MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____ T.V. Dudar
«_____» _____ 2021

MASTER THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Adaptation of the Kyiv city ecosystem to climate changes»

Done by: student of the EK-211M group, Maryna A. Mushta
(student, group, surname, name, patronymic)

Supervisor: Ph. D. in Eng., Associate Professor of the Ecology Department, Marharyta M. Radomska
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KYIV 2021

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ Т.В. Дудар
«_____» _____ 2021 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»,
ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Адаптація екосистеми міста Києва до кліматичних змін»

Виконавець: студентка групи ЕК – 211М Мушта Марина Андріївна
(студент, група, прізвище, ім'я, по батькові)

Керівник: канд.техн.наук, доцент кафедри екології Радомська Маргарита Мирославівна
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Консультант розділу «Охорона праці»: _____ Кажан К. І.
(підпис) (П.І.Б.)

Нормоконтролер: _____ Явнюк А.А.
(підпис) (П.І.Б.)

КИЇВ 2021

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Environmental Science

Specialty, Educational and Professional Program: specialty 101 "Ecology", Educational and Professional Program: "Ecology and Environment Protection"

(code, name)

APPROVED
Head of the Department
_____ T.V. Dudar
«____» _____ 2021

MASTER THESIS ASSIGNMENT

Maryna A. Mushta

1. Theme: «Adaptation of the Kyiv city ecosystem to climate changes» approved by the Rector on September 15, 2021, № 1872/ст

2. Duration of work: from 15.09.2021 to 15.12.2021

3. Output work (project): maps, ecological passports of the city and district, a detailed plan of the Osokorky massif, personal observations, data from the meteorological center, public feedback, scientific papers and articles on climate change, textbooks and other educational materials.

4. Content of explanatory note: (list of issues): analytical review of the literature on the topic of diploma, assessment and characterization of negative effects of climate change on urban ecosystems, physical and geographical characteristics of Osokorky massif, use of remote sensing data to assess the state of geosystems, recommendations for improving environmental protection and mitigation of climate change in the study area.

5. The list of mandatory graphic (illustrated materials): tables, figures.

6. Schedule of thesis fulfillment

№	Task	Term	Advisor's signature
1	Obtaining the topic of the task, searching for literature sources and analysis of previous research	05.09.2021-15.09.2021	
2	Writing a review of the problem on the topic of the study (Chapter I)	16.09.2021-30.09.2021	
3	Choice of research methodology (Chapter II and)	01.10.2021-15.10.2021	
4	Obtaining and conducting experimental research (Chapter III and Chapter IV)	16.10.2021-26.10.2021	
5	Writing of Chapter V	27.10.2021-04.11.2021	
6	Formulation of conclusions and recommendations of qualification work	05.11.2021	
7	Registration of the explanatory note to the preliminary representation at department, consultation with the normcontroller	21.11.2021-25.11.2021	
8	Preliminary defense	26.11.2021-30.11.2021	
9	Taking into account comments, recommendations and preparation for defense	15.12.2021	
10	Presentation of work to the department	01.12.2021-28.12.2021	
11	Defense of qualification work	29.12.2021	

7. Consultant(s) of certain chapter(s):

Chapter	Consultant (academic rank, S.N.P)	Date, signature	
		Given by	Accepted by
Labor Precaution	PhD, Associate Professor of the Department of Civil and Industrial Safety, Kazhank Kateryna I.		

8. Date of task issue: «15» September 2021

Diploma (project) advisor: _____ Marharyta M. Radomska
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ Maryna A. Mushta
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

Кафедра екології

Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»

(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____ Т.В. Дудар
«____» _____ 2021 р.

ЗАВДАННЯ
на виконання дипломної роботи
Мушти Марини Андріївни

1. Тема роботи «Адаптація екосистеми міста Києва до кліматичних змін» затверджена наказом ректора від «15» вересня 2021 р. №1872/ст

2. Термін виконання роботи: з 15.09.2021 р. по 15.12.2021 р.

3. Вихідні дані роботи: карти, екологічні паспорти міста та району, детальний план території масиву Осокорки, особисті спостереження, дані метеорологічного центу, відгуки населення, наукові роботи та статті по зміні клімату, підручники та інші навчальні матеріали.

4. Зміст пояснювальної записки: аналітичний огляд літератури за темою диплома, оцінка та характеристика негативних наслідків змін клімату на міські екосистеми, фізико-географічна характеристика масиву Осокорки, застосування даних ДЗЗ для оцінки стану геосистем, рекомендації щодо вдосконалення природоохоронної діяльності та пом’якшення наслідків змін клімату на досліджуваній території.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та аналіз попередніх досліджень	05.09.2021-15.09.2021	
2	Написання огляду проблеми за темою дослідження (Розділ I)	16.09.2021-30.09.2021	
3	Огляд та вибір методики дослідження (Розділ II)	01.10.2021-15.10.2021	
4	Проведення досліджень (Розділ III та IV)	16.10.2021-26.10.2021	
5	Написання Розділу V	27.10.2021-04.11.2021	
6	Формулювання висновків та рекомендацій кваліфікаційної роботи	05.11.2021	
7	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	21.11.2021-25.11.2021	
8	Попередній захист	26.11.2021-30.11.2021	
9	Урахування зауважень, рекомендацій та підготовка до захисту	15.12.2021	
10	Представлення роботи на кафедру	01.12.2021-28.12.2021	
11	Захист кваліфікаційної роботи	29.12.2021	

7. Консультація з окремого(мих) розділу(ів):

Розділ	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	к.т.н., доцент кафедри промислової та цивільної безпеки ФЕБІТ НАУ, Кажан Катерина Іванівна		

8. Дата видачі завдання: «15» 09 2021 р.

Керівник дипломної роботи (проекту): _____ Радомська М.М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ Мушта М. А.
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Adaptation of the Kyiv city ecosystem to climate changes»: 95 pages, 5 figures, 12 tables, 58 references.

Object of research – effects of climate changes on urban ecosystem.

Aim of work – to develop NBS project for one of the Kyiv districts.

Methods of research: search, analysis and synthesis of information, comparative analysis, visual observations, statistical data processing.

The paper considers the challenges of urban ecosystems through climate change and methods of adaptation of urban ecosystems to climate change; the current state of urban infrastructure in Kyiv has been studied; the strengths and weaknesses of Kyiv's urban infrastructure in the conditions of climate change are analyzed and organizational, technical and natural solutions for the adaptation of Kyiv's city are identified. Based on these data, the current state of urban infrastructure in the Osokorky area was determined and a project of "natural solutions" for the north-western part of the Osokorky district was developed. As a result, of the analysis, the author offers recommendations for measures to mitigate climate change in the ecosystem of Kyiv.

NATURE BASED SOLUTIONS, CLIMATE CHANGE, LANDSCAPING, URBAN ECOSYSTEM, CLIMATE CHANGE MITIGATION, GREEN ROOF, LOCAL TEMPERATURE, URBAN INFRASTRUCTURE, ENVIRONMENTAL IMPACTS, NATURE PROTECTING ACTIVITY.

CONTENT

LIST OF SYMBOLIC NOTATIONS, ABBREVIATIONS AND NOTIONS

NBS – Nature based solutions;

Etc. – Etcetera;

CO2 – Carbon dioxide;

USA – United States;

UK – United Kingdom;

PM_{14} – Inhalable particles;

E95 and E40 – international corridors;

EBRD – European Bank for Reconstruction and Development;

ME "Pleso" – Pleso Municipal Enterprise;

LU – Law of Ukraine;

NPAOP – Regulations on labor protection;

DBN – State building codes;

DSTU – National Standards of Ukraine.

INTRODUCTION

Relevance of the work. Over the past several decades, human activity resulted in observable warming of the atmosphere and ocean has been observed, as well as changing frequency and intensity of precipitation and cyclones, the rate of ice melting, the sea level rises, etc. These physical changes have significant impact on cities around the world, although this impact can vary significantly depending on the geographic region. Many of these changes have already become real manifestations of gradual climate change. Since climate has decisive effect on most natural processes in ecosystems, the consequences of its changes are manifested in all components of environment, however, the essence and depth of expected and unpredicted changes vary considerable from component to component. Climate change is affecting all ecosystems on the planet, but in the given work the focus is on urban ecosystems, because the tendency to urbanization is growing.

Aim and tasks of the diploma work

Aim of the work – to develop NBS project for one of the Kyiv districts.

Tasks of the work:

1. To analyze the imbalance in urban ecosystems due to climate changes;
2. To identify the methods of adaptation to climate changes in urban ecosystems;
3. To investigate the current state of urban infrastructure in Kyiv;
4. To analyze the strengths and weaknesses of Kyiv urban infrastructure in the face of climate change;
5. To study the organizational, technical and nature based solutions for adaptation for Kyiv;
6. To define the current state of urban infrastructure in Osokorky district;
7. To develop NBS project for north-western part of Osokorky microdistrict and to develop recommendations on the climate change mitigation activities in Kyiv city ecosystem.

Object of research – effects of climate changes on urban ecosystem.

Subject of research – climate change mitigation activities in Kyiv city ecosystem.

Methods of research – search, analysis and synthesis of information, comparative analysis, visual observations, statistical data processing.

Scientific novelty of the obtained results.

1) For the first time, the weaknesses and strengths of Kyiv's infrastructure were assessed.

2) Analysis of green areas of the Osokorky district and special project of "green roofs" was developed for this area.

3) Further development of the principles of climate change adaptation and mitigation for urban district.

Practical importance of the obtained results. The NBS project for north-western part of Osokorky microdistrict was developed and can be used as a sample for developing similar projects for other urban areas.

Personal contribution of the graduate: research and analysis of literature, research of current state of urban infrastructure in Kyiv, creation of recommendations and development of the NBS project for north-western part of Osokorky microdistrict.

Approbation of results.

Мушта М.А., Радомська М.М. Правове забезпечення адаптації до змін клімату: тези доп. III Всеукраїнській науково-практичній конференції «Євроінтеграція екологічної політики України», м. Одеса, 20-22 жовтня 2021 р. – С. 149-152.

Publications*:*

Radomska M.M., Mushta M.A., Nazarkov T.I. Nazarkov T.I. Protection of urban plant associations from climate change pressures to support ecosystem services provision // Екологічна безпека та технології захисту довкілля. – 2021. – №3.

CHAPTER 1
IMBALANCE IN URBAN ECOSYSTEMS DUE TO CLIMATE CHANGES

1.1. Urban ecosystems

Urban ecosystems or urban ecosystems are artificial heterotrophic anthropogenic ecosystems that arise as a result of the development of cities and represent the concentration of the population, residential buildings, industrial, domestic, cultural objects, etc. Unlike agrocenoses, they have no elements of self-regulation.

The development of an urban ecosystem requires three main components:

1) Geographic environment - the natural basis of the ecosystem.

2) Urban population (social complex) - a set of people connected by social relations and the urban environment.

3) The urban environment, which includes interconnected and interpenetrating subsystems (environments): a transformed geographic natural environment, landscape-architectural, socio-economic, social production [1].

Urban ecosystems, unlike natural ecosystems, are an amalgamation of natural and man-made elements. The interaction of these two elements is influenced by such factors as culture, personal behavior, politics, economics and social organization, which is a distinctive feature of urban ecosystems [2].

1.2. Challenges for urban ecosystem raised by climate changes

For the purpose of our analysis, we will divide the challenges raised by climate change at urban areas into three categories [3]:

1) challenges for abiotic components – changes in the non-living components of urban ecosystem, which affect the living conditions of urban residents;

2) challenges for biotic components – threats raised by changing climate for people and other living organisms and communities at urban areas;

3) challenges for artificial components of urban ecosystem, including buildings, elements of built infrastructure, etc.

1.2.1. Challenges for abiotic components of urban ecosystem

These challenges are the direct consequences of climate changes and they represent the essence of this phenomenon. However, they involve not only the atmosphere, but the hydrosphere as they are in dynamic balance and interconnected, mutually reflecting all changes.

Higher temperatures in cities (Less cold days and nights). Changing urban temperatures are driven both by large-scale climatic changes and ongoing urbanization. There is agreement that the current changing climate has to be kept well below an average global increase of 2 °C to avoid major future climate-driven catastrophes.

Extremely high temperatures directly lead to death from cardiovascular and respiratory diseases, especially among the elderly. For example, during a period of extreme heat in the summer of 2003, an additional 70,000 deaths were reported in Europe. In addition, high temperatures in the air increase levels of ozone and other pollutants, which exacerbates cardiovascular and respiratory diseases. At the same time, during high heat levels of plant pollen and other aeroallergens increase. They can provoke asthma, which affects about 300 million people. A further rise in temperature is expected to increase this burden [4].

"Heat Waves" and "heat island". As a result of climate change, scientists predict that periods of extremely hot weather will become more frequent, intense and long in most land regions. There is, however, no standard definition of extremely hot weather, or heat waves due to different local acclimatization of the population, depending on the region. Extremely hot weather causes more damage to cities (the so-called "heat island" effect) because cities retain heat better than the surrounding rural areas. In the average developed country, in a city with a population of 1,000,000 people, the air temperature is 1-3° C higher than in the surrounding areas.

Increased PM_{14} and CO2 level and "Oxygen starvation". Urban heat island and overall

increased thermal background increases the level of air pollution, causing health issues for humans and animals. Resulted from strong air pollution, poor visibility leads to emergency situations, both in transport and industrial sectors. For people who are at risk (elderly and sick people) adaptation to new conditions may be not possible. Therefore, deaths are possible.

Intense and unexpected precipitation (weather extremes). Increasingly variable rainfall patterns are likely to affect freshwater resources. Lack of safe water can compromise hygiene and increase the risk of diarrhea. The frequency and intensity of flooding is also increasing, and the frequency and intensity of heavy rainfall will also increase during this century. Excessive precipitations impose additional pressure on urban infrastructure, in particular storm drain and water treatment facilities. Overfilled storm drains prevent surface run-off removal and contribute to road accidents, soil pollution and erosion, damage buildings and roads, increase frequency of landslides and subsidence [5, 6].

Droughts. Insufficient moisture is also a possible outcome of climate change, which is conditioned by shifting precipitation patters. Currently, at least 1% of the total land area is considered extremely arid. By 2100, this figure could reach 30%. It also compromises safe water supply, preservation of urban green plantations and exacerbates the intensity and pressure of urban heal island.

An increase in the number of powerful tropical cyclones. Tropical cyclones are one of the most expensive and ruinous types of catastrophes, and the frequency and severity of the inheritance have grown since 1970. The global warming contributes to growing intensity of tropical cyclones in most regions, in which they are established.

Sea level rise. Average sea level has risen globally over the past several decades, but the rate varies considerably across geographic regions. Thermal expansion or an increase in the volume of water in the ocean as it warms is considered the main cause of sea level rise, but ice melting may play a more significant role in the future. When the temperature rises to certain values, the rate of ice melting can reach unprecedented rates. The rising sea is a major problem for coastal cities, as it causes loss of land and provokes other negative hydrological phenomena, as tsunamis and flooding.

Natural disasters. Natural disasters of geological nature can be also triggered by the

changing of functional processes of atmosphere and hydrosphere, causing colossal damage to biota and man-made infrastructure.

Natural disasters have both immediate and long-term effects on health care. The consequences of floods and storms are not only the actual death of people and damage to their health, but also long-term damage to facilities that provide the health care system. Power outages can disrupt hospitals. Drinking water supply can also be complicated in the event of damage to water supply facilities, or due to lack of electricity.

1.2.2. Challenges for abiotic components of urban ecosystem

Being affected by direct manifestations of climate changes, living organisms of urban ecosystems are forced to respond in different manner. Thus, indirect consequences of climate changes are displayed in changes of diversity and structure of urban communities, as biota fails to adapt to new conditions and either shifts its habitat or disappears. Humans are not ready to escape from the economic and social benefits provided by the city and undergo unusual health pressure.

Declining biodiversity in cities. Biodiversity at urban areas is essential for maintaining health, quality of life, social and economic sustainability of large and small cities. It reflects the successful coexistence of man and nature and brings urban residents closer to rural people. Moreover, it provides adaptation services at urban areas, by lowering temperatures, improving air, water and soil quality, as well as providing protection from the sun and regulating water runoff, particularly in floods. Due to its ability to absorb carbon dioxide, floral community can significantly reduce the degree of climate change. Although urban biodiversity is only a small part of the global biodiversity on the planet, it is of particular importance due to its close proximity to the bulk of the world's population.

The Congress of the Council of Europe believes that sustainable development involves integrated solutions and that urban biodiversity strategies should be considered alongside other environmental policies, including spatial planning, transport and mobility, energy resources, water use and waste disposal [7].

Overpopulation. This is both the reason and the outcome of climate changes. When

the rural areas lose their economic potential due to changing climate and reducing yields, their residents and pushed to move to urban areas in search for employment and life supporting services. The resulted pressure on ecosystems, services and infrastructure is increasing, leading to failures and competition for resources. Poverty is becoming a complicating factor that exacerbates the health effects of climate change. With the increase in the number of people moving to cities and rising temperatures, as well as the rapid aging of society, the threat of rising heat deaths in the future will become real. Additionally, extreme heat and natural disasters will affect growing population of cities and put unbearable burden on medical system.

Unusual phenomena in the animal world. Transformation of living conditions put animals under thriving pressure, leading to migration, atypical behavior and intensive reproduction. The recent examples are:

- the presence of ladybirds on the beaches of the Sea of Azov and the Kuban (this is a seasonal migration in search of food, but due to extreme conditions (heavy rain and wind) insects washed ashore) [8];
- the invasion of mosquitoes in Crimea (their number is due to the warm winter and rather rainy spring) [9];
- the invasion of giant jellyfish in the Sea of Azov (the reason for the invasion was the heat, because jellyfish reproduce abundantly in such weather) [10].

Development of pathogens: The physical effects of climate change, including temperature, precipitation, humidity and sea level rise, can change the area of distribution, cyclicality and methods of transmission of some infectious diseases. Floods can contaminate the water supply system with pathogens can lead to an increase in intestinal disorders and respiratory diseases, both in developed and developing countries.

1.2.3. Challenges for man-made objects

Climate change disasters damage assets, thereby changing the urban way of life. Such assets include: natural resources (natural capital), social relations (socio-political capital), skills and health (health), infrastructure (physical capital), financial resources (financial

capital).

Physical damage. Climate change directly affects the material infrastructure of cities - its network of buildings, roads, sewers and energy systems - which, in turn, affects the well-being and quality of life of people. This will be especially noticeable in the lowest places above sea level in coastal areas, where many of the world's largest cities are located. Although this area covers only 2% of the total area, this area is home to about 13% of the world's urban population.

Significant destruction of housing and administrative stock takes place due to increasing number of natural disasters and catastrophes associated with climate change. From this point of view, the most costly and devastating natural disasters are floods, which are likely to occur in different regions of the world as a result of increased rainfall.

In addition, coastal erosion and seawater intrusion can destroy premises and make some areas uninhabitable. Sedimentation or lowering of the earth's crust is another "long-term" factor that poses a risk to the residential and commercial stock of cities. The subsidence rate can reach one meter in 10 years, which will lead to the destruction of pipelines, house foundations and other infrastructure. In coastal cities, in particular, rising sea levels can destroy roads and erode the cushion of the road surface, as well as bridge piers.

Heavy rainfall and recent flooding and replenishment developments could lead to long-term disruption of transport infrastructure, destroyed highways, seaports, bridges and airports.

Rising air temperatures, in particular during long drying periods and higher average temperatures, destroy expensive coatings and lead to more frequent repairs. In addition to the direct threat to human life, the destruction or damage of transport systems and the long-term disruption of communications, the system significantly affects all aspects of urban life.

By their nature, cities are centers of high energy demand and related resources. Climate change can disrupt the capacity and supply structure of energy. The combination of urban population growth, changing local favorable conditions, the accumulation of heat in urban areas and the economic need for development, can significantly increase energy needs. Climate change is also affecting energy production and distribution.

As the temperature rises and the amount of precipitation decreases, the structure, selection and distribution of water may be disturbed: on the one hand, the weakening of water strains is proposed due to changes in precipitation, lowering river levels, groundwater inflow and, in coastal areas, groundwater penetration. waters and rivers of salt water. On the other hand, with increasing temperatures, more frequent periods of extreme heat and increasing demand for water in cities. Climate change due to rainfall and sea levels can also affect urban water quality and treatment. Natural disasters related to climate change can also affect the sewage systems of urban areas, which already identify a number of problems, especially in developing countries.

Economic losses. Further increases in the frequency and intensity of extreme weather conditions, as well as long-term changes, will increase the vulnerability of urban economic assets and, consequently, the cost of doing business. Climate change will affect a wide range of economic activities, including trade, manufacturing, tourism and insurance services.

The direct effects of climate change and extreme weather conditions on the economy include damage to buildings, infrastructure and other assets. These effects will be particularly severe in regions where industrial facilities are located in vulnerable areas, such as coastal areas and flood-prone plains.

Indirect consequences of climate change are delays in the implementation and termination of contracts related to the impact of climate on the transport, communications and energy systems. Retail and commercial services are also threatened, as these changes affect the supply chain, distribution network and transport system, as well as the consumption process.

The tourism industry and related services depend entirely on the reliability of transport infrastructure, which includes airports, seaports and highways.

Climate change in certain regions can affect air temperatures, thereby changing seasonal tourism and tourism infrastructure. Natural disasters that lead to transport delays or flight cancellations can also negatively affect tourism. The local urban economy may suffer significant financial losses and job losses, as in many cases leisure and tourism are key sources of income for cities. At the same time historical values and monuments, as well as cultural resources and archeological sites, are also threatened by climate change and their

loss will inevitably reduce tourist attractiveness of some destinations.

The insurance industry also depends on climate change, especially in terms of extreme weather conditions affecting large areas. Climate change may increase the demand for insurance services and at the same time reduce the amount of insurance claims. The cost of insurance services is likely to increase significantly if the number of irregular but catastrophic natural disasters increases. The expectation of the occurrence of events that lead to large losses is likely to affect the amount of insurance compensation [11].

1.3. Human health effects from climate changes

Climate change threatens human wellbeing in terms of medical, social and economic effects.

1.3.1. Social and economic effects

Economic effects incorporate primarily direct losses as a result of more frequent natural disasters and weather extremes and expenditures on elimination of their consequences. However, it also includes indirect losses due to both weather extremes and steady shift in weather patterns, such as:

- Food loss
- Loss of natural resources
- Expenses on adaptation to new conditions (transformation, retrofitting, support and maintenance of infrastructure and man-made objects and natural objects, valuable for ecosystem services provision);
- Spending on medical care
- Energy costs for cooling

Growing economic problems cause social tension, loss of community cohesion and increased interpersonal aggression. Under urban conditions this eventually results in increased violence and crime and disruption of urban communities. Lack of understanding and cooperation prevents efficient work on mitigation of climate changes and adaptation to

their consequences.

1.3.2. Effects on human health

Climate change contributes to an increasing global burden of disease, and this trend is expected to worsen in the future. The latest report from the Intergovernmental Panel on Climate Change confirmed the vast body of evidence of human impacts on local and global climate, and highlighted the many health implications of such impacts both mental and physical.

Climate variability and change lead to death and disease as a result of natural disasters such as heat waves, floods and droughts. In addition, many serious diseases are extremely sensitive to changes in temperature and rainfall patterns, these are malaria and dengue, as well as malnutrition and diarrhea, which are other leading causes of death. The most prominent human health effects from changing climate are:

The impact of climate on human health will not be uniform across all cities in the world. Urban populations in developing countries, especially small island states, arid and high mountain areas, and densely populated coastal areas, are considered to be particularly vulnerable [12, 13].

A person's psychological health is also highly dependent on changes in the environment, which is often omitted from the relevant research activities and regulations.

Thus, extreme weather conditions can cause stress and other consequences for mental health, especially when the effects of catalysis and new living conditions affect her loved ones.

People who are prone to mental illness are especially vulnerable to extreme heat. Studies have shown that the presence of pre-existing mental illness increases the risk of death during heat waves by as much as three times.

Unfortunately, people taking medications for mental illness that make it difficult to regulate body temperature are at the highest risk of adverse effects. Therefore, they are very difficult to experience sudden changes in temperature and its sharp rise.

The very term "global climate change" causes fear and anxiety in people. Yes, this is

indeed a problem, but some people are too anxious to make rational decisions.

Of course, vulnerable groups, such as children and the elderly, pregnant and postpartum women, people with pre-existing mental illness, low-income people and emergency workers, are most at risk.

People with low incomes are not able to materially adapt their lives to new conditions (buy air conditioning or a fan) and quickly create new living conditions after natural disasters and accidents.

And, of course, emergency workers suffer from the effects of climate change because they work in dangerous areas of activity, and the frequency and severity of dangerous situations and cataclysms is only increasing.

1.4. Consequences of climate change for urban biodiversity

Climate change threatens biodiversity, but biodiversity is a key element for the reduction of climate change effects. These threats are valid for urban biota, as well as inhabitants of not developed areas.

Biodiversity in cities consists of plants, animals and microorganisms that are inherent in certain territories. Of course, the biodiversity in coastal, mountainous and lowland cities is very different. And the strength of the influence of climate change will depend on the location.

Changes such as projected temperature changes, changes in precipitation, extreme events and rising CO2 concentrations will affect individual survival opportunities of species, population dynamics, species distribution patterns, reproduction processes, growing season duration, species interactions and ecosystem services as a result of spatial or temporal reorganization.

Changing living conditions will affect living activity of species, limiting their access to water and food during the growing season. The northern regions will suffer the most, as there will be strong temperature changes.

Some urban areas have a higher plant richness compared to their natural counterparts because there is an influx of foreign plant material (creation of new locations, etc.). With

the change of urban climate, it is possible to change the invasiveness of alien species, as well as increase the spread of diseases and pests.

There is clear evidence that climate change is already affecting biodiversity and that it will continue to do so. And the worst form of this impact if extinction of species, primary the most unique – endemic species with narrow tolerance to fluctuations to environment conditions. For example, amphibians breed in water, and any reduction or change in rainfall can lead to a drop in their birth rate. Moreover, the increase in ambient temperature is closely related to outbreaks of fungal disease, which contributes to the reduction of amphibian populations.

Climate change is likely to especially affect urban inland water ecosystems and their inhabitants. Thus, in recent decades, more than 20% of the world's freshwater fish species have disappeared, are endangered or become rare. Freshwater biodiversity is declining at a much faster rate than species biodiversity in most terrestrial ecosystems.

Changes in precipitation patterns will lead to changes in the flow regime of many rivers and lakes, which will affect the spawning patterns and food habits of many species.

Human interventions to combat climate change can exacerbate adverse impacts on numerous wetlands. For example, measures to combat climate warming are likely to increase the demand for fresh water to meet urban and agricultural needs. The possible result will be a decrease in the flow of rivers and streams, leading to the loss of ecosystem services and species-providers.

As a result of the reaction of lakes and streams to climate change growth, reproduction and distribution of biodiversity in lakes and streams will be affected. The changes in the reproductive capacity of migratory birds whose breeding cycle is associated with lakes and streams will also occur. Genrally many species will shift their habitats further to the pole, thus changing the composion of urban fauna on their way.

The coastal ecosystems will be damaged, putting at risks many species, adapted to a very narrow range of environment conditions, due to a complex of factors:

- increased erosion of the coastal zone,
- more extensive flooding in the coastal zone,
- more extensive flooding of the territory by storm surges;

• an increase in the temperature of the surface layer of seawater;

• reduction of sea ice cover.

Such changes will most likely affect the composition and distribution of coastal city species.

1.5. Climate change issues of urban areas in geographical context

As it was previously mentioned, the possible consequences of climate changes in cities of the world depend on their geographical location, which defines the typical climate and intensity of changes. Climate zones are continuous or discontinuous area that run parallel to the planet's latitudes. They differ among themselves in terms of air motion and the quantity of solar energy. Terrain relief, proximity to the sea or ocean are also important climate-forming factors.

By the classification of the Soviet climatologist B. Alisov, there are seven main types of the Earth's climate: equatorial, two tropical, two temperate and two polar (one each in the northern and southern hemispheres). In addition, Alisov identified six intermediate belts, three in each hemisphere: two subequatorial, two subtropical, as well as subarctic and subantarctic. And the forms and intensity of climate changes manifestations can be formulated in different manner for each climate area.

Implications for cities in Arctic and Antarctic climatic zone:

- the climate is changing, about 2 times faster than the world average;
- the snow period has decreased by an average of 2 weeks and will be shorter;
- reduction in the total area of arctic ice;
- the average annual temperature in Antarctica and the Arctic is gradually increasing;
- the number of natural disasters is increasing;
- soil changes in northern latitudes;
- the level of the World Ocean rises;
- destruction of the natural habitat of many species of animals and plants.

Implications for cities in Subarctic and Subantarctic climatic zone

- high humidity;

- flooding of coastal cities;

- global migration;

- high frequency of cataclysms;

- animal migration;

- an increase in the mortality rate of the population of cities, flora and fauna due to cataclysms, lack of resources and diseases (rather, due to diseases that emigrants "bring" and which are not typical for these territories);

- destruction of infrastructure;

- violation of the usual way of life of the indigenous inhabitants of cities;

- violation of ecological balance, displacement of some biological species by others.

Implications for cities in Moderate climatic zone

- high humidity, but also strong evaporation;

- flooding of coastal cities;

- increased fog and smog;

- overpopulation in cities due to migration and lack of resources;

- strong sandstorms in the cities of the steppe zone;

- large-scale fires;

- an increase in the number of storms and tornadoes (especially in North America due to the relief);

- high frequency of cataclysms, atypical for cities;

- migration of animals typical for tropical climates;

- an increase in the mortality of the population of cities, fauna and flora due to cataclysms, lack of resources, the struggle for territories and diseases;

- destruction of infrastructure;

- violation of the usual way of life of the indigenous inhabitants of cities;

- violation of ecological balance, displacement of some biological species by others;

- an increase in electricity consumption for air conditioning in the summer season.

Implications for cities in Subtropical climate zone

- high humidity, but also strong evaporation;

- global migration;

- strong sandstorms;
- large-scale fires;
- high frequency of cataclysms;
- animal migration;
- an increase in the mortality of the population of cities, fauna and flora due to cataclysms, lack of resources and diseases;
- destruction of infrastructure;
- violation of the usual way of life of the indigenous inhabitants of cities;
- violation of ecological balance, displacement of some biological species by others;
- an increase in electricity consumption for air conditioning in the summer season.

Implications for cities in Tropical climate zone

- flooding of most coastal cities;
- unsuitability of some territories due to high temperatures;
- high humidity, but also strong evaporation;
- global migration;
- strong sandstorms;
- lack of resources, especially drinking water;
- high frequency of cataclysms and devastation due to them;
- animal migration;
- an increase in the mortality of the population of cities, fauna and flora due to cataclysms, lack of resources and diseases;
- large-scale fires;
- destruction of infrastructure;
- violation of the usual way of life of the indigenous inhabitants of cities;
- violation of ecological balance, displacement of some biological species by others;
- an increase in electricity consumption for air conditioning in the summer season.

Implications for cities in Subequatorial climatic zone

- flooding of most coastal cities;
- unsuitability of some territories due to high temperatures;
- high humidity, but also strong evaporation;

- large-scale fires;

- lack of resources, especially drinking water;

- high frequency of cataclysms;

- animal migration;

- an increase in the mortality of the population of cities, fauna and flora due to cataclysms, lack of resources and diseases;

- destruction of infrastructure.

Implications for cities in Equatorial climate zone

- flooding of coastal cities;

- unsuitability of most territories due to high temperatures;

- high humidity, but also very strong evaporation;

- large-scale fires;

- lack of resources, especially drinking water;

- high frequency of cataclysms;

- animal migration;

- an increase in the mortality of the population of cities, fauna and flora due to cataclysms, lack of resources and diseases [14, 15, 16, 17, 18].

Although we tried to divide the impact of climate change on the cities of the world by climatic zones, for a detailed study and analysis, we need to take a specific city, since climate changes occur unevenly across the planet.

1.6. Hotspots of urban ecosystems degradation

Due to combination of geographical and climate factors some cities are more affected as compared to the others. This is especially true for coastal cities, urbanities of arid areas and agglomerations in the poorest regions of the world.

Rising humidity and high average temperatures could make many cities uninhabitable by 2100. The risk group includes cities in countries such as Qatar, Saudi Arabia, Bahrain, the United Arab Emirates and other cities in the Middle East.

According to the calculations of climatologists, at the current rate of growth in

greenhouse gas emissions, the average air temperature in the Gulf countries may reach 74-77 ° C by 2070. This will make urban areas unsuitable for people. An exception may be large metropolitan areas with a developed air conditioning system. But even in them, people will be able to leave the house only at night.

Climate change is already making itself felt in cities. This manifests itself in unusually high summer temperatures in cities in Europe, China, South Korea and Argentina, as well as wildfires in the state of California. Climate change is a catalyst for droughts in cities in Africa and the Middle East, snowstorms in Nepal and torrential downpours that have caused floods in Canada.

According to the expert community, the sea level rise in the 21st century will be up to 1 m. In this case, lowland cities, coastal areas and small islands will be the most vulnerable. The first at risk are the cities of the Netherlands, Bangladesh and small island states such as the Bahamas and Maldives.

Significant areas can be flooded in cities in countries such as Russia, USA, UK, Italy, Germany, Denmark, Belgium, Iraq, Thailand, China, Japan and Vietnam.

Another important consequence of climate change is the lack of drinking water, which will be especially severe in cities of Central Asia, the Mediterranean, South Africa, Australia, etc.

The epidemics of tropical diseases such as malaria and fever are also forecasted to spread in tropical regions, especially in sub-Saharan Africa.

Climate change can affect not only human health, but also increase the risk of political divisions and conflicts over access to water and food resources [19, 20, 21].

1.7. Conclusions to Chapter 1

The analysis of the climate change factors having the most intensive impact on urban ecosystems was conducted. The recipients of the damage were defined as economic and social system of cities, mental and physical health, ecosystem services and biodiversity of urban areas. The most important issues and their consequences are summarized in table 1 [22].

Table 1

Challenges and consequences

№	Challenges for urban ecosystem raised by climate changes	Main predicted consequences
1	2	3
1)	Higher temperatures in cities	• Increased energy demand for cooling; • Less damage to the transport system from snow and ice, but more from overheating and high humidity during periods of heavy rainfall and extreme conditions. • Changes in the area of permafrost; • Damage to buildings and infrastructure. Damage to flora and fauna.
2)	Heat Waves	• Decrease in the quality of life of people in warm regions due to the lack of air conditioning; • Impact on people from risk categories (elderly, young and poor), including a significant number of deaths. • Dramatic increase in the energy used for air conditioning. • Damage to flora and fauna.
3)	Intense and unexpected precipitation.	• Destruction of settlements, economy, transport by floods. • Growing number of deaths and injuries, damage to tangible assets and infrastructure. • Emerging potential ability to use rainwater to generate electricity in many regions. • Damage to flora and fauna.

table 1 cotinuation

1	2	3
4)	Droughts	• Lack of water for people, industry and services; • Reduced the amount of electricity generated by hydroelectric power plants. Migration of people • Damage to flora and fauna.
5)	Increased number of powerful tropical cyclones	• Destruction of settlements by floods and wind. • Destruction of the water supply system. • Termination of insurance coverage in areas with a high degree of risk (at least in developed countries). • Growing number of deaths, injuries, significant property damage. • Population migration. • Damage to flora and fauna.
6)	Sea level rise	• Floods and flooding of coastal cities. • Reduction in the amount of fresh water due to the penetration of sea water into it. • Growing number of deaths, injuries, significant property damage. • Population migration. • Damage to flora and fauna.
7)	Declining biodiversity in cities	• Damage and degradation of flora and fauna. Destruction of trophic chains. • Arrival of new species that will be more adapted to new climate conditions, thereby displacing species that will be less prepared.

table 1 cotinuation

1	2	3
8)	Overpopulation	• Migration of the rural population to the cities, due to lower yields and loss of economic potential. • Competition for resources. • Ecosystem failure due to pressure on infrastructure and ecosystem services. • Poverty and as a consequence of the deterioration of people's health. • Excessive burden on the medical system.
9)	Unusual phenomena in the animal world	• Damage to flora and fauna. • Changing population trends to sharp increase or decline in the population. • Imbalance in the ecosystems of these populations.
10)	Water resources scarcity	• Complicated system of drinking and industrial water supply. • Increase in tariffs. • Deterioration of human life and health.
11)	Destruction of structures and territories that are not designed for new weather conditions	• The economic downturn is caused by high maintenance and construction costs. • Need in reconstruction and retrofitting of the existing buildings, accounting future temperatures and weather conditions in general. • Migration of people due to destruction of residential and technical buildings, as well as the danger to life and health of people.

End of table 1

1	2	3
12)	Increased PM_{14} and CO2 level and "Oxygen starvation"	• Respiratory and cardiovascular disorders in humans and animals. • Mental disorders in humans and behavior disorders among animals.
13)	Economic damage	• Increased tariffs for commodities • Investments in adaptation to new climatic conditions. • Rising medical care expenses. • Increased energy demand for cooling.
14)	Development of pathogens and new species	• Extinction and weakening of populations. • Emergence of new viruses and other pathogens • Competition among species and change of communities composition.
15)	Natural disasters (earthquakes, landslides)	• Damage to flora and fauna. • Migrations. • Economic losses. • Injury and death of people, as well as destruction of their habitat.

CHAPTER 2
METHODS OF ADAPTATION TO CLIMATE CHANGES IN URBAN ECOSYSTEMS

2.1. Approaches to adaptation climate changes: urban areas context

Adaptation is a process during which the functioning of the system is established or maintained (that is, the maintenance of its basic parameters) when the conditions of the external and / or internal environment change [23].

Climate change adaptation is the adaptability of natural or man-made systems in response to real or anticipated climate change, which reduces vulnerability and exploits favorable conditions [24].

Compared to other responses to climate change, adaptation is the longest but most effective process that contributes to the "survival" of any system, even under adverse conditions.

Adaptation to climate change in urban ecosystems is a complex process that has a certain structure, includes various methods, constant monitoring and development, based on pressing problems.

Like any process, adaptation to climate change in urban ecosystems can be divided into three phases:

- creating a base for the adaptation process,
- identifying risks and finding solutions,
- implementing "decisions made" and monitoring the situation.

All adaptation phases complement each other and are performed in order. For the most effective result, you can and should use several methods and tools at each of these stages. The set of methods and tools is determined based on the specific problem and context. There are a huge number of methods and tools that are included in the adaptation process, but there are those that must be present without fail. Only after completing the mandatory points in each stage of the adaptation process, it can be considered that the main steps in this process

have been completed [25, 26].

In general, all methods of adaptation to climate change can be divided into organizational and technical. If we consider the phases of the adaptation of urban ecosystems itself, then in the first and second phases, it is organizational methods that are used to a greater extent. But the third phase already consists of technological and only partially organizational.

Adaptation to climate change is becoming an element of urban governance everywhere. World experience helps to formulate ten basic principles (steps) for developing an adaptation strategy applicable to any territory:

1. Decision on the need for adaptation and mitigation. Supporting commitment to develop and implement an adaptation strategy at the highest level of leadership. Creation of a management system at the city (region) level.

↓

2. Training of specialists and active participants in the development. Implementation of the adaptation strategy. Awareness of the widest circles of the population.

↓

3. Identification of the main stakeholders and ensuring proper interaction with them.

↓

4. Debugging of work in conditions of uncertainty (there will be no other conditions).

↓

5. Study of the key impacts of climate change and vulnerabilities, potential for reducing greenhouse gas emissions.

↓

6. Consideration of a wide range of alternative solutions in the field of adaptation.

↓

7. Ranking of solutions applicable in specific conditions by priorities.

↓

8. Making necessary changes in existing policies, structures and processes.

↓

9. Avoiding, as far as possible, making erroneous decisions leading to negative or

exclusively short-term positive effects.

↓

10. Ensuring monitoring of the consequences of climate change, the need for adaptation, implementation of the adaptation strategy. Regular assessment of the results obtained and making appropriate adjustments to the action programs.

Engineering and technological solutions are usually implemented within existing programs (disaster risk management and water resource management). However, the importance of social, institutional measures is growing; ecosystem-based measures; and adaptation margins [27].

2.2. Methods of adaptation to climate change

To address such important issues as climate change, a number of technological, natural and social solutions need to be used to adapt cities, but the question remains how best to integrate these different but complementary solutions for maximum benefit.

2.2.1. Urban technology solutions

Nowadays, technological solutions for adapting cities to climate change are constantly emerging, progressing and being investigated for efficiency. Thus, air conditioning is a technological solution during heatwaves. Another technological solution is switching to system heating and cooling using cooling towers or centralized distribution, which will also help save energy and reduce sensible heat.

There are also simple but highly effective technological solutions to help cities build more resilient systems. These are building materials (increase the albedo of urban surfaces to reflect sunlight). A material such as light paint will help reduce the heat load on buildings in summer, and permeable sidewalks that replace asphalt can reduce city heat and storm water runoff by reflecting radiation, providing evaporative cooling and allowing the underlying soil to absorb rainfall.

Information and data technology solutions (online maps of temperatures, weather

conditions, air composition, etc.) can inform decision-makers in real time. Thus, accelerating the decision-making process and the transition to real action in case of emergency. Sensors and automated or unmanned systems (such as on-demand irrigation systems) are becoming more common in smart cities to save money (reusing water before or during droughts and floods). Although technological solutions are an area that is constantly developing or improving, they still remain inaccessible to many cities. Since not everyone has the resources to implement and maintain them. The use of new technological solutions requires social and state intervention.

2.2.2. Urban nature-based solutions

In order to provide a variety of ecosystem services, such as improving the environment and promoting health and well-being, nature-based solutions (for example, the use of vegetation and blue-green infrastructure) are most often used.

The most effective natural solutions are in preventing extreme heat, drought or flooding.

Tree cover is often used to cool transport corridors. However, regional forest cover can influence mesoclimatic patterns.

In cities that are prone to flooding, bioswales are often used along streets or built wetlands to help regulate vertical and horizontal hydrological flows.

However, nature-based solutions, when deployed on a large scale, can pose significant financial and management challenges. Natural solutions in cities are very sensitive to many climate issues, as changes in temperature and rainfall will affect the green infrastructure itself. For this reason, natural solutions require adequate management to maintain desired functions and performance as the environment changes. Consequently, the resilience of urban vegetation to variations in future climate change must be supported to ensure that the effectiveness of natural solutions will not diminish and thereby create new problems.

Despite all the positive aspects of natural solutions, it is not fully understood how and whether they can replace gray infrastructure.

2.2.3. Urban social solutions

Social solutions to climate change are based on the study of social values that motivate people to change their behavior and habits. These decisions can contribute not only to the adoption of new, but also previously inconvenient measures. Social mobilization initiatives (from government-led planning processes to local initiatives at the local level) are needed to reduce perceived barriers to sustainable climate solutions and motivate action through engagement, learning and hands-on participation. Many social decisions target inequalities and impact on vulnerable groups of people, such as those who may have fewer resources for technological solutions, less access to cooler private or public green spaces, and less access to information about adaptation.

In cities with many poor communities, awareness of climate risks may be high, but the capacity to defend itself may be limited. That is why one of the main tasks of adaptation is to reduce the poor population through government assistance.

The inability to participate in decision-making processes related to adaptation and mitigation for certain segments of the population can further exacerbate the risks associated with climate change.

Existing models of vulnerability highlight the need to take structural inequalities into account when designing incentives, public participation and contingency plans that do not exacerbate existing inequalities. Strategies such as building alliances between municipal and local institutions may be necessary to stimulate cooperation in regional processes (eg transport networks, water systems and land use policies).

2.3. Nature based solutions for urban adaptation

NBS refers to the use of nature in tackling challenges such as climate change, food security, water resources, or disaster risk management, encompassing a wider definition of how to conserve and use biodiversity in a sustainable manner. By going beyond the threshold of traditional biodiversity conservation principles, this concept intends to additionally integrate societal factors such as poverty alleviation, socio-economic development and

efficient governance principles [28].

Nature-based solutions are the actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively. Such solutions bring more diverse, natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

The main characteristics of NbS include the following:

1) NbS has a broad definition and scope. While the concept is based on climate change mitigation and adaptation, it is being used to address multiple policy challenges simultaneously. Conserving biodiversity and improving ecosystem services are being used as a basis for finding solutions to major challenges such as climate change and disaster risk reduction, ending with poverty alleviation and the promotion of a green economy.

2) Scales of the concept from the point of view of "nature". Despite the breadth of the concept, what sets NbS apart from traditional engineering approaches is its versatility, conservation and enhancement of natural capital, and the ability to adapt and create resilience in landscapes.

3) Integration and management-based approaches are used to create and manage NbS. Thus, this concept differs from more traditional and top-down conservation activities in that, for example, through protected areas, solutions are sought to meet the needs of a wide range of stakeholders. To this end, collaborative approaches to the design, creation and management of natural solutions are promoted.

4) NbS is action and this will require a focus on regulatory frameworks, planning systems and economic instruments.

Adapting to current or future impacts of climate change includes a range of measures that can be used to reduce societal vulnerability and increase adaptive capacity and resilience. Potential adaptation measures to combat climate change can be very different and effective at different spatial and temporal scales.

Vegetation does play an important role in bringing urban climates closer to pre-development conditions. Urban green infrastructure and natural solutions are critical concepts in addressing urban climate change. Urban green infrastructure is a concept in

which planning decides a lot and therefore focuses on the strategic role of integrating green spaces and associated ecosystem services into urban planning at various levels.

2.3.1. Green and Blue Infrastructure for microclimate regulation

Temperature in cities is a parameter that rises due to active anthropogenic activity. But it can be strategically controlled with a network of planned urban green spaces.

The creation of green infrastructure involves the selection of suitable surfaces, their spatial organization and management. The potential for temperature reductions from vegetation is much higher in densely built-up areas than in sparsely built-up areas, with variations due to prevailing wind direction and time of day.

Although there is always a preference for "concentration" of green spaces, individual urban trees also contribute to lower urban temperatures.

The climatic characteristics depend on the characteristics of the plants themselves, such as the shape of the leaves and crown, where the rare crowns with large leaves have a higher cooling capacity.

New types of vegetation systems, such as green roofs and green walls, can also maintain the temperature balance of urban areas. In planning such solutions it is very important to account appearance of the buildings themselves, as this affects the suitability for each form of plant association.

The advantage of these systems is that they can be both standalone "cooling" systems, or as an addition to the existing blue-green infrastructure. They also allow more rational use of space that is usually not taken to create green spaces. Green walls are a great way to reduce the temperature of buildings themselves, which saves energy on air conditioning.

The effectiveness of vegetation depends on the species composition. Different species have different cooling capacities and different cooling modes, such as evaporative or shadow cooling, as well as control variables such as irrigation and water levels in the substrate. A very important point is the type and as they can be used to create green roofs, etc.

The cooling effect is different for blue and green infrastructure. For example, the

surface temperature of the water is lower compared to areas with vegetation, which, in turn, are noticeably colder than streets and roofs. This means that the cooling effect of the water surface is greater than in a system of parks with vegetation, which in turn is influenced by the time of day, with the greatest difference between park and water bodies during the day.

Research shows that to maximize the efficient use of urban cooling space, more waterways and green spaces and water areas need to be concentrated in city centers, compared to the alternative approach of small parks distributed throughout the city.

2.3.2. NBS for the regulation of urban hydrology

Green infrastructure and natural solutions such as green roofs, rain gardens and biological forests are used to reduce localized flooding, economic loss and discomfort during high-frequency storms.

It is important to remember that these small-scale natural solutions have little impact on large-scale catastrophic events such as river floods, coastal floods or very intense cloud emissions that pose a great threat to urban infrastructure and communities. Thus, it is necessary to work on several spatial scales, with particular attention to both the installation of local solutions and the development of zoning rules for housing development, the planning of safer pre-foreseen flood zones that form an integrated and multifunctional urban drainage system.

Green roofs have been proven to greatly affect annual storm water runoff as well as peak costs. For the greatest efficiency, green roofs should be thick enough as they have limited storage capacity. This means that thinner green roofs will be ineffective in very long or heavy rains.

Green roofs and other vegetated systems can adversely affect wastewater quality if poor quality fertilizers are used or if they contain nutrient-rich compost without the addition of substances such as biochar. If space permits, then an alternative solution is used to drain stormwater to the ground - Bioswales, biofilters, raincoats or other types of retaining beds with plants.

Ground systems can be built with a thicker base than roofs, allowing the use of large

perennials, shrubs and small trees. Also, one of the functions of green infrastructure is the potential for infiltration and evapotranspiration [29].

2.4. Methodology for the choice of NBS

Before creating a climate change adaptation plan and choosing possible medots, we must analyze the current situation and identify the main problems that we want to cope with.

There are cases when the solution to problems lies only in the education of people (most often these are very small areas and projects), in landscaping of territories (if the infrastructure is already prepared for changes in housing) and in technical solutions (when the main problem is outdated equipment, etc.). But the most reliable and effective approach is a comprehensive solution to the problem.

Thus, indicators for methodology selection falls into the following categories [30]:

- Sectors to be covered by the NBS: transport, buildings, industrial enterprises, energy, water supply and sewerage, solid waste and land use
- Climate change manifestation to be tackled: urban heat island, drought, flooding, soil erosion, etc.
- Indicators of the quality of environmental assets (air, water, soil, sources of pressure on the environment).
- Indicator of resource availability: existing green spaces, biodiversity and ecosystem structure).

These indicators are necessary to develop the framework and concept of the complex of NBS for each specific case. The role of the exact parameters is further considered in table 2.1.

Table 2.1

Valuation parameters for the design of NBS

№	Parameters	Meaning
1	2	3
1.	Area of the studied territory	Based on the size of the territories, we can determine the right number of green spaces, budget, and so on.

table 2.1 cotinuation

1	2	3
2.	Amount of vegetation	With data on the amount of real vegetation, we can count an unreliable amount. According to the standards for residential areas, the normal rate of landscaping is 8.4 sq.m. /person [31]. The amount of vegetation also affects whether the project is on review, because this is one of the main indicators of the unpreparedness of the territory for climate change.
3.	Area of built-up areas	The area of built-up areas affects the microclimate, more precisely, the temperature regime of the territory. After all, even just by painting the roofs of buildings in a light color, we will already reduce their heatability and reduce the overall temperature of the territory. And also it is a supposed place to place green roofs, fences, etc.
4.	Availability of "intensive" roads	In this mixture, the highest temperature and amount of emissions.
5.	Availability of water objects on the studied territories	Water objects are natural thermostats and their absence significantly affects vegetation, temperature, circulation and as a consequence for human health.
6.	Composition of atmospheric air	Thanks to the knowledge of the composition of atmospheric air, we can select plants that are resistant and adapted to such conditions.
7.	Type and composition of soils	Thanks to the knowledge of the composition of the posts, we can select typical to this type of soil and resistant plants.
8.	Composition of water	Thanks to the knowledge of the composition of the water in the chosen territory, we can select resistant and adapted to such conditions plants, find out whether additional filtration is needed and whether such a composition of water is suitable for watering vegetation.
9.	Composition of biodiversity	These data will help determine the indigenous plant species of the selected territory.

End of table 2.1

1	2	3
10.	Awareness and awareness of the population	This data will indicate whether additional *social solutions* are needed, such as: to inform people about the treatment of plants, about the importance of this project, about working together to achieve a common goal.
11.	Budget	Unfortunately, not all costs can be covered by the state / city. Therefore, it is necessary to calculate the approximate allowable budget of the project in order to attract third-party investors if necessary.
12.	Excellent weather conditions	- temperature; - rainfall; - humidity; - wind speed and direction; - Number of freeze and thaw cycles. All these parameters affect the choice of plants and the method of landscaping the territory.
13.	Ability to install «*NBS* ».	Is there a place in this area to install green roofs, etc. As well as the alleged possibility of introducing technological solutions (for example, solar panels).
14.	Actual carbon dioxide equivalent emissions	This indicator is also key in the choice of territory, vegetation and the method of landscaping, because this is one of the main "engines" of increasing local temperature.
15.	Presence of "dark" zones	This is the presence of dark surfaces that heat up quickly, thereby raising the ambient temperature.

2.5. Conclusions to Section 2

Nature-based solutions have a key role to play in making cities livable and sustainable. Vegetation in various forms can contribute to climate adaptation to varying degrees, depending on the type and quality of raw materials, as well as on climatic and socio-ecological conditions [32].

The indicators developed in this section are the basis for gathering information and making decisions about choosing an NBS. They cover technological, economic and social

aspects. As well as aspects of living nature: biodiversity, physical and psychological health of living organisms.

CHAPTER 3
CLIMATE CHANGE CONTEXT OF THE CITY OF KYIV

3.1. Current state of urban infrastructure in Kyiv

Kyiv is one of the largest cities in Ukraine. This is a metropolis in which a huge number of people live, the infrastructure is very developed, on the territory of which there are large "sleeping areas", as well as a lot of enterprises, factories, factories, etc.

Kyiv is located on seven hills and has a height difference between the upper and lower points of about 100 meters. Therefore, cold air in winter moves from the top points down, usually to river valleys, and lowers the temperature there. In addition, in winter it is several degrees warmer in the city center than in the outskirts - due to dense buildings, the terrain of "sleeping" microdistricts located on the plains and the wind blowing heat between high-rise buildings, and in the southern part of the city it is usually warmer than on north (since the sun almost always shines from the south).

Transport. Transport remains the main source of emissions in Kyiv pollutants and greenhouse gases into the air due to the large number of old vehicles running on fossil fuels, the large number of congestion due to the high intensity of transit traffic on the international corridors E95 and E40 and uneven population and activity in different areas of the Dnieper.

The city needs additional efforts to develop its network and modes of public transport in order to create a satisfactory alternative to the predominant use of private vehicles and to ensure the accessibility of environmentally friendly modes of transport.

Buildings. The indicators of buildings focus on the consumption of electricity and fossil fuels in the residential and municipal sectors.

From a social point of view, district heating and electricity metering at the individual level is a positive phenomenon, but low housing efficiency leads to high energy consumption and significantly affects the growth of air pollution and greenhouse gas emissions in Kyiv.

Industrial enterprises. The main problems in this sector are due to high levels of

energy consumption in industrial processes, as well as the lack of electricity from the grid, as well as at the national level, electricity from renewable sources. The sector is responsible for a significant negative contribution to air quality, greenhouse gas emissions and soil quality. Lack of monitoring of industry indicators complicates comparative analysis and response at the city level.

Energy supply. Residents and businesses of Kyiv are supplied with a large amount of energy. The electricity distribution network is kept in good condition, but the level of wear of the heating network is significant, which necessitates significant investments.

As at the national level, the share of energy from renewable sources is low, and better incentives and support for innovative technologies are needed to encourage its use and energy transition. A large share of energy produced from fossil sources makes a significant contribution to the problems that Kyiv faces in the areas of air quality and greenhouse gas emissions.

Water supply and sewerage. In this sector, the main challenge is the state of water supply and sewerage networks. Despite the fact that the connection to these networks is comprehensive and provides high rates of access to water and wastewater treatment, significant segments of the networks are in poor technical condition and need urgent investment to ensure their suitability for future needs. The city is in urgent need of improvement rainwater drainage systems, which are also a challenge to climate change.

Municipal solid waste management. Annual indicators of solid waste generation show an upward trend. At the same time, the management of waste after its collection is unsatisfactory and there is no comprehensive system of separate waste collection.

The percentage of residents who use the waste collection service is 100%. However, the level of recycling is 7.2%, and most solid waste is disposed of in landfills, as well as wastes of III and IV hazard classes.

The existing landfill ("Landfill No.5") was to be closed in 2018 due to unsatisfactory condition, significant adverse environmental impact and exhaustion of its capabilities. At this stage, there are no other sites for landfill construction. There are also no waste processing plants, and the capacity of the Energia waste incineration plant is much smaller than the amount of waste to be disposed of.

Land use. Challenges include rapid population growth, threats to growing green space and biodiversity, significant disparities between the city's place of residence and place of work, leading to significant traffic and traffic congestion, increasing congestion in the city, and significantly affecting air quality and greenhouse gas emissions, inefficient land use, including use of brownfield zones. Infrastructure and land use practices are insufficient for a city of this size and status as Kyiv, and require significant investment to provide adequate services to the city's residents and resilience to climate change.

Green infrastructure. In 2017, Kyiv was recognized as the greenest capital of Europe; and this status is confirmed by the share of greenery within the city, exceeding 50%. Despite the significant share of greenery, public green spaces are constantly exposed to the risk of encroachment and development, and therefore need close attention. Although the Green Zones sector in the EBRD's System of Indicators falls under the GREEN category, there is a need for continued support in order to maintain this indicator at a high level, so it is classified as a high priority.

3.2. Strengths and weaknesses of Kyiv infrastructure in the face of climate change

Urban infrastructure provides the livelihood of citizens, and all the necessary facilities are urban infrastructure. It is divided into: communal infrastructure systems; transport infrastructure; social infrastructure; recreational infrastructure. There is also an administrative infrastructure that provides city management and provides state and municipal services. Banking and insurance services, housing and communal services, fire safety, police, removal and processing of household waste, landfills and a number of other infrastructure facilities.

Public utility system of the city is a complex of institutions and enterprises responsible for timely and normal provision of services to the population in the field of public utilities (sewerage and water supply, heating, electricity, transport and roads, utilities, etc.). In modern conditions, it is used to define the set of structures, buildings, systems and services necessary for the functioning of the branches of material production and to ensure the living

conditions of society.

Together, these enterprises and organizations of housing and urban planning constitute an independent branch of the city's life support system - utilities. As it is the most important man-made system of life support in the city, its resilience is of extreme importance, unfortunately it is also the most affected by the climate change effects (Table 3.1). However, in time interventions and complex actions may support and even increase the resilience of urban public utility system [33].

Table 3.1

Strengths and weaknesses of Kyiv public utility infrastructure in the face of climate change

№	Infrastructure component	Strengths of Kyiv urban infrastructure	Weaknesses of Kyiv urban infrastructure
1.	Facilities and networks of sewerage and water supply	good location of the sewer network	emergency condition of collectors, energy-consuming and outdated equipment
2.	Heating system	Adjustable heat supply	energy-consuming and outdated equipment in older part of city
3.	Power supply	location of power supply facilities throughout the city	unpreparedness for extreme situations and lack of alternative power source, extremely low level of renewable sources involvement, outdated equipment
4.	Gas supply	-	energy-consuming and outdated equipment
5.	Communications	well-developed network, the ability to quickly receive information and mass alert the population	partly outdated equipment
6.	Hydraulic structures	quick response to problem situations and prompt resolution of minor breakdowns	unpreparedness for extreme weather conditions such as flooding, outdated equipment

Transport infrastructure - a set of facilities (enterprises, institutions) engaged in repair, construction and reconstruction, as well as maintenance of roads, bridges and other roads. Transport infrastructure ensures the availability of smooth and high-quality roads, as well as keeping them in good condition [34].

The transport infrastructure of the city of Kyiv includes highways, railways and waterways. Bridges across the Dnieper have a particularly important role in transport connections, and subways play an important role in intercity passenger transportation.

The system of highways in Kyiv consists of two systems - radial-circular in the right bank and rectangular, elongated along the Dnieper - in the left bank.

Public transportation uses metro, bus, trolleybus, and tram lines, as well as a funicular. All public transport is operated by Kyivpastrans, besides the metro. The Kyiv Urban Electric Train is a joint project of Kyivpastrans and Ukrzaliznytsia. Kyivpastrans does not operate minibuses. As in most urban areas transport infrastructure is one of the most demanding and problematic branches. At the same time it makes considerable contribution to the formation of the urban heat island and this effect is increasing due to growing population, number of personal cars and warming climate. As a result, transport system of the city is among the major targets for reorganization towards the reduction of climate change contribution and its accelerated degradation (Table 3.2) [35].

Table 3.2

Strengths and weaknesses of Kyiv transport infrastructure in the face of climate change

№	Infrastructure component	Strengths of Kyiv urban infrastructure	Weaknesses of Kyiv urban infrastructure
1	2	3	4
1.	Street and road network	most of the roads have been recently repaired	rapid wear, heat deformation
2.	Bridges, tunnels, interchanges	a large number of bridges, which helps to reduce the load; well thought out interchanges;	rapid wear, heat deformation, partly outdated equipment

End of table 3.2

1	2	3	4
3.	Parking lots	the ability to equip multi-storey parking lots with green roofs and green "walls"	insufficient number of parking spaces; lack of green areas along parking lots
4.	Car service	readiness to respond quickly and repair vehicles in critical situations	old and energy-consuming equipment in state agencies
5.	Public transport	reasonably well thought out public transport routes	old and energy-consuming equipment; the use of low-quality fuels, which further pollutes the atmosphere; vulnerability to weather extremes
6.	Sidewalks and boulevards	recent renovation; alternative to public transport and cars	lack of network throughout the city; partly in bad conditions
7.	Bicycle paths	alternative to public transport and driving, no emissions	lack of network throughout the city
8.	Vehicles park	possibility of quick individual movement in critical situations	considerable share of old cars and cars in bad technical condition; low quality of fuels, causing high volume of emissions; vulnerability to weather extremes.

Social infrastructure - a set of facilities (enterprises, institutions, organizations and facilities) that provide conditions for the functioning of social production and livelihoods, the formation of physically and intellectually developed, socially active individual [36].

The functions of the social infrastructure of the city are fundamentally different from each other, but complementary in the implementation of social and economic development

and the creation of comfortable living conditions in its territory, as well as a positive image of the city. Therefore, they have different level of vulnerability to climate changes and make contribute to the manifestations of climate changes in both positive and negative manner (Table 3.3) [37].

Table 3.3

Strengths and weaknesses of Kyiv social infrastructure in the face of climate change

№	Infrastructure	Strengths of Kyiv urban infrastructure	Weaknesses of Kyiv urban infrastructure
1	2	3	4
1.	Health services	a large number of medical centers; good training of specialists	lack of experience and understanding of medical changes imposed by climate changes; insufficient material and medical provision; old equipment in public hospitals; old buildings
2.	Education services	High research and innovation potential for the development and improvement of methods and instruments to adapt and cope with climate change and its consequences	low awareness of climate change and consequences; insufficient research in the field of climate change and lack of a clear action plan for its consequences; insufficient material and technical provision
3.	Culture services	large amount of cultural heritage is located in green areas (which already reduces the effects of climate change) and is already protected by the state	Much of territory and buildings of cultural heritage are in an emergency condition, which can deteriorate due to sudden changes in weather conditions and high temperatures;

End of table 3.3

1	2	3	4
4.	Sport facilities	Support of healthy lifestyle, which increases health status and resistance to climate change pressures; good training of specialists	Lack of facilities available for public; worn equipment and lack of maintenance for public facilities
5.	Trade services	Kyiv is one of the largest trade centers in Ukraine, the trade infrastructure is very well developed and routes are well thought out	trade services depend on weather conditions, the quality of roads and the willingness of people to quickly respond to a emergency situation
6.	Catering services	well developed subject to stability and prevention of global/local climate change	dependence on imported food and insufficient food supplies for emergency situations; growing demand on services by growing population; lack of efficient regulation of the retailers activity
7.	Emergency services	good training of specialists	insufficient equipment to respond to the effects of climate change in a city as large as Kyiv; old and energy-consuming equipment

Recreational infrastructure is a set of means to ensure the organization and implementation of recreational activities (tourist facilities, facilities / accommodation and food, environmental education centers, elements of recreational facilities, etc.) [38].

Recreational infrastructure is one of the most important in climate change, as it includes the "green and blue" zones, which are the key to solving this problem.

Since forests, parks, lakes, and so on, are natural filters of atmospheric air, natural reducers of local temperature, a habitat for animals and a resting place for people (which

affects psychological health), special attention should be paid to this area to increase its adaptation services and reduce possible threats (Table 3.4).

Kyiv is a fairly green city. Green zones are located throughout its territory and the main task of the residents of Kyiv is to ensure the safety and support of these territories.

Table 3.4

Strengths and weaknesses of Kyiv recreational infrastructure in the face of climate change

№	Infrastructure	Strengths of Kyiv urban infrastructure	Weaknesses of Kyiv urban infrastructure
1	2	3	4
1.	Urban forests	large territories, and many are the territories of the natural reserve fund	insufficient plant care, large amounts of garbage, poaching and looting; no irrigation system; lack of staff and equipment; outdated equipment; not all plant species are resistant to future climate changes
2.	Parks	large number of parks, which are fairly evenly located across the territory of Kyiv and have good structure	insufficient plant care, large amounts of garbage; no irrigation system; lack of staff and care devices; outdated equipment; not all plant species are resistant to future climate changes; overuse for recreation
3.	Squares	large number of squares, which are fairly evenly located across the territory of Kyiv and have good structure	waste management issues; lack of staff and outdated equipment; not all plant species are resistant to future climate changes; pressure from urban air pollution; soil erosion

End of table 3.4

1	2	3	4
4.	Gardens	good training of workers; good enough care about plants and compliance with Ukrainian legislation	waste management issues; outdated equipment; the unwillingness of young professionals to work for low wages; not all plant species are resistant to future climate changes pressure from urban air pollution; overuse for recreation
5.	Water objects (natural and artificial)	there are many water bodies in Kyiv: lakes, ponds, powerful river system – all able to provide temperature reduction and water supply of plant communities nearby and the implementation of the irrigation system	insufficient maintenance, waste management issues; lack of staff and care devices; not all plant and animal species are resistant to future climate changes; pollution with urban runoff and industrial discharges; some rivers are directed into underground channels; illegal extraction of construction materials; overuse for recreation; construction in floodplains

Several official documents, plans and programs at the city level on adaptation and mitigation to climate change were developed:

- Report on the Strategic Environmental Assessment of the Green City Action Plan for Kyiv;

- Draft Green City Action Plan for Kyiv;

- Assessment of the vulnerability of the city of Kyiv to climate change;

- Letter of appeal of the Deputy Minister Ms. Iryna Stavchuk dated 03.03.2020 №26 / 1.4-3-5650 to the regional state administrations and the Kyiv City State Administration with recommendations on the inclusion of climate issues in state planning documents;

- Manifesto of the "Cities for Life" campaign (Main slogan: "Kyiv - climate strategy!");

- Master plan of the city of Kyiv for the period up to 2020 (current).

These documents are a good start in this direction, but their practical implementation hasn't started yet.

Despite the apparent remoteness of the global climate crisis for Ukrainian cities and their communities, infrastructure solutions to reduce greenhouse gas emissions are extremely important. Low energy efficiency of buildings, high losses of heat, gas and electricity in the face of rising energy prices, on the one hand, exacerbate the problem of poverty and social inequality, and on the other hand, are the cause of significant greenhouse gas emissions.

The deterioration and obsolescence of Soviet-era infrastructure also increases vulnerability to climate change, such as heavy rains, heat waves and other abnormal weather events. During the 30 years of independence at the national level, Ukraine has not been able to invent a consistent approach to sustainable infrastructure development - on the contrary, control over it has been increasingly strengthened by oligarchic structures and local clans. Nevertheless, significant positive developments in the direction of decarbonisation exist - thanks to local initiatives and international networks, such as the Covenant of Mayors [39].

3.3. Organizational and technical solutions for adaptation

Climate change in Kyiv is considered one of the more timely tasks in the chain of cumulative natural and climatic transformations and urges the creation of an effective management system to predict, eliminate or reduce its unfavourable results.

To mitigate the climate change in Kyiv and adapt to the changes that have already occurred, it is necessary to implement a list of legal, financial and organizational measures. It is necessary to follow the example of countries with developed economies and first create a strategy for the metropolis of Kyiv, and then a program for the metropolis to prevent weather changes and adapt to some of them.

Based on the study and assessment of the leading points affecting climate change in Kyiv, which are listed in the Kyiv city strategies for preventing and adapting to climate change, it is necessary to form financial, organizational and legal framework for preventing

climate change and adapting to climate change:

1. *Modernization (rehabilitation) of buildings and infrastructure facilities.* This primarily applies to older residential buildings, the social and industrial sectors and includes a number of engineering works to improve the thermal performance of the building, reduce energy and water losses. Examples: insulation of walls, windows, doors, installation of solar panels on roofs, renovation of water, sewage, electrical, ventilation networks, new compact design of buildings with windows facing south and reduced glass sections of the walls, houses are built taking into account the wind rose, and the walls are painted in light colours.

2. *Formation of climate-friendly architectural environment.* Design of climate-friendly building environment is a fresh strategy for the formation of architecture and construction in Ukraine, which implies a list of effective actions to take into account the impact of environmental factors in the design, construction and operation of houses and structures to ensure suitable environmental and climatic conditions for human life. An important improvement of this kind is street planning taking into account the prevailing direction of wind that allows to create optimum wind conditions, cooling of buildings, constructions, industrial and inhabited areas.

3. *Development of efficient transport and logistics systems that stimulate the transition to environmentally friendly vehicles.* Ukraine has had some success in developing more environmentally friendly vehicles. Thus, the HADI-34 AIS car was presented at the 21st International Motor Show SIA

-2013, which took place in Kiev in the spring of 2013. On 1 liter of gasoline, the car drove 575 km.

Kyiv is a large transport hub, through which a huge number of trucks pass every day, which, according to the latest data, is 80% higher than the load according to the norms. This leads to the destruction of the road surface and the intense emission of pollutants, especially CO2. Thus, there

The transport scheme of Kyiv needs not only to improve the quality of roads, but also to properly distribute the load. It is very important to assess trade and transport flows in order to identify real existing or potential environmental problems and develop an effective logistics strategy.

4. Development of green infrastructure via l*andscaping of squares and buildings.* Landscaping and gardening are important not only for the formation of the urban environment, visual effect, but also for the optimization of climatic conditions. Greenery is a biological filter from harmful substances that we emit into the atmosphere, it is a "supplier" of oxygen and a natural regulator of the local temperature. Vegetation reduces the temperature in summer, maintains humidity and air mobility.

Unfortunately, there are no vegetation records and audits of green spaces in Kyiv. The tree accounting is scattered across enterprises and does not have a complete picture. Because of this factor, it is difficult to analyze, manage, plan and control green areas. In addition, there is an imperfect system of financing and public procurement of tree and shrub seedlings. One of the reasons is untimely tenders for the purchase of seedlings, which in turn affects the planting of plants.

Developed countries place a lot of emphasis on landscaping and plant conservation, especially at construction sites, as this mitigates the negative impact of anthropogenic activities on the health of living organisms.

Recommended actions are:

- landscaping and restoration of existing green areas (parks, gardens, squares, etc.)
- creation of laws that would oblige the planting of the first number of trees in adjacent and roadside areas (for example, not less than 1 tree per 10 square meters);
- conducting an audit and formation of green inventory of urban plantations;
- creation of new green zones in built-up areas of Kyiv (for example, creation of a green zone on Poznyaki metro station, near Auchan hypermarket: planting of trees around the perimeter (tree / bush every 3-4 meters and creation of "Green roof" on the roof of the building because it has flat and large area)

5. Implementation of *resource-saving technologies and renewable energy sources.* In order to save energy, reduce greenhouse gas emissions and protect the city's climate, it is necessary to introduce efficient, environmentally friendly, and the same resource-saving technologies and machines that are based on renewable energy sources.

To provide for the technical re-equipment of production through the introduction of innovative technologies, projects for the implementation of energy-efficient and resource-

saving technologies, low-waste and zero-waste, environmentally friendly processes, there are two documents in Ukraine: the Energy Strategy of Ukraine for the period up to 2030 and the State Strategy for Environmental Policy of Ukraine for the period until 2020.

6. *Improving the waste management system.* One of the priority tasks for Kyiv is to improve the processing of industrial and household waste with the creation of an effective waste management system, aimed at reduction of landfilling as a major practice of waste management, since landfills are considerable contributors of greenhouse gases.

7. *Modernization of housing and public utility services.* It is particularly important for water supply, drainage and sewerage systems, as well as improving energy conservation and conservation of housing. There is also need to expand open spaces not covered with concrete or asphalt

8. *Promoting the development of green culture and improving the environmental knowledge of citizens.* Raising environmental knowledge, culture and public awareness will help involve local population and authorities in the implementation of adaptation actions and environment protection programs. The proposed action should include:

- introduction of the position of "special climate manager", who is responsible for the promotion of environmental knowledge and awareness of the population of the district;
- conducting lectures and interactive activities in schools and kindergartens;
- introduction of the course "Ecology as a means of saving money" or "Ecology. How to save money and the environment?" for 11 classes or first courses of universities [40].

3.4. Conclusions to Section 3

Over time, the urgency of climate change issues has increased despite the lack of scientific consensus on a range of related issues. Obviously, in parallel with scientific research, countries and regions, cities need to actively work to identify their own specifics and vulnerabilities to climate change, as well as to develop adaptation programs to them. World experience has certain developments in this direction, and this area of knowledge and practice is constantly growing. An important quality is the coverage of the existing horizon of knowledge and experience along with the constant monitoring of ongoing changes, the

inclusion of new emerging tools and achievements in the arsenal.

Ukraine, in turn, has its own approaches and is working out the principles of adaptation programs to negative climate change. Kyiv is the most striking example of a city that needs adaptation to climate change due to the large volume and amount of anthropogenic activity. The proposed conclusions and recommendations are the subject of a broad scientific, managerial, expert discussion. In conditions of high uncertainty and complex schemes of the mutual influence of many factors, any such analysis, any created model has the potential for improvement.

CHAPTER 4
DEVELOPMENT OF THE NBS PROJECT FOR NORTH-WESTERN PART OF OSOKORKY MICRODISTRICT

To develop the project, we chose the city of Kyiv, Darnytskyi district, the Osokorky district.

We chose this area because of the high density of buildings, not a large number of greenery, high congestion of adjacent roads, constant population growth and high surface temperatures compared to other areas of Kyiv.

4.1. Analysis of current situation

Osokorky housing estate is the youngest massif in Kyiv - its construction began in 1993 on drained wetlands around the village Osokorky. It is located in Darnytskyi district, between the Dnieper River, Mykola Bazhan Avenue and Lake Vyrlytsia. It borders with the Pozniaky, Kharkiv and garden plots and the Nizhni Sady garden and country estates.

The development of the Osokorka and Pozniaky housing estates was largely due to the construction of the Southern Bridge Crossing and the construction of the Syretsko-Pecherska Metro Line.

Until the 1990s, the Osokorki were mostly floodplain meadows, where the inhabitants of the surrounding villages, streams, swamps and lakes grazed cattle. For the construction of the metro, Bazhan Avenue and new housing estates, drainage of wetlands and alluvium began. This has led to dramatic changes in local landscapes. Osokorki was divided into two parts by the embankment on which Bazhan Avenue was laid. The outlines of the shoreline of the surrounding bays of the Dnieper and the lakes that existed between Osokorki and Bortnychi - Vyrlytsia, Nebrezha, Martysheva, Tyagly - have changed dramatically. On the territory of the private sector and garden plots there are a number of so-called Osokorkiv lakes, the largest of which have their own names and are on the balance of the municipal ME "Pleso" - Zaryvakha, Pidbirna, Yaremine [41].

Current state of urban infrastructure in Osokorky district:

Transport. The transport infrastructure of this area is well developed. The Siretsko-Pecherskaya metro line runs along the border of the district, as well as a very intensive road (traffic load about 8-9 points) - Bazhana Avenue runs along this border. The main centers of transport routes are metro stations, from which public transport routes begin / end. The main, but less intensive roads are also considered: P. Grigorenka Avenue, st. Revutsky, st. Gmyri and st. Rudenko, street Chavdar. The South Bridge was built on the western side, through which the longest European highway E40 cools.

These roads are a place of accumulation of automobile emissions, and become the center of high temperature.

Buildings. There are a lot of buildings in the study area, most of them are high-rise buildings. The eastern part of the district is a building built during the Soviet era. Therefore, their condition is quite unsatisfactory, and sometimes emergency. The western part of the array - new buildings. + - 10 years of houses, and some are still under construction (in the southern part). There are also several shopping malls (Pyramid and Aladdin), two hypermarkets (Epicenter and Metro), several large supermarkets (such as Novus) and many small shops / outlets. In some places, the density of buildings is very high, which reduces the ventilation of the area and reduces the area of greenery.

Industrial enterprises. In the study area there are enterprises of the furniture, textile and automotive industries (car washes, one hundred: collection and repair). The main contribution of such enterprises is a fairly high consumption of resources and local decline in air quality, increased greenhouse gas emissions and reduced soil quality.

The lack of monitoring of these indicators complicates the analysis and response at the district level.

But a more global contribution to the change of the local microclimate is made by enterprises that are located near the study area and belong to the not insignificant objects of Darnytskyi district. These are the Bortnytsia aeration station (red circle) and the Energia waste incineration plant (blue circle). Permanent construction on and near also contributes.

Energy supply. Residents are supplied with a large amount of energy. The electricity distribution network is kept in good condition. But since this territory is conditionally

divided into an old and a new microdistrict, the quality and condition of the electricity network is different. In the new part, there are no special problems, but in the old part, the level of deterioration of the electricity network is significant, which requires significant investments.

Almost all buildings use a centralized electrical grid, but in one new building, solar panels were found that covered one of the walls of the building.

Water supply and sewerage. In this sector, the main challenge is the state of water supply and sewerage networks for the old part of the study area. In new buildings, the condition is in most cases satisfactory, but the level of wear is growing rapidly for unknown reasons.

Municipal solid waste management. Waste management after collection is unsatisfactory and there is no holistic system of separate waste collection.

From the observations we can conclude that the sorting of garbage is only in two, a maximum of three categories: plastic / glass and other household waste. Most of the sorting is in the new part of the array.

Land use. Construction is constantly taking place in this area. Construction near Chavdar Street, Revutsky Residential Complex, etc. Moreover, the Osokorki district is planned to be enlarged - Osokorki Central - south of Osokorki North (the area we are studying).

Although it is planned to create the Osokorky Ecopark, the number of built-up areas will increase in parallel.

Green infrastructure. There are no large green areas in the study area, there is only vegetation along the main streets and near houses. Nearby are the middle green areas around the study: the embankment of Lake Teglya, Lake Silver Circle, Lake Vyrlytsia, Lake Nebrezh, Lake Lebedyne and Lake Poznyaki. To the west of the study area is the private sector, where there is more dense vegetation. But we believe that this is not enough to significantly reduce local temperature and reduce emissions.

Strengths and weaknesses of Osokorky district urban infrastructure in the face of climate change (Table 4.1, 4.2, 4.3, 4.4):

Table 4.1

Strengths and weaknesses of Osokorky district public utility infrastructure

№	Infrastructure component	Strengths	Weaknesses
1.	Facilities and networks of sewerage and water supply	good location of the sewer network, satisfactory condition in the new part of the array	emergency condition of collectors, energy-consuming and outdated equipment, in the old part of the array
2.	Heating system	Adjustable heat supply and the ability to regulate the supply of heat to each apartment (new part of the array), satisfactory condition in the new part of the array	energy-consuming and outdated equipment in older part of array
3.	Power supply	satisfactory condition in the new part of the array	unpreparedness for extreme situations and lack of alternative power source, extremely low level of renewable sources involvement, outdated equipment
4.	Gas supply	-	energy-consuming and outdated equipment prone to losses and emissions
5.	Communications	well-developed network, the ability to quickly receive information and mass alert the population	partly outdated equipment in older part of array
6.	Hydraulic structures	quick response to problem situations and prompt resolution of minor breakdowns, satisfactory condition in the new part of the array	unpreparedness for extreme weather conditions such as flooding, outdated equipment in older part of array

Table 4.2

Strengths and weaknesses of Osokorky district transport infrastructure

№	Infrastructure component	Strengths	Weaknesses
1.	Street and road network	most of the roads have been recently repaired	rapid wear, heat deformation
2.	Bridges, tunnels, interchanges	large number of bridges near metro stations, reducing transport load; well thought out interchanges	rapid wear, heat deformation
3.	Parking lots	availability of multi-storey car parkings, the ability to equip them with green roofs and green "walls"	insufficient number of parking spaces; lack of green areas along parking lots; high price of multi-storey car parks, which makes it impossible for part of the population to use them
4.	Public transport	Satisfactory layout transport of routes	old and energy-consuming equipment; the use of low-quality fuels, which further pollutes the atmosphere; vulnerability to weather extremes
5.	Bicycle paths	-	only one bicycle path on Bazhan Avenue
6.	Vehicles park	Relatively new vehicle park in the new part of the district	considerable share of old cars and cars in bad technical condition in older part of array; low quality of fuels, causing high volume of emissions; vulnerability to weather extremes

Table 4.3

Strengths and weaknesses of Osokorky district social infrastructure

№	Infrastructure	Strengths	Weaknesses
1.	Health services	numerous new medical centres; good training of specialists	lack of experience and understanding of medical changes imposed by climate changes; old equipment in public hospitals; most of the medical centres are private
2.	Education services	high research and innovation potential for the development and improvement of methods and instruments to adapt and cope with climate change and its consequences; very well developed educational infrastructure in the new part of the array	low awareness of climate change and consequences; insufficient material and technical provision
3.	Sport facilities	Support of healthy lifestyle, which increases health status and resistance to climate change pressures; good training of specialists; many sports facilities in the new part of the array	worn equipment and lack of maintenance for public facilities; sports facilities are mostly private
4.	Trade services	the trade infrastructure is very well developed and routes are well thought out; European highway E40	High turnover of cargo vehicles, producing increased amount of emissions
5.	Catering services	well developed and diverse	dependence on imported food; growing demand on services by growing population;
6.	Emergency services	good training of specialists; availability of private emergency services	old and energy-consuming equipment in older part of array

Table 4.4

Strengths and weaknesses of Osokorky district recreational infrastructure

№	Infrastructure	Strengths	Weaknesses
1.	Urban forests	present a few kilometres from the study area	insufficient number on the territory
2.	Parks	-	absent in this territory
3.	Squares	large number of squares, which are fairly evenly located across the district and have good structure	waste management issues; lack of maintenance; large areas of paved surface, which contribute to the increase of air temperature in summer
4.	Gardens	-	absent in this territory
5.	Water objects (natural and artificial)	there are many water bodies around of district: lakes, ponds, near river Dnipro system	no water bodies within the area; insufficient maintenance, waste management issues; low diversity of species; hydrobionts are vulnerable to future climate changes; pollution with urban runoff and industrial discharges; illegal extraction of construction materials; construction in floodplains

4.2. Description of the chosen sites

Table 4.5

Description of the chosen sites

№	Parameters	Value
1	2	3
1.	Area of the studied territory	S = 3191195 m²,

table 4.5 cotinuation

1	2	3
2.	Existing plantations	small green plantings along the streets, a mini park with an alley, Skandy Park, Wikibiz Square and lake embankments. But all these objects have a very small amount of high and low vegetation. Approximate percentage of green area: 20%
3.	Area of built-up areas	The approximate percentage of built-up area is 75-80%, but this value is constantly growing.
4.	Availability of "intensive" roads	Very intensive traffic load about 8-9 points) - Bazhana Avenue runs along this border. Less intensive roads are P. Grigorenka Avenue, st. Revutsky, st. Gmyri and st. Rudenko, street Chavdar.
5.	Availability of water objects on the studied territories	There are no water bodies in the study area, but there are 7-8 fairly large water bodies around.
6.	Composition of atmospheric air	Air Quality Index at the time of project development in the range of 40-112 values (Harmful level for vulnerable groups) [42].
7.	Type and composition of soils	The sands are slightly turf, slightly humus and non-humus Sod-medium-and slightly podzolic sandy and loamy soils [43]. In most places where there is vegetation, the soil is brought.
8.	Composition of water	Water in all investigated points around the project area belongs to the II class of water quality - "good", 3 quality categories "quite clean". In terms of total mineralization, the studied waters correspond to the natural mineralization of the 2 hydrochemical regions of Southern and Eastern Polissya. Exceedances of MPC for recreational and fishery use were not detected. We can note only the excess of eutrophication for the lake due to content of nitrates. All reservoirs are also characterized by slightly inflated pH and, accordingly, the alkaline reaction of water [44].

table 4.5 cotinuation

1	2	3
9.	Composition of biodiversity	Common ash, White acacia, Common oak, Sugar maple, Maple, Delta poplar, Italian poplar, Horsetail chestnut, Linden, Willow, Birch, Ambrosia polynolista, Coastal-aquatic vegetation of lakes [45]. The fauna is very sparse (stray cats and dogs, several species of birds such as magpies, crows and pigeons, and insect species bordering on coastal species), most species are presented outside the study area.
10.	Awareness and awareness of the population	Most people in this array are informed and understand the importance of such decisions (and are likely to support this project). However, it is necessary to inform some groups of the population about the treatment of plants, the importance of this project and the prospects for joint work.
11.	Budget	Unfortunately, not all costs can be covered by the city/district. In this project it is planned to attract additional funds, like third-party investors if necessary (large enterprises / facilities such as Epicenter, Metro, Novus, etc.).
12.	Weather conditions	- *Temperature:* The average annual air temperature in 2017, according to the Kyiv Observatory, is +9.5 0C, which exceeds the average norm set by long-term observations by 1.8 0C. The warmest month of 2017 is July, with an average monthly temperature of 22.4 0C. The coldest months are January and February, with an average monthly temperature of -0.5 0C below zero. - *Rainfall:* The average annual rainfall in 2017 was 654 mm with an average annual rate of 650 mm. - *Wind direction:* The prevailing wind direction is western in summer and northwestern in winter.

End of table 4.5

1	2	3
13.	Ability to install «*NBS* ».	This area has promising buildings for green roofs, green fences and more. And also includes the possibility of implementing technological solutions (eg, solar panels).
14.	Actual carbon dioxide equivalent emissions	13.12.2021: 340-360 ppbv [46].
15.	Presence of "dark" zones	All residential buildings have dark roof surfaces.

4.3. Types and structure of green roofs

To mitigate the effects of climate change at the local level, we have developed a plan for landscaping with green roofs.

Green roofs are the creation of green space at the top of the building structure. It can be above, at or below the roof level [47].

Benefits of greening roofs:

✓ Green roofs provide thermal insulation: in summer, they serve to reduce heat, in winter they retain heat, which in turn improves the level of living comfort.

✓ Green roofs last much longer than usual due to the fact that the insulating layers are protected from ultraviolet radiation and other negative natural phenomena. This saves a lot of money in the long run.

✓ Restores the lost natural environment and provides temporary or permanent shelter for birds and insects.

✓ During heavy rains, the green roof system retains and gradually drains water, which unloads the house drainage system and urban drainage systems.

✓ From the point of view of ecology, landscaping of roofs significantly improves the local microclimate by restoring the vegetation layer.

- ✓ The plant layer filters the air from pollutants and dust, reducing CO2 levels.
- ✓ Green roofs are a component of sustainable development in construction. Accessible roofs can be additional public spaces, playgrounds, sports areas and meeting places.

Scheme-plan of landscaping the roof. Any green roof consists of several layers. Green roof pie includes:

1) Stand. This is the first layer, which is the load-bearing structure of the roof. These can be concrete slabs (for flat roofs), solid lattice (for pitched). If the stove is flat, it is recommended to create a small slope.

2) Waterproofing layer. All plants without exception need watering. But this effect is very harmful to the materials from which the roof is made. In this case, waterproofing is used, the soil is protected from the roof. Polymer membranes or polyethylene film are used. Liquid rubber is perfect. Waterproofing can be located directly on the roofing.

3) Thermal insulation. Basically, the thermal insulation layer is created from plates made of cork. Extruded polystyrene foam or polyurethane foam is also used. Slabs must be laid very tightly. When the upper layers do not create enough pressure, you can connect them using a special glue.

4) Root barrier. Needed to protect the roof from damage that can cause deep-rooted roots. Represents a polymeric usual film or foil. A film with a metal coating is very suitable. It is laid on a layer of waterproofing. Landscaping roof scheme

5) Drainage layer. It retains a certain amount of water needed for plant life. The water must move freely towards the gutter on the roof.

6) Filtration layer. Needed to trap unwanted rainfall. Geotextiles are an excellent filter. Moreover, the geofoil prevents mixing of soil and drainage layer.

7) Lattice. If you want to green a sloping roof, use a geogrid. It is a plastic cell and relatively light.

8) Fertile soil. Soils used on the roof should be light in weight, warm, porous and moisture-resistant. It is recommended to use a light soil mixture consisting of neutral peat, fine expanded clay and perlite. You can add clay, slate, sand.

9) Plants. Therefore, after all the layers are concluded, you can plant the plants [48].

System solutions. Green roofs are divided into two types: extensive and intensive. As a basis for the types of system solutions (intensive and extensive solutions), we have chosen the development of the company "Exquisite Gardening" - a landscape design studio that deals with green roofs. Based on their classification, we have selected the best solutions for certain types of buildings [49, 50, 51].

Table 4.6

<table>
<tr><th colspan="2">Type of system solutions</th><th>Advantages</th><th>The selected building of our project</th></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td></tr>
<tr><td colspan="3">Extensive (are roofs that are covered with a relatively thin layer of substrate with hardy plants (sedums, grasses, cereals), which in the future minimizes the care of them)</td><td>7 buildings</td></tr>
<tr><td>Economical roof</td><td colspan="2">• Classic multilayer structure with drainage and storage element and system filter.
• Relatively low biodiversity: sedums are mainly used as a plant layer.
• The most cost-effective system solution for a green roof.
• Can be used on inverted roofs, with some clarifications.
• Landscaping the roof, which requires minimal maintenance.</td><td>- Borys Hmyria Street, 7
- Covered parking (Larysa Rudenko Street, 17)
- Velmart (10 Vyshniakivska Street)
- VK Express (9 Larysa Rudenko Street)
- NOVUS (Prospect Mikoli Bazhana, 8)
- NOVUS (3 Mykhailo Hryshko Street)</td></tr>
<tr><td colspan="2">Recommended plant types</td><td colspan="2">Sedum, Crassulaceae, perennials, flowering herbaceous plants: all species combined with a remarkable ability to regenerate, self-propagate and resistance to water and thermal stress.</td></tr>
<tr><td>Lightweight roof</td><td colspan="2">• The easiest system solution for a green roof.
• It is possible to install an irrigation system for regions with arid climates.
• Can be used on flat roofs (without drainage slopes), with certain restrictions.
• Reliable anti-erosion solution; used only with a reliable waterproofing system.
• Slightly increased maintenance and installation costs compared to the economical roof.</td><td>- Multi-storey car park (Elizaveta Chavdar Street 13)</td></tr>
<tr><td colspan="2">Recommended plant types</td><td colspan="2">Individual Plug Plants (varieties of sedums, grasses, herbs and perennials)</td></tr>
</table>

table 4.6 cotinuation

1	2	3
Intensive (roofs are so-called "roof gardens", they require a larger layer of substrate, they can plant all the plants - perennials, shrubs and trees, arrange playgrounds and more. In short, a real garden, only on the roof)		8 buildings
Garden on the roof	• Multilayer system solution with drainage and storage element. • Using a green roof as additional living space. • Intensive type of landscaping. • Flower beds from perennials, lawns for rest, curtains from bushes, recreation areas, etc. • Automatic watering is possible. • Can be used on inverted roofs, with some clarifications.	- Epicenter (40 Petro Hryhorenko Avenue), but with partial space for solar panels
Recommended plant types (related breeds are presented and remote priority)	Perennial herbaceous plants, soil cover, small shrubs, trees with a maximum height of 2-4 meters.	
Roof landscape	• Multilayer system solution with drainage and storage element. • Landscaping of roofs of underground parking lots. • The "greenest" system solution with relatively low weight. • Unique landscape design; it is possible to grow everything from perennials to trees. • Can be used on inverted roofs.	- Piramida shopping mall (4 Oleksandra Myshuhy Street) - Gymnasium "Kyivska Rus" (Borysa Hmyri Street, 2B) - Scandinavian Gymnasium (3B Borys Hmyri Street) - Lyceum "Intellect" (34A Mykola Bazhan Avenue) - School №316 (32A Mykola Bazhana Avenue) - Gymnasium of International Relations №323 (Oleksandra Myshuha Street, 5) - *METRO Cash&Carry* (street Petro Hryhorenko Avenue, 43)
Recommended plant types (related breeds are presented ин remote priority. Preferred are dwarf subtypes)	• **Fir-tree, Pine-tree, birch, linden-tree, oak, aspen + lawn** (moss, some bulbs, different types of meadow flowers and bells, oregano, cloves, lavender) • Pine-tree, Birch, maple, oak, willow, juniper • Chestnut, fir-tree, silver fir, honeysuckle, spirea, brier • Birch, maple, fir-tree, poplar, lilac, honeysuckle, brier	

End of 4.6

1	2	3
Solar panels on the roof	• Favorable combination of green roof and solar panels. • Possibility of growing vegetation under the panels. • Stable and "impenetrable" fastening of the system. • Passed testing in the wind tunnel. • Increased base support of solar panels to reduce vegetation shading. • Easy maintenance. • Increased performance of solar panels. • Can be used on inverted roofs, with some clarifications.	- Epicenter (40 Petro Hryhorenko Avenue), but with partial space for a roof garden
Recommended plant types	Sedum, Crassulaceae, perennials, flowering herbaceous plants: all species combined with a remarkable ability to regenerate and resistance to water and thermal stress + Solar panels	

There are a large number of low-rise buildings with flat roofs in the study area. We have selected 15 objects. Including: 5 schools, 2 parking spaces, 2 hypermarkets, 3 supermarkets, 2 shopping malls, 1 unknown building. Look at the Fig.4.1.

Fig.4.1 Location of green roof in project

- area for creating green roofs

4.4. Economic and environmental parameters of the proposed project

The cost of a green roof includes:

- installation price:
- price of materials;
- price of vegetation;
- design price;
- price of development and creation of documentation;
- price of transportation;
- price of preparation of the object (repair, if the site needs it);
- price of additional materials to create a recreational area.

Also, it is important to account running costs on the maintenance of green areas, which is also paid. The price also depends on the location. Below is the average cost in Europe.

Economical roof: Average cost: 29-35 €/m2

Lightweight roof: Average cost: 35-40 €/m2

Roof landscape and Garden on the roof: Average cost: 52 €/m2

Approximate roof area of objects and price (without additional materials for repairs, prices for maintenance and prices for documentation):

- Epicenter = 37898 m2 = 1970696 € + the price of solar panels
- Pyramid shopping mall = 11004 m2 = 572208 €
- Gymnasium "Kyivska Rus" = 5372 m2 = 279344 €
- Scandinavian Gymnasium = 4141 m2 = 215332 €
- Lyceum "Intellect" = 4141 m2 = 215332 €
- School №316 = 4141 m2 = 215332 €
- Gymnasium of International Relations №323 = 5509 m2 = 286468 €
- Multi-storey car park = 1841 m2 = 64435 – 73640 €
- METRO Cash & Carry = 16160 m2 = 840320 €
- Borys Hmyria Street, 7 = 4922 m2 = 142 738 – 172270 €
- Covered parking (Larysa Rudenko Street, 17) = 1895 m2 = 54955 – 66325 €
- Velmart = 1619 m2 = 46951 – 56665 €

- VK Express = 1813 m2 = 52577 – 63455 €

- NOVUS (Prospect Mikoli Bazhana, 8) = 11727 m2 = 340083 – 410445 €

- NOVUS (3 Mykhailo Hryshko Street) = 3622 m2 = 105038 – 126770 €

Total: 115805 m2 = 5401809 – 5564602 €

Payback period:

This project is designed for the long term. Therefore, his Payback will take about 5-10 years on average, depending on the object, but it will be very beneficial in terms of ecosystem resilience and human health. The project is not a platform for direct earnings, but a tool for improving the environment, which in turn will save money in the future.

The individual pay back period for each site will be as follows:

- Epicenter = 5-6 years (solar panels are provided at this facility, so the payback period is quite large, but accounting recreational opportunities, this period can be reduced, as the entrance to the green zone can be set extra);

- Piramida shopping mall = 5-6 years (accounting the entrance fee and increase in sales of the mall);

- Gymnasium "Kyivska Rus" = 7-10 years (as these are educational institutions, but the earnings can be invested in material provision of training process and thus attract new students to the institution and save on heating and cooling);

- Scandinavian Gymnasium = 7-10 years (as these are educational institutions, but the earnings can be invested in material provision of training process and thus attract new students to the institution and save on heating and cooling);

- Lyceum "Intellect" = 7-10 years (as these are educational institutions, but the earnings the earnings can be invested in material provision of training process and thus attract new students to the institution and save on heating and cooling);

- School №316 = 7-10 years (as these are educational institutions, but the the earnings can be invested in material provision of training process and thus attract new students to the institution and save on heating and cooling);

- Gymnasium of International Relations №323 = 7-10 years (as these are educational institutions, but the earnings the earnings can be invested in material provision of training process and thus attract new students to the institution and save on heating and cooling);

- Multi-storey car park = 5 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects);

- METRO Cash & Carry = 5 years (accounting recreational opportunities, this period is quite short (despite the cost of installation), as the entrance to the green zone can be charged);

- Borys Hmyria Street, 7 = 5-7 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects);

- Covered parking (Larysa Rudenko Street, 17) = 5-7 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects);

- Velmart = 5-7 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects);

- VK Express = 5-7 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects);

- NOVUS (Prospect Mikoli Bazhana, 8) = 5-6 years (quite a long period, because the object will not generate income and invest in mitigation of climate change effects and has a fairly large area);

- NOVUS (3 Mykhailo Hryshko Street) = 5-6 years (the facility will not have a direct income, but it is quite budget and efficient and has a fairly large area).

There is a range of risks for the implementation of the project. The possible event tree is given on Fig. 4.2, including potential solutions for mitigation of risks.

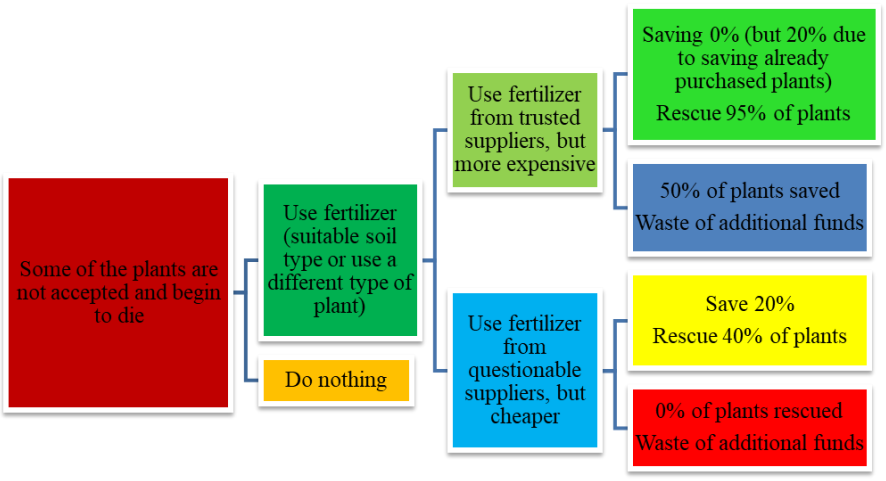

Fig. 4.2 The possible event tree, including potential solutions for mitigation of risks

4.5. Other recommendations for the district

The aim of the project is to reduce local temperature and mitigate the effects of climate change. The project plans to create 15 green roofs. This will of course contribute to the reduction of temperature (according to forecasts, this reduction by 3-5 * C).

However, for greater efficiency, we give the following recommendations:

- landscaping within the system *"15 minutes walk"* – a park is awailable to any resident at the distance of 15 minutes walk;

- installation of green fences where possible (for example, the fence of the gymnasium "Kyivska Rus");

- painting "dark" roofs and buildings in light color (almost all buildings in the area have a dark color of roofs, which increases the local temperature when heated. This is a relatively budget, but very effective measure);

- modernization of buildings and structures in the old part of the array;

- allocation of area for blue infrastructure, which will contribute to the reduction of thermal pressure and improve the quality of air;

- installation of solar panels (this is advisable, as there are suitable areas for this);

- modernization of housing and communal services in the old part of the array;

- repair of hydraulic structures and drainage canals (because this area is prone to flooding);

- dissemination of environmental knowledge, culture and awareness.

Some measures are easy and some are very difficult to implement, but with all the recommendations, this area has great potential for adaptation to the effects of climate change.

4.6. Conclusions to Chapter 4

The selected area is in satisfactory environmental condition. Most of the environmental problems arise at the area of the old part of the array and need attention.

The project involves the design of NBS in the form of green roofs for the study area.

Both intensive and extensive types of green roofs were used in the project. 15 sites were identified for the creation of green areas: 7 buildings with extensive roofs and 8 - intensive. The sites include 5 schools, 2 parking spaces, 2 hypermarkets, 3 supermarkets, 2 shopping malls, 1 unknown building.

Approximate roof area of objects is 115805 m2 and the price (without additional materials for repairs, prices for further maintenance and prices for documentation) is 5401809 - 5564602 €. Payback period: about 5-10 years.

This project will be effective provided good maintenance, lack of negligence and additional recommendations.

CHAPTER 5
LABOR PRECAUTION

Any activity must be accompanied by instructions and labor protection measures. They must comply with the requirements and the Regulation on the development of safety rules approved by the Order of the Committee for Supervision of Compliance with Safety Rules of the Ministry of Labor and Social Policy of Ukraine since January. 29, 1998, No. 9 (NPAOP 0.00-4.15-98).

The subject of this section: a young professional who works in the field of climate change, the environment and nature conservation. The working conditions of such a specialist include several places of work. The first is the office, and the second is the natural site (taking measurements, inspecting the territory, creating a photo).

5.1. Organization of the working place of junior expert on climate change

The workplace of a climate change specialist consists of two sites - an office and a natural field site, then the measures and instructions should be divided into two groups.

Since the first place of work is an office, the exact working conditions are established here. The organization of work in the office is regulated by the following documents:

- Regulation of the Cabinet of Ministers of Ukraine «Hygienic Classification of Labor (by Indicators of Hazard and Danger of Factors of the Production Environment, Severity and Intensity of the Labor Process) » [52];
- the Order of Ministry of Social Policy of Ukraine «On Approval of Requirements for the Safety and Health of Workers during Work with On-Screen Devices» [53];
- LU «On Labour Precaution» [54].

And:

- related sanitary and hygienic standards;
- an accompanying set of requirements.

The second place of work - a natural site - cannot be regulated and normalized by

standards, since these are unpredictable conditions and are independent of the subject. The only way to control and secure work at a given workplace is through personal safety rules, which must be observed by the employee himself.

Requirements for working conditions in the office:

1. Sanitary rules and requirements:
   - ✓ daily wet cleaning;
   - ✓ standardized first aid kit in easily accessible place;
   - ✓ automatic fire alarm system with smoke detector installed;
   - ✓ one CO2 fire extinguisher per every 20 m2 of area, in an easily accessible place.
2. Furniture and arrangement requirements:
   - ✓ all working places' seats should have backs;
   - ✓ at least 0.6 m distance from the display to the eyes;
   - ✓ nonflammable floor;
   - ✓ finishing materials and furniture should have quality certificates that indicate that toxic and poisonous substances (gases) are not released during burning in case of combustion;
   - ✓ all grounded metal objects, such as radiators, plumbing and gas pipelines, must be covered with a dielectric shield.
3. Requirements to premises with computing devices:
   - ✓ at least 6 m2 of space allocated for each computer;
   - ✓ at least 20 m3 per each user of space volume;
   - ✓ at least 1 m between the computer and the wall with a window;
   - ✓ at least 1.2 m between the sides of the monitors;
   - ✓ at least 2.5 m between the back of the monitor and another computer or working place;
   - ✓ passages should be at least 1 m wide.
4. Powering and wiring requirements:
   - ✓ only three-pin connectors are allowed;
   - ✓ only use of specially designed extension cords is allowed;

- ✓ in a room where five or more computers work, a switch is needed for all electrical equipment except lighting, in an accessible place;
- ✓ individual, grouped three-conductor wiring with wires of phase, working zero and protective zero;
- ✓ the protective zero is used for grounding, using a working zero as a protective zero is prohibited;
- ✓ the cross section of the working zero and protective zero should be not less than the phase conductor (cord);
- ✓ when the plug is plugged in, the protective zero must be connected first, otherwise a spark will occur;
- ✓ sockets should be mounted on a non-flammable substrate, 3-6 pieces per unit, wires in 69 metal sleeves, along walls or under the floor;
- ✓ wires should be connected only by soldering, joints carefully isolated.

5. It is forbidden to:
   - ✓ use wires, switches, sockets and extension cords, that are damaged or not;
   - ✓ designed to connect computers;
   - ✓ use homemade extension cords;
   - ✓ use non-standard electrical equipment and infrared lamps for space heating.

5.2. Analysis of hazard factors at the working place

The main factors that influence a climate change expert are:

1. At the office workplace:

• Physical - parameters of the microclimate and ventilation in the working area, deviating from the permissible and optimal (including pressure, temperature, humidity and air circulation);

• Physical - non-ionizing electromagnetic fields and radiation;

• Physical - ineffective natural and artificial lighting.

1. On a natural site:

✓ Biological (risk of exposure to pathogenic organisms and products of their life cycle);

- ✓ Mechanical (risk of injury when creating measurements, photos and when inspecting the territory on your own negligence).

2. At the office workplace:

- ✓ Physical - non-ionizing electromagnetic fields and radiation;
- ✓ Physical - microclimate parameters (pressure, temperature, humidity and air circulation), as well as ventilation parameters in the working area, deviating from the permissible and optimal norms;
- ✓ Physical - ineffective natural and artificial lighting.

The identification and classification of harmful and hazardous factors that affect the junior climate change specialist at his workplace is carried out on the basis of two regulations:

- State Sanitary Norms and Rules “Hygienic classification of labor on the indicators of harmfulness and danger factors of the production environment, the severity and intensity of the labor process” [52].

- Order of the Ministry of Social Policy № 207 of 02/14/2018 "On Approval of the Requirements for the Safety and Health of Workers in Working with Display Devices" [53].

5.2.1. The microclimate and ventilation

Microclimate is a complex of meteorological conditions in the room. Microclimate is highly important for office premises. It is he who affects the physical and psychological health of workers. As workers spend much of their time in them and require comfortable conditions to be the most productive.

It includes:

1. temperature,
2. air movement rate,
3. the content of particulate matter (dust) in the air,
4. number of air ions,
5. relative humidity,
6. air exchange,

7. the presence of pleasant odors (aromatherapy),

8. etc.

The specifications are given in Pic. 5.1.

Optimal and permissible microclimate parameters values for category Ib premises

Microclimate parameters values	Cold	Warm
Room temperature		
Optimal value	21-23°C	22-24°C
Permissible value	20-24°C	21-28°C
Actual value	17-23°C	21-25°C
Relative humidity		
Optimal value	40-60%	40-60%
Permissible value	Up to 75%	60% , if t°C=27 °C
Actual value	50%	60%
Room's air velocity		
Optimal value	0.1 m/s	0.2 m/s
Permissible value	<0.1 m/s	0.1-0.3 m/s
Actual value	-	-

,

Fig. 5.1 Optimal and permissible microclimate parameters values for category Ib premises [55]

In this case, in the cold season, all microclimatic parameters are within normal limits. The room is equipped with a general ventilation system.

The room has access to natural air for ventilation and is equipped with batteries and air conditioners to maintain the desired temperature. The cooling situation in the warm season is in accordance with the norms, as there are air conditioners and windows, which are the main source of free cooling.

5.2.2. Natural and artificial illumination

A number of legislative documents regulate the coverage of the workplace in the

office during the operation of electronic computing devices.

Work in the office on personal devices belongs to the 7 categories of visual works - this is working with luminous material or in hot shops. This information can be found in DBN B.2.5-28-2006 "Engineering equipment of buildings and structures. Natural and artificial lighting. "

In this place of work (office), natural and artificial lighting are used. It features 4 holes with a size of 1300x1400 mm., Which provide good natural lighting. Indoors are spit = rejuvenated by the comprehensive artificial lighting system: the overall system of artificial lighting and additional local lighting for each separate workplace. General lighting provide new energy-saving LED lamps, and additional lighting is provided with individual energy-saving LED lamps. Flickering and reflection, as well as the pulsation of lighting was not observed.

5.2.3. Non-ionizing electromagnetic fields and radiation

Non-ionizing electromagnetic fields and radiation in the workplace in the office are regulated by a number of documents (Given in Fig. 5.2):

- State Sanitary Norms and Rules of the Work with Visual Display Terminals of Electronic Computing Machines [56].

- State Sanitary Norms and Rules of the Work with Sources of Electromagnetic Fields, of Population Protection from the Influence of Electromagnetic Radiation [57].

These rules establish requirements for protecting employees and preventing harmful visual, psychophysical and emotional stress. Stress is caused by sedentary work, which involves only the upper limbs, with increased eye pressure and the generation of electromagnetic fields.

Sources of electromagnetic radiation and fields in the office space are:

- ✓ personal devices (mobile phones, chargers, power supplies, etc.),
- ✓ computers,
- ✓ Wi-Fi routers,
- ✓ transformer boxes,

✓ cables, cords, other.

Types of field	Admissible field parameters		Allowable surface density of energy flow (intensity of energy flow), W/m
	for an electrical component (E), V/m	for a magnetic component (H), A/m	
Electromagnetic field intensity:			
60 kHz – 3 mHz	50	5	
3 kHz – 30 mHz	20	-	
30 kHz – 50 mHz	10	0.3	
30 kHz – 300 mHz	5	-	
300 kHz – 300 hHz	-	-	10
Electromagnetic field In visible spectrum:			
400-760 mm In infrared spectrum:	-	-	10.0
0.76-10.0 mkm	-	-	35.0-70.0
Intensity of electric field of visual display terminal			20

Fig. 5.2 Admissible parameters of electromagnetic non-ionizing radiation and electrostatic field for the office working place [58]

5.2.4. Biological hazards and safety

The risk of negative biological impact on a young climate change specialist is possible in the office and is very unlikely in the natural territory. This can occur by contact with infected and sick people or animals. Since these events are almost impossible to predict, it is impossible to regulate and control them.

Biosafety regulation in working conditions is guided by state sanitary standards and

rules "Hygienic classification of labor on the danger and danger of the factors of the production environment, the severity and intensity of the employment process" and the Law of Ukraine "To provide the sanitary and epidemiological welfare of the population". These documents regulate the working conditions and differentiate the classes on the volume of hazardous biological factors.

According to this classification, field work belongs to category 3.3 due to possible contact with infected organisms.

Despite the fact that biosafety factors are very difficult to predict, if you follow the set of biosafety rules, the probability of negative influence can be reduced to zero. This is: to collect information about possible risk,

- avoiding close work with suspiciously looking people and animals;
- work with special protective equipment (for example masks and respirators);
- Work with special protective objects of clothing (for example, rubber gloves and boots).

Harmful (hazardous) factor		*Working conditions class*					
		Permissible		Harmful		Hazardous	
		2	3.1	3.2	3.3	3.4	4
		Excess over MPC, times					
Pathogenic microorganisms	Highly dangerous infections	-	-	-	-	-	+
	Pathogens of other infections diseases	-	-	+	+	-	-

Pic.5.3 Hazard classes of working conditions by biological factors in the air

5.3. Organizational and technical measures of harmful and dangerous factors mitigation

Since the office space is located in a new building (the building is about 10 years old), it does not require global measures. In general, the condition is satisfactory, with the exception of a few outlets (which need to be replaced), periodic checks of heating equipment and replacement of some lighting elements.

The microclimate of this room is periodically slightly lower than standards in the cold season. This is due to the personal need of workers and partly untimely switching on of heating systems in the city. In order to minimize the consequences of the last problem, you need to carry out the following work:

1. Distribution of portable heaters inside the office for quick and efficient heating of the common space and upper / lower extremities (but without intense infrared directional beam heating systems);

2. Sealing cracks and gaps, as well as spaces behind radiators with special insulation and / or heat-reflecting materials;

3. Providing employees with personal protective clothing (warm clothing, shoes, and gloves) in accordance with the requirements.

5.4. Fire safety

Office premises with computer equipment belong to category - D "Small fire hazard" in accordance with DSTU Б В.1.1-36:2016 “Definition of Category of Premices, Buildings and External Facilities According to Explosion and Fire Hazard”.

The main hazards (fire and explosive) are carried by such materials and objects: electrical wiring and cords, personal computers, copiers and scanners, mobile phones, chargers, power supplies, etc.

The most obvious reasons for a possible fire:

- short circuit
- failure of electrical wiring and equipment
- human factor.

The fire protection of each office should include, in accordance with the established category:

- 1 standard fire extinguisher (powder, water or water-foam) with a charge weight of 5 kg + 1 additional fire extinguisher with a charge weight of 3 kg;
- 1 fireproof cover (blanket);
- 1 box of sand;

- 2 shovels;

- 2 swabs or trim and hook;

- 2 axes

- fire alarm system (one light and sound alarm above the main exit and smoke detectors near the main transformer box).

The fire alarm system of the entire building includes: - light and sound alarms;

- signs "exit" above emergency exits;

- smoke detectors (CO2 type);

- sprinkler systems;

- central control panel.

The Fire Safety System also includes design solutions that provide for an emergency exit system, two emergency doors at a maximum distance of 50 m form the furthest workshop and 40 m from one another, as well as evacuation plans, which must be in every room and in the corridors.

Preventive and protective measures are also included in the fire safety section. These are fire safety briefings for quadruple personnel with evacuation training, a monthly check of the entire power supply and security system, a daily check of personal electrical equipment and the availability of fire safety information materials.

5.5. Conclusions to Chapter 5

After creating and writing the labor precaution section, we can conclude that the Assistant Climate Change Workplace is in good condition, although minimal adjustments are needed. The only drawbacks are a slight deviation in temperature during the cold season. Considering all of the above problems, we would suggest the following solution:

• Take organizational measures to eliminate microclimate violations in the cold season: use local heating devices permitted by standards.

These relatively simple and budgetary measures can quickly and effectively remedy the situation. All other factors, including fire safety, comply with legislation and applicable norms and standards.

CONCLUSIONS

1. Climate change has a strong impact on cities, including urban population, infrastructure, fauna and flora. Challenges for urban ecosystem raised by climate change include not only direct changes of abiotic factors and their effects on biotic components of urban ecosystem, social and economic system.

2. Methods of adaptation to climate changes in urban ecosystems are divided into: urban technology solutions, urban nature-based solutions and urban social solutions. Nature-based solutions involve working with nature to solve societal problems and involving the protection, restoration or management of natural and semi-natural ecosystems; or creating new ecosystems in and around cities.

3. Over time, the urgency of climate change has increased. Obviously, in parallel with research, cities need to work on identifying their own vulnerability to climate change and pay close attention to developing adaptation programs.

Ukraine has its own approaches and programs to adapt to negative climate change. Kyiv is the brightest example of a city that needs to adapt to climate change due to the large volume and amount of anthropogenic activity. Any conclusions and recommendations in this area are the subject of extensive scientific, managerial, expert discussion.

4. After analyzing the map of the temperature of Kyiv, we chose one of the districts of the city, which has a fairly high temperature compared to others. We have identified 15 objects and created a project of Green Roofs on them. We calculated the approximate cost, area and payback period. The recommendations on what types of green roofs to use and what vegetation to plant were also given.

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