need for extensive investments and thorough planning to meet the challenges that the changes in the climate pose for Copenhagen. But by acting at the right time we can minimise expenditure on preventing and rectifying damage, and climate adaptation may help to create green growth for Copenhagen.

The work is not done with this plan. There are many uncertainties associated with how the climate will develop in the future, and the plan will therefore have to be regularly updated so that it reflects the latest knowledge at all times. This version of the Copenhagen climate adaptation plan is a starting point for adapting Copenhagen to the climate of the future, so that Copenhagen will continue to be an attractive and climate-adapted city in the future.

OVERVIEW OF COMBINED ACTION

The overview below shows all the projects in the climate adaptation plan. A more detailed description of each individual project is given in the project overview section.

Projects launched in 2011 are incorporated into the ordinary budget of the Technical and Environmental Administration. Other project proposals are awaiting funding. The project proposals will be assessed individually and raised by application to future budget negotiations.

YEAR / Project	2011	2012	2013	2014	2015 →
STORMWATER					
Reduction in the hydraulic load on watercourses	Establishment of cooperation between catchment municipalities	Clarification of need for retarding of stormwater in catchment	Implementation	Implementation	Implementation
Costs	DKK 0	DKK 200,000	DKK 0	DKK 0	DKK 0
Information on the public's options for climate-proofing	Preparation and printing of information material		-	-	-
Costs	DKK 100,000 (TMF)		-	-	-
Plan B	Clarification of whether Plan B can be carried out within wastewater plan. Preliminary investigation of hot spots in city	Detailed planning of Plan B solutions			
Costs	DKK 200,000 (TMF)	DKK 300,000			
Opening of piped watercourses	Complete plan for hydraulics in watercourses	Detailed planning	Implementation	Implementation	Implementation
Costs	DKK 150,000 (TMF)	DKK 450,000	DKK 30 million	DKK 30 million	DKK 30 million
Disconnection of stormwater from sewer (SUDS)	Clarification of legal situation regarding	Planning included in wastewater plan in 2012	Implementation	Implementation	Implementation
Costs	DKK 150,000 (TMF)	-	-	-	-

YEAR / Project	2011	2012	2013	2014	2015 →
Coordinated wastewater planning	Initiatives for cooperation	Planning	Planning	Planning	
Costs	DKK 0	Charges	Charges	Charges	
Quantification of the effect of different SUDS solutions	Preliminary project where the SUDS elements are chosen. Design of test. Literature study	Full-scale testing of different SUDS elements with measurement of effect	Full-scale testing of different SUDS elements with measurement of effect	Full-scale testing of different SUDS elements with measurement of effect	
Costs	DKK 300,000 (TMF)	Charges	Charges	Charges	
SEA					
Surveying of coastline	Description of task	Surveying	-	-	-
Costs	DKK 0	DKK 100,000	-	-	-
Choice of instruments	Political decision on principle of protection against sea	Preparation of proposals	Preparation of proposals	Adoption of proposals	-
Costs	DKK 100,000 (TMF)	-	-	-	-
WARMING					
Monitoring of temperature	Measurements of temperatures (Project desired to be linked to existing measuring stations in city				
Costs	DKK 0	DKK 200,000	DKK 50,000	DKK 50,000	DKK 50,000
Assessment of extent of necessary measures		Model calculations etc. showing how green Copenhagen has to be to level out and balance the city's future surface temperatures			
Costs		DKK 350,000			

YEAR / Projekt	2011	2012	2013	2014	2015 →
SOIL AND GROUND-WATER					
Risk of infiltration to drinking water to the drinking water resource		Description of mechanisms and performance of model calculations. Coordination with GEUS			
Costs		DKK 75,000			
Calculation of effects of increased infiltration of stormwater	Detailed calculations				
Costs	DKK 75,000 (TMF)				
Opportunity for utilization of surplus dirt	Description of possibilities and treaths with arranging dirt and soil to concrete use				
Costs	DKK 50,000 (TMF)				
Monitoring of groundwater level and possible updating of groundwater model	Localisation and possible new establishment of bearing points in primary and secondary groundwater reservoir, position-finding and map drawing				
Costs	DKK 150,000 (TMF)				
BUILDINGS					
Registration of buildings in areas at risk	Description of the task	Registration and mapping			
Costs		DKK 100.000			
Upgrading of qualifications/ training	Description of the task	Preparation of teaching material and holding of 1st round of instruction			
Costs		DKK 200,000			

YEAR / Project	2011	2012	2013	2014	2015 →
EMERGENCY PREPAREDNESS					
Warning system	Establishment of warning of rain and high waters	Establishment of warning of rain and high waters	Establishment of warning of rain and high waters		
Costs	DKK 0				
Updating of emergency preparedness plan	Review of emergency preparedness plan on basis of climate adaptation plan				
Costs	DKK 0				
GREENER CITY					
Planting strategy			Specific research, monitoring etc. for selection of species that thrive, cool and support biodiversity in the city		
Costs			DKK 400,000		
Green and Blue Structure plan	Based on climate adaptation plan and wastewater plan, a specific complete plan is drawn up that reconciles climate adaptation concerns with recreational and local conditions				
Costs	DKK 250,000 (TMF)	DKK 250.000			
Watering		Development of cost-effective and sustainable watering system using rainwater			
Costs		DKK 500,000			

YEAR / Projekt	2011	2012	2013	2014	2015 →
GREEN GROWTH					
Utilisation of growth potential in climate adaptation	Competitive tender on management of future stormwater				
Costs	DKK 250,000 (TMF)				
FINANCING					
Financing of measures	Description of the task	Model for financing and distribution of costs			
RiskChange, Development of decision support tool	Participation in project	Participation in project	Participation in project	Participation in project	
Costs	DKK 0	DKK 0	DKK 0	DKK 0	
Activity	Description of the task	Model for financing and distribution of costs	Model for financing and distribution of costs	Model for financing and distribution of costs	
Costs		DKK 1.5 million	DKK 1.0 million	DKK 0.5 million	
CROSS-CUTTING PROJECTS					
Pilot project for climate adaptation	Designation of area for demonstration project	Establishment	Establishment	Establishment	
Omkostninger	DKK 0	DKK 15 million	DKK 15 million	DKK 15 million	

PROJECT OVERVIEW

In the following, a description is given of the need for future action based on the account of the effect of climate change on Copenhagen.

The necessary future action and the financial costs, as far as possible, are described for each area.

STORMWATER

PROJECT: REDUCTION OF THE HYDRAULIC LOADING OF WATERCOURSES

The aim of the project is to limit the hydraulic loading of watercourses from separate stormwater runoffs principally in the municipalities in the catchments of the Harrestrup Å and Søborghusrenden rivers.

The costs of implementing the project are borne by the municipalities concerned. There is therefore no expenditure on implementation for the City of Copenhagen. The necessary investments will be qualified in connection with execution of the first and second phases of the project with clarification of payment conditions and identification of options and needs. The project is a direct continuation of a project on re-establishment of the Harrestrup Å river and central government water plans. The project will require cooperation at all levels in the municipality.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Establishment of a cooperative project between the catchment municipalities. Clarification of payment conditions	Analysis of needs and options for retarding in the catchment	Detailed project planning and execution	Detailed project planning and execution	Detailed project planning and execution
Costs	DKK 0	DKK 200,000	DKK 0	DKK 0	DKK 0

The project is carried out by the Technical and Environmental Administration in cooperation with the Economic Administration, Copenhagen Energy and the catchment municipalities. It is partly financed through wastewater charges.

PROJECT: PASSING ON KNOWLEDGE TO THE PUBLIC/BUSINESSES ON OPTIONS FOR CLIMATE-PROOFING

The aim of the project is to provide information on how private individuals can climate-proof their own assets and TO inform them where they can seek advice.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Preparation of information material and implementation of action	-	-	-	-
Costs	DKK 100,000				

The project is carried out in cooperation between the Technical and Environmental Administration and Copenhagen Energy.

PROJECT: PLANNING AND IMPLEMENTATION OF PLAN B SOLUTIONS IN THE CITY OF COPENHAGEN

The aim of the project is to convey extreme rain on the surface to places where little damage—or no damage at all—occurs. It is to be clarified as one of the first things whether Plan B solutions are within or outside the legal framework of the utility company.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Clarification of whether Plan B can be carried out within wastewater plan				
Preliminary study of hot spots in the city	Complete plan for Plan B solutions in Copenhagen	Detailed project planning and execution	Detailed project planning and execution	Detailed project planning and execution	
Costs	DKK 200,000	DKK 300,000	Funded by charges	Funded by charges	Funded by charges

The project is to be carried out as a cross-cutting project in the Technical and Environmental Administration in cooperation with Copenhagen Energy and the Culture and Leisure Administration. Expenditure on implementation of Plan B is subject to great uncertainty, and depends among other things on how great a portion—if any—can be funded from charges.

PROJECT: OPENING OF PIPED WATERCOURSES

The aim of the project is to optimise the utilisation of the municipality's watercourse systems so that as much stormwater as possible can be removed taking account of the environmental conditions of the watercourse. The risk of floods in the river valleys is thus reduced.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Analysis of whether the hydraulic system of the watercourse system can be utilised for climate-proofing	Comprehensive plan for draining stormwater away through the watercourses under peak load	Detailed project planning and execution	Detail-projektering Detailed project planning and execution	Detailed project planning and execution
Costs	DKK 150,000	DKK 450,000	DKK 30 million	DKK 30 million	DKK 50 million

The project is to be carried out in the Technical and Environmental Administration. The expenditure on implementation is subject to great uncertainty.

PROJECT: DISCONNECTION OF STORMWATER FROM THE SEWER

The aim of the project is to climate-adapt the volume of wastewater conveyed to the sewer, and consequently reduce the likelihood of flooding in the city. A detailed project is to be carried out clarifying the legal situation regarding payment and identifying needs and options.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Clarification of legal situation concerning payment conditions, and identification of needs and options				
Preliminary investigation of hot spots in the city	Detailed project planning and execution	Detailed project planning and execution	Detailed project planning and execution	Detailed project planning and execution	
Costs	DKK 150,000	Funded from charges	Funded from charges	Funded from charges	Funded from charges

The project is to be carried out as a cross-cutting project in the Technical and Environmental Administration in cooperation with Copenhagen Energy. Expenditure on implementation is borne by Copenhagen Energy with resources funded by charges.

PROJECT: QUANTIFICATION OF THE EFFECT OF DIFFERENT SUDS ELEMENTS

The aim of the project is to bring about dimensioning conditions for the correct dimensional design of SUDS solutions and professionally qualified planning of the use of SUDS. There may be a literature study/gathering of experience and a practical study/trial of the effects, dimensional design, space requirements and prices of a large number of different SUDS elements.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Preliminary project where the SUDS elements to be quantified are selected. Design of test/ measurement programme				
Literature study/gathering of experience	Full-scale testing of different SUDS elements with measurement of effect	Full-scale testing of different SUDS elements with measurement of effect	Full-scale testing of different SUDS elements with measurement of effect		
Costs	DKK 300,000	Funded by charges	Funded by charges	Funded by charges	

The project is to be carried out by the Technical and Environmental Administration in cooperation with Copenhagen Energy.

PROJECT: COORDINATED WASTEWATER PLANNING IN THE WHOLE CATCHMENT OF LYNETTEFÆLLESSKABET

The aim of the project is to ensure optimal transport, storage and treatment of wastewater in the catchment of the Lynetten sewage treatment plant and the Damhusåen sewage treatment plant.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	City of Copenhagen takes initiative for co-operation to be introduced in the catchment municipalities	Planning initiated	Planning	Planning completed	
Costs	DKK 0	Funded by charges	Funded by charges	Funded by charges	

The project is to be carried out in cooperation with all the catchment municipalities in Lynettefællesskabet and their utility companies.

SEAWATER

PROJECT: SURVEYING OF COASTLINE

The aim of the project is to bring about accurate data on the coastal profile of the municipality in order to be able to assess in which areas there is a need for further coastal protection.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Description of task	Surveying	-	-	-
Costs	-	DKK 100,000	-	-	-

The project is carried out in cooperation between the Economic Administration and the Technical and Environmental Administration. The work is to be coordinated with the municipal planning work and the municipality's other activities relating to surveying and mapping. Funding is sought via the 2012 budget.

PROJECT: SELECTION OF INSTRUMENTS

The aim of the project is to make a decision on what instruments are to be used to protect the city against storm surges from the sea. Rapid implementation has high priority, as local plans and building permits in the areas at risk have to drawn up in accordance with the principles in this decision.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Political discussion on principle of protection against the sea	-	-	-	-
Costs	DKK 100,000	-	-	-	-

The project is carried out in cooperation between the Economic Administration and the Technical and Environmental Administration. A recommendation for a decision is to be drawn up on the basis of an assessment of what overarching options there are for protecting the city against storm surges from the sea. A number of technical solutions are to be assessed more closely.

Based on the decision in principle, an investigation is made of technical and economic consequences in connection with implementation of the project.

WARMING

PROJECT: MEASUREMENT OF TEMPERATURE

The aim of the project is to map the temperature conditions in Copenhagen and measure the trend in temperature conditions at street level.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY					
Costs	DKK 0	DKK 200,000	DKK 50,000	DKK 50,000	DKK 50,000

Measurements of temperatures at street level are performed at existing measuring stations for air quality etc. supplemented by new measuring stations. The project is carried out in the Technical and Environmental Administration.

PROJECT: BALANCING OF THE CITY'S SURFACE TEMPERATURE

The aim of the project is to assess the size of green spaces necessary to climate-adapt the city.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY		Model calculations			
Costs		DKK 350,000			

Model calculations etc. showing how green Copenhagen has to be to even out and balance the city's future surface temperature. The project is carried out in the Technical and Environmental Administration.

SOIL AND GROUNDWATER

PROJECT: RISK OF INFILTRATION TO THE DRINKING WATER RESOURCE

The aim of the project is to analyse the long-term options for extracting drinking water in the municipalities of Frederiksberg and Copenhagen.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY					
Costs		DKK 75,000			

When the sea level rises and the total formation of groundwater is reduced, there will be a shift in the balance between sea water and groundwater and between fresh and saline groundwater. It will be relevant to take a closer look at what changes will take place in the longer term, particularly in relation to the possibility of maintaining the present-day extraction of drinking water that takes place in the municipalities of Copenhagen and Frederiksberg.

The project is carried out in cooperation between the municipalities of Frederiksberg and Copenhagen and the respective utility companies.

PROJECT: CALCULATIONS OF EFFECTS OF INCREASED INFILTRATION OF STORMWATER
The aim of the project is to shed light on the possibilities and effects of local infiltration of stormwater.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Detailed calculations				
Costs	DKK 75,000				

The municipality has an objective of increased infiltration of stormwater. Increased infiltration will lead to increased formation of groundwater. There is a need for calculations of the possibilities for and effects of increased local infiltration. Calculations are initially made of the overall effect on groundwater formation of full implementation of the targets for local infiltration. More detailed calculations should subsequently be made of the local options for infiltration in selected areas.

The project is carried out by the Technical and Environmental Administration.

PROJECT: POSSIBILITY OF PUTTING SURPLUS SOIL TO USE IN CLIMATE ADAPTATION
The aim of the project is to study how surplus soil from projects in the municipality can be used as well as possible as a local resource.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Description of options for and problems with passing on soil from source to practical application				
Costs	DKK 50,000				

Building projects etc. in the municipality result in large volumes of surplus soil annually. The soil may be clean or slightly to severely polluted and has to be disposed of in accordance with the roles applicable to landfilling of soil. It is energy-demanding and expensive to transport soil. At the same time, the climate plan points to needs for terrain elevation and for the construction of dikes.

The project is carried out by the Technical and Environmental Administration.

PROJECT: MONITORING OF GROUNDWATER LEVEL

The aim of the project is to generate knowledge on development in the groundwater level.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Localisation and where appropriate new establishment of bearing points in primary and second groundwater reservoir. Position-finding and drawing of maps				
Costs	DKK 150,000				

The project is carried out by the Technical and Environmental Administration.

GREENER CITY

PROJECT: PLANTING STRATEGY

The aim of the project is to draw up a strategy for new planning that is adapted to the climate of the future.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY			Implementation of research and monitoring		
Costs			DKK 400,000		

Specific research, monitoring etc. to select species that thrive, cool and support biodiversity in the city. The project is carried out in cooperation between research institutions and the Technical and Environmental Administration.

PROJECT: GREEN AND BLUE STRUCTURE PLAN

The aim of the project is to draw up a plan for practical blue and green measures that coordinate action in relation to wastewater and recreational interests etc.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Preparation of plan	Preparation of plan			
Costs	DKK 250,000	DKK 250,000			

Based on the climate adaptation plan and wastewater plan, a specific comprehensive plan is prepared that reconciles climate adaptation concerns with recreational and local conditions. The project is carried out by the Technical and Environmental Administration and the Culture and Leisure Administration.

PROJECT: WATERING SYSTEMS FOR TREES AND GREEN SPACES
The aim of the project is to develop a sustainable watering system.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY		Development of watering system			
Costs		Dkk 500,000			

Development of cost-effective and sustainable watering systems with stormwater. The project is carried out in cooperation between the Technical and Environmental Administration, the Culture and Leisure Administration and where appropriate in cooperation between Copenhagen Energy, relevant research institutions and business partners.

BUILDINGS

PROJECT: REGISTRATION OF BUILDINGS IN AREAS AT RISK
The aim of the project is to register the current safety of buildings in relation to climate change, and to issue an action plan. The need for investment in connection with climate adaptation of the municipal properties is to be analysed.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Description of task	Registration and mapping			
Costs	-	DKK 100,000			

The project is carried out in cooperation between the Technical and Environmental Administration and the Culture and Leisure Administration. The work is to be coordinated with the municipal plan work and the municipality's other activities relating to surveying and mapping.

PROJECT: UPGRADING OF QUALIFICATIONS/TRAINING
The aim of the project is to draw up guidelines and a syllabus/material for municipal employees with relevant contacts with the public, with a view to ensuring basic knowledge of the significance of climate change and options for public action.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Description of task	Preparation of teaching material and holding of 1st round of instruction	-	-	-
Costs	-	DKK 200,000	-	-	-

The project is carried out in cooperation with the Technical and Environmental Administration and Københavns Ejendomme (Copenhagen Properties).

EMERGENCY PREPAREDNESS

PROJECT: WARNING SYSTEMS
The aim of the project is to ensure a better warning time for extreme weather events.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Establishment of warning system	Establishment of warning system	Establishment of warning system		
Costs	DKK 100,000				

A broader and safer system is to be established to warn of extreme weather events. Including a local weather radar for Copenhagen, which will be able to provide more reliable warning of extreme rain and consequently the possibility of a more targeted response by the emergency services.

The project is carried out in cooperation between the Economic Administration, Copenhagen Energy and the Technical and Environmental Administration.

GREEN GROWTH

PROJECT: UTILISATION OF GROWTH POTENTIAL IN CLIMATE ADAPTATION
The aim of the project is to provide inspiration for a comprehensive solution for the management of stormwater in urban areas.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY					
Costs	DKK 250,000				

Competitive tendering on management of the stormwater of the future in an urban context.

Development of comprehensive and sustainable solutions. The project is concerned with developing technical and designed solutions of high quality, where advisers and businesses are invited to take part in the development project.

FINANCING OF MEASURES

PROJECT: FINANCING MODELS FOR CLIMATE ADAPTATION

The aim of the project is to describe methods of financing major climate adaptation activities with long timeframes.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Description of the task	Model for financing and cost distribution	Model for financing and cost distribution	Model for financing and cost distribution	
Costs		DKK 1.5 million	DKK 1.0 million	DKK 0.5 million	

The project is carried out in cooperation between the Economic Administration and the Technical and Environmental Administration.

PROJECT: DEVELOPMENT OF DECISION SUPPORT TOOL

The aim of the project is to develop methods to support decision-making on long-term investments in climate adaptation

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Participation in project	Participation in project	Participation in project	Participation in project	
Costs	DKK 0	DKK 0	DKK 0	DKK 0	

The project is carried out in cooperation between the Technical and Environmental Administration, the National Environmental Research Institute of Denmark, DHI, the Technical University of Denmark etc. The project is to improve the descriptions and management of the uncertainties and provide a better framework for making decisions about climate adaptation measures have to be taken in practice.

PILOT PROJECT FOR CLIMATE ADAPTATION

PROJECT: PILOT PROJECT FOR CLIMATE ADAPTATION

The aim of the project is to climate-adapt an area of housing in the existing city with a view to demonstrating opportunities and limitations on implementation. Experience from the project can be used in connection with climate adaptation in the rest of the city.

YEAR	2011	2012	2013	2014	2015 →
ACTIVITY	Designation of project area and preparation of project	Implementation of project	Implementation of project	Completion and evaluation	
Costs	-	DKK 15 million	DKK 15 million	15 million	

A demonstration project with an international format that is to inspire and profile the city and provide experience for climate adaptation of the remaining part of the city. Method development for discussion of green growth. The project is carried out in cooperation between the City of Copenhagen, Copenhagen Energy, a housing company, insurance companies, central government, research institutions.

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