TECHNICAL TRANSACTIONS 11/2018
ARCHITECTURE AND URBAN PLANNING
DOI: 10.4467/2353737XCT.18.159.9415
SUBMISSION OF THE FINAL VERSION: 28/10/2018

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Forecasted climate changes and their influence on cities and regions in 2050 in terms of extreme hydrological events

Prognozowane zmiany klimatyczne i ich wpływ na miasta i regiony w 2050 roku w kontekście ekstremalnych zjawisk hydrologicznych

Abstract

Global climate change is a problem which arises numerous theories and uncertainties, especially in terms of speculated human impact. Independent from the fact, what is the main driver for the changes, some of the climate shifts are visible already nowadays. Both contemporary and future cities will have to face such problems. Although climate change may cause numerous effects on different fields, a special stress in this article is laid on hydrological events – which are possible to observe even in these days. The purpose of this article is to indicate the main approaches both to the issue of climate change and activities undertaken by cities in relation to hydrological threats.

Keywords: climate change, extreme weather events

Streszczenie

Kwestia zmian klimatycznych jest tematem, wokół którego narastają liczne teorie i niepewności, w szczególności odnośnie spekulowanego wpływu antropogenicznego. Niezależnie od tego, co jest ich główną przyczyną, niektóre z prognozowanych zmian można już zaobserwować współcześnie. Pomimo że skutki zmian klimatycznych można obserwować na wielu polach, w tym artykule nacisk położony jest na ekstremalne hydrologiczne zjawiska klimatyczne, których narastanie można zaobserwować już w chwili obecnej. Miasta, zarówno obecnie, jak i w przyszłości, będą się musiały z tego typu problemami zmierzyć. Celem tego artykułu jest wskazanie głównych podejść zarówno do kwestii zmian klimatycznych, jak i działań podejmowanych przez miasta w związku ze zmieniającym się klimatem i zagrożeniami hydrologicznymi.

Słowa kluczowe: zmiany klimatyczne, ekstremalne zjawiska pogodowe

1. Introduction

Global climate change and its consequences are becoming today's most pressing issue. Despite numerous international investigations, the exact mechanism of their occurrence is ambiguous and accordingly, universal climate change adaptation strategies have not yet been developed. The cities and regions are especially vulnerable in terms the factor of water.

Numerous investigations conducted by NASA [9] and other organizations of International Climate Change Panel confirm the flux of our climate [1]. The scientists claim that since the 1950s the changes in the climate are extraordinary. The mean temperatures have risen what is visible in the atmosphere, ocean levels and melting glaciers. Given the complexity of climate no confident prediction about future global mean temperature or its impact can be made [1].

Nowadays the approach towards architecture and urban planning is based on the sustainable development rules which are understood as a proper balance between environmental, social and economic aspects. There are many approaches being developed to deal with climate change hazards, especially in terms of water, as they strongly influence the relation between water and city.

The aim of this article is to draw attention to urgent problems of climate change and extreme weather events in terms of water along with providing examples of possible approaches to the problem.

2. The evidence of global climate change and its characteristics

In terms of climate change and anthropogenic influence there are many often contradictory theories arising. Climate change as a complex topic, apart from scientific insight gained some interest of different groups dealing with it on daily basis.

We can distinguish three main groups of people dealing with the climate change problems: the scientists form IPCC (International Panel of Climate Change, organized by United Nations), the second group consisting of scientists called skeptics and the third group- politicians, environmentalists and media. According to scientists from IPCC, climate change is caused by burning fossil fuels like oil, coal and natural gas. Because of that the emission of CO_2 is arising and may dangerously heat the planet. This group also supports the view on anthropogenic influence of climate change [11].

As stated by second, sceptic group of scientists – there are many reasons why the climate changes – like sun position, cloud and ocean movements along with other numerous complex inputs. None of them is fully understood and there is no evidence that anthropogenic CO_2 emissions are the dominant factor in climate change. One of them is American atmospheric physicist known for his work in the dynamics of the middle atmosphere, retired professor from Massachusetts University of Technology, who regularly confirms his thesis on research articles and scientific books [7, 8].

For the third group global warming alarmism provides most favorable aspects – for politicians it is money and power whereas for environmentalists these are finances for their organizations and confirmation of their devotion to the idea that man is destructive force acting upon nature [11].

2.1. The acknowledged facts of climate change

Regardless of the fact if we agree on anthropogenic influence on climate change or not, there is some unquestionable information about it.

First of all, the climate has been always changing. The proof for this is visible on charts presenting climate changes since ages. Another fact is that CO_2 is a greenhouse gas without which life on earth is not possible, but increased concentration of it to atmosphere should lead to global warming. Atmospheric levels of CO_2 have been increasing since the middle ice-age. Apart from this, by 1800–2000 global mean temperature has increased slightly and erratically by 1°C*. But only since 1960s has man's greenhouse emissions been sufficient to play a role.

Given the complexity of climate no confident prediction about future global mean temperature or its impact can be made [11].

2.2. Forecasted climate changes – potential ways of climate shifts

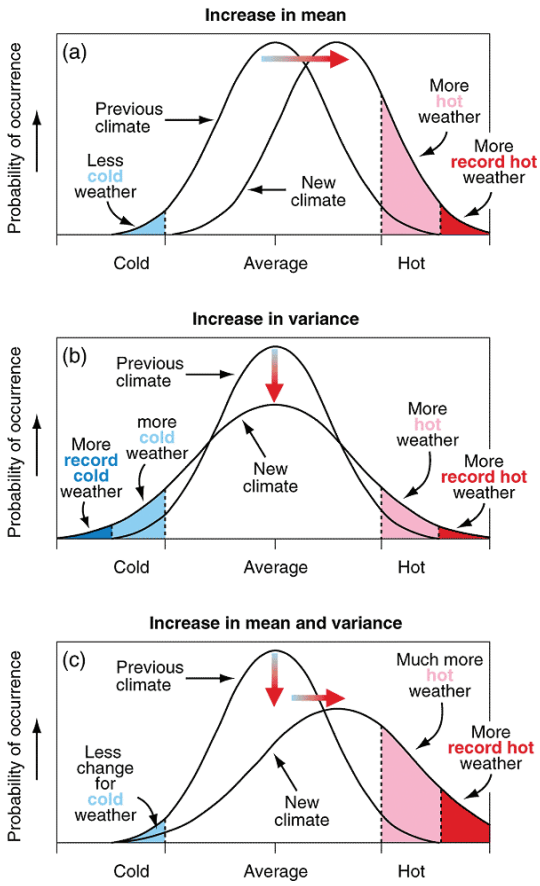

Fig. 1. Schematic presenting possible changes in climate and the effect on extreme temperatures (source: [3])

The schematic above is showing the effect on extreme temperatures. If considered potential climate changes, three different results can be expected. When for a normal distribution of temperature, the mean temperature increases it can lead to longer seasons (without transitional seasons), for example longer summer growing season and longer winter season almost without existence of autumn and spring. In the situation when the variance increases extreme weather events can grow i.e. extreme precipitation and droughts. There is also a possibility of growth both the mean and variance increase what can result in both in prolonging the seasons without transitional seasons and increase in extreme weather events [3].

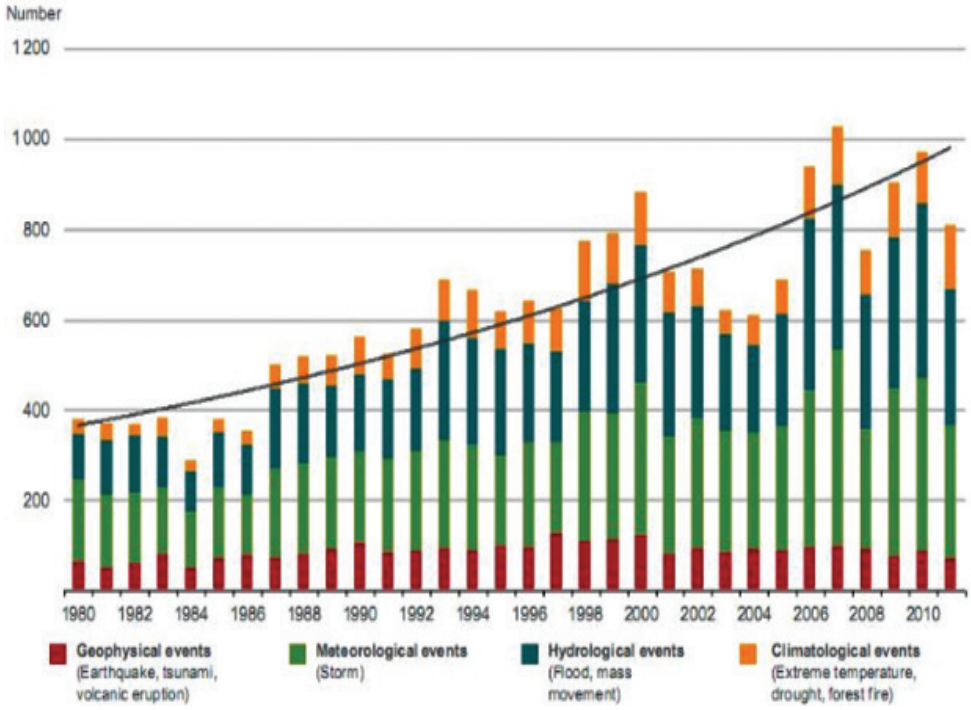

Fig. 2. Natural catastrophes worldwide 1980–2011. Number of events with trend (source: [16])

If we consider the natural catastrophes worldwide at the time 1980-2011 a tendency of a slight growth of natural catastrophes worldwide is observed (according to the chart [16]. The number of hydrological events grew remarkably).

3. The sustainability context of climate change

Contemporary approach towards planning involves attempts towards sustainable development – finding the right balance between social, economic and environmental issues. As one of the UN Habitat sustainable development goal climate action has been indicated, which confirms the significance of the problem and the need to undertake sever steps on regular basis.

3.1. Social aspects of climate change – the problem of awareness

It is important to note that, not only economic and ecological aspects play crucial role in terms of climate change. Not less important is the underestimated social factor.

At both the business and household levels information is needed about beliefs, knowledge and attitudes towards energy use, climate change science and policy, as well as current behaviors regarding energy use. Information is needed about strategies that will be most effective at encouraging households and businesses to reduce energy use. Information is also needed about strategies that will be most effective at helping households and businesses adapt to changes in climate.

At the community, local and state government levels research is needed to understand and measure communities' state of readiness for managing the impacts of climate change; how communities are currently affected by climate change; and how community design can be altered to better prepare communities for further climate change [30].

4. Cities and regions most threatened with climate change in 2050 in terms of hydrological events

Although climate change may cause numerous effects on different fields, a special stress in this article is laid on hydrological events – which are possible to observe even in these days.

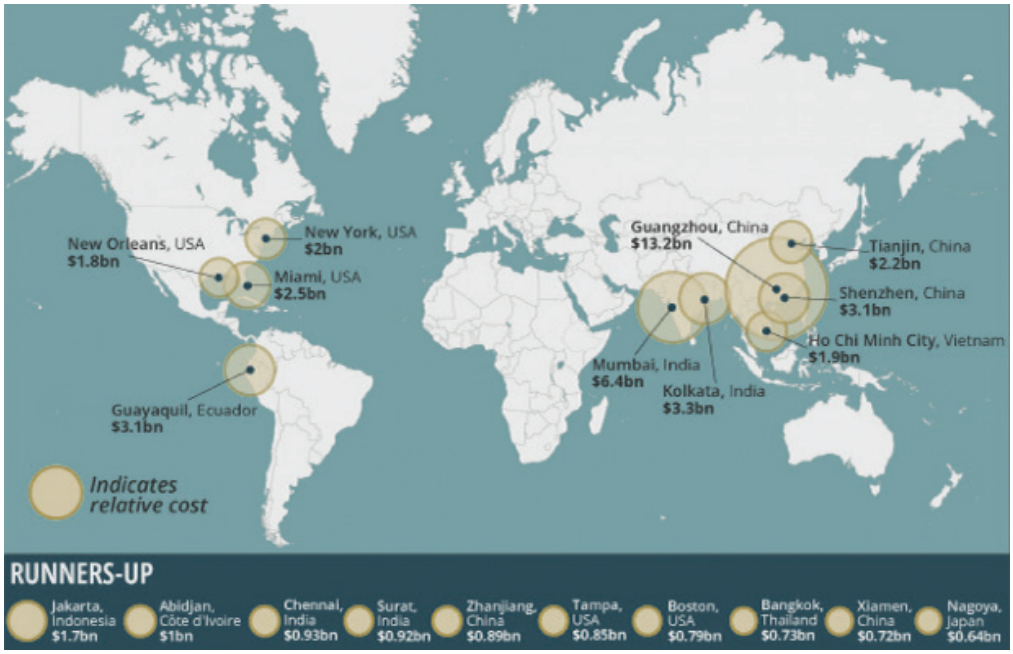

Fig. 3. Cities with the ten highest annual flood costs by 2050 (source: [2])

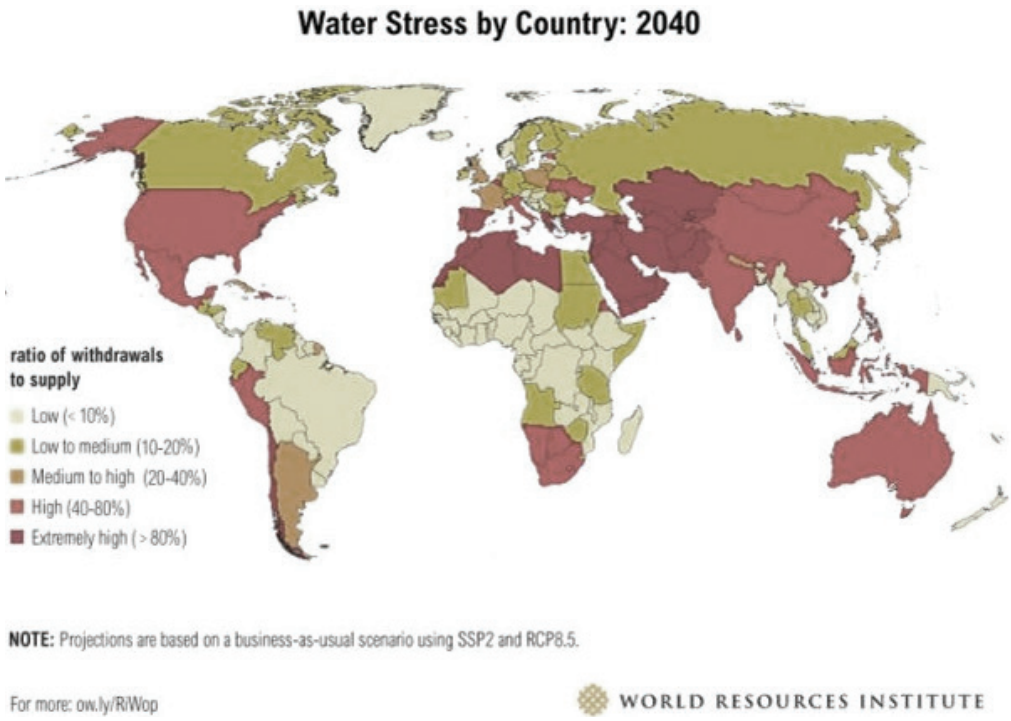

Fig. 4. Water Stress by Country 2040 (source: [5])

Fig. 5. Climate change impacts around the world (source: [15])

The map above presents cities with the ten highest annual flood costs by 2050. Most at risk are the safety and the economic development of communities in Small Island Developing States, Least Developed Countries, African countries, and other countries that have significant populations who are vulnerable to the impacts of climate change. The world's 136 largest cities could be facing annual flood losses of US $1 trillion (1,000,000,000,000$) by 2050 [5].

If we consider water stress by country 2040 [6], nearly 634 million people – one tenth of the global population – live in at-risk coastal areas, just a few meters above existing sea levels. Three quarters are located in Asian flood-prone densely-populated river deltas or in low-lying small island states.

Climate change has a remarkable impact specially on hydrological events such as: wildfires, species impact, floods, sea level rise, water stress, melting ice and crop changes. The changes can be observed around the whole world [15] It is also projected to increase the frequency and severity of climate-related hazards, such as: storms, extreme precipitation, flooding, sea-level rise, heat waves increase in the spread of vector borne diseases [10] This all leads to the conclusion, that severe actions at all levels need to be undertaken to deal with those issues.

Although Poland is not remarkably threatened with extreme hydrological events, an increase of some of the can be observed already in a form of extreme precipitations and floods. These are increasing in frequency in recent years.

5. Adaptation and mitigation strategies and actions of the cities and regions

Although the terms of climate adaptation strategy and contingency measures, solutions for climate change may seem similar it is important to distinguish between on the spot, contingency solutions which are just dealing with existing problems and long term adaptation strategies which are prevention of problems.

Fig. 6. schematic showing of possible approaches of cities towards climate change

5.1. Contingency measures for hydrological events caused by climate change

A few contingency measures can be differentiated in dealing with climate change in terms of water. If the need is to direct the water into desired direction, there are dikes or sandbags used. In terms of reduction of water masses these are usually rainwater retention basins. In order to collect rainwater, the water is used for building or watering the fields. An extreme solution, but still present is surrending from the effects: escape, move out from a certain location or even region.

5.2. Adaptation strategies for hydrological events caused by climate change

Both architectural and urban concepts can take into account the role of the climate factor in specific design solutions – adaptation strategies. Scientists around the world develop numerous strategies helping to deal with climate hazards like floods. One of the solution is green street storm water planter. This constitutes a typical adaptation strategy approach. Thanks to storm water Planter in Philadelphia the excess water can be quickly piped. While drought, the planted greenery prevents form excess heating. Green streets utilize green storm water infrastructure (GSI) to capture storm water at its (source and minimize the amount of pollutants that reach the river, and the many tributary streams within the city. Green streets are a key component of the City of Philadelphia's Green City, Clean Waters initiative, an innovative program to achieve federal water quality mandates by managing storm water from impervious surfaces citywide utilizing green storm water management practices [16]

Fig. 8. Storm water Management Practices, Philadelphia (source: [17]): A.Stormwater tree trench, B) Stormwater planter, C) Stormwater bumpout (midblock), D) Stormwater bumpout (corner), E) raingarden (corner) F) raingarden (large)

5.2.1. Stormwater management practices on the example of Philadelphia

The city of Philadelphia developed several stormwater management practcies configurations, which are visible on the pictures below. They shape an overlook of accessible and diverse methods avalaible for contemporary cities interested in in climate adaptation in terms of hydrological events. The methods developed by Philadelphia Water Department rely on bioinfiltration and bioretention processes. They consist of vegetated depressions or basins that use surface storage (such as vegetation, planting soil, outlet controls) and other components to treat, detain, and retain stormwater runoff. These practices enable reducing stormwater volume and pollution thanks to filtering runoff through a vegetated soil medium that promotes evapotranspiration. In terms of diversity, a variety of configurations can be distinguished from relatively large and open vegetated basins to small-scale configurations contained within flow-through planter boxes [18].

5.2.2. Amphibious house system

Another promising solution against flooding are amphibious houses. One of such solutions has been proposed by the architects from BACA. UK's first amphibious house developed by them is able to float on floodwater like a boat [15]. It has been designed on the flood-prone river island near Marlow in Buckinghamshire.

While floods the building can raise and float on the water with no damage to the structure itself. As floodwaters fill the fixed "dock" beneath the three-bedroom home, the water levels push the buoyant house upwards. The structure is attached to four guideposts that extend upwards and allow for a 2.5-meter-high floodwater clearance, to ensure that the home does not float away.

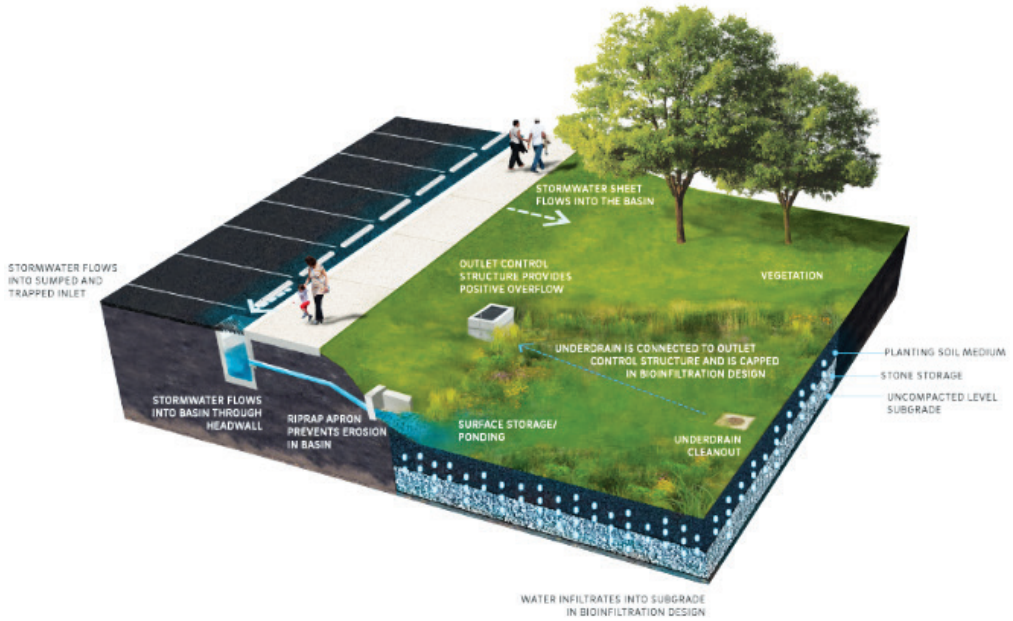

Fig. 9. Bioinfiltration/Bioretention Basin with Typical Features (source: [18])

Fig. 10. Flow-Through Planter Box with Typical Features (source: [18])

Coutts from baca architects explains that, the design was developed according to the Archimedes principle: "the house's mass and volume are less than the equivalent of water, and that's what creates buoyancy".

The form of the house is traditional, lightweight timber-framed structure. Inside the structure there is an excavated "wet dock" made from steel sheet piling with a mesh base to allow water to enter and escape naturally.

The structure of clad in zinc shingles with glazed gables structure is independent of the house. It faces a small garden, which slopes up from the edge of the river and is designed to provide an early warning of flooding.

Fig. 11. Site plan and view of amphibious house, BACA architects (source [19])

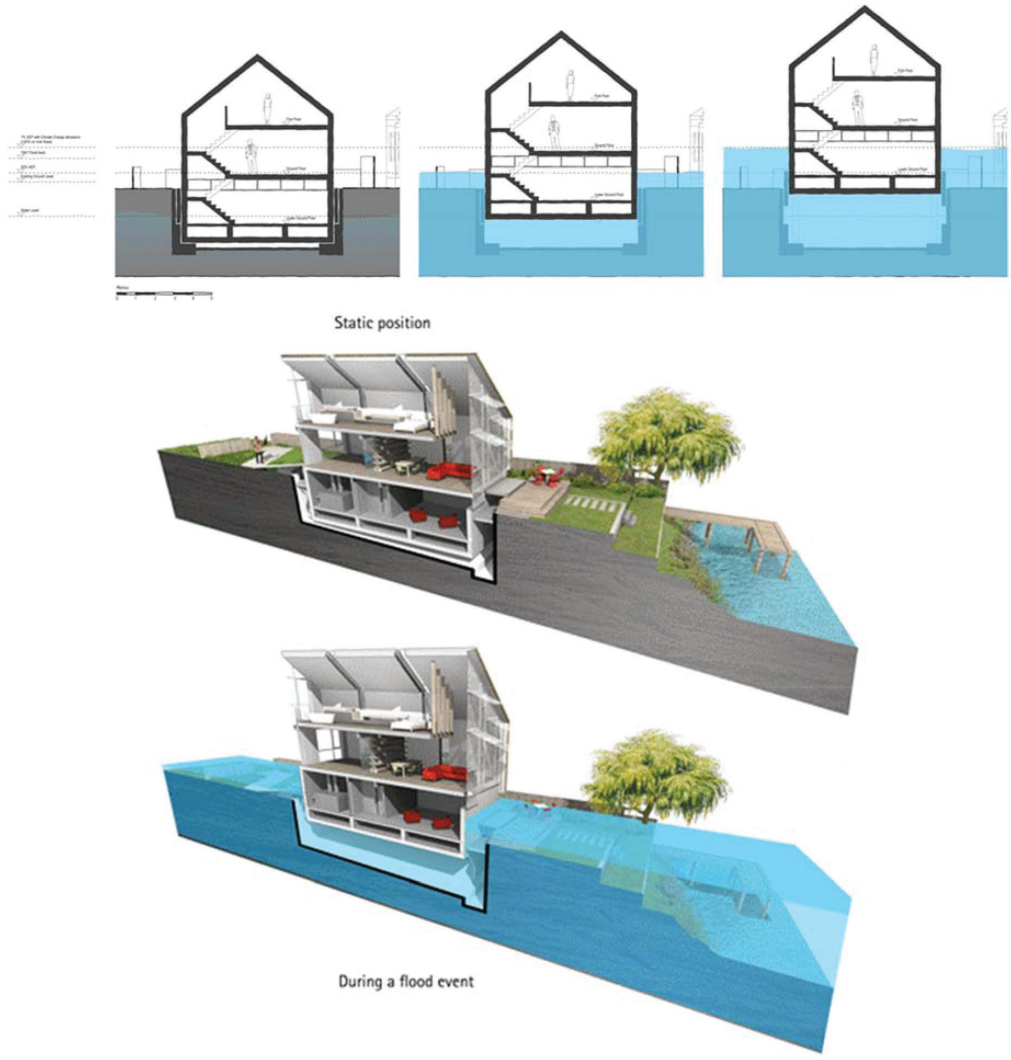

Fig. 12. Amphibious house at resting position and flood event (sources: [15, 19])

5.2.3. Shade balls

To prevent from evaporation consitently often the shade balls over water pool are being used. The plastic balls, which can save water and protect water quality, are an attempt to cope with severe droughts [14] The shade balls used in water basins threatened with droughts are made of high-density polyethylene (HDPE) with carbon black additive to protect the plastic from ultraviolet radiation. Adding carbon black also prevents the formation of bromate, which causes stomach problems when water contaminated with it is consumed.

Fig. 13. Shade Balls, California (source: [14])

It is predicted that the use of shade balls could save millions of gallons of water. This This rather new concept incorporates small, black, plastic balls floating on the water's surface. Their aim is to help reducing about 90 percent of the total evaporation and maintain respectable water quality. The balls have been successfully used in several locations during extreme droughts such as Ivanhoe Reservoir, the Elysian Reservoir or Upper Stone Canyon Reservoir. In each of those locations, the slowing of natural evaporation brought significant improvement.

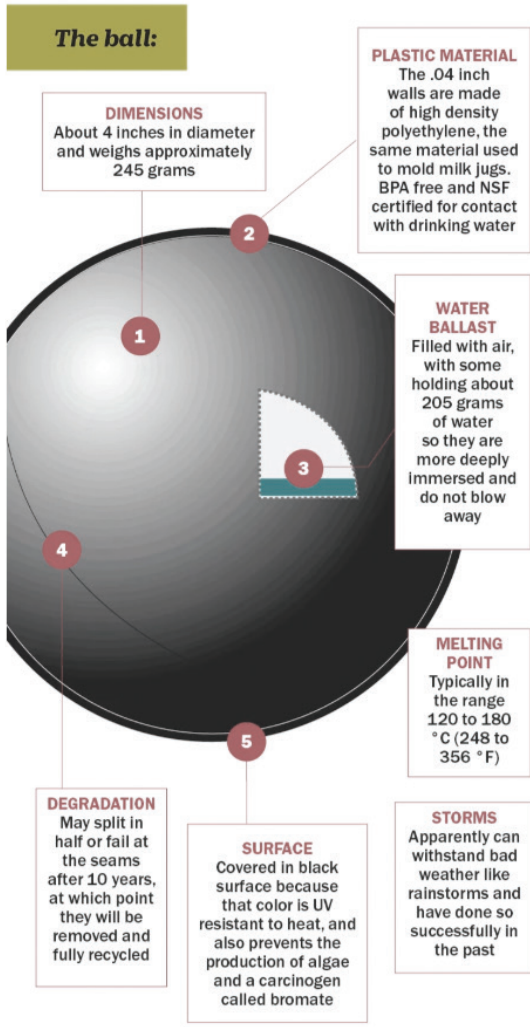

Fig. 14. Shade Balls, infographic- basic parameters (source: [21])

5.2.4. Flood–resistant garage on the example of Deggendorf, Germany

Another method of adaptation to climate change was developed in Germany by the Raumzeit office located in Berlin. It is a flood-resistant garage, located in Deggendorf in the South of Germany in the flood-prone location.

Fig. 15, 16. The view of flood–resistant garage (source: [22])

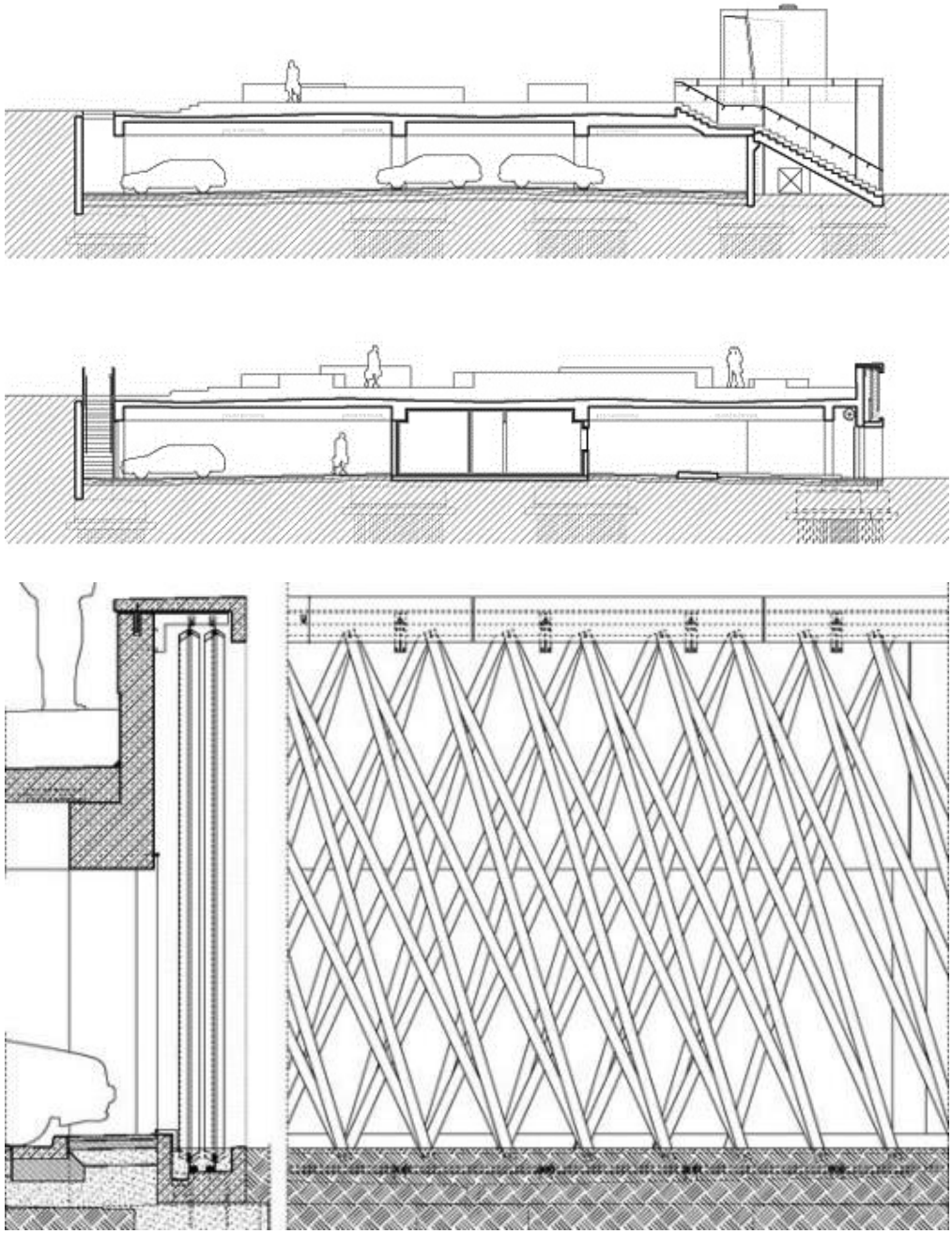

Fig. 17, 18. Flood–resistant garage – construction sections (source: [22])

The parking deck is conceived as an urban infrastructure in the landscape area: with a length of 345 meters, the building runs along the flood dike, passes under a federal highway and connects the city park with the new pedestrian bridge over the Danube.

The terrain slope along the flood dike is used to make it possible for the large volume of construction to disappear in the landscape. A new public park could thus be created on the roof of the parking deck: as show the so-called dike gardens, which have been designed by K1 Landschaftsarchitekten. With the green roof of the parking deck, the parking area is recovered in the long term as a landscape space.

The parking deck extends 330 meters along the flood dike and undercuts the highway. The facade in the direction of Ackerloh consists of green and yellow aluminum bars, which are arranged so that a wave pattern is created. Waves should also appear on the roof: There is currently a park landscape created with paths, flowerbeds and lawns in waveform – the so-called dike gardens. The 11,000 square meters become an integral part of the garden show grounds, which are protected from floods.

The ground-breaking ceremony for the dike parking deck took place on April 15, 2011, together with the official ground-breaking ceremony. About two years later, towards the end of April 2013, the dikes were almost completely poured out. And the view from one of the two-meter-high dikes already held at this time, which the concept has promised: The perspective on the exhibition contributions changes, the "real" flood dikes, which were relocated to give the Danube more room at high tide, are clearly visible with a small turn around its own axis.

Definitely, there are many more adaptation strategies against the mentioned factors, and the several strategies mentioned are just a tip of an iceberg showing the complexity of the problem. The researchers are still conducting new investigations and developing new ideas of how to successfully mitigate or adapt to climate change hazards.

6. Urban and regional adaptation strategies for hydrological events caused by climate change

In terms of developing urban resilience, the ability to deal effectively with current social, economic and ecological problems – like climate change hazards – there is a well-known initiative of 100 most resilient cities. As the approach to the sustainable development was insufficient in some cases, the concept of resilient cities was developed. Cities called resilient successfully faced not only the sustainability problems, but also developed their own strategy for dealing with alarming problems of our times like poverty, immigration or natural disasters.

There is an international competition where the cities can compete to become the most resilient ones, but they can also share the strategies. The aim of this is to help cities with building their resilience to the physical, social, and economic challenges that are a growing part of the 21st century. Cities in the 100RC network are provided with the re(sources necessary to develop a roadmap to resilience along main pathways [12].

Due to the complexity of the issues they are dealing with, only one of them will be mentioned, referring to various goals of sustainable development and as one of final effects solving also the problems related to climate problems.

However, it should be emphasized that there are numerous other crucial urban adaptation strategies and they can be an interesting basis for further considerations and inspirations for other cities.

The cities example show that climate change and extreme weather events can be treated as a driver for development rather than the (source of problem. An example for this the Danish city of Vejle, projected to be totally underwater in future years. With the help of experts and specialists it developed interesting strategy triggering the city development.

Water in Vejle is seen both as an asset and a challenge. As this city is designated as one of ten Danish risk areas where there is a significant flood risk due to rising sea levels, increasing rainfall and flooding. The assets which are most vulnerable to climate change, belong the harbour, the coastal area, the urban core and some of our infrastructure (small bridges and tunnels in west side urban core). Although the water and sewage system are not prepared for heavy rain and flooding, some of the energy transformer stations and communication

Fig. 19. 'Fjordbyen' in Vejle – prospective laboratory for water management (source: [23])

infrastructure in the city are also vulnerable to flooding, today the city has a well-functioning emergency response capability, as well as climate and risk management action plans

Vejle's assets and communities are threatened by flooding from the fjord. Therefore the main aim of the city is providing the city's edges to be safe and protected during storms and rising water levels.

There was a plan to use 'Fjordbyen' as a laboratory to improve water management by exploring innovative and integrated solutions such as retrofitting new public spaces. The aim is to encourage economic growth whilst reducing risk. This action is also included in the City Development Plan. Reductions the risk of flooding will be met by the city be means of following measures such as designing flood defenses to encourage investment, development and real estate value. Moreover, it was planned to use Østbykvarteret as a demonstration area where flood management interventions have a recreational and community value. Apart from this, there was also a plan of Protect the hinterland areas of the Grejs River by installing integrated flood solutions along the road infrastructure to decrease the waterflow.

The aim of Vejle was to show how small cities can solve big problems and show great responsibility, which can be a good- role model for other cities.

Along with Vejle there are numerous other cities dealing with extreme hydrological events in creative way (such as Rome, Singapore and others), treating them as a challenge and opportunity for future development. Their strategies, along with Vejle are available on the webpage of the organizers 100 resilient cities

7. Conclusions

The impact of global climate change on cities and regions is unequivocal. Climate change may have major and unpredictable effects on the extreme weather conditions and the results brought about. For these reasons the climate change needs to be properly respected in urban planning process.

Consequently, the importance of climate change in sustainable planning cannot be underestimated. While planning process the environmental factors and their changeability need to be seriously taken into consideration. Although, there are numerous strategies developed and implemented, particular problems following extreme hydrological events definitely need further investigation and profound insight in terms of mitigation and adaptation.

Moreover, one ideal solution or adaptation strategy for regions threatened with alarming environmental problems does not exist. Each area should be treated individually and requires distinctive approach. Definitely, new environmental challenges of the cities in the early 21st age require not only new technical and technological solutions, administrative in crisis planning or cost recalculation, but also of the new socio-ecological reflectivity and new empathetic urban policy.

The essay is limited to certain networks of relationships, draws attention to the particular processes, and the directions of research, that I suggest, require further thoughts and refine.

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