THE CLIMATE CHANGE ADAPTATION STRATEGY FOR THE CITY OF WARSAW BY 2030 WITH THE PROSPECTS UNTIL 2050

URBAN ADAPTATION PLAN

Project LIFE_ADAPTCITY_PL co-funded from the funds of the European Commission financial instrument LIFE+ and the National Fund for Environmental Protection and Water Management
The Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050 Urban Adaptation Plan has been developed through the concerted effort of Warsaw residents, entrepreneurs, representatives of various organisations, and the City of Warsaw authorities.

Warsaw, 4th July 2019
Dear Reader,

Climate change affects most European cities, including Warsaw. For the sake of residents’ safety, we must be prepared for extreme weather events, such as heat waves, droughts or heavy rains, which are more and more frequent. For this purpose, the Urban Adaptation Plan was created. The strategic document will set the directions for the spatial development and the budget of the city. It is not only a theory, but real actions that strengthen the city’s resilience. Implementation of the Plan will positively affect the quality of life of Warsaw residents - provide a sense of comfort and protect their health.

Can cities play an important role in the fight against global warming? Certainly Yes! It is important to invest in public transport, renewable energy sources, improve energy efficiency and air quality, greening the city and save water resources. Thinking about future steps, we all have to look through the climate lens and raise awareness. We also have to take care of nature, because we are a part of it.

Rafał Trzaskowski
Mayor of Warsaw
 CONTENTS

6 Introduction
9 1. Factors determining the preparation of the document
9 1.1. Formal considerations
9 1.2. Climatic conditions
14 2. Information about the document – works format
16 3. Diagnosis
16 3.1. Climate of Warsaw and its expected changes
22 3.2. TOWS Analysis
32 3.3. Priority areas
40 3.4. Adaptation options
45 4. Adaptation of Warsaw to climate change
45 4.1. Priority and rules
48 4.2. Lines of action
52 4.3. Advantages of taking action to adapt to climate change
53 5. Guidelines for implementing documents
53 5.1. Links to the Warsaw development programming documents
54 5.2. Links to the planning documents
55 5.3. Strategy implementation
57 5.4. Monitoring and evaluation
60 Glossary of terms
64 Bibliography
Big cities today are already experiencing the effects of the climate change which affect many aspects of their functioning. Intense urbanization and high population density, decrease in the share of biologically active area and hence reduced potential of rainwater retention, all that reinforces the consequences of these changes. On top of that, there are extreme weather events, such as heavy precipitation, rainstorms or floods. Heat waves and droughts cause a lot of material and immaterial damage and pose direct risk to human health and life.

The subject of climate change has been treated very seriously in Warsaw for many years. In 2008 the Climate Protection Team was appointed with one of the objectives: to inspire and launch activities mitigating climate change impacts by reduction of the emission of greenhouse gases, particularly, carbon dioxide. As a result of this action, in 2009 Warsaw joined the European initiative The Covenant of Mayors, and in 2011 Sustainable Energy Action Plan for Warsaw in the perspective of 2020\(^1\), and then in 2015, the Warsaw Low Carbon Economy Plan\(^2\) were adopted. The preparation of the Adaptation Strategy constitutes the next, natural step in the implementation of the City’s climate policy. This document sets the action lines consistent with the United Nations Sustainable Development Goals\(^3\), especially with Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable, and Goal 13 Take urgent action to combat climate change and its impacts.

The best tools of modern climatology – the hydrodynamic climate models - have been used to carry out the analyses and prepare forecasts concerning the climate changes that will take place in the Warsaw agglomeration in the 21st century. The results suggest that the climate in Warsaw will be significantly warmer in future. So much so, that it will transfer us all into a yet unknown climate zone. The temperature growth trends are visible in all the analysed thermal characteristics. The simulations also point to an increase in both average and maximum precipitation levels, while at the same time they do not forecast any substantial changes regarding periods without precipitation.

Therefore it has become necessary to assess which groups of residents and which sectors of the city life are exposed to climate change. Such an assessment makes it easier to take decisions about the lines of action and investment outlays which can prevent huge financial losses or threats to the life and health of the city residents. Public participation is one of the main success factors in the implementation of individual measures and in adapting them to the residents’ needs. It will also help to involve the residents, from the very beginning, in the protective actions, which will result in more rational and informed behaviour in case of threat and, in addition, will increase their safety. Finding the

\(^1\) The document adopted by a resolution of the Warsaw City Council No. XXII/443/2011 dated 8 September 2011
\(^2\) The document adopted by a resolution of the Warsaw City Council No. XXII/522/2015 dated 10 December 2015
\(^3\) More at http://www.un.org.pl/
right solutions will also have positive impact on various elements of the infrastructure thus improving the comfort of living in the city.

Climate change adaptation action entails substantial expenditure, which should be seen in relation to the level of losses incurred during undesirable weather events. With the awareness growing as a result of the availability of climate change forecasts, it is possible to undertake action to prevent or mitigate the negative impacts of climate change. Thus it is possible to avoid damage caused by extreme weather events whose cost would be disproportionately high compared to the cost of preventive action. It should also be noted that adaptation action creates a new market for innovative solutions, improving the standing of the city in Poland and in Europe. It is expected that, in the nearest future, there will be a significant increase in the use of funds for adaptation-related projects. The European Union, taking notice of this trend and the need for protection against the negative consequences of climate change, has included expenses related to such actions in its policies. This funding will only be available to the local government authorities that have the relevant strategic documents in place.

Adaptation and mitigation actions must be implemented simultaneously, while the resources available in the city must be used in a rational manner. Integration of those actions will help to improve the condition of the environment, the quality of the urban space and to raise the climate policy awareness of the city residents, thus influencing the quality of our life and that of the future generations.
1. FACTORS DETERMINING THE PREPARATION OF THE DOCUMENT

1.1. FORMAL CONSIDERATIONS

Climate Change Adaptation Strategy for the city of Warsaw is consistent with the EU commitments of Poland regarding adaptation to climate change. On 29 October 2013, the Council of Ministers adopted the document „Strategic adaptation plan for sectors and areas vulnerable to climate change by 2020 with the prospects until 2030“ (SPA 2020), which „... was prepared with the aim to provide conditions for stable social and economic development in the context of the risks posed by climate change, but also to take advantage of the positive effect that the adaptation actions may have not only on the condition of the environment in Poland, but also on the economic growth."

Since urban areas are the ones where negative impacts of the climate change will be the strongest, in January 2017 the Ministry of Environment launched a two-year project evaluating the vulnerability to climate change of the biggest Polish cities and planning adaptation measures appropriate to the identified threats, reflected in the Urban Adaptation Plan of individual cities.

Warsaw was not part of the ministerial project because the preparation of the documents programming the development of the city, taking into account the climate risk, had begun 2.5 years earlier. The project entitled „Preparation of a climate change adaptation strategy for the city of Warsaw, with the use of city climate mapping and with public participation“, in short, ADAPTCITY, of which this document is the most important deliverable, was launched on 1 July 2014.

1.2. CLIMATIC CONDITIONS

Climate change, that is, the process of climate warming, is already taking place and will continue. The forecasts of the Fifth Report of the Intergovernmental Panel on Climate Change - IPCC\(^5\)) show that Poland will experience the highest increase in temperature among the countries of our region - together with countries such as Sweden, Latvia and Lithuania. The occurrence of very high temperatures can increase the death rate, particularly in big cities, exposed to the so called urban heat island effect. In the period 1750 - 2013, the average annual temperature in Warsaw rose by almost 2\(^\circ\)C, and, according to the two climate change scenarios developed for the purpose of this report, by the end of the century, depending on the action taken, it can grow by 3.5\(^\circ\)C to 5\(^\circ\)C.

Both the findings of UN Intergovernmental Panel for Climate Change studies as well as the KLIMADA\(^6\) project, predict that Poland will experience a significant increase in the frequency/intensity of heat waves, occurrence of droughts, the number and intensity of floods, heavy rainfalls and strong winds. The analyses conducted for the purpose of this document have shown that Warsaw is exposed to the same threats. This is an important reason to undertake action to adapt to climate change.

---


\(^6\) KLIMADA Project “Development and implementation of the strategic adaptation plan for the sectors and areas vulnerable to climate change, coordinated by the Ministry of Environment; http://klimada.mos.gov.pl/
At the same time, the Special Report of the Intergovernmental Panel for Climate Change concerning the reduction of the global rise in temperature to 1.5°C emphasizes that at present, the level of global warming has risen by about 1°C compared to the pre-industrial era, while it is possible to avoid long-term and irreversible negative impacts of climate change by limiting the increase in the average global temperature to not more than 1.5°C. Any warming of the climate higher than 1.5°C increases the risk of long-term or irreversible changes. According to the report of the World Meteorological Organization, the year 2018 was one of the warmest years on record (that is, from the 19th century). In spite of the Agreement concluded at the Climate Summit in Paris in 2015, world greenhouse gas emissions are still growing (e.g., between 2017 and 2018 they increased by 1.6%), whereas according to the above mentioned Special Report, by 2030 they should fall by 45% compared to the 2010 levels.

With the continuing climate change, it is important to manage the climate risk properly. This is made possible by providing appropriate tools, especially to the local government. Such tools will help improve the adaptability of households, enterprises, public institutions, civil society organisations as well as individual residents. They will also help increase awareness, build up knowledge and share information and will influence the ability to implement measures that enhance the resilience of the city and its infrastructure, enabling it to avoid damage and to restore proper operation of the city functions, both with respect to the residents and the economy, if any negative consequences of climate change occur.

The most important objective of the measures adapting Warsaw to climate change is to improve the safety of its residents, exposed directly or indirectly to weather extremes and their effects. These measures should focus on protecting the city against the consequences of extreme weather events and on mitigating their impact, such as losses caused by flooding and heavy rains, increase in the mortality rate caused by heat waves, decline in the diversity of the ecosystems providing services to the city and its residents.

There are numerous analyses focusing on the economic rationale for adaptation to climate change. They all indicate that failure to take appropriate action will lead to the generation of inaction costs, that is, costs that may arise as a result of future damage, which will be considerably higher, both economically and socially, than the costs the adaptation measures.

According to the Green Paper on Insurance of Natural and Man-made Disaster in the initial period of adaptation, focused on management issues, one should expect growth in the economy and in employment. The second phase should contribute to the reduction of losses associated with extreme weather events. The third phase means a high rate of return on the investments made.

Adaptation to climate change is a process which definitely enhances the competitiveness of the city, improves the quality of life and healthcare, helps create attractive and safe spaces, improves the level of environmental protection and creates demand for modern technologies and jobs.

---

7 IPCC Special Report of 8 October 2018, on reducing the global temperature growth to 1.5°C, https://www.ipcc.ch/


2. INFORMATION ABOUT THE DOCUMENT – WORKS FORMAT

The city of Warsaw began the work on preparing the documents programming the development of the city while taking account of the climate risk, on 1 July 2014, with the accession to the ADAPTCITY project. The Project made it possible to have a number of expert analyses carried out and to secure the broad stakeholders' commitment. The structure of the document follows the guidelines of the Ministry of the Environment for preparing documents of this type.10

This document, the “Climate Change Adaptation Strategy for the city of Warsaw by 2030, with the prospects until 2050. Urban Adaptation Plan” defines the city’s policy aimed at preparing and adapting Warsaw to the progressing climate change.

---


11 The document plays the role of a policy document for the Strategy #Warszawa2030 and sets the rules and guidelines for the urban climate change adaptation programmes, in accordance with the Regulation No. 1868/2017 of the Mayor of Warsaw dated 5 December 2017 on introducing standard documents programming the development of the city of Warsaw.
The work on the Adaptation Strategy began with the Team working on the document getting acquainted with the good practices applied in Stuttgart, a partner of the ADAPTCITY Project. Drawing from the experience of the German partner, after conducting a number of studies and analyses, the Committee of Scientific Consultants developed the Warsaw Climatic Atlas. The work on the maps was conducted by scientists from the Faculty of Geography and Regional Studies of the Warsaw University, with the participation of the Warsaw University Interdisciplinary Centre of Mathematical Modelling. The Atlas comprises maps which provide a lot of valuable information, showing the threats that the city may face. They present the occurrence of various weather events in Warsaw in recent years, including precipitation, a rise in temperature, storms or strong winds, as well as a list of scenarios predicting what pattern they may form as a result of climate change by the end of the 21st century. They show the risk of the occurrence of heat waves, harsh frosts, severe precipitation, heat island effects appearing in different places in the city.

The development of the Adaptation Strategy has been a multistage process, conducted with the broad participation of the public. The document is the effect of the cooperation between the residents of Warsaw, representatives of civil society organisations, entrepreneurs, a team of scientists and experts and the city authorities. The participation process began in September 2016, when the first of six meetings of the Warsaw Round Table for Adaptation to Climate Change (WOSAK) was held. WOSAK’s work was completed in January 2017 with the drafting of the Assumptions to the Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050. That document was the subject of public consultation conducted between February and June 2017. The problems related to climate change were discussed with the residents of the city at 18 meetings and during outdoor family picnics. Groups of professionals were also invited to debate (teachers, healthcare sector, services responsible for security and crisis management and the institutions in charge of the broadly understood water management) as were City Bureaus and organisational units of the Warsaw City Hall. This activity resulted in the preparation of the document “Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050. Urban Adaptation Plan”, submitted to the people of Warsaw for consultation in February-March 2019.

After collecting the opinions and examining the list of problems, the final draft of the Adaptation Strategy was prepared, taking account of the entirety of the issues related to adapting Warsaw to climate change. The document describes the main threats resulting from climate change and the related risk areas that may affect Warsaw and its residents. It also proposes the lines of action needed to protect us against the negative impacts of the climate change-related phenomena.

---

12 The maps are available at mapa.um.warszawa.pl
13 The report on the WOSAK work available on adaptcity.pl
14 http://adaptcity.pl/pobrania/publikacje/
15 The report on public consultations concerning the assumptions to the Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050 available on konsultacje.um.warszawa.pl
16 The report on public consultations concerning the document “Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050. Urban Adaptation Plan” available on konsultacje.um.warszawa.pl
3. DIAGNOSIS

3.1. CLIMATE OF WARSAW AND ITS EXPECTED CHANGES

The geographical location makes the climate of Warsaw a result of the combined impact of humid and mild sea air, dry and harsh continental air and icy cold Arctic air or hot Mediterranean air (transitional climate). This means that these four different air masses move over the city, changing with great frequency, and as a result, the weather is extremely variable.

Throughout almost entire 20th century, the climatic conditions of Warsaw were the following:

• The average annual temperature for individual years in this period ranged from 7°C to 8°C. Within a year, the lowest temperatures were noted in January, the highest – in July. The average number of hot days during the year (with average temperature above 25°C) was about 40.

• The annual precipitation was approx. 520 mm, the highest monthly precipitation was noted in July, the lowest – in February.

• Snow coverage was present for 50 to 60 days in a year with 33 freezing days (average temperature below 0°C).

• Average wind speed in the city was approx. 4 m/s.

![Fig. 2 Average temperature in Warsaw in the period 1750 – 2013 and possible change scenarios](image)

1 10-year moving average with probability 95%
Based on:

**Moderate scenario**, labelled as RCP 4.5, that is, representative GHGs concentration pathway (RPC) leading to radiative forcing (an alteration in the radiative equilibrium in the Earth’s atmosphere connected with a distortion in the climate system) at the level of 4.5 W/m². For such a scenario to occur it will be necessary to reduce the use of energy, to halt the changes in land use, to increase the share of forested areas and deploy carbon capture and storage technologies.

**High concentration scenario** labelled as RCP8.5 that is, representative GHGs concentration pathway (RPC) leading to radiative forcing (an alteration in the radiative equilibrium in the Earth’s atmosphere connected with a distortion in the climate system) at the level of 8.5 W/m². This “business as usual” scenario means that nothing will change in the functioning of the city. The population will increase significantly while the income will rise relatively slowly, changes in technology and improvement of energy efficiency will be rather modest, leading, in the long term, to high demand for energy and high emission of greenhouse gases not accompanied by any policy addressing climate change.

Already at the end of the 20th century and at the beginning of the 21st century these conditions have changed. The following has been observed since the 1990s:

• An increase in the average annual temperature. The average annual temperature in the city has already exceeded 8°C and in the central parts of the city – even 10°C. The increase in temperature can be blamed on both, the so called urban heat island effect and the global climate warming.

• Shorter periods with snow coverage and a greater number of hot days. A decrease in the number of freezing days has not been observed. There have been more sudden and heavy rainfalls in the summer.

The observations and studies conducted in the years 1981 – 2014 have made it possible to describe the key phenomena connected with climate which have negative impact on the city and its residents.

1. Increase in air temperature and thus an increase in the number and intensity of very hot days.

In the period 1981 – 2014, an annual increase was observed in the number of hot days and tropical nights (according to the scenarios applied by the IPCC, adapted for the purpose of assessing the changes in the climate of Warsaw, this increase will be progressing (Fig. 3., Fig. 4.). This leads to a greater demand for cooling in summer and therefore potential shortage of energy, possible deterioration of air quality (occurrence of smog in summer - photochemical smog), deepening of the urban heat island effect (Fig. 5.), increased demand for water or direct threat to the lives of the residents. Those most vulnerable to the risks associated with high air temperature and solar exposure are mainly elderly people (over 65 years of age), young children, people suffering from respiratory system and cardio-vascular diseases, people with disabilities, especially with reduced mobility, as well as the homeless.
Fig. 4. Number of tropical nights in Warsaw 2008 – 2014 and forecasted by 2090 according to the moderate scenario of temperature increase

Source: Compiled by Kinga Nelken, on the basis of climate change scenarios for the city of Warsaw in the 21st century.

Fig. 5. Average annual air temperature in Warsaw in the years 2008 – 2014 and the temperature forecasts by 2090 under the moderate scenario of temperature increase

Source: Compiled by Kinga Nelken, on the basis of climate change scenarios for the city of Warsaw in the 21st century.
2. Increase in the frequency and intensity of precipitation causing local flooding

The period under analysis, the years 1981 - 2013 was marked by a statistically significant increase in annual precipitation, mainly in the southern part of Warsaw. The number of days with high precipitation (above 10 mm of water/m²) increased and growing single rainfall levels (over 90 mm of water/m²) were observed. It is expected that this trend, according to the climate change scenarios for the city, will continue. First of all, the number of short-time rainfalls with high intensity, causing local flooding will grow (Fig. 6., Fig. 7.). This will lead not only to transport difficulties but will also pose a threat to property and lives of the people who will find themselves within the reach of the quickly rising waters.

Fig. 6. Forecasted annual precipitation by 2090
Source: Compiled by Paweł Milewski, on the basis of climate change scenarios for the city of Warsaw in the 21st century.

Fig. 7. Forecasted annual precipitation by 2090 according to the extreme climate change scenario.
Source: Compiled by Paweł Milewski, on the basis of climate change scenarios for the city of Warsaw in the 21st century.
3. Increase in the intensity and scale of flooding or drought

In the years 2008 - 2014, in Warsaw, dry periods prevailed, but the rainy periods occurring between them had unprecedented intense nature. According to forecasts, we should expect an increase in the frequency of extreme events such as floods. The above is confirmed by the results of the KLIMADA project, which concludes that as a result of climate change, in the coming years, the number of floods will increase.

In 2010, the flood wave moved through Warsaw twice in rapid succession (in May and June). Another similar event, albeit on a smaller scale, took place in 2012. The levees along the Vistula River protect the city from a 1-in-100 year flood wave (Table 1). It is, however, anticipated that such flooding might occur more than once in a century, although the anticipation is based on historical data, and not only on analyses of future climate changes. Locally, also smaller water courses within the city limits may pose a threat, such as Bródnowski Canal, the Długa River or the Służewiecki Brook, whose swelling waters can be even more troublesome because of the increasing scale of single extreme rainfalls.

Table 1. Flood risks in Warsaw by districts

<table>
<thead>
<tr>
<th>Districts that can potentially be flooded</th>
<th>Number of people living in the areas that can potentially be exposed to flooding in case of a flood from the Vistula River</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-in-10-year flood Probability of occurrence – once in 10 years</td>
</tr>
<tr>
<td></td>
<td>p=10%</td>
</tr>
<tr>
<td>Right bank</td>
<td>103 787</td>
</tr>
<tr>
<td>Wawer</td>
<td>2 428</td>
</tr>
<tr>
<td>Praga Pd.</td>
<td>83 772</td>
</tr>
<tr>
<td>Praga Pn.</td>
<td>1 399</td>
</tr>
<tr>
<td>Rembertów</td>
<td>0</td>
</tr>
<tr>
<td>Targówek</td>
<td>0</td>
</tr>
<tr>
<td>Białołęka</td>
<td>16 188</td>
</tr>
<tr>
<td><strong>Left bank</strong></td>
<td><strong>7 061</strong></td>
</tr>
<tr>
<td>Wilanów</td>
<td>907</td>
</tr>
<tr>
<td>Mokotów</td>
<td>4 318</td>
</tr>
<tr>
<td>Śródmieście</td>
<td>0</td>
</tr>
<tr>
<td>Żolibórz</td>
<td>208</td>
</tr>
<tr>
<td>Bielany</td>
<td>1628</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>110 848</strong></td>
</tr>
</tbody>
</table>

Source: Zasięg zalewów dolinowych Wisły w gorsecie warszawskim. Witold Jaworski, Michał Marcinkowski, Artur Magnuszewski 2005
4. Increased intensity of storms and strong winds

The number of days with strong wind and the average wind speed throughout the year decreased in the years 1981 - 2013. However, isolated episodes of hurricane wind in the city led to ever more dangerous effects. They had been brought by increasingly deeper low-pressure systems flowing over Poland from the Atlantic. Combined with violent storms, strong wind always brought serious negative impacts on the city: disruptions of power supply, fallen trees, disruptions in transport services as well as fatalities. At present, there are no reliable predictions as to changes in the intensity of storms and strong winds by the end of the 21st century. Some positive phenomena that may occur as a result of the predicted climate change should also be brought to attention.

Higher air temperature, both within the urban heat island and as a result of the overall change of the climate may lead to the following:

- Decrease in the number of days with snowfall and thus to shortening the periods with snow cover,
- Extending the plant growing season,
- Shortening of the heating period.

However, it must be remembered that the threats resulting from climate change are disproportionately higher than the benefits.
3.2. **TOWS ANALYSIS**

The diagnosis of the status of climate change and Warsaw’s options to adapt to them has the structure of TOWS analysis, while its individual elements bear their own names derived from the nature of the conducted analyses.

First, the **Exposure Analysis** was performed, which constituted the Analysis of climate threats. Further analyses were conducted only with reference to the threats identified at this stage. Opportunities (that is, reduction of the scale of the threats), resulting from the exposure analysis, were taken into account only at the stage of developing the actions on the basis of the entire analysis.

---

20 The English abbreviation SWOT reads as: Strengths, Weaknesses, Opportunities, Threats. The SWOT analysis is carried out by analysing the factors described by the letters of the acronym, from the strengths through to threats. TOWS means an analysis of the same elements carried out in the reversed order, from threats through to strengths.

21 Names of the analyses have been adopted following the Podręcznik adaptacji dla miast – wytyczne do przygotowania Miejskiego Planu Adaptacji do zmian klimatu, Ministerstwo Środowiska, 2014 [Adaptation Manual for Cities – guideline for preparing an Urban Climate Change Adaptation Plan, Ministry of Environment 2014].
During the **Vulnerability Analysis**, based on the assessment of the potential occurrence of negative and positive impacts on the city (people, built-up areas including technical infrastructure and the natural environment, together with green and blue infrastructure) as a result of climate change threats (flood events, flooding, heat waves, droughts, violent storms, strong winds), the vulnerability of the city to climate change was estimated.

This was followed by the **Adaptability Analysis**, which assessed the characteristics of the city and the actions that the urban community can take or is prepared to take in case of extreme weather events and other negative effects of climate change, which consequently help to withstand these adverse phenomena.

The next step was the **Susceptibility Analysis** - analysis of interdependencies between elements of the TOWS analysis. In particular, this analysis sought answers to the questions of how adaptability affects the reduction of vulnerability (resilience assessment) and how the scale of climate threats affects the city’s resilience level (susceptibility assessment). The extent to which the city is unable to cope with the negative impacts of climate change or seize the opportunities associated with climate change has been determined. Susceptibility is a function of the type, intensity, scale and speed of the changes to which a city is exposed, its vulnerability and adaptability.

**Fig. 8. Names and sequence of the analyses carried out for the purposes of the Climate Change Adaptation Strategy for the city of Warsaw shown on the TOWS analysis diagram**

Source: Authors’ own compilation.
3.2.1. Exposure Analysis
(analysis of climate threats and opportunities)

In the analysis of the city’s exposure, a number of climate factors have been taken into account, analysed on the basis of data from the years 1981 – 2014, including the following:

- Average air temperature,
- Extreme above-zero temperature,
- Extreme sub-zero temperature,
- Solar radiation,
- Annual precipitation,
- Heavy rainfalls,
- Snowfall and snow buildup,
- Humidity,
- Average wind speed,
- Maximum wind speed,
- Tornadoes and whirlwinds,
- Storms (lightning),
- Drought,
- Floods,
- Growing season,

and the current level of exposure has been determined using a three-grade scale: high, medium, low.

Possible directions of changes in these climate factors were analysed, taking into account the analysis of climate change scenarios for Warsaw. The trend of the change had an impact on the raising or lowering of the current assessment.
## Exposure to climatic factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Scale of phenomenon</th>
<th>Probability of occurrence during a year – so far</th>
<th>Exposure so far</th>
<th>Climate change by 2050</th>
<th>Future exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average air temperature</td>
<td>8,6-8,8 °C</td>
<td>n/a, whole year</td>
<td>Low</td>
<td>Increase by 1-2 °C</td>
<td>Low</td>
</tr>
<tr>
<td>Annual precipitation</td>
<td>520-540mm</td>
<td>n/a, whole year</td>
<td>Low</td>
<td>Increase by 3-5%</td>
<td>Low</td>
</tr>
<tr>
<td>Average wind speed</td>
<td>4,3-4,4 m/s</td>
<td>n/a, whole year</td>
<td>Low</td>
<td>Lower average speed</td>
<td>Low</td>
</tr>
<tr>
<td>Humidity</td>
<td>78-80%</td>
<td>n/a, whole year</td>
<td>Low</td>
<td>No change or decrease</td>
<td>Low</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>1600-1700 hours</td>
<td>18-19%</td>
<td>Low</td>
<td>No change or decrease</td>
<td>Low</td>
</tr>
<tr>
<td>Tornadoes and whirlwinds</td>
<td>0</td>
<td>&lt;1%</td>
<td>Low</td>
<td>No change</td>
<td>Low</td>
</tr>
<tr>
<td>Plant growing season</td>
<td>210-220 days</td>
<td>60%</td>
<td>Low</td>
<td>Extension by 10-20 days</td>
<td>Low</td>
</tr>
<tr>
<td>Extreme above-zero temperature</td>
<td>&gt;30 oC approx. 7 days per year</td>
<td>2%</td>
<td>Medium</td>
<td>Increase by 2-4 days</td>
<td>High</td>
</tr>
<tr>
<td>Extreme sub-zero temperature</td>
<td>&lt; -10 oC, 14 days per year</td>
<td>4%</td>
<td>Medium</td>
<td>Decrease by 5-10 days</td>
<td>Low</td>
</tr>
<tr>
<td>Heavy rainfall</td>
<td>Heavy rainfall above 10mm approx. 13 days per year</td>
<td>3,50%</td>
<td>Medium</td>
<td>Increase by 7-8 days, higher maximum level of precipitation</td>
<td>High</td>
</tr>
<tr>
<td>Snowfall and snow buildup</td>
<td>50 to 60 days per year with snow coverage</td>
<td>15% (snow coverage)</td>
<td>Medium</td>
<td>Fewer days with snow coverage</td>
<td>Low</td>
</tr>
<tr>
<td>Drought</td>
<td>Dry periods exceeding 20 days - 2 times a year</td>
<td>10-11%</td>
<td>Medium</td>
<td>No change in no. of days</td>
<td>Medium</td>
</tr>
<tr>
<td>Maximum wind speed</td>
<td>Wind speed &gt;10m/s</td>
<td>do 30%</td>
<td>Medium</td>
<td>No change or slight decrease</td>
<td>Medium</td>
</tr>
<tr>
<td>Storms (lightning)</td>
<td>Number of storms per year – approx. 30</td>
<td>8%</td>
<td>Low</td>
<td>Increase in number and strength</td>
<td>Low</td>
</tr>
<tr>
<td>Floods</td>
<td>1-in-100, 1-in-500 or 1-in-1000-year flood</td>
<td>1%</td>
<td>High</td>
<td>Increase in number</td>
<td>High</td>
</tr>
</tbody>
</table>

Source: Authors’ own compilation.
### HIGH AND MEDIUM EXPOSURE

Future high exposure for the following climate factors:

- **extreme above-zero temperature** – the period in which such temperatures occur may significantly extend, increasing the number of events such as very hot days, tropical nights and the related negative effects on people’s health;
- heavy rainfalls – both the volume of a single rainfall may increase as well as the number of days with high precipitation which have so far caused severe losses in the city because of flooding;
- floods – there may be an increase in the number of events involving high water level in the Vistula River or its tributaries located within the city limits; the high water level may increase further.

Future medium exposure for the following climate factors:

- **droughts (dry periods)** – the length of periods without precipitation may remain the same but the severity of droughts will increase because of the increasing average and maximum air temperatures and the variability of the precipitation characteristics;
- **strong wind** – episodes of strong wind have so far brought seasonal problems for the functioning of the city; this should essentially not change, the strength of the wind and the number of strong wind periods should not change, either.

### LOW EXPOSURE

For the following climate factors the exposure will fall to low:

- extreme sub-zero temperatures – the current medium exposure of the city has been replaced with low exposure in this respect because the number of such days may decrease even by half, below the number of days with extreme above-zero temperature;
- snowfall and snow build-up – the current medium level of exposure has been replaced with low exposure in this respect, because together with the decrease in the number of days with low temperature, the number of snowfalls and the period with snow coverage will decrease from several dozen to just several days in a year.

Further analyses take into account the climate threats to which the city’s exposure will be medium or high.
3.2.2. Analysis of vulnerability and adaptability

The analyses focus on the city characteristics from the point of view of climate change, namely its vulnerability and adaptability\(^{22}\). Vulnerability is a set of city’s weaknesses, adaptability is its strength. Their assessment has been based on the assumption that a specific climate threat identified in the exposure analysis occurs.

During the works, a set of climate maps of Warsaw was prepared, presenting both the diversity of the city's climate components as well as the elements related to its vulnerability\(^{23}\).

A number of city’s features have impact on its vulnerability to climate change and its adaptation capability. Starting from the location, which is determined by the natural factors, from the landform features, the character of the natural vegetation, through the quality of soils or geological formations to be found in the ground, the quality of hydrographic (river) network, to man-made factors such as density, height and other properties of buildings, availability of municipal infrastructure, modifications to the terrain, plant cover, hydrographic network and others. The man himself, or rather the features of the population living in a given city, is also an element of the city’s vulnerability. These may be people who are well informed, aware of the risks and acting responsibly in the face of a threat, or those who are unaware and unable to cope with crisis situations.

In order to assess these two elements which constitute Warsaw’s specific characteristics in the face of climate change, i.e. its vulnerability and adaptability, the most important facts about the city were reviewed and divided into strengths demonstrating the adaptability of Warsaw and weaknesses demonstrating its vulnerability.


\(^{23}\) More to be found on the website adaptcity.pl and in section ADAPTCITY on the website mapa.um.warszawa.pl
Then, the strengths and the weaknesses were analysed by sector:

- human health and healthcare system,
- crisis management system
- public awareness,
- transport and communications,
- buildings and other enclosed structures,
- agriculture and forestry,
- Warsaw’s nature system,
- energy sector,
- water and wastewater management,
- waste management.

<table>
<thead>
<tr>
<th>HIGH VULNERABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The highest vulnerability</strong> has been identified for the following sectors:</td>
</tr>
<tr>
<td>- health, buildings and network facilities, nature system and energy sector (energy supply) – in case of heat waves;</td>
</tr>
<tr>
<td>- public awareness, transport and communications infrastructure, buildings and water management – in case of heavy rainfall events (flooding);</td>
</tr>
<tr>
<td>- crisis management, transport and communications as well as buildings and network facilities – in case of floods;</td>
</tr>
<tr>
<td>- public awareness and agriculture and forestry as well as the city’s nature system – in case of drought;</td>
</tr>
<tr>
<td>- public awareness, crisis management system and the city’s nature system – in case of strong winds.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HIGH ADAPTABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The highest level of adaptability</strong> has been identified for the following sectors:</td>
</tr>
<tr>
<td>- transport and communications, the city’s nature system and the energy sector – in case of heat waves;</td>
</tr>
<tr>
<td>- health, agriculture and forestry, the city’s nature system and waste management – in case of flooding;</td>
</tr>
<tr>
<td>- crisis management, buildings and network facilities, nature system and water management – in case of floods;</td>
</tr>
<tr>
<td>- human health, crisis management and the energy sector – in case of drought;</td>
</tr>
<tr>
<td>- construction sector and network facilities – in case of strong winds.</td>
</tr>
</tbody>
</table>
3.2.3. Susceptibility Analysis

The next step was to show the interdependencies between the elements of the climate change TOWS analysis carried out for Warsaw. It is not sufficient to determine the level of adaptability and vulnerability in case of threat for selected sectors. It is also required to examine to what extent the sectors’ adaptability reduces their vulnerability level and then how these factors depend on the actual scale of climate threats. Revealing these interdependencies is the subject of the susceptibility analysis.

Resilience assessment

The first part of the susceptibility analysis is the resilience assessment. Resilience is the difference between the vulnerability and the adaptability assessments. The resilience was low when high vulnerability was linked with low or medium adaptability. The resilience was described as medium when the levels vulnerability and adaptability were similar. The resilience was assessed as high when the level of adaptability was much higher than vulnerability.

In order to create proper conditions for adapting Warsaw to climate change it is necessary to increase the city’s adaptability and to reduce its vulnerability to the threats in the sectors where the diagnosis indicated low resilience.

<table>
<thead>
<tr>
<th>RESILIENCE ASSESSMENT LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>The low resilience diagnosis has been given for the following sectors:</td>
</tr>
<tr>
<td>• public awareness – with respect to high temperatures, rainfall and floods;</td>
</tr>
<tr>
<td>• transport and communications – with respect to rainfall, floods and strong winds;</td>
</tr>
<tr>
<td>• construction sector – with respect to high temperatures, rainfall and floods;</td>
</tr>
<tr>
<td>• nature system – in case of high temperatures, drought and strong winds;</td>
</tr>
<tr>
<td>• health and crisis management – in case of high temperatures;</td>
</tr>
<tr>
<td>• water and wastewater management – in case of heavy precipitation;</td>
</tr>
<tr>
<td>• agriculture and forestry – in case of drought.</td>
</tr>
</tbody>
</table>
In order to produce an overall assessment related to the adaptation of Warsaw to climate change, the relationship between the city’s exposure to climate change (threats) and its resilience (strengths and weaknesses) was analysed for individual sectors. These interdependencies constitute the susceptibility assessment.

The susceptibility assessment is a function of resilience assessment and exposure assessment. Susceptibility is high where high exposure coincides with low or medium resilience to a given threat. Susceptibility is described as medium if the exposure to a threat is at medium level and the resilience is medium or high. Susceptibility is low when the exposure level is low and resilience is high.

The susceptibility assessment for Warsaw has been made with respect to the threats the exposure to which has been assessed as medium (strong winds and drought) or high (floods, extreme temperature levels and rainfall). As a result of the analyses it has been established that for Warsaw to be able to adapt to climate change it is necessary to increase its resilience in the sectors where susceptibility to a given threat has been assessed as high.

<table>
<thead>
<tr>
<th>SUSCEPTIBILITY ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIGH</strong></td>
</tr>
</tbody>
</table>

The high susceptibility diagnosis has been given for the following sectors:

- residents’ awareness, transport and communications and construction sector – with respect to high temperatures, rainfall, floods and strong winds;
- nature system – with respect to high temperatures, floods, drought and strong winds;
- agriculture and forestry – in case of high temperatures, drought, precipitation and strong winds;
- crisis management – with respect to high temperature, rainfall and floods;
- health and energy sector – with respect to high temperatures, floods and strong winds;
- water and wastewater management – in case of floods and rainfall.
3.2.4. Risk Analysis

In the process of adapting Warsaw to climate change it is necessary to build the resilience to the identified threats, in particular for the sectors with high susceptibility. In order to ensure that the resilience is developed in a responsible manner, a risk analysis has been carried out to determine the scale and the probability of the negative impacts that the identified threats may bring. The analysis has shown which adaptation measures should be undertaken in the first place so as to avoid the most probable negative effects. Prevention and protection of the city against the most probable impacts should be treated as the most urgent, priority issue to address.

During the work, the sectors where divided into the following areas:

- Human life and health – sectors: healthcare system, crisis management and public awareness;
- Elements of technical infrastructure – sectors: construction, transport and communications;
- Green and blue infrastructure – sectors: agriculture and forestry and the Warsaw’s nature system;
- Supplies of utilities for the city – sectors: energy, water management, waste management

For these areas the analysis was conducted concerning 5 most important threats identified during the exposure analysis, that is, heatwaves, flooding, flood events, droughts and strong winds.

<table>
<thead>
<tr>
<th>THE HIGHEST PROBABILITY IS ASSOCIATED WITH THE FOLLOWING THREAT IMPACTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Higher mortality or damage to health suffered by a number of people as a result of heatwaves;</td>
</tr>
<tr>
<td>• Single deaths and people harmed as a result of strong winds;</td>
</tr>
<tr>
<td>• Area-specific disruptions to the functioning of technical infrastructure and disruptions in utilities supply as a result of floods;</td>
</tr>
<tr>
<td>• Technical infrastructure failures as a result of heatwaves, flooding or strong winds;</td>
</tr>
<tr>
<td>• Spot damage to green infrastructure or small damage in larger areas of the city as a result of flood, drought or strong winds;</td>
</tr>
<tr>
<td>• Small spot damage to green and blue infrastructure as a result of flooding.</td>
</tr>
</tbody>
</table>
3.3. PRIORITY AREAS

Risk analysis by sector is not sufficient for a city covering a large area, such as Warsaw. It has been established that threats significant in one part of the city are not so important in another part. This applies, for instance, to the flood risk which covers about 25% of Warsaw’s area whereas on the remaining area it is not very significant. It is expected that part of the adaptation measures will have to be implemented as a reaction to or protection against specific impacts occurring as a result of flooding, flood risk or occurrence of urban heat island effect. The risk analysis has been conducted on the basis of the assessment of the key climate change threats, thermal and hydrological (Fig. 9).

Figure 9. Today’s climate threats for Warsaw

The threats are spatially diversified, which is connected with density of development, landform, distance from water courses, etc. The biggest threats appear in densely built-up areas, situated relatively close to the Vistula riverbed – in the southern part of Praga-Północ and in the western part of Praga-Południe, in Żoliborz as well as in the eastern part of Mokotów, where there is a synergy between thermal and hydrological threats (mainly flood-related). The second area with high scale climate threats is Green Ursynów (the area west of the Puławska Street and the edge of the Kabaty Woods up to the border of the district), where hydrological threat is related to the risk of flooding after heavy rains and springtime snowmelt. The Vistula river valley stands out as an area of high hydrological threat but low thermal threat, which is connected with the impact of surface water on the local climate, reducing the thermal contrasts.

In the western districts (Bemowo, Wola, Bielany, Włochy) there are small areas with high thermal threat (resulting from the high influx of solar energy converted into heat, the so called active surface) and low level of hydrological threat. In the districts with lower density of development and substantial share of green areas (part of Wawer, Wesoła, Białoleka) there are moderate climate threats, connected with the relatively low albedo of the active surface and no significant hydrological threat. More than 25% of the area of Warsaw lies within the zone of high thermal threat and moderate hydrological threat (for instance Targówek, northern part of Praga-Północ, Śródmieście, Ochota, Wola, Mokotów,

---

The studies prepared for the purposes of the ADAPTCITY Project made it possible to carry out an overall assessment of the scale of thermal and hydrological threats. For each threat three classes were distinguished. Their combination resulted in showing the cumulative threat on a five-grade scale, from the highest to the very low threat. The list of studies used to make this assessment is included in the Bibliography.
Ursus). The thermal threat is connected mainly with the type of land cover and high temperature of the active surface; the hydrological threat – with the risk of local flooding as a result of heavy rainfall events. The areas with low climate threats are situated mainly on the outskirts of the city suburbs, surrounded by green spaces, with low-rise and dispersed development.

Taking into account the basic information about the exposure to climate threats\(^{25}\) and the combination of thermal and hydrological threats, it is possible to describe the climate threat exposure by districts, divided into five groups.

\(^{25}\) 14 types of climate threat information were analysed: impermeability, density of development, share of built-up and urbanized areas, albedo, greenspaces quality indicator, average temperature, coverage with biologically active surfaces, flood risk, number of warm nights, threat of local flooding, periods without precipitation, increase in the number of housing units, urban heat island effect and the share of greenspaces and forests. Then, an integrated classification was prepared for individual districts, dividing the climate threat into five categories, from the highest to the lowest.
I. GROUP WITH MODERATE CLIMATE THREAT (194.9 KM², 37.7% OF THE CITY AREA).

This Group includes the following districts: Wesoła, Rembertów, Wawer and Białołęka.

Wesoła

This is a district with a substantial share of green spaces and forests. No significant increase in the number of housing units is foreseen in these areas by 2030. At present and in future there are and will be a lot of permeable areas and the density of development is and will be low. The biggest threat is and will be posed by heavy rains that may cause local flooding. The district is situated outside the Warsaw’s urban heat island. However, the fact that it is surrounded by coniferous forests, often growing on sandy soil, may be conducive to local, significant rise in temperature. The occurrence of at least two-week periods without rain that is twice as frequent in this district as in other parts of the city, may lead to plant wilting as well as to breakouts and spreading of dangerous forest fires.

Rembertów

This is a district with a substantial share of green spaces and forests. No significant increase in the number of housing units is foreseen in these areas by 2030. At present and in future there are and will be a lot of permeable areas and the density of development is and will be low, although slightly higher than in the Wesoła district. The biggest threat is posed by heavy rains that may cause local flooding. The district is situated outside the Warsaw’s urban heat island. However, the fact that it is surrounded by coniferous forests, often growing on sandy soil, may be conducive to local, significant rise in temperature. The occurrence of at least two-week periods without rain that is twice as frequent in this district as in other parts of the city, may lead to plant wilting and breakouts and spreading of dangerous forest fires.

Wawer

In the Wawer district, the situation is similar to that in the districts of Wesoła and Rembertów, that is, green spaces and forests play an important role and the development of housing units (by 2030) is foreseen at a moderate level. At present as in future, there are and there will be a lot of permeable areas, the density of development is low and it may become moderate in future. The source of the biggest threat are heavy rains that may cause local flooding. Long periods without rain are typical for the Wawer area, whereas the rainfalls, when they occur, are intense. In addition, part of the district, including the built-up areas, is at risk of flooding from the Vistula River. The district is situated outside the Warsaw’s urban heat island. However, the fact that it is surrounded by coniferous forests, often growing on sandy soil, may be conducive to local, significant rise in temperature. At the same time, the occurrence of at least two-week periods without rain that is twice as frequent in this district as in other parts of the city, may lead to plant wilting and breakouts and spreading of dangerous forest fires.
Białołęka

The situation in the Białołęka district, where at present the threats are low, may change in future (by 2030), because of the forecasted intensive development of housing units, which may lead to significant increase of climate threat. First of all, as a result of the higher development density and the growth of impermeable area, the risk of local flooding will be greater. Currently, the biggest threat for Białołęka is flood on the Vistula River which may inundate a significant part of housing estates in Tarchomin and Nowodwory as well as those located further away from the river, towards Annopol and Brzeziny. Because of heavy rainfall, local watercourses such as the Długa River may also be a threat. The Białołęka district, currently classified within the group with moderate threat, may in future be shifted to the group of significant threat.

II. GROUP WITH SIGNIFICANT CLIMATE THREAT (112.8 KM2, I.E. 21.8% OF THE CITY AREA).

This Group includes the following districts: Ursynów, Wilanów and Bielany.

Ursynów

This is a district with a smaller area covered by green spaces and forests (compared to Group I) and with forecasted significant increase in the number of housing units by 2030, which in future may lead to higher climate threat. First of all, as a result of increased density of development and greater impermeable area the risk of local flooding will grow. In the northern part of Ursynów, the urban heat island effect exists. Some surfaces covered with concrete may heat up to more than 40° C. What is particularly tiring for the residents is the occurrence of hot nights with temperature above 20°C, which do not allow people to rest and recover. The large area of the Kabaty Woods has some heat mitigating impact. In the southern part of Ursynów there is a high threat of heavy rains which often result in local flooding.

Wilanów

This is a district which, similarly to Ursynów, has fewer green spaces and forests (compared to Group I) and where significant increase in the number of housing units is forecasted by 2030. In future this may lead to higher climate threat, such as locally higher temperatures (local heat island) or to local flooding due to increased development density and larger impermeable area. In case of a catastrophic flood on the Vistula River, a substantial part of Wilanów may be flooded with a water column 2-3 m high. The district is also exposed to heavy rainfall. The risk is aggravated by the rising water of local watercourses, e.g. Potok Służewiecki, following heavy rains. Wilanów is situated outside the Warsaw’s urban heat island.

Bielany

Green spaces and forests play a great role in the Bielany district, but in spite of that, the district lies on the border of the Warsaw urban heat island. What is particularly tiring for the residents is the
occurrence of hot nights with temperature above 20°C, which do not allow people to rest and recover. In future, the situation may change for the worse because of the significant increase in the number of housing units forecasted by 2030, which will increase the climate threat. First of all, as a result of the growth in development density and larger impermeable area, the risk of local flooding will grow. Green spaces constitute an important element in the district’s water management. They help to significantly delay the drainage of water after a heavy rain and by “retaining” water during hot periods, they substantially reduce the level of heat felt. The parts of Bielany district bordering the Vistula River are at risk of inundation during a flood event. These include mainly the Bielański Forest and the Młociński Forest.

III. GROUP WITH STRONG CLIMATE THREAT (87.2 KM2, I.E. 16.8% OF THE CITY AREA).

This group includes the following districts: Targówek, Bemowo, Włochy and Ursus.

**Targówek**

In this group, Targówek is the district with the lowest climate threat, where an important role is played by green spaces and forests, but this may change as a result of the significant development of housing units by 2030. First of all, as a result of the growth in development density and larger impermeable area, the risk of local flooding will increase. The most troublesome effect for the residents of Targówek, and especially Zacięsze, may be local flooding following a heavy rainfall. Heavy rains also pose a risk of flood from local canals, especially the Bródnowski Canal. The district is situated within the limits of the Warsaw urban heat island and, as a consequence of the housing development, the heat island effect may intensify. Particularly tiring for the residents are hot nights with temperature above 20°C, which do not allow people to rest and recover.

**Bemowo**

The situation in Bemowo is similar to Targówek, although the role of green spaces and forests is less significant. For the residents of Bemowo the most troublesome weather events are heatwaves. The district is situated on the border of the Warsaw heat island, which may extend and intensify as a result of the significant increase in the number of housing units forecasted by the year 2030. The areas covered tightly with concrete may heat up even to 40°C. Particularly tiring for the residents are hot nights with temperature above 20°C, which do not allow people to rest and recover. Thick greenery in housing estates as well as the numerous parks and squares help reduce the nuisance caused by these phenomena.

**Włochy**

This is a district with a small share of green spaces and forests. An increase in the number of housing units is forecasted by 2030. Heatwaves are the weather event most troublesome for the residents. The district is situated on the border of the Warsaw’s urban heat island. With the high sun exposure, the vast areas covered with warehouses and storage spaces heat up even above 40°C.
Particularly tiring for the residents are hot nights with temperature above 20°C, which do not allow people to rest and recover. Heavy rains cause serious problems leading to a threat of local flooding. Most of the rainwater drainage systems are based on absorbing wells which are not able to absorb huge amounts of water in a short time during an above-average rainfall event.

**Ursus**

The Ursus district, similarly to the Włochy district, has a low percentage of green spaces and forests and by 2030 an increase in the number of housing units is forecasted. This may contribute to extension and intensification of the Warsaw’s urban heat island effect, which is already present within the limits of the district. Some spaces in the post-industrial areas heat up to more than 40°C during hot weather. Particularly tiring for the residents are hot nights with temperature above 20°C, which do not allow people to rest and recover. In Ursus there is a high threat of heavy rains which may cause local flooding.

**IV. GROUP WITH HIGH CLIMATE THREAT (53.6 KM², I.E. 10.4% OF THE CITY AREA).**

This group includes the following districts: Mokotów, Żoliborz and Ochota.

**Mokotów**

The Mokotów district's exposure to negative impacts of climate change and extreme weather events varies. The Upper Mokotów lies within the limits of the Warsaw’s urban heat island and therefore heatwaves may be the most troublesome for the residents there. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. In future, Mokotów may be in a difficult situation because of the little role played by green spaces and forests and the forecasted significant increase in the number of housing units by 2030. First of all, as a result of the growing density of development and larger impermeable area, the risk of local flooding will grow. Floods pose the greatest threat to Lower Mokotów. In case of a catastrophic flood on the Vistula River, almost the entire area may be flooded with a water column 2-3 m high. The threat is aggravated by the rising water of local watercourses, e.g. Potok Służewiecki, following heavy rains.

**Żoliborz**

For the residents of the Żoliborz district the most troublesome may be the heatwave events. The district is situated on the border of the Warsaw urban heat island. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. Thick greenery at the housing estates as well as numerous parks and squares help to reduce the nuisance caused by these phenomena. Żoliborz is a district with high percentage of impermeable areas. In future, Żoliborz, similarly to Mokotów, may find itself in a difficult situation because of the significant increase in the number of housing units by 2030. It is the area with the heaviest short-term rainfalls which lead to local flooding.
Ochota

Ochota is situated in the centre of the Warsaw urban heat island, therefore heatwaves may be the most troublesome phenomenon for the residents. During the hottest days the temperature in Ochota may be 6 degrees higher than outside the city. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. Ochota is a district with high percentage of impermeable areas, which cover more than 70% of the district’s surface. Such a situation aggravates the heat and contributes to excessive accumulation of rainwater in undesirable places on the surface, leading to local flooding. In future the situation may deteriorate because of the little role played by green spaces and forests and the forecasted significant growth in the number of housing units by 2030.

V. GROUP WITH THE HIGHEST CLIMATE THREAT (68.7 KM2, I.E. 13.3% OF THE CITY AREA).

This group includes the following districts: Praga-Południe, Praga-Północ, Wola and Śródmieście.

Praga-Południe

The Praga-Południe district, and especially Saska Kępa and Gocław, is the area with high threat of floods. In case of a catastrophic flood, the area may be inundated by a water column 3 m high, and the cubature of the flooded buildings may exceed 1 million m³. In the part of Warsaw on the right bank of the Vistula River, the centre of the urban island effect is located near Rondo Wiatracyjne. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. The post-industrial and residential areas heavily covered with concrete (61% of the district’s area) may heat up to more than 40°C. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. The small percentage of green spaces and forests makes the situation even worse. An increase in the number of housing units is forecasted in the area by 2030.

Praga-Północ

The Praga-Północ district, and especially its centre and the area surrounding the ZOO, is the area with higher threat of flood. In case of a flood event, the area may be hit by a water column from 0.5 to 2 m high, and locally reaching even 4 m. Praga-Północ is situated within the limits of the Warsaw urban heat island. During the hottest days, the temperature in Praga-Północ may be 4-5 degrees higher than outside the city. The post-industrial and residential areas heavily covered with concrete (61% of the district’s area) may heat up to more than 40°C. Particularly tiring are hot nights with temperature above 20°C, which do not allow people to rest and recover. The small percentage of green spaces and forests makes the situation even worse. An increase in the number of housing units is forecasted in the area by 2030.

Wola

In the Wola district the climate threat is very high, with the role of green spaces and forests assessed as moderate and a significant increase in the number of housing units is forecasted by 2030. In future this may lead to increased climate threat exceeding the current levels. First of all, as a result of the higher development density and the growth of impermeable area the risk of local flooding will increase. Wola is situated at the centre of the Warsaw urban heat island and therefore heatwaves may be the most troubleso-
me weather events for the residents. During the hottest days the
temperature in Wola may be 5-6 degrees higher than outside the
city. Particularly tiring are hot nights with temperature above 20°C,
which do not allow people to rest and recover. Wola is a district with
high percentage of impermeable areas, which cover almost 70% of
the district’s surface. This aggravates the heat and contributes to
excessive accumulation of rainwater in undesirable places on the
surface, leading to local flooding.

Śródmieście

Śródmieście district is the area with the highest climate threat in
Warsaw. This is caused by little number of green spaces and fo-
rests. However, by 2030 no significant increase in the number of
housing units is forecasted. Śródmieście is situated at the centre
of the Warsaw urban heat island therefore heatwaves may be
the most troublesome phenomenon for the residents. During the
hottest days, the temperature in Śródmieście may be 6 degrees
higher than outside the city. Particularly tiring are hot nights with
temperature above 20°C, which do not allow people to rest and
recover. Śródmieście is an area with high share of impermeable
surfaces – almost 70% of the district’s area. The quick drainage
of water from such areas during rain often leads to local flooding
that may affect especially the Powiśle area, which is also vulne-
rable to flood risk.
3.4. ADAPTATION OPTIONS

The adaptation options provide a response to the identified climate change threats. They include suggestions of possible actions to address a particular climate threat. The implementation horizon has been set at the year 2050 (assuming that there will be no changes to the present analyses), which is a reference point for the assessment of the measures currently applied to adapt Warsaw to climate change. The maximum version of the plan consists of 5 sets of measures.

<table>
<thead>
<tr>
<th>PACKAGE 0 Awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>The package comprises adaptation options ensuring the swift implementation of Packages 1-5, which aim to adapt the City to climate change and minimise its impacts by preparing the public (education), creating appropriate information and warning systems as well as establishing appropriate structures and ensuring cooperation.</td>
</tr>
</tbody>
</table>

Examples of measures to be adopted under Package 0:
- To create a coherent system for early warning against regional threats,
- To create coherent systems for informing the residents about threats,
- To educate various age, social and professional groups about climate change and adaptation
- To conduct joint information campaigns about climate change, including threats and adaptation measures
- To create a uniform brand for the actions related to climate change and adaptation,
- To cooperate at the local, national and international level on climate change adaptation
- To cooperate with non-governmental organisations and promote grass-root initiatives related to climate change adaptation.

<table>
<thead>
<tr>
<th>PACKAGE 1 Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>The package comprises adaptation options aiming to combat the increased mortality during hot weather periods and reduce the range of the urban heat island effect.</td>
</tr>
</tbody>
</table>

Examples of measures to be adopted under Package 1:
- To develop a system for monitoring the urban heat island effect,
- To control the effect and the shape of the urban heat island,
- To ensure proper airing and ventilation of the city, including protection of the ventilation corridors,
- To create urban infrastructure that improves/facilitates the functioning of people and animals in the city during periods with high temperature, e.g. construction of fountains, water curtains and drinking water fountains, etc., |
• To create or ensure easy/universal access to cooling oases, e.g. by appropriate air-conditioning systems, green spaces, shaded spaces with benches, places with access to water – e.g. urban beaches and bathing water areas, including access to drinking water – e.g. drinking water fountains, etc.,
• To apply green areas maintenance methods that do not disturb the function performed by plants, that is, the reduction of the ambient temperature,
• To create and support the development of the infrastructure that contributes to cooling the environment, such as green roofs and walls as well as other vertical green structures, to promote among the residents the idea of creating “balcony gardens”,
• To protect the existing green areas and increase their share in the overall city area, including small green belts, squares, pocket parks,
• To provide access to as many green areas as possible,
• To increase the share of biologically active areas by reducing impermeable surfaces, e.g. by desealing the impermeable surfaces,
• To promote and introduce solutions that adapt buildings to climate change,
• To protect highly vulnerable groups (elderly people, sick people, children) from heat,
• To protect the existing green areas, in particular, trees and places surrounding them,
• To introduce a system for monitoring trees in the city,
• To extend green spaces adjacent to streets,
• To improve the thermal comfort of the passengers waiting for public transport (including green stops, shaded areas, cool enclaves).

PACKAGE 2 Wind

The package comprises adaptation options aiming to combat the increased mortality and damage caused by strong winds.

Examples of measures to be adopted under Package 2:
• To introduce a system for taking stock of the green spaces and for monitoring of trees in the city and a permanent programme for tending to / replacement of trees,
• To introduce protected zones around old trees (heritage trees),
• To create warning systems and to introduce a ban on entry/to issue warnings against entry to parks, forests during high wind,
• To conduct educational, information and promotional campaigns focused on improving knowledge about rules of maintaining green spaces, particularly trees, in good condition.
### PACKAGE 3 Water

The package comprises adaptation options aiming to eliminate the damage related to the variability of water flow of the Vistula River, including both floods and excessively low water level as well as the development of the riverside areas.

The Package also includes adaptation options designed to eliminate the damage caused by heavy rainfalls, floods caused by smaller watercourses in the city bursting their banks and by local flooding.

Examples of measures to be adopted under Package 3:

- To protect, modernise and construct hydrotechnical and land improvement facilities,
- To maintain the adequate discharge capacity at the so called “Warsaw corset” [the narrow section of the Vistula riverbed] – a pinch point on the Vistula River,
- To maintain proper flood defence infrastructure and preparedness of emergency services, to move the sensitive infrastructure away from the flood plains,
- To improve the critical public infrastructure on flood plains,
- To create water retention systems in the city – to regenerate and upgrade water reservoirs and green spaces in order to improve retention capacity, to protect, restore and create water retention areas, to develop a system of micro water retention, to adapt areas with other functions to perform the retention function temporarily,
- To apply green areas maintenance methods that do not disturb the water retention function performed by plants,
- To prepare guidelines in order to enforce natural groundwater retention in the city by preventing sealing and overdrying of the ground,
- To apply systemic management of rainwater, including management of rainwater at source (to promote solutions using permeable surfaces, de-sealing of impermeable surfaces).
### PACKAGE 4 Infrastructure

The Package groups all the options to prevent damage to technical infrastructure as a result of extreme weather events, such as heatwaves, local flooding and strong winds and to adapt the infrastructure to climate change.

Examples of measures to be adopted under Package 4:

- To introduce solutions that increase the city’s energy independence, including increased share of renewable energy,
- To put overhead power lines underground in the sites particularly exposed to high winds,
- To replace and modernise power grid infrastructure,
- To apply rainwater collection solutions,
- To place various forms of greenery within the transport system as well as facilities for retention of rainwater and slowing down the surface drainage,
- To apply solutions protecting the infrastructure from extreme weather events,
- To improve the standards of buildings and premises as well as the surrounding space.

### PACKAGE 5 Green spaces

The package consists of adaptation options aiming to protect the city’s nature system from the consequences of drought, local flooding.

Examples of measures to be adopted under Package 5:

- To apply a systemic approach to developing elements of green and blue infrastructure,
- To create systems for protection of the existing green infrastructure areas and to increase their surface,
- To create a system for calculation and taking account of opportunity costs related to city investment projects that have adverse impact on urban green areas,
- To transform degraded land into green spaces, especially around buildings,
- To create systems for the protection of the existing and the creation of new elements of blue infrastructure,
- To take proper care of the green infrastructure before and during dry weather periods,
- To collect and use rainwater to water the plants,
- To involve residents in the system of urban green spaces maintenance,
- To use new (more drought resistant) species for new planting, to deploy systems for irrigation of urban green spaces during drought,
- To make a valuation of the ecosystem services.
4. ADAPTATION OF WARSAW TO CLIMATE CHANGE

4.1. PRIORITY AND RULES

In spite of the efforts of the international community, climate change is progressing. For Warsaw and its residents it means the growing threat of a greater number and intensity of extreme weather events, primarily heatwaves, drought, strong winds, flood events and local flooding. Considering this, the members of the Warsaw Round Table for Adaptation to Climate Change (WOSAK)\textsuperscript{26} proposed that the city of Warsaw and its residents should be guided by the following motto:

\begin{quote}
\textbf{WARSAW – A COMMUNITY ACTING RESPONSIBLY IN THE FACE OF CLIMATE CHANGE.}
\end{quote}

The following PRIORITY has been adopted:

\begin{quote}
\textbf{TO PREPARE WARSAW TO THE IMMINENT CLIMATE CHANGE, MAINLY BY MITIGATING ITS IMPACTS AND ENSURING SMOOTH FUNCTIONING OF THE CITY WITH ACCEPTABLE COSTS FOR ECONOMY, SOCIETY AND NATURE.}
\end{quote}

The rules by which the authorities, the residents and the entrepreneurs of Warsaw should be guided are the following:

1) The authorities of Warsaw, when preparing planning documents, especially those pertaining to spatial development and adoption of the city budget, shall take into consideration the need for action aimed at adaptation to climate change and its consequences;

\textsuperscript{26} Warszawski Okrągły Stół ds. Adaptacji do Zmiany Klimatu, known as WOSAK [Warsaw Round Table for Climate Change Adaptation] was convened by Mayor of Warsaw and comprised representatives of non-governmental organisations, academia, Warsaw City Hall and the entities providing services for the residents of the city. The aim of WOSAK was to enable cooperation between the local government, academia, non-governmental and business communities on preparing the Climate Change Adaptation Strategy for the City of Warsaw. It was an advisory body that prepared recommendations on the directions and the manner of implementing the Strategy.
2. When undertaking investment or procurement activities (wherever it is justified) the need for climate change adaptation action shall be considered and the standards and norms resulting from future climate conditions shall be applied;

3. The Warsaw administration shall introduce model solutions aimed at adaptation to climate change and its consequences;

4. The needs of the emergency services shall be the priority in Warsaw, both in developing spatial development solutions and in the management of individual facilities;

5. Individual areas of Warsaw (according to their local specificity) and social groups (according to their vulnerability) shall be given equal treatment from the point of view of adaptation action;

6. Information about climate change, its consequences and the meteorological data shall be collected in a uniform manner and shall be fully available for the services and entities managing the climate risk; the information and the data shall be also relayed to the population and the business community of Warsaw in a clear manner – the threats shall not be concealed;

7. In Warsaw, the authorities, the local communities and the business community shall regularly conduct educational activities to inform about climate change threats and their consequences according to the following principle: see, touch, understand, act; every important activity in the city aiming to protect the climate or adapt to climate change shall be used as an opportunity to educate and inform the residents in order to raise their climate awareness;

8. Conditions shall be created for local activism and strengthening the self-organisation and self-sufficiency (using the social capital) in the face of the appearing threats;

9. The areas of Warsaw and the places exposed to high climate change risk must be covered by contingency plans developed with the participation of the public;

10. Because of the specific nature of climate change and its consequences, Warsaw shall be guided by the following rules when dealing with vital detailed issues:

- During the hot season, measures shall be applied to reduce the heat entering building structures whereas in the cold season the escape of heat from building shall be prevented;
- Rainwater shall be properly managed, in particular, it should be managed where generated;
- Green and blue infrastructure shall be preserved, strengthened and developed as much as possible with reference to the concept of ecosystem services.
The following should be done in order to reduce the threats to Warsaw while following the above mentioned rules:

1. To ensure the possibility of safe management or collection of water in Warsaw;
2. To ensure operation of the technical infrastructure and supplies in Warsaw in case of extreme weather events;
3. To ensure that human health and lives are protected in case of extreme weather events – mainly heatwaves, floods and heavy rains and sanitary and epidemiological threats related to them;
4. To support responsible local activities preventing and removing the impacts of extreme weather events, particularly strong wind.
4.2. LINES OF ACTION

I. TO ENSURE CONSISTENT IMPLEMENTATION OF MEASURES THAT WILL GUARANTEE WARSAW’S ADAPTATION TO CLIMATE CHANGE.

In order to maximise the resilience of the city to climate change it is necessary to ensure that activities undertaken by Warsaw, in all areas, take into account the climate change aspect. For a successful outcome it is particularly important to develop the city space in a manner that takes account of the need to adapt to these changes. Therefore, when preparing development programming documents, both at the strategic and the executive level, the threats that the city will have to face must be considered. With appropriate action, the consequences will certainly be mitigated and the smooth functioning of the city will be ensured. For Warsaw, it is especially important is to draw attention to the development of areas at risk of flood as well as construction of systems to control the water flow. This problem should be viewed from the point of view of the infrastructure, bearing in mind the social aspect.

In particular, the following actions should be undertaken:

- To monitor climate change and collect data about threats,
- To optimise the system for coordination of the adaptation process,
- To make the adaptation process more coherent, in particular, by ensuring that provisions included in the Warsaw development programming documents, planning and financial documents are consistent,
- To ensure that the Warsaw development programming, planning and financial documents take account of the climate change adaptation requirements relevant to the appearing threats.
II. TO ENSURE COOPERATION IN THE FIELD OF CLIMATE CHANGE ADAPTATION AT THE LOCAL, REGIONAL AND NATIONAL LEVEL.

Extreme weather events occurring as a result of climate change do not need to originate inside Warsaw in order to have negative impact on the city. What is more, they are not limited to the city administrative boundaries but often cover wider areas. That is why Warsaw must seek to establish cooperation at both the local as well as regional and national levels. It is necessary to develop mechanisms for communication and access to information as well as to create common programmes and undertake joint action. To ensure security it is necessary to optimise the system whereby the city administration and the residents work together with emergency and law enforcement services.

It is important to build cooperation with the residents of Warsaw and with the neighbouring local communities, including local authorities, and to foster common education and experience/good practices sharing with regard to spatial interdependence of climate change-related extreme weather events.

In order to eliminate or reduce the negative impact of extreme weather events it is necessary to ensure proper functioning of the links between the green and the blue infrastructure on the area much larger than just the area of Warsaw. This is one of the reasons why Warsaw, apart from the above mentioned cooperation, should engage in joint activities with administrative institutions, non-governmental organisations or entrepreneurs, both at the local (metropolitan) and national level and at the international level.

In particular, the following should be done:

- To form and optimise a system of joint cooperation,
- To develop channels for efficient communication between the stakeholders for the purpose of collecting data and exchanging information about the occurrence of adverse weather events and their consequences, within the framework of various data collection systems: local, regional and national,
- To create a platform for exchange of information, experience, good practices concerning adaptation activities and their effectiveness,
- To implement systemic solutions that enable participation of the entities responsible for green areas maintenance in the design and construction works related to infrastructure projects,
- To develop and implement common procedures, warning and information systems in case of the occurrence of extreme weather events and their consequences,
- To conduct joint workshops, exercises and training courses for local government administration, the institutions monitoring the environment and the services, guards and inspectorates as part of crisis management.
III. TO RAISE AWARENESS OF HOW TO BEHAVE IN THE FACE OF CLIMATE CHANGE

In order to improve the security of the residents and ensure proper quality of life it is particularly important to develop the society that is well informed and responsible for the decisions and choices it makes. It is necessary to foster attitudes of caring for one another, e.g. by building civic and social competencies, both among residents and administration officials. One of the tools to achieve the desired results is to educate the society and the Warsaw city administration, as well as the entities in charge of spatial planning, provision of utilities and security, about the nature and scale of the threats related to extreme weather events and to create a system of information about extreme weather events and the appropriate conduct when they occur.

In particular, the following should be done:

- To keep raising the awareness and understanding of climate change among the residents in order to improve their ability to respond to the risk,
- To educate the public about the impacts of climate change, adaptation actions and response when the threat occurs,
- To ensure regular access to information about the possible threats and the way to respond to them,
- To promote and inform the stakeholders about the climate change adaptation activities,
- To provide specialist education focused on improving awareness, skills and knowledge, especially among administration officials, decision makers, municipal services, planning specialists, urban planners, architects,
- To raise awareness of local governments within the Warsaw Metropolitan Area about spatial interdependence of climate change-related extreme weather events,
- To develop pilot preventive projects as elements of education and good practices building,
- To introduce a system of prohibitions, recommendations and restrictions related to risks (such as a ban on entry into forests because of fire risk, restrictions in the use of water at the time of water deficit, prohibition on entry into parks or cemeteries in case of strong winds), as an element of education on threats and risks.
IV. TO IMPROVE WARSAW’S RESILIENCE TO CLIMATE CHANGE

In order to ensure that Warsaw’s resilience reaches the adequate level, it is necessary, in particular, to attach the same importance to the green and the blue infrastructure as to the technical infrastructure and the built-up areas. The green and blue infrastructure is, on the one hand, a tool for mitigating and adaptation to climate change, on the other hand, it is threatened by this phenomenon and requires protection from extreme weather events. The current change in the approach to this infrastructure makes it also necessary to draw attention to the need to ensure the provision of ecosystem services in the context of climate change and extreme weather events. This applies in particular to such services as the conditions for the provision of high quality food, provision of drinking water, climate regulation and protection from natural threats, soil erosion control or recreational spaces.

In particular, the following should be done:

- To strengthen the role of the green and blue infrastructure,
- To adapt the water management system, in particular, to improve biodiversity and retention capability of green spaces while increasing their overall area, to restore the retention capability of impermeable surfaces, to create infrastructure capable of retaining water on site,
- To improve the resilience of technical infrastructure to extreme weather events and to ensure its efficient operation and the provision of utilities to the city when such extreme weather events occur,
- To take action to reduce the severity of extreme weather events and their impact on the health and life of the residents,
- To adapt the social infrastructure so as to ensure security to all those who need it in case of extreme weather events.
4.3. ADVANTAGES OF TAKING ACTION TO ADAPT TO CLIMATE CHANGE

The implementation of the guidelines set out in this document will enable the management of climate risk in Warsaw by 2030 and after that date. The adaptability of the entire city as well as that of the individual districts, households, businesses and institutions will improve as will the adaptation capability of the residents and civil society organisations.

It will contribute to a significant improvement of the quality of life in the city and will help protect the residents’ health. The process of Warsaw’s adaptation to climate change will undoubtedly make the city more competitive, it will help to develop the labour market, to create attractive and safe spaces, will improve the quality of the environment and introduce more effective mechanisms for its protection. It will also result in creating demand for modern technology and innovative solutions in Warsaw.

A lot of the solutions adapting the city to climate change will be multi-functional in character and will be developed together with the residents of Warsaw in the process of co-designing and co-creating, thus enabling the use of the social capital built in the process.

It will also impact on the rise of awareness, knowledge gathering and information exchange as well as the ability to implement adaptation measures improving the resilience of the city and its infrastructure. In particular, it will contribute to ensuring the security of the residents and to avoiding losses or increasing the ability to quickly restore functioning of the city, its residents and businesses, in case of negative impacts of climate change.

**EXPECTED DIRECT BENEFITS**

- Increased biodiversity, leading to ecological added value for the city and strengthening of the ecosystems providing ecosystem services to the city and its residents.
- Improved security and better health protection as well as comfort and quality of life for residents.
- Increased public awareness and engagement of residents.
- Reducing financial and material losses.
- Improving the city’s competitiveness and creating new jobs.
5. GUIDELINES FOR IMPLEMENTING DOCUMENTS

5.1. LINKS TO THE WARSAW DEVELOPMENT PROGRAMMING DOCUMENTS

The document plays the role of a policy paper for the Strategy #Warszawa2030 and sets out the principles and guidelines for the urban programmes for climate change adaptation.

The issues presented in the Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050, because of their specific nature, are linked with a number of areas, both social and economic, as well as the area of nature. It covers a range activities, from “soft” ones (educational, informational, organisational) to “hard” ones (investment, technology), touching upon practically all areas of the city’s functioning. For Warsaw to adapt to climate change, it is necessary to ensure that the documents programming the city’s development are consistent and to make sure that projects are implemented in accordance with the established adaptation action lines. It is important to ensure that the preparation of the programmes for achieving the operational objectives of the Strategy #Warszawa2030 is realised taking account of the principles and guidelines set forth in this document as well as in cooperation between the individual areas.

Figure 9.
Source: Authors’ own compilation.
5.2. LINKS TO THE PLANNING DOCUMENTS

As the analyses conducted as part of the ADAPTCITY project show, the main climate change-related threats for Warsaw are thermal threats (the urban heat island effect) and hydrological threats (local flooding following heavy rainfall and floods). At the same time, the work adapting the city to climate change should be linked with the measures to reduce the emission of greenhouse gases.

In order to achieve the appropriate effects it is necessary to ensure the proper correlation between the strategic and the planning documents. The shaping of the spatial planning policy in a manner that protects the city from the negative impacts of climate change is a necessary condition for the success of the entire enterprise. That is why spatial planning is a very important tool in mitigating the impacts of climate change and implementing adaptation mechanisms; it also guarantees that the right microclimate is created in the city.

The inclusion in the spatial planning of the guidelines for the adaptation of the city to climate change will make it possible to reduce the consequences of climate threats. Such use of spatial planning is based primarily on applying the basic instruments of spatial planning, such as determination of the land use or ensuring coherent use of various environmental forms in a given area, which will enable informed management of spatial resources. Thanks to spatial planning it is possible to specify the function of a given area and thus prevent it from being managed in an inappropriate way, and limit the range and influence the shape of the heat island. Sustainable development, protection of open and green spaces and local management of rainwater are particularly important. It is necessary for planning documents to take account of the results of the monitoring of urban heat island effect and the results of the analyses that provide information about the potential threat of flooding and the risk of flood from the Vistula River.
5.3. STRATEGY IMPLEMENTATION

The process of the adaptation of Warsaw to climate change, consistent with the direction set out in the Adaptation Strategy is supervised by the Mayor of Warsaw supported in this task by the Climate Protection Team. The coordination of the adaptation process is the responsibility of the bureau nominated by the Mayor of Warsaw to perform, among others, the following tasks:

- To cooperate in creating programmes and annual plans for the areas related to climate change adaptation,
- To monitor climate change and to assess its impact on the city, including a diagnosis of the city ecosystem's resilience to climate change,
- To evaluate the Climate Change Adaptation Strategy for the city of Warsaw,
- To perform the reporting tasks in connection with the adaptation process,
- To update, on the basis of the analysis and assessment of the progressing climate change, the lines of action necessary to minimise the costs resulting from the damage caused by extreme weather events and the need to ensure security and comfort of life to the residents,
- To study the adaptation awareness and needs among the city's residents and selected city administration units.

The Climate Change Adaptation Strategy for the city of Warsaw is a horizontal document, which means that it requires coherent action on the part of all entities responsible for individual areas of the functioning of the city. The Adaptation Strategy will be implemented via implementing documents. The principles and the lines of action included in this document shall constitute the guidelines that should be taken into account during the development of all the implementation documents in Warsaw, including the programmes that describe in detail the implementation of the operational objectives of the Strategy #Warszawa2030 or other mandatory tasks of the city. Thus the entities preparing and implementing the programmes are the direct implementers of the provisions of the Adaptation Strategy.

The programmes of the operational objectives of the Strategy #Warszawa2030, which should, in particular, include the guidelines of the Adaptation Strategy have been presented in Table 3 below.

---

27 Regulation No. 1823/2008 of the Mayor of Warsaw dated 7 July 2008 on appointing the Climate Protection Team, as amended.
Table 3. Programmes for the operational objectives of the Strategy #Warszawa2030 that are particularly important for the process of Warsaw’s adaptation to climate change, pursuant to the Climate Change Adaptation Strategy for the city of Warsaw by 2030 with the prospects until 2050.

<table>
<thead>
<tr>
<th>Operational Objective Programmes</th>
<th>Unit within the Warsaw City Hall responsible for the preparation and implementation of the operational objective programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. We care for one another</td>
<td>Bureau responsible for strengthening local communities</td>
</tr>
<tr>
<td>1.2. We decide about our city together</td>
<td>Bureau responsible for development of civil society</td>
</tr>
<tr>
<td>2.1. We can access a wide housing offer</td>
<td>Bureau responsible for housing policy</td>
</tr>
</tbody>
</table>
| 2.3. We use services close to home | Bureaux responsible for the policies:  
  • educational,  
  • social welfare,  
  • health |
| 3.1. We take advantage of attractive public space | Bureau responsible for spatial policy                                                                       |
| 3.2. We live in clean natural environment | Bureau responsible for environmental protection policy                                                       |
| 3.3. We use a friendly transport system | Bureau responsible for transport policy                                                                     |
| 4.1. We develop our creative potential | Bureau responsible for educational policy                                                                     |
| 4.2. We generate innovation      | Bureau responsible for economic policy                                                                        |
| 4.4. We inspire the world        | Bureaux responsible for the policies:  
  • economic,  
  • educational.                                                   |

Source: Authors’ own compilation.
5.4. MONITORING AND EVALUATION

Monitoring

In order to optimise the process of Warsaw’s adaptation to climate change, ongoing monitoring of climate change and assessment of its impact on the city will be conducted, including a diagnosis of the resilience of the city’s ecosystem to climate change.

In addition, the indicators adopted in individual programmes will be used to monitor the implementation of the Adaptation Strategy provisions.

Reports concerning the level of implementation of measures adapting the city to climate change will be prepared in a three-year cycle by the bureau responsible for the coordination of the adaptation process in the city.

Evaluation

In order to assess the relevance, effectiveness, sustainability, efficiency and usefulness of the actions adapting Warsaw to climate change, evaluation studies will be carried out.

Ongoing evaluation will be conducted to assess whether the actions undertaken so far have been implemented in accordance with the adopted Adaptation Strategy guidelines, whether they bring the expected effects, and whether they are adequate to the threats resulting from the constantly changing climate.

In particular, the results of the monitoring of the implementation of adaptation activities contained in individual programmes, as well as the monitoring of climate change and the assessment of its impact on the city will be used for evaluation purposes.

The results of the on-going evaluation will make it possible to introduce appropriate adjustments to the programmes and the guidelines included in the Climate Change Adaptation Strategy for the city of Warsaw. In addition, on the basis of the evaluations, a decision may be taken concerning the need to update this document.

It is also planned to carry out a final ex-post evaluation in order to make a comprehensive assessment of the effects of including the Adaptation Strategy guidelines in the implementing documents.

The evaluation studies will be conducted by the bureau responsible for the coordination of the adaptation process in the city.
GLOSSARY OF TERMS

Climate change adaptation – according to the United Nations, it is the adaptation to changes in the ecological, social and economic systems in response to the actual or expected climate changes and their effects or impact. This applies also to modification of processes, practices and structures that lead to reducing possible losses and to using the opportunities related to climate change.

Albedo – the ratio of the radiation reflected to the radiation received; it describes the ability of a given surface to reflect radiation.

Very hot days – days with temperature above 30°C.

Supply of utilities and food to the city – supply of utilities such as electricity, heat, gas, water or disposal of wastewater and solid waste, ensuring proper functioning of the city as well as the provision of the appropriate quantity and quality of food products.

Extreme weather events – violent and intense precipitation, strong winds, heat waves, thunderstorms, storms, tornadoes, hailstorms, etc.

Heatwaves – continuous sequence of at least 3 days when the average maximum temperature reaches at least 30°C; that is, during such period there are both very hot days (with maximum temperature above 30°C), and hot days (with maximum temperature above 25°C), with two conditions that must be met: 1) the number of very hot days should exceed or at least equal the number of hot days, 2) the sequence of hot days between the very hot days may not exceed three.

Global climate warming – a phenomenon related to the increasing concentration of greenhouse gases in the atmosphere, such as carbon dioxide, methane or nitrous oxide. Global warming is the increase in the natural greenhouse effect. The essence of the effect is that greenhouse gases found in the atmosphere let through the sun radiation, which heats the Earth, but retain the long-wave thermal radiation emitted from the Earth’s surface. The captured thermal radiation heats the Earth’s atmosphere, and the rest of it flows into space. The increased concentration of greenhouse gases in the atmosphere means that a greater proportion of the long-wave radiation is directed back to the planet’s surface. Greenhouse gases form a heat trap that works just like a greenhouse. Without greenhouse gases, the Earth’s average temperature would be about 33°C lower, i.e. -18°C, while it is currently +15°C.28

Technical infrastructure – pursuant to the Act dated 21 August 1997 on real property management (Journal of Laws of 2018, item 2204), technical infrastructure facilities shall mean roads and water supply, sewage, heat distribution, electric, gas and telecommunications pipework, cables, facilities and fittings, built under ground, over ground or above the ground.

Green and blue infrastructure – a network of nature-related links which has a positive effect both on the conditions of life in a city and on the city’s nature environment. It includes green spaces, e.g. parks, squares, landscaped greens, street greenery, green roofs and walls as well as water resources such as rivers, streams, ditches, lakes and water reservoirs, marshes and various solutions for rainwater management.

Housing unit (number) – number of flats in a selected period in selected areas

Urban heat island effect – a phenomenon that occurs in urban areas, where temperature in the city is higher than in the surrounding area. It concerns, in particular, centres of densely built-up

cities, without green areas and water courses or water reservoirs. High daily and annual variability is characteristic of urban heat island effect, it also occurs more frequently in summer than in winter. The biggest differences in temperature occur during clear, cloudless nights, when the heat captured in the city during the day is released.

**Intergovernmental Panel on Climate Change (IPCC)** – a team of climate scientists conducting assessment studies on the basis of which governments and international organisations may initiate action and set policy frameworks to counter climate change. IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme, to assess the risk related to human impact on the climate. Since 1989, IPCC has been regularly preparing reports on the present and forecasted changes of the climate. The Fifth Assessment Report, AR5, was published on 2 November 2014. The Special Report on Global Warming of 1.5 °C was released on 8 October 2018.

**Tropical nights** – nights during which air temperature does not fall below 20°C.

**Resilience of the city to climate change** – ability of the city to prepare for the threats related to extreme weather events while maintaining proper functioning of the city.

**The Covenant of Mayors** – the biggest initiative of city authorities in the world concerning energy and climate, grouping representatives of almost 8 thousand local and regional authorities which voluntarily implement the European climate and energy objectives in their areas and implement the integrated programme for mitigating climate changes and adapting the cities to their impacts. Warsaw has been a member of the Covenant since 2009.

**Biologically active surface** – native soil covered with plants together with surface water on a building plot, as well as 50% of the total surface of terraces and flat roofs, landscaped as permanent lawns or flower beds on a soil ensuring the natural vegetation, with an area not smaller than 10 m².

**Impermeable surface** – surface that is not capable of filtering water.

**Climate risk** – the risk, the scale of the effects and the probability of their occurrence, resulting from the intensity, scale and speed of climate change and extreme weather events related to it, which may have negative impact on people, built-up areas, including technical infrastructure and the natural environment, including the green and blue infrastructure.

**Ecosystems services** – benefits that the natural environment brings to humans and the economy, such as conditions for good quality food production, supply of drinking water and wood, climate regulation and protection from natural threats, soil erosion control and space for leisure activities.

**Climate threat** – includes thermal, hydrological threats as well as a threat of drought and strong winds. The degree of thermal threat to the city results from the assessment including average total solar radiation, albedo of the active surface, land cover and average temperature of the active surface whereas the degree of hydrological threat results from the assessment of the scale of local flooding after heavy rains and submersion as a result of flood. The degree of drought threat is a resultant of the thermal threat and is expressed by the length of the period (days) without precipitation and with high temperature. The degree of threat of strong wind is a combined result of its strength and duration.

---


3) IMGW, 2012, Publikacje projektu POIG 01.03.01-14-011/08-00 o akronimie KLIMAT pt. „Wpływ zmian klimatu na gospodarkę, środowisko i społeczeństwo” dostępne na stronach internetowych http://klimat.imgw.pl, moduł: Związek klimatu Polski w II połowie XX w. z procesami skali globalnej i regionalnej oraz Klęski żywiołowe a bezpieczeństwo wewnętrzne (cywilne i ekonomiczne) kraju.

4) Błażejczyk Krzysztof, Żmudzka Elwira, Kuchcik Magdalena, Milewski, Paweł, Nelken Kinga, Leziak Kamil, Mapy rozkładu różnych charakterystyk temperatury powietrza i opadów atmosferycznych w Warszawie wraz z komentarzem, opracowanie na zlecenie Fundacji Instytut na rzecz Ekorozwoju w ramach projektu ADAPTCITY.


10) Obszary potencjalnego zainwestowania w budownictwo mieszkaniowe i priorytety w zakresie infrastruktury miejskiej w perspektywie do 2030 roku – analiza, REAS, Warszawa, grudzień 2014.

11) Uchwała Nr 184/13 Sejmiku Województwa Mazowieckiego z dnia 25 listopada 2013 r. w sprawie programu ochrony powietrza dla stref województwa mazowieckiego, w których został przekroczyony poziom docelowy benzo(a)pirenu w powietrzu aktualizowana uchwałą nr 99/17 z 20 czerwca 2017 r. Sejmiku Województwa Mazowieckiego. Uchwała opublikowana została w Dzienniku Urzędowym Województwa Mazowieckiego z 2017 r. poz. 5966. Program obowiązuje od 7 września 2017 r. do 31 grudnia 2024 r.
12) Uchwała Nr 186/13 Sejmiku Województwa Mazowieckiego z dnia 25 listopada 2013 r. w sprawie programu ochrony powietrza dla strefy aglomeracji warszawskiej, w której zostały przekroczone poziomy dopuszczalne pyłu zawieszonego PM10 i dwutlenku azotu w powietrzu zaktualizowana uchwałą nr 96/17 z 20 czerwca 2017 r. Sejmiku Województwa Mazowieckiego. Uchwała opublikowana została w Dzienniku Urzędowym Województwa Mazowieckiego z 2017 r. poz. 5963. Program obowiązuje od 7 września 2017 r. do 31 grudnia 2024 r.


20) Instytut Ochrony Środowiska, Miejsca Zalewuć ulic w czasie intensywnych opadów na terenie Warszawy, sierpień 2007.

21) Mapy dostępne na portalu www.mapa.um.warszawa.pl

22) Dane dotyczące demografii Warszawy, GUS, 2017.
Authors:

**Institute for Sustainable Development:**
Andrzej Kassenberg,
Wojciech Szymalski

**City of Warsaw:**
Leszek Drogosz,
Marta Bugaj,
Izabela Jakubczak