CLIMATE-RESILIENT DEVELOPMENT: IINNOVATIVE CLIMATE SOLUTIONS AND MEASURES TOWARDS THE CARBON RESILIENCE IN PUBLIC SPACES AND BUILDINGS

OCTOBER 2023

CLIMATE-RESILIENT DEVELOPMENT: INNOVATIVE CLIMATE SOLUTIONS AND MEASURES TOWARDS THE CARBON RESILIENCE IN PUBLIC SPACES AND BUILDINGS

Authors: Zuzana Hudeková, Bratislava-Karlova Ves
Lenka Nemcová, Bratislava-Karlova Ves
in cooperation with the team of the Project Management Department of the Local Government Office of the Bratislava-Karlova Ves Municipality and partners of the DELIVER project

Graphic processing and printing:
Polygrafické centrum
POLYGRAFICKÉ CENTRUM
Vajnorská 142, 831 04 Bratislava
www.polygracentrum.sk
ba@polygracentrum.sk

The text has not been proofread

Bratislava, October 2023

ISBN: 978 - 80 - 570 - 4933 - 3
EAN: 9788057049333

European Commission

The publication was produced as part of the project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, *DELIVER: Sídliská ako živé miesta odolné voči zmene klímy*, LIFE17 CCA/SK/000126 – LIFE DELIVER, financially supported by the European Commission, from the financial instrument for the environment: the LIFE program, from the sub-programme "Climate Protection".

More information about the DELIVER project can be found on the website http://odolnesidliska.sk/.

KRI

Bratislavské regionálne ochranárske združenie BROZ

iepd INŠTITÚT PRE PASÍVNE DOMY

CONTENTS

I. CHALLENGES AND IMPACTS OF CLIMATE CHANGE IN URBAN ENVIRONMENT – INTRODUCTION

1. Climate-resilient development

Between 2022 and 2023, the Intergovernmental Panel on Climate Change (IPCC) 1´ published its sixth summary assessment report, titled «Climate Change 2022: Impacts, Adaptation and Vulnerability2." This comprehensive report not only assesses the far-reaching impacts of climate change on ecosystems, biodiversity, and human communities but also delves into the threats, capacities, and limitations of nature and human societies in adapting to the climate change impacts.

The report paints a stark picture of the climate crisis, highlighting the extensive losses and damages it has already inflicted on humanity and ecosystems worldwide. These impacts are projected to intensify with each degree of warming, underscoring the urgency of addressing climate change.

In the face of this challenge, the IPCC's sixth assessment report emphasizes the framework of climate-resilient development, a pathway that combines adaptation and mitigation strategies. This approach entails adapting to the impacts of climate change while simultaneously reducing greenhouse gas emissions to promote sustainable development for all.

The IPCC's sixth assessment report serves as a critical guide for policymakers, scientists, and communities worldwide, providing a comprehensive understanding of climate change and outlining a roadmap for a climate-resilient future.

The IPCC's sixth assessment report underscores the urgent need for implementing measures to achieve a climate-resilient and sustainable world. The world faces a complex and interconnected set of challenges that demand simultaneous attention. The urgency of the climate crisis calls for unprecedented action on a global scale.

Therefore, it is imperative to start implementing the concept of climate-resilient development without delay. Climate-resilient development in cities holds particular significance. The construction industry, responsible for 38% of total global energy-related CO2 emissions, will play a pivotal role in achieving greenhouse gas reduction targets. Simultaneously, increased attention must be paid to adapting residential environments to the new conditions arising from climate change.

This brochure aims to present innovative climate-resilient development solutions implemented in Bratislava-Karlova Ves Municipality during the in-depth renovation of public buildings and public spaces.

These adaptation and mitigation measures were implemented within the DELIVER project: Developing resilient, low – carbon and more Livable urban Residential area(www.odolnesidliska.sk) as well as within other projects implemented by the Bratislava – Karlova Ves Municipality.

Picture No. 1: View of the Dlhé Diely housing estate – Bratislava Karlova Ves
(source: archives of the Bratislava-Karlova Ves Municipality)

1 IPPCC – Intergovernmental Panel of Climate change (IPCC) is a scientific body that assesses the risks of climate change. It is part of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), both of which are affiliated with the United Nations.

2 The report was written by 270 authors from 67 countries. https://apps.ipcc.ch/report/authors/report.authors.php?q=36&p=

2. Impact of Climate change in cities

The urban environments differ significantly from the surrounding natural landscape in several characteristics (temperature, humidity, and air pollution, among others). These differences encompass temperature, humidity, air pollution, and several other factors. In densely populated areas, non-permeable surfaces like concrete and asphalt dominate, leading to a higher thermal storage capacity. These surfaces absorb heat during the day and release it at night, influencing the temperature profile of the surrounding urban environment. The increase in urban temperature is further exacerbated by heat emissions from industrial processes, combustion engines in transportation, and the heating of buildings. The interplay of these factors creates a phenomenon known as the urban heat island (UHI). Literature suggests that the temperature difference between a city and its surroundings can range from 0.5 to 1.5 °C, with extreme cases reaching up to 10 °C, particularly during exceptionally hot days. The uneven surface of the city increases friction, which impedes the movement of air masses up to a height of 1,000 meters above the city. The air layers above the city warm up and, together with the presence of condensation nuclei, help to increase cloudiness over cities compared to the surrounding countryside. On average, this difference is 5 to 10 %. Due to the increased cloudiness, the amount of precipitation could also increase, but due to the fact that in the urbanized environment, impervious surfaces occupy a high percentage share, the natural water cycle is significantly disrupted and negatively affected.

Due to the distinct environmental characteristics of urban areas, the expected consequences of climate change are likely to have a more pronounced impact on cities in the coming years. Among the most pressing climate-related challenges facing cities are:

- Heatwaves: Cities are particularly vulnerable to heatwaves due to the urban heat island effect, which can exacerbate the intensity and duration of heat events.
- Decreased precipitation: In some regions, particularly in the south of Slovakia, climate change is projected to lead to a decrease in overall precipitation,
- Prolonged droughts alternating with heavy rainfall: Climate change is expected to increase the frequency and intensity of droughts, followed by periods of heavy rainfall.
- Local floods, storms, and windstorms: Extreme weather events such as heavy rainfall, storms, and windstorms are projected to become more frequent and intense, increasing the risk of local flooding, damage to infrastructure, and disruptions to daily life.

These climate-related challenges will require cities to adapt and develop resilience strategies to mitigate their impacts and ensure the well-being of their residents.

In relation to buildings and public spaces, the EU-level technical guidance on adapting buildings to climate change was published in spring 2023. (*EU-level technical guidance on adapting buildings to climate change*)[3].

This document focuses on the main climate hazards that can affect urban environments. These hazards are divided into four categories in accordance with Annex A of the EU[4] Taxonomy:

- Hazards related to temperature
- Hazards related to wind
- Hazards related to water
- Hazards related to the movement of solid matter

While all climate hazards can affect urban environments, depending on their geographical location and other factors, six of them have been identified as "priority hazards". These are climate hazards that significantly affect urban environments (buildings and their users, public spaces, etc.) and are typical for cities throughout Europe, including Slovakia. They are:

Heatwaves (temperature-related hazards)

Strong storms with gusty winds, including snow, dust, and sand storms (wind-related hazards)

1. Drought (water-related hazards)
2. Heavy rainfall – rain/hail/snow/ice (water-related hazards)
3. Floods – river, pluvial (water-related hazards)
4. Landslides and ground subsidence (hazards related to the movement of solid matter)

Picture No. 2: Heavy rainfall, its occurrence is expected to become more frequent and alternating with periods of drought according to climate scenarios, Bratislava Karlova Ves (source: archive of Bratislava-Karlova Ves Municipality, 2019)

3 https://climate-adapt.eea.europa.eu/en/metadata/guidances/eu-level-technical-guidance-on-adapting-buildings-to-climate-change

4 https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

MEASURES AND INNOVATIVE SOLUTIONS FOR BUILDINGS AND PUBLIC SPACES

1. Assessment of the vulnerability and risks for buildings and infrastructure

Vulnerability and risk assessment is commonly used to evaluate the potential impacts of climate change on systems and key sectors. It is also an effective tool for identifying the most critical areas where adaptation measures need to be implemented, as well as for setting priorities. For this reason, it is optimal to first conduct a vulnerability assessment before making a decision to implement specific adaptation measures on buildings and infrastructure.

Buildings and infrastructure can be vulnerable from the perspective of the structure itself and the materials used (low resistance to overheating) or from the perspective of its location (for example, in areas at risk of flooding, landslides, etc.). The impacts of climate change on buildings and infrastructure will vary in different regions, which means that reducing vulnerability and increasing the resilience of the urban environment must always be assigned to a specific climate hazard.

Existing methods for climate vulnerability and risk assessment (CVRA) are based on the following key concepts and definitions

Box No. 1: Basic terms used in vulnerability and risk assessment

Adaptive capacity [Source: ISO 14090:2019] is the ability of systems, institutions, people, and other organisms to adjust to potential damage, exploit opportunities, or respond to consequences. It is a set of properties and capabilities that allow a system to absorb, adapt to, and recover from the impacts of climate change.

Vulnerability [Source: ISO 14090:2019] is the susceptibility or predisposition to be adversely affected. Vulnerability includes a range of concepts and elements including sensitivity or susceptibility to damage and lack of capacity to cope with damage and adapt.

Sensitivity [Source: ISO 140902019] is the degree to which a system or species is affected, either adversely or beneficially, by climate variability/variability or its change. Sensitivity is determined by the properties of the system or species that make it more or less resilient to the impacts of climate change.

Hazard [Source: ISO 140902019] is a potential source of damage. The potential for damage may relate to loss of life, injury, or other health impacts, as well as damage and losses to property, infrastructure, livelihoods, service delivery, ecosystems, and environmental resources.

Impact [Source: ISO 140902019] is the effect on natural and anthropogenic systems. In the context of climate change, the term "impact" is primarily used to refer to the effects on natural and human systems as a result of extreme weather and climate events and climate change. Impacts generally relate to the effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure as a result of the interaction of climate change or hazardous climate events that occur over a certain period of time and the vulnerability of the exposed society or system.

Exposure [Source: ISO 140902019] is the presence of people, their livelihoods (ways and means of making a living), species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural values in places and environments that could be affected.

Risk [Source: ISO 140902019] is the effect of uncertainty on objectives. It is a measure of the likelihood and impact of a negative event. In the context of climate change, risks can arise from the potential impacts of climate change, as well as from human responses to climate change.

Picture No. 3: Exposure of the residential environment to flash floods – a rainfall-runoff model Bratislava-Karlova Ves (source: DHI)

Currently, there are several methodologies that are directly applicable to the assessment of climate vulnerability and risk of buildings and surrounding public spaces. These methodologies can also provide a sufficient level of detail and are generally in line with the accepted definitions of vulnerability and risk, as defined by the 5th and 6th IPCC assessment reports (AR5 and AR6) [5].

One of the complex tools for assessing buildings, which is mentioned in the EU-level Technical Guidance on Adaptation of Buildings to Climate Change, is the innovative tool Klimasken (www.klimasken.sk, https://www.klimasken.sk/en/, which was created in the frame of the DELIVER project (described in more detail in Chapter III.).

2. Adaptation and mitigation measures on buildings and public spaces in relation to climate threats in Bratislava-Karlova Ves

A summary of adaptation measures for buildings and public spaces in relation to climate hazards is drafted in Table 1. The complex approach to the implementation of deep renovations of two public buildings is described in the section "Climate-resilient public buildings – Deep green renovation of Kindergarten Koliskova 14, Bratislava-Karlova Ves and Deep green renovation of the Primary School A. Dubčeka, Majerníkova 62, Bratislava-Karlova Ves." Moreover, the implemented measures were closely linked to environmental education and biodiversity conservation measures – and all to together in its complexity is representing the key innovation realised in the frame of the project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area .

5 In the document "Technical guidelines at the EU level on the adaptation of buildings to climate change", a short list of methodologies and approaches that are most applicable to the evaluation of the vulnerability of buildings is presented in table 3.2 and in the annex.

Table.1: Adaptation measures for buildings and public spaces in relation to climate threats – description and measures (for the period 2016-2023)

Adaptation measure	Type and place where the measure was implemented	Link and impact on reducing vulnerability to climate hazards	Additional notes
Renovated insulation (building envelope and roof)	building envelope, roof – Kindergarden Kolískova, A.Dubčeka Primary school	the heat	Mitigation effect - impact on energy savings (reduced energy consumption and cost reduction during the heating season).
Exterior shading for windows	Exterior electrically controlled blinds on the windows - Kindergarden Kolískova, A.Dubček Primary school and fixed lamella blinds – Primary school A.Dubček	the heat	Adaptation effect and at the same time mitigation effect - cooling of buildings without the need for air conditioning
Photovoltaic (PhV) and photothermic (solar) devices on roofs	Roof - Kindergarden Kolískova, Primary school A. Dubček	the heat	Mitigation effect - securing a source of clean energy. It also acts as a shading device. The possibility of connecting with green roofs (in the case of Kolískova Kindergarten and A.Dubček Primary School, the building's statics did not allow this)
Green/Vegetation roof	Green/Vegetation roof - small roof over the entrance of the A.Dubček Primary school, green roof on the extension to the building of the Local Government Office of the Municipality of BA-Karlova Ves	the heat, flash flood, floods	Mitigation effect - impact on energy savings (better thermal insulation, reduced energy consumption and cost reduction during the heating season), improvement of the efficiency of photovoltaic devices, support for biodiversity.
Green facades	Green facades, walls and vertical cable systems with climbing plants - Kindergarden Kolískova, A.Dubček Primary school	the heat, flash flood, floods	Mitigation effect - impact on energy savings (reduced energy consumption and cost reduction during the heating season), support of biodiversity,
Controlled ventilation system with heat recovery	Ventilation system with heat recovery - Kindergarden Kolískova, A.Dubčeka Primary school	the heat	Mitigation effect - impact on energy savings (reduced energy consumption and cost reduction during the heating season), increase in the quality of the indoor environment.
Collection of rainwater in the retention tanks (underground and other) and its secondary use (watering, sanitary purposes)	Underground retention tanks - captured water is used for flushing - Kindergarden Kolískova, A.Dubček Primary school. Underground and above-ground retention tanks - captured water is used for irrigation of greenery - public space – Kaskády, area of A. Dubček Primary school, pedestrian zone Pribišova, Culture Center in Karlova Ves , Kindergarten Suchohradská, children's playground in the inner block of Majerníkova 36-58, entrance to Local Government Office of BA-Karlova Ves Municipality	the heat, drought, floods	Mitigation effect - saving drinking water, saving energy for water treatment and purification.
Rain gardens, ponds, and other elements of sustainable rainwater management	Elements of sustainable rainwater management - climatic ponds in the atriums - Kindergarden Kolískova, wetland beds - public space Kaskády.	the heat, drought, floods	Flood protection. Favourable effect on the microclimate, natural filtration of pollutants, etc.
Permeable surfaces - parking lots and others	Permeable surfaces - parking lot - Kindergarten Kolískova, inner atriums of A.Dubček Primary school	the heat, drought, floods	Favourable influence on the microclimate, support of a small water cycle, protection against flooding, etc.
Exterior shading of exposed public spaces and children's playgrounds	Outdoor shade sails in playgrounds of the Kindergarten in Karlova Ves (20 sails) and in the public spaces, playgrounds and sandboxes (26 sails).	the heat,	Adaptation effect - health protection from the point of view of the most vulnerable population groups

Picture No. 4: Gazebo for the needs of an outdoor eco-classroom near the school garden in the sports and recreation area Majerníkova 60-62, Bratislava-Karlova Ves Municipality. Capturing rainwater from the gazebo roof in a tank and utilizing it to irrigate fruit bushes and herbs was a part of eco-educational activities. The overflow from the tank at the top provides drinking water for birds and insects.
(source: archives of the Municipality of Bratislava-Karlova Ves)

III. EXAMPLES OF IMPLEMENTED INNOVATIVE MEASURES IMPLEMENTED ON BUILDINGS AND PUBLIC SPACES IN BRATISLAVA-KARLOVA VES MUNICIPALITY

1. KLIMASKEN – a tool for assessing the vulnerability and risks of buildings

General overview – Tool description

KLIMASKEN is a tool for assessing buildings in terms of their contribution to climate change and adaptation to climate change. The tool is composed of several dozen indicators that the user fills in with the required data. The main index and its partial components are then determined from them using simple calculations.

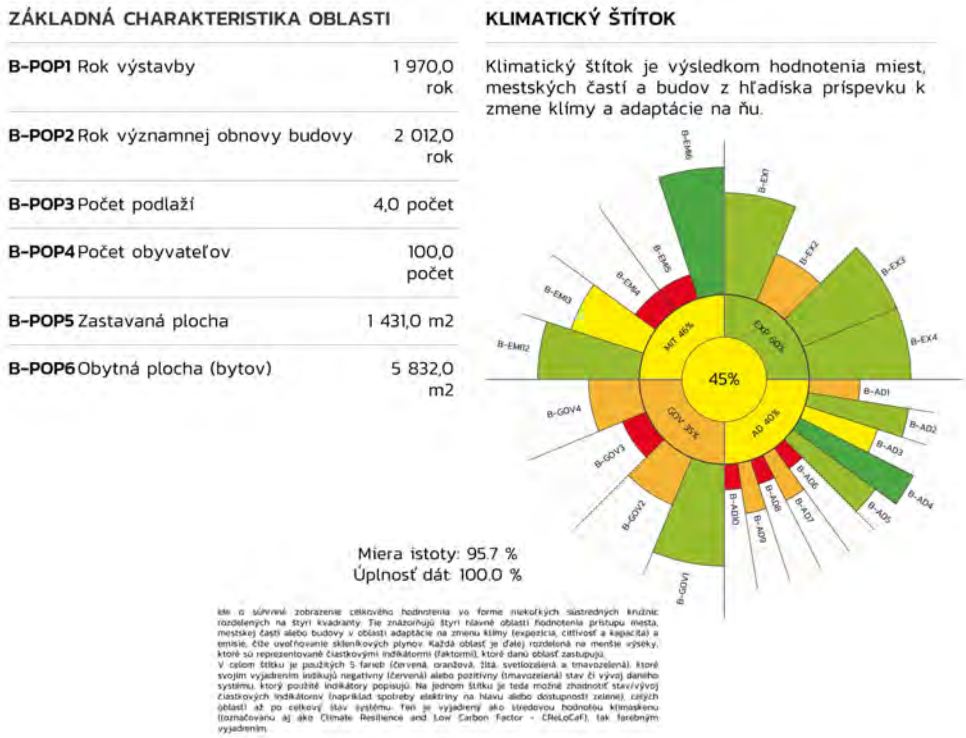
The result of the assessment is a "climate label" that shows the four main areas of building assessment in the field of adaptation to climate change (exposure, sensitivity, and capacity) as well as in the field of emissions, i.e., the amount of greenhouse gas emissions produced.

It is a summary representation of the overall assessment in the form of several concentric circles divided into four quadrants. These represent the four main areas of assessment of the approach of a city, municipality, or building in the field of adaptation to climate change (exposure, sensitivity, and capacity) and emissions, i.e., the release of greenhouse gases. Each area is further divided into smaller sections, which are represented by partial indicators (factors) that represent the area.

Five colours are used throughout the label (red, orange, yellow, light green, and dark green), which indicate the negative (red) or positive (dark green) state or development of the system described by the indicators used. On a single label, it is therefore possible to assess the state/development of partial indicators (such as electricity consumption per capita or the availability of greenery), entire areas up to the overall state of the system. This is expressed as the central value of Klimasken, as well as a colour expression.

<u>1.1. Implemented measure:</u> Case study of climate resilience assessment – residential house Karloveská, Levárska, Silvánska, Bratislava-Karlova Ves Municipality

Concrete apartment building between Karloveská 57, Levárska and Silvánska streets was evaluated using the KLIMASKEN tool. The evaluated building received 45% (out of 100%). The building was built in 1970, renovated in 2012 with a total living area of 5832 m^2 apartments. 100 residents live in the panel house.



INDIKÁTORY EXPOZÍCIE VOČI PREJAVOM ZMENY KLÍMY

B-EX1	Povodňové riziko	1,0 číslo
B-EX2	Ohrozenie technickej infraštruktúry záplavami	8,0 Body
B-EX3	Ohrozenie stavby extrémnymi meteorologickými javmi	7,0 Body
B-EX4	Rozdiel priemernej ročnej teploty vzduchu v sledovanom roku oproti dlhodobému priemeru	1,5 °C

INDIKÁTORY CITIVOSTI A ADAPTÍVNEJ KAPACITY

B-AD1	Tepelná ochrana obvodových stien	80,0 mm
B-AD2	Tepelná ochrana strechy	240,0 mm
B-AD3	Transparentné konštrukcie	3,2 Body
B-AD4	Tieniace konštrukcie a tienenie konštrukciami	0,7 Body
B-AD5	Tienenie konštrukciami a zeleňou	50,0 %
B-AD6	Vegetačné a štrkové strechy	0,0 Body
B-AD7	Farebné vyhotovenie	2,0 Body
B-AD8	Chladiace zariadenia	3,0 Body
B-AD9	Vetracie zariadenia	2,5 Body
B-AD10	Kapacita budovy na akumuláciu dažďovej vody	0,0 %

INDIKÁTORY PRODUKCIE SKLENÍKOVÝCH PLYNOV A JEJ ZNIŽOVANIE

B-EMI12	Spotreba tepla v budove	702,4 kg CO2e/obyv.
B-EMI3	Spotreba elektriny v budove	1 027,2 kg CO2e/obyv.
B-EMI4	Výroba elektriny v budove	0,0 kg CO2e/obyv.
B-EMI5	Produkcia zmesového komunálneho odpadu v budove	1 843,4 kg CO2e/obyv.
B-EMI6	Produkcia odpadovej vody v budove	20,1 kg CO2e/obyv.

INDIKÁTORY PRIPRAVENOSTI INŠTITÚCIE NA REALIZÁCIU OPATRENÍ

B-GOV1	Technické zabezpečenie budovy pred záplavami a prívalovými zrážkami	12,0 Body
B-GOV2	Zadržiavanie zrážkovej vody v okolí budovy	0,3 koeficient
B-GOV3	Zachytávanie zrážkovej vody na budove	0,0 koeficient
B-GOV4	Zaistenie prevencie proti živelným udalostiam	3,0 Body

POMOCNÉ INFORMÁCIE

Miera istoty:	95,7 %
Úplnosť dát:	100,0 %

Picture No. 5: Detailed results of the assessment of the climate resilience of the building

Funding of the measure

- Project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EK, LIFE program, from the "Climate Protection" subprogramme.

2. Selected measures implemented on buildings

2.1. Green/Vegetation roofs

General description[6]

Vegetation roofs are an effective adaptation-mitigation measure in an intensively urbanized area, where is a lack of open green space. Vegetation roofs can be built on buildings with a flat or sloping roof (with an inclination of up to 45°). Vegetated roofs are divided into two types: intensive and extensive. The type of roof is determined by the species composition of the plants and the associated parameters, such as the thickness of the substrate.

Intensive vegetation roofs have most of the area covered with low to medium-high vegetation (most often different types of grasses, perennials, or smaller shrubs), under which there is a substrate several tens of centimetres thick and an insulating layer. In order to maintain prosperous conditions for the roof vegetation, regular maintenance and regular watering according to the need and the selected types of planted vegetation are mostly required.

An extensive vegetated roof, on the other hand, is usually almost maintenance-free (maintenance 3-4 times a year) and covered with undemanding types of plants (e.g., mosses, stonecrops, succulents, grasses and herbs) with a substrate thickness of up to 20 to 25 cm.

Vegetation roofs contribute to mitigating climate change and reducing greenhouse gas emissions in two ways. The first is the absorption of carbon by the roof vegetation itself, which uses it as a building block for its own growth and binds it in its own organism. Another way is to improve the thermal insulation parameters of the building's roof and prevent excessive overheating of the building during summer heat waves, or its cooling. Thanks to the increased insulation, active mechanical cooling is not required to ensure thermal comfort in the building (e.g., by air conditioning devices, although very widespread, but disadvantageous from the point of view of mitigation), which reduces energy consumption. The specific mitigation benefit will depend on the type of building on which the green roof is placed, the location of this building itself, its orientation to the four cardinal directions, and the heating method. The effect of this measure must also be assessed together with other implemented measures on the building, which also contribute to the reduction of greenhouse gas emissions. In general, the gross mitigation benefit for new biomass on the vegetated roof is: 1 ton of new biomass = 3.67 ton absorbed CO_2. If the building is in a worse energy standard and heating with fossil fuels, the benefit will be higher than for an existing low-energy building. Published research shows that green roofs have the potential to improve the thermal performance of the roof system with the help of shading, insulation and evapotranspiration, thereby reducing the energy demand of the given building. Published data show that green roofs can save from 1.8 kWh/m^2 to 6.8 kWh/m^2 for cooling and 6.44 kWh/m^2 for heating.

The energy saving for air conditioning in the case of a green roof is up to 150W/m^2 (Handley, 2010) and this is also related to the estimated reduction in CO_2 emissions based on energy savings (the emission reduction estimate is linked to the saved energy multiplied by 0.537 kWh, which represents the carbon intensity for electricity Defra/ Carbon Trust).

Adaptive effect of the measure

Green roofs have a significant impact on preventing overheating of buildings during heat waves. Thanks to the shading effect of vegetation and additional insulation (soil substrate and technical insulation layers), they can keep the internal temperature of the building up to several degrees' Celsius cooler than in a comparable building with a traditional roof. Through evaporation from the roof vegetation, they also slightly contribute to cooling their surroundings. Another adaptive effect of green roofs is the capture and slowing down of runoff of rainwater, thus helping to manage rainwater in the city and reduce the risk of local floods. 1 m^2 of an extensive green roof with a substrate thickness of 25 cm can capture around 137 liters of rainwater (which is a comparable amount of water in a filled bathtub). Green roofs have a maximum runoff coefficient of 85 to 90% lower than impermeable surfaces.

However, the intensity of the adaptive effect of green roofs varies significantly depending on the type and implementation of the measure.

Biodiversity impact of the measure

Vegetation roofs provide shelter and living space for many animals in a highly urbanized environment. Depending on the type of green roof implementation, the degree of impact from the point of view of biodiversity also depends. Extensive vegetation roofs with low species diversity and mostly low vegetation provide shelter mainly for invertebrates. Intensive vegetation roofs with more diverse and lush vegetation provide space for life, food or rest for a wider range of animals, including birds, pollinators, etc. In order to increase the biodiversity effect, it is possible to supplement the vegetation roof in addition to normal vegetation, e.g., a small water feature, such as a birdbath, that can be used to provide water for birds during dry periods, or various pieces of wood and plant debris that can be used to create a natural water feature.

It is important to keep the birdbath full of water during dry periods.

On the roofs, it is possible to integrate elements such as beehives, a rich assortment of flowering nectar-producing plants, the creation of other innovative elements that will support biodiversity (places that will be a refuge for suitable animal species, watering holes for bees and birds, etc.).

6 Source: Catalogue of selected adaptation and mitigation measures https://lnk.sk/bed7

To support biodiversity, it is recommended:

- Preserve diversity and variety (diversification of plant species and layers), i.e. plant different species with different plant heights. Preference should be given to domestic species; in some cases, it is also possible to "transfer" a part of the flowering meadow to the roof by means of machining.
- If it is technically possible, use a substrate with a thickness of more than 20 cm, if this is not possible at least between 8 and 10 cm. It is recommended to use a local substrate with a quality close to natural soil (preferably local soil).
- Placement of elements to support biodiversity (rocks, dead wood, possibly a water feature, or shelters on the roof), a watering hole/ birdbath for birds and insects.
- Do not use automatic irrigation, not only to save water, but also to support natural processes.

In the study, where knowledge was collected from 31 vegetation roofs (Grooves-Green ROOfs Verified Ecosystem), 200 plant species were identified, of which 70% grew spontaneously. At the same time, more than 300 species of fauna, including 250 species of insects, were identified. Also, from this point of view, vegetation roofs can serve as "bio corridors" for various species, as they provide the necessary shelter and food, which allows birds and other species to nest and reproduce.

Additional information for the implementation of the measure

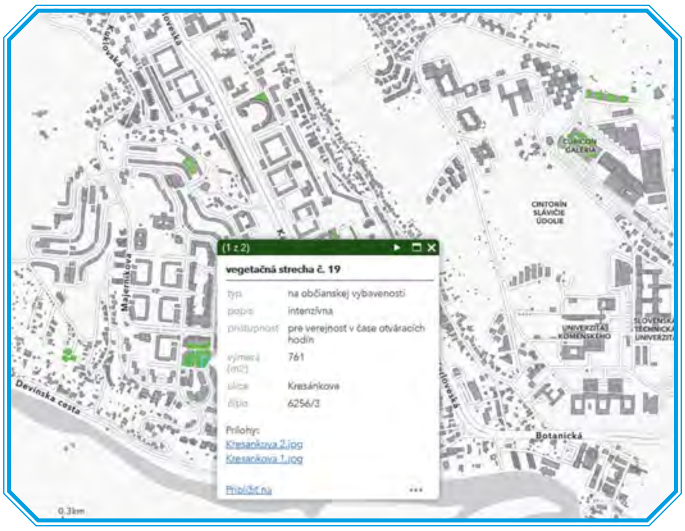
- The technical parameters of the building are the basic condition and limit for choosing a suitable type of vegetation roof. Intensive roofs are significantly more demanding in terms of sufficient load-bearing capacity and statics of the roof structure and are feasible on roofs with a low slope. Extensive roofs generally do not require increased roof load-bearing capacity requirements and can also be implemented on roofs with a higher slope (up to approx. 30°).
- The surface of roofs is exposed to extreme temperatures during summer heat waves, and therefore it is necessary to consider a suitable species composition of vegetation (especially in the case of maintenance-free extensive roofs) or an efficient irrigation system in the case of intensively vegetated roofs.

2.1.1. Implemented measure: Map of green roofs in Bratislava-Karlova Ves Municipality

The comprehensive mapping of vegetated roofs in Bratislava Karlova Ves is an important step towards increasing the adaptive capacity of the community to climate change. As part of the interactive map Green, climate-resilient and nature-friendly Karlova Ves[7], a map of vegetation roofs was created based on the mapping, which is available at: https://mapy-karlovaves.hub.arcgis.com/apps/55367f5573454228b76ef25e5c18d7b1.

Here, in addition to the location of each vegetation roof, there is also information available, for example, whether it is an extensive vegetation roof or whether the vegetation roof is accessible to the public etc. All publicly available vegetation roofs are accompanied by photos.

The total area of currently realized green roofs in the territory of Karlova Ves is over 10,300 m2.



Picture No. 6: Map of green roofs (source: https://mapy-karlovaves.hub.arcgis.com/)

Funding of the measure

– Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection.

7 Source: Green, climate-resilient and nature-friendly Karlova Ves – mapping of vulnerable places and gradually introduced measures to increase the resilience of the urban area to the effects of climate change: https://mapy-karlovaves.hub.arcgis.com/

2.1.2. Implemented measure: Vegetation roof on the extension of the Municipality Office of the Bratislava-Karlova Ves

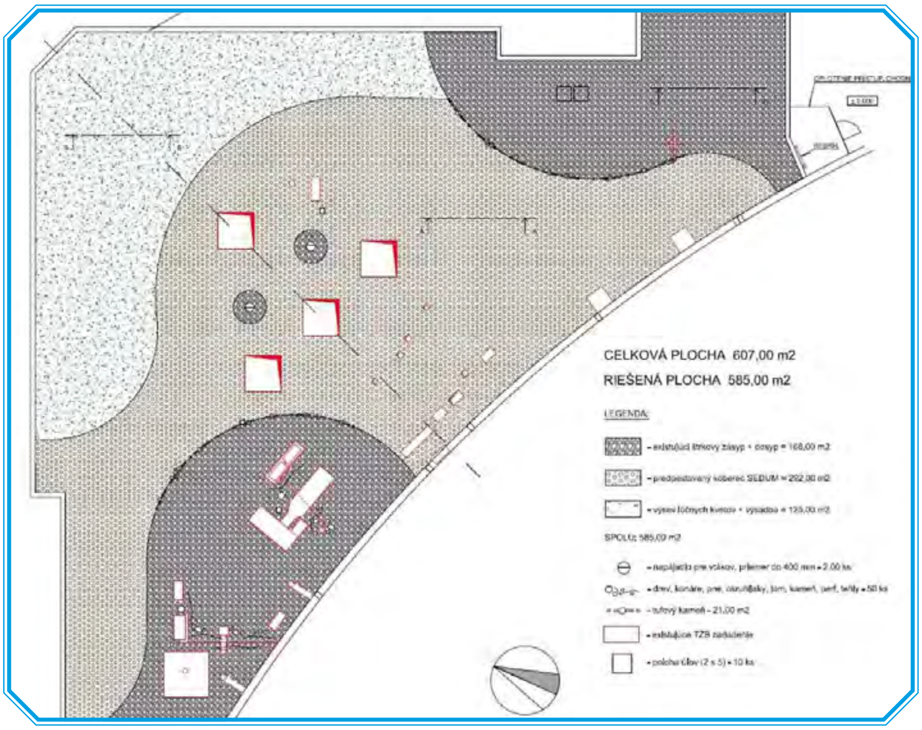
The extensive vegetation roof is located on the roof of the extension of the Local Government Office of the Bratislava-Karlova Ves Municipality, in the location of the existing buildings and infrastructure. The goal was to create a model vegetation roof with the function of rainwater retention and the integration of innovative elements that will support biodiversity (dead wood, watering holes, a rich assortment of flowering nectar-producing plants). Another goal was to increase the visual value of the proposed space, as it is visually located next to the staircase leading to the first floor of the office and is thus fully visible to visitors, but also to office workers, as well as from the residential areas next to the building.

The extensive vegetation roof was designed as a single unit, consisting of three parts:

a) original roof with existing gravel filling with an area of 168.00 m^2 = area with existing ventilation and air conditioning equipment for the building, lines and cables equipped with elements to maintain biodiversity – long wooden branches, tree stumps with a height of 300-600 mm, pebbles, quarry stone, perforated bricks – loosely laid
b) area covered with a pre-grown SEDUM carpet with an area of 292.00 m^2 = area with existing skylights of the roof of the building and with ventilation and air conditioning elements, pre-grown carpets supplemented with 2 gravel areas of r = 690 mm, supplemented with two watering holes / birdbaths for birds and bees made of frost-resistant glazed ceramics, diameter up to 400 mm,
c) an area of 125.00 m^2, with a wildflower meadow and perennial plantings.

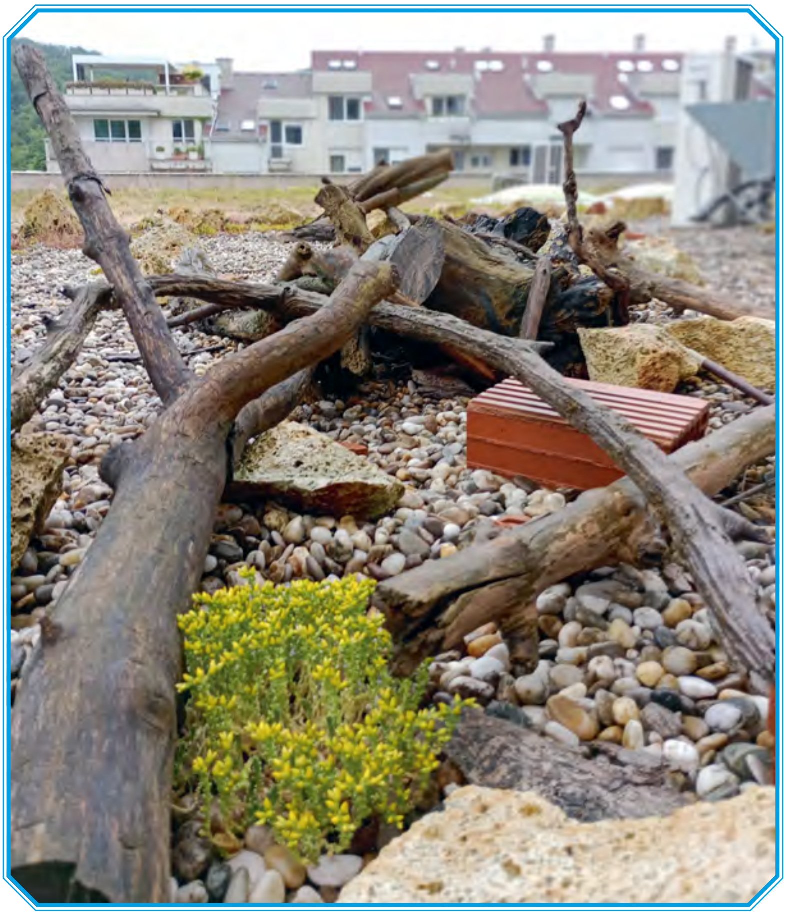
The area a) and b) is optically divided by loosely laid tuff stones with a length of 10.00 and 11.00 mm, which also serve as elements to support biodiversity.

At the same time, the entire area optically acts as a slight gradation of the terrain from the original area – gravel, through the SEDUM carpet – low vegetation to planted perennials and sown meadow flowers – higher vegetation, towards the windows – the view of the local government office building. The floor plan of the area is designed dynamically – with curves, suppressing the austere shapes of the equipment on the roof and the floor plan itself. Only natural materials are used.



Picture No. 7: Project documentation – vegetation roof – overall solution (source: arch real, s.r.o.)

Picture No. 8: View from above of the vegetated roof after implementation (source: archive of Bratislava-Karlova Ves Municipality)



Picture No. 9: Detail of dead wood and other elements to support biodiversity in one part of the vegetated roof (source: archive of Bratislava-Karlova Ves Municipality)

Picture No. 10: A watering hole /birdbath for the fauna on the vegetated roof (source: archive of Bratislava-Karlova Ves Municipality)

Picture No. 11: Perennial flower bed on the vegetated roof (source: archive of Bratislava-Karlova Ves Municipality)

Funding of the measure

- Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection (project concept, technical documentation)
- Project PERFECT: : Planning for Environmental Resource eFficiency in European Cities and Towns, EC, program Interreg Europe (project documentation, static assessment).
- OP KŽP: Implementation of solutions for sustainable rainwater management in Bratislava – Karlova Ves Municipality, NFP310020V730, EC, the European Structural and Investment Funds (implementation)

2.1.3. <u>Implemented measure:</u> Small green roofs implemented in the sports and recreation area in Bratislava-Karlova Ves with the involvement of children

An innovative green element has been added to the sports and recreation area near the A. Dubček Primary School at Majerníková street 60-62. The unattractive-looking roofs of four civil defense ventilation covers and a changing room container were given a new look and an important environmental message during a renovation in the frame of project DELIVER. They are all sloped to one corner so that the collected rainwater can travel from the newly installed gutter directly to the collection containers. The water is used to water the local vegetation. You can find here mini succulents, primarily stonecrops and several varieties of rock roses. The pupils of the A.Dubček Primary school helped the DELIVER project partner Bratislava regional conservation association (BROZ) to plant succulents in the prepared substrate. This type of vegetated roofs is called extensive, which means that it is easy to maintain and water. Due to the low variety of species and mostly low vegetation, mostly invertebrates find shelter here. Through the evapotranspiration process from the vegetation of the roofs, they will also slightly cool their surroundings. An important part of the implementation of this measure is the educational function, since one does not normally see what a vegetation roof looks like up close, and here the opportunity was created to see how the vegetation roof is constructed and children have the opportunity to observe the vegetation and other organism at the level of a their eyes.

Picture No. 12: A small vegetation roof on the ventilation cover of civil protection (source: archive of BROZ)

Funding of the measure

- Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection (implementation)

2.2. Controlled ventilation system with heat recovery

General description[8]

An effective technical solution for ensuring fresh air in the interior and minimizing heat loss through ventilation is a controlled ventilation system with heat recovery. With controlled ventilation with heat recovery, fresh air is supplied to the building often according to the CO_2 level in the interior, depending on the number of people present. Controlled ventilation with heat recovery from the exhaust air can improve thermal comfort at relatively low costs. It can be also combined with the cooling function to ensure a reduction in the interior temperature. Controlled ventilation with heat recovery primarily helps to ensure a higher quality of the indoor environment and also helps to reduce heating costs in winter as well as cooling costs in hot weather.

Adaptive impact of the measure

During hot weather, overheating of the interior of buildings also occurs due to thermally inefficient ventilation through windows, which is necessary to ensure fresh air in the room. Controlled ventilation with heat recovery is a more effective tool for reducing heat losses and ensuring thermal comfort in the interior during heat waves. During the summer months, it helps to maintain thermal comfort in the interior by using cooler night air, removing warm waste air from warmer rooms and cooling the air supplied to the rooms.

Air conditioning ensures the exchange of air and its required quality (temperature, CO_2 concentration, etc.) in the entire building, or in its individual rooms. The system can be installed as a central ventilation system (air exchange in the entire building) or as a local ventilation system (for individual rooms), where the air supply and exhaust are handled separately for each room.

An important requirement for air conditioning is the volume of air that the unit is able to exchange and adjust to the required quality. Depending on the size of the building and the number of rooms, local or central units with capacities from 15 m^3 to 1000 m^3 / h can be installed. The system is thus limited by the amount of air that can be exchanged, and also by its space requirement. For a room of 20 m^2, it is necessary to exchange 20-30 m^3 of air per hour (depending on the use of the room and the number of people). A common solution is to ventilate houses by vacuum ventilation using a ventilation unit with automatic regulation, which ensures a constant vacuum for air exchange (Malý et al., 2019). The implementation of the measure is often necessary in the implementation of new buildings or significant renovations of buildings in order to meet current thermal engineering standards (from February 1, 2021, buildings with almost zero consumption).

The indoor air quality

Controlled ventilation with heat recovery primarily helps ensure a higher quality of the indoor environment. From the results of CO_2 concentration measurements in classrooms9, carried out as part of the Healthy School project in the Czech Republic, it is clear that the hygienic CO_2 concentration limit of 1500 ppm will be exceeded in a relatively short time, usually already during the first half of the lesson. Even ventilation during breaks or during the day will not significantly reduce the CO_2 concentration. During the day, the level of CO_2 concentration around 3000 ppm was repeatedly reached. Such concentration can manifest itself in pupils' sleepiness and loss of concentration.

In addition to its general benefits, controlled ventilation is also important in reducing the risk of COVID-19 transmission. The concentration of CO_2 in classrooms is not a direct measure of viral load, but it is a good indicator of the level of aerosol contamination. As air becomes stale, the concentration of aerosols increases, which can increase the risk of infection.

2.2.1. Implemented measure: Controlled ventilation with heat recovery Kindergarten Kolískova 14, Bratislava-Karlova Ves

The ventilation system for a kindergarten building was designed to provide controlled ventilation for the kitchen, playrooms, and bedrooms. The system also ensures thermal comfort and hygienic air exchange. The ventilation system is divided into the following devices based on purpose:

Device No. 1 – Heat recovery ventilation with summer cooling of the kitchen space
Device No. 2 – Heat recovery ventilation of playrooms, bedrooms, and social spaces

8 Source: Catalogue of selected adaptation and mitigation measures https://lnk.sk/bed7
9 Source: https://amitomation.cz/jaka-je-spravna-koncentrace-co2-ve-zdrave-budove/

The basic characteristics of the heat recovery ventilation for playrooms, bedrooms, and social spaces are as follows:

- Filtered air supply and exhaust
- The device operates with fresh air
- Fan motors controlled by EC motors
- Heat recovery with plate heat exchanger (HRS)
- Air thermal treatment – electric heater

Compact underfloor units were designed and implemented, located in the back of the classroom spaces. The unit is placed on a steel frame and hinges, which is attached through damping pads to the structural ceiling construction.

Picture No.13: Controlled ventilation with heat recovery – fabric sleeves under the ceiling with fresh air supply. Pipes that draw in fresh air from atria and exhaust waste air. (source: archive of Bratislava-Karlova Ves Municipality)

After drawing in fresh air from the atria, the air in the supply section of the unit is filtered, preheated, or precooled in a plate heat exchanger SZT – in case of need heated in an electric heater and in the summer without additional thermal treatment. The supply air is transported by a fan and VZT piping to distribution elements (textile sleeve outlets), through which it is distributed to playrooms and bedrooms.

The exhaust of contaminated air from social spaces is through exhaust plate valves. The extracted air is supplied to the exhaust section of the VZT unit through the exhaust pipe. After filtering, it transfers heat in the plate heat exchanger for heat recovery to the incoming fresh air and is blown out to the open atmosphere on the facade wall of the building through a grid. The connection of the ventilation unit to the electrical power is ensured by MaR – measurement and control system.

In March 2019, measurements of the indoor environment at Kolískova 14 Kindergarten were carried out by the Office of Public Health of the Slovak Republic (hereafter ÚVZ). ÚVZ measured CO_2 values in the bedroom in the range of 173 to 904 ppm. In 2022, the installation of the air-conditioning system, which ensures controlled ventilation with recuperation, was completed. In March 2023, the measurements were repeated by the Office for Public Health. ÚVZ measured CO_2 values in the same bedroom in the range of 121-319 ppm. The measurements clearly showed a positive reduction of harmful CO_2 values in the indoor environment of the kindergarden.

An innovative solution is the intake of fresh air in the specially designed inner atriums of the kindergarten. In order to ensure a suitable microclimate and cool fresh air in the summer months, small cooling climatic ponds with fountains and green walls were built here. Measurements in the atrium at the Kolískova Kindergarten[10] confirmed slightly lower average temperatures than e.g., the outer area of the kindergarten itself. The temperature maximum usually occur earlier in the atrium, which is probably related to the maximum glare of the atrium walls during the earlier midday hours. In the later afternoon hours, when the maximum temperatures in the yard are reached, it is already cooling down in the atrium. This is probably caused by the combined effect of the shading of the atrium during the afternoon and the constructed pond, from which the air around the atrium is cooled by water evaporation. It is expected that the effect of overheating the air at maximum glare of the walls will be further reduced over time, as the cable system with climbing plants is installed on the walls. When they grow up, they will protect the walls from overheating even better and can therefore be expected to enhance the positive effect on the microclimate of the atrium and thus even cooler air in the summer months.

10 Source: Point/profile measurement of temperatures and humidity for the needs of evaluating vulnerability (exposure) in the area under consideration and on pilot areas after the implementation of measures in the area under consideration in the Bratislava-Karlova Ves municipality (year 2022). Partial report https://lnk.sk/bar5

Picture No.14a and 14b : Inner atriums with ponds in the Kolískova Kindergarten, from which fresh air is drawn in and distributed throughout the building. (source: archives of the Bratislava-Karlova Ves Municipality)

Funding of the measure

- Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection (implementation of the ventilation with heat recovery, green infrastructure)
- Project MITADAPT: Low -carbon Bratislava Karlova Ves resilient toward climate change- adaptation and mitigation approach, No. ACC02P02, Norwegian grants and co-financing from the Slovak Republic (implementation of the ventilation with heat recovery, green infrastructure).

2.3. Green/vegetation walls

General description[11]

By the term vegetation walls, we understand the walls of buildings covered with vertical greenery of different technical designs and different species composition. The main types (categories) of vegetation walls include vegetation facades and so-called living walls.

Vegetation facades are formed by climbing plants growing directly on the surface of the wall or on a supporting overhanging structure. The roots of the plants are in the ground near the wall and the plant gradually overgrows the surface of the wall from bottom to top.

Mitigation effect of the measure

Climbing plants significantly reduce the temperature of walls, not only depending on the climate zone, but mainly on the area they cover. The temperature reduction is thus in the range of 10 to 30 degrees Celsius. It has been calculated that a reduction in wall temperature by 5.5 degrees Celsius will save 50% of the electrical energy used for air conditioning. When we take into account that 1/3 of the energy used for heating in winter is spent on walls cooled by the wind, climbing plants (especially evergreens such as ivy) provide energy savings.

Adaptive impact of the measure

The external wall of buildings is exposed to weather conditions and solar radiation throughout the year, which leads to relatively large temperature fluctuations on its surface. The overheating of the external wall can be effectively prevented by shading it with vertical vegetation, which also has a positive impact on the thermal comfort in the interior. Additionally, this vegetation cools its surroundings as well as the building through evaporation. It is recommended to implement vegetated walls that are set back from the wall by a few centimetres to ensure air circulation between the vegetation and the wall. In this case, the positive cooling effects are maintained (by shading and cooling through evaporation of plants), the wall structure is protected (from mechanical damage, dirt, acid rain, radiation, etc.) and the possible negative impact of the vegetation wall on the wall surface is minimized (for example, due to the influence of excessive moisture, disruption of the structure by plant tendrils, etc.). The intensity of its effect subsequently depends on the selected type and design of the vegetated facade.

Biodiversity impact of the measure

Flowers blooming on the wall attract insects during flowering and can even hibernate in the soil substrate in the wall during the winter. Therefore, this measure clearly increases biodiversity in an urbanized environment.

Picture No.15: Kindergarden Kolískova: Three vegetated walls made of stainless steel mesh with climbing plants and fifteen vertical wire systems with wrapping plants (source: archive of the Bratislava-Karlova Ves Municipality)

11 Source: Taken https://odolnesidliska.sk/wp-content/uploads/2021/03/Katalog-AM-opatreni.indd-slabe-rozlisenie_FINAL_FINAL.pdf

2.3.1. Implemented measure: Green walls of Kindergarten Kolískova 14, Bratislava-Karlova Ves

Climbing plants were planted to create green walls on the exterior facades of the kindergarten building and in two interior atria of the object. The plants are pulled along specially created structures, i.e. along guide ropes, on nets and directly along the facade Plantings of climbing plants near constructions and directly on facades consist of the following species:

- Akebia quinata (five-numbered akebia) – grows to a height of 5 – 10 m, deciduous, blooms V-VI
- Lonicera henryi (Henry's earthworm) – grows to a height of 6 – 8 m, evergreen, blooms V-VII
- Lonicera caprifolium (goat's earthworm) – grows to a height of 5 – 7 m, deciduous, blooms V-VII
- Campsis radicans (rooting trumpet plant) – grows to a height of 10-15 m, deciduous, blooms VII – IX
- Hedera helix (climbing ivy) – grows to a height of 20 m, evergreen
- Parthenocissus quinquefolia (five-leaved peahen) – grows to a height of 10 m, striking autumn coloration

Special constructions have 2 types according to their use:

1. Stainless steel cable net X-TEND – CX020200E: The net is intended for climbing plants on the area of side facades, the size of the net is 45.175 m2, it is 6950 mm wide and 6500 mm high. The net is placed 0.5 m above the ground. It is stretched on perimeter ropes, the anchors of the perimeter rope are welded after approx. 1.5 m.
2. Stainless steel cables dia. 4 mm, 7x7 – I820-0400: Ropes are intended for climbing individual plants and are placed in the positions between the windows on the eastern facade and also in the atriums, also in the positions between the windows. The cable is placed 0.5 m above the ground and stretched on anchors.

The ropes are intended for climbing individual plants and are placed in the positions between the windows on the eastern facade and also in the atriums, also in the positions between the windows.

When choosing suitable species and the overall concept of the solution, the conditions of the changing climate (undemanding to irrigation), but also plants that are nectar-producing and support pollinators, or have edible fruits (Akebia quinata) were taken into account.

Picture No. 16: Green walls at Kindergarten Kolískova (source: archives of the Bratislava-Karlova Ves Municipality)

Funding of the measure

- Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection (implementation of green infrastructure)
- Project MITADAPT: Low -carbon Bratislava Karlova Ve resilient toward climate change- adaptation and mitigation approach, No. ACC02P02, Norwegian grants and co-financing from the Slovak Republic (implementation of green infrastructure).

2.4. Collection of rainwater into underground tanks and its secondary use – watering, sanitary purposes

General – description

Th issue of rainwater collection is currently being discussed quite frequently by professionals, as well as by the general publicThe growing need to manage rainwater effectively, particularly at its source, by capturing or infiltrating it directly on-site is gaining significant attention. Water conservation is rapidly becoming one of the most pressing issues of this millennium. This concern is particularly heightened considering the adverse effects of climate change, which include alternating periods of drought and intense rainfall, potentially leading to flooding.

Rainwater can in many cases replace drinking water (utility water for flushing toilets, cleaning, and washing vehicles) after minimal treatment. In the case of irrigation, it is even more suitable than drinking water. Rainwater can typically replace up to 50% of drinking water. The less water is extracted from the natural landscape, the more water is left to natural ecosystems, streams, and wetlands. The less water that needs to be treated, transported, and cleaned, the more energy and resources are saved. Therefore, in view of the scenarios for the future development of climate change and its impacts in Slovakia, including the more frequent occurrence of drought (and the subsequent impact on water availability), further rationalization and reduction of water consumption is needed everywhere where it is possible while maintaining hygienic standards and the necessary comfort of life.

In addition to reducing the need for tap water, domestic use of stormwater also reduces stormwater runoff into sewers and street drains, thereby reducing the load on sewers. Although the roof areas of houses comprise only a fraction of the total area of urban surface runoff, even small reservoirs reduce this runoff, thus having a positive effect on the drainage of the area.

The storage tank is the basic component of the entire system of using rainwater from the surface runoff. There are several methods for collecting rainwater. In the last period, however, the industrial production of storage tanks made of plastic materials began.

Currently, there are several options for the location of rainwater storage tanks from the surface of buildings, considering the size of the plot, the layout of the building and other marginal conditions.

The placement of a rainwater storage tank underground is considered to be the most advantageous layout solution. The reason is to prevent the access of sunlight, which is essential for the formation of microbiological processes that negatively affect the sensory properties of water.

2.4.1. <u>Implemented measure:</u> Collection of rainwater in reservoirs (underground and other) and its secondary use (watering, sanitary purposes) Kindergarden Kolískova 14, Bratislava-Karlova Ves

Rainwater from the roof is drained through sewer pipes to a water tank. The tank has a usable volume of 33m^3. The water from the storage tank is used in the building as utility water for flushing toilets. The rainwater tank has a built-in overflow into the drainage pipe, which is stored in the permeable layer of the soil. On the route of the sewerage, there are built: one sewer shaft, crawlable and three non-climbable, a filter shaft is located in front of the rain tank. From the rainwater tank with a volume of 33 m^3, an external utility water supply is led to the building, using a self-priming submersible pump in the rainwater tank. This pipe was laid in a slope to the rain tank. The service water supply supplies all toilet bowls and urinals with service water. In case of lack of rainwater, the service water system is supplemented with potable water. The supply of potable water to the rain tank is solved separately by means of an outlet to the free surface without connecting with useful rain water. The switching of potable water into the rain tank is controlled by a float valve, where the on and off of the potable water inflow is set, according to the height of the rain water level (the water level in the rain tank does not interfere with the potable water outlet).

Picture No.17: Underground retention tank for rainwater (source: archives of Bratislava-Karlova Ves Municipality)

Funding of the measure

- Project DELIVER: DEveloping resilient, low- carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, the LIFE program, Climate Protection (implementation of green infrastructure)
- Project MITADAPT: Low -carbon Bratislava Karlova Ve resilient toward climate change- adaptation and mitigation approach, No. ACC02P02, Norwegian grants and co-financing from the Slovak Republic (implementation of green infrastructure).

2.5. Photovoltaic (PhV) and photothermic devices on roofs

General – description

The production of energy (heat or electricity) from renewable energy sources refers to various technologies for the production of energy in a sustainable manner without the use of fossil fuels such as oil, natural gas, or coal. This kind of production is more ecological, supports the decentralization of energy production, and production is usually located closer to the place of consumption. For the purposes of this publication, the installation of equipment for the production of energy from renewable sources means their installation for the purpose of covering primarily individual consumption by school facilities, in particular energy produced through:

– photovoltaic panels,
– photothermic panels (solar)

Mitigation effect of the measure

Producing electricity from the sun through photovoltaic (PV) panels will reduce the production of electricity from sources with a higher carbon content. The carbon footprint of electricity from the usual energy mix (fuel + production) in the Czech Republic is 0.613 kg/kWh, in the SR 0.161 kg/kWh. The carbon footprint in the production of electricity from RES is approx. 0.04 kg/kWh, depending on the type of renewable source.

Photothermal panels (solar panels) use the same principle as PhV panels, but they use the energy of sunlight to heat hot water, not to produce electricity. The installation costs of thermal panels are lower than those of PV panels.

A detailed comparison includes e.g. this article (http://www.solarnispolecnost.cz/cz/fotovoltaika-a-fototermika-porovnani). Photothermic panels can be installed on roofs and in gardens, e.g. family homes. The mitigation benefit is similar to that of PhV panels – their use for DHW heating will reduce the production of electricity from sources with a higher carbon content. In the conditions of the Czech Republic and Slovakia, electricity (boilers), or coal and natural gas are most often used for the preparation of domestic hot water.

Adaptive impact of the measure

The installation of renewable energy sources is neutral from the point of view of adaptation, but in some forms of renewable energy production, it is also possible to identify a slightly positive adaptation effect. In the case of photovoltaic or solar thermal panels installed on the roof or external structure of a building, their surface shades the building structure, thus contributing to reducing the potential overheating of the building and maintaining thermal comfort in the building's interior. The installation of devices using renewable energy sources also diversifies energy sources, increases self-sufficiency and reduces the dependence of the entity on central supply networks, thus increasing resilience in the event of failures of central distribution networks caused by extreme weather conditions.

2.5.1. Implemented measure: Solar water heating at Kindergarden Kolískova 14, Bratislava-Karlova Ves

Before the deep renovation, hot water preparation was carried out in a plate heat exchanger via district heating. This method of hot water preparation was discontinued and replaced by hot water preparation in hot water tanks with the help of a solar system.

In order to save energy, a solar system for hot water preparation was installed in the building. The solar kit consists of 20 solar collectors oriented horizontally and placed on a flat roof on a structure facing south. The system consists of five rows of four collectors. The solar kit also includes 2x tanks (with a volume of 2x 950 liters with an electric heating element 2x8kW – 400V), a connection kit for mounting collectors on a flat roof, a mounting kit for collectors, venting, a pumping group with a pump, an expansion tank for solar with a volume of 80 liters, antifreeze and regulation. The tanks and the pumping group with the expansion tank are located in the space of room -1.32 in the basement of the building.

The distribution lines from the collectors to the pumping group and the Domestic hot water (DHW) tank are led across the roof and within the facade insulation in a groove. The lines are copper and were vented at the highest points. They are insulated with a thickness of 13mm, 19mm on the roof. The solar system was implemented according to the technological specification of the supplier of the solar system.

Picture No. 18 and No. 19: Hot water tanks heated through photovoltaic panels (source: archive of the Municipality of Bratislava-Karlova Ves)

Funding of the measure

- project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC under the LIFE programme, from the sub-programme "Climate Protection" (implementation)
- project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financed by the State`s budget of Slovak republic (implementation).

3. Selected measures implemented on public spaces

3.1 Measures in public spaces aimed at reducing sensitivity to the impact of heat and extreme rainfalls

Public spaces in residences can be divided according to type and function. From a spatial perspective, we can distinguish four basic types of public spaces: streets, squares, green areas, and other areas. While the first two categories are relatively clear-cut, even though they may have additional subtypes such as waterfronts and arcades as a subtype of a street, green areas include parks, residential green areas, suburban recreational forests, remnants of original ecosystems, etc. Other areas are unclassifiable spatial formations that do not have either spatial boundaries or a clear functional content. The division by function offers a wide range of types of public spaces (social, representative, commercial, gathering, transport, recreational, residential, with an environmental function, etc.) or with various combinations and mixes of functions.

This whole breadth already suggests that there is no single solution that would be universal. All adaptation measures must be adapted not only to the prevailing function of the public space, but also to the local context and cultural identity. Nevertheless, we can outline several generally applicable principles from the use of surfaces, water management and the use of water features and greenery, shading, etc.

Minimizing the proportion of impervious surfaces and replacing them with permeable surfaces

The quality of surfaces in public spaces significantly contributes to the aesthetic quality of the entire public space. When designing or reconstructing surfaces in public spaces, the most environmentally friendly solutions for walkway surfaces should be used, taking into account the carbon footprint of the material used.

Impervious surfaces represent a physical barrier to rainwater infiltration in urban environments, which can cause local flooding and problems with drainage and sewer systems in the case of heavy rains. Increasing the proportion of permeable areas will contribute to the infiltration of part of the rainwater at the point of impact and will reduce the volume of rapidly runoff water and reduce the possible flood wave. At the same time, this will reduce the load on the sewer network and wastewater treatment plants, thus contributing to the efficiency of water management in the urban settlement.

Sustainable rainwater management – capturing and infiltration

In an intensively urbanized environment, it is advisable to support the creation of new elements for sustainable rainwater management. Among these are also nature-based measures for capturing and infiltrating rainwater, such as collection ponds and other retention areas, rain gardens, etc., or direct capture of rainwater into accumulation tanks and use of rainwater for irrigation of greenery in public spaces.

During intensive rainfall, it is important to capture rainwater in the place where it fell and at the same time slow down the runoff of water from the area. The captured water can then be gradually infiltrated into the soil, or retained on site and cooled its surroundings through evaporation, as well as directly from the surface of the water body, thus helping to maintain a pleasant microclimate.

Infiltration and retention areas are particularly used in spatially limited areas (for example, when infiltrating rainwater within communications, or in heavily urbanized areas).

Terrain modelling to capture and slow down rainwater is possible in grassy areas in public greenery. It is extremely important to allow infiltration from hardened surfaces to green areas. Currently, common barriers include curbs, poor slope of hardened surfaces, or the green area is at a higher level than the hardened surface, which leads to clogging and washing out of parts of the soil onto the sidewalk or communication, as it is dry and compacted does not have sufficient ability to capture rainwater.

Shading on Public Spaces

The effectiveness of shading depends on several factors, including – the material used and its properties (there is a difference in shading between vegetation and artificial elements, differences are also in the density or transparency of the artificial materials, the extent of shading, properties of surrounding areas, etc. Theoretically, shading of closed spaces can block approximately 65% to 90% of the heat that we would receive from direct sunlight. However, in the case of shading of public spaces, the effectiveness is lower due to the influence of unshaded surroundings and other factors.

In general, a more significant cooling effect is achieved by shading through mature trees. A large park covered with trees in a suitable species and age composition can reduce air temperature in the summer during heat waves by up to about 30%. Public spaces shaded by trees can provide cooler temperatures during heat waves in the range of 2°C to about 12°C or more (depending on species, age, and spatial structure of the undergrowth, etc.).

Adaptive impact of measures

Elements of sustainable rainwater management based on the principle of green infrastructure or nature-based solutions contribute to water retention, replenish groundwater reserves, purify the water and remove harmful substances from water. By being able to accumulate large amounts of rainfalls (similar to the effect of a "sponge"), they can significantly mitigate flooding from flash floods.

The effectiveness of shading in relation to cooling the microclimate is evaluated according to several factors that influence it. In addition to temperature, it is also the speed of air flow. Shaded environments have the following positive effects:

- shaded areas do not accumulate as much solar energy as unshaded areas and release less heat in the later hours of the day than shaded areas.
- shaded areas improve the perceived temperature – people in the shade often feel a temperature that is 10°C – 15°C lower than the actual air temperature.

Research and practical experience show that evaporation from wetlands and other moisture-loving vegetation that is well-supplied with water has a very positive impact on microclimatic conditions. In addition, as described in previous articles, this is cooling by means of evaporation from the water surface, as water consumes 2500 kJ to evaporate 1 mm of water/m^2.

Currently, there is not much research that deal with the combined cooling effect of water evaporation and evaporation from wetlands and other vegetation. However, in several studies, the favourable state of moisture in the surrounding soil has been pointed out, which also has a positive impact on cooling the environment.

Mitigation impact of measures

The average values of carbon sequestration for individual types of nature-based areas in cities have been investigated in several studies. In the case of blue and blue-green infrastructure, the highest values of carbon sequestration apply – 36.1 kg C / m2. Similarly, significant contributions are made by areas of urban greenery connected to grey infrastructure (28.9 g C / m^2).

Biodiversity impact of measures

The positive impact of created wetlands on local biodiversity is high. After the creation of a water body, it is immediately occupied by water-bound animals such as dragonflies, water beetles, frogs, etc., which cannot do without the existence of this water body. In addition, stable wetlands serve as watering holes for insects, birds and small mammals such as hedgehogs.

Wetlands, by their existence, increase the chances of animals surviving in times of heat and drought. Created wetlands are used in many countries as green infrastructure for rainwater retention (including pre-treatment of wastewater), but they can also be "hotspots" of biodiversity. In some studies, the number of plant species (including several protected species) has increased by more than 200%.

3.2 Implemented measure: Public space Kaskády – sustainable rainwater management

The elements of sustainable rainwater management created on the public space Kaskády have the character of blue-green infrastructure that supports infiltration of rainwater from paved walkways and the surrounding sloping terrain. Rainwater is gravity-fed to infiltration areas – rain lawns of bowl-shaped gardens, gullies, and wetland beds.

Grey infrastructure will be used in the form of two underground retention tanks, where rainwater is collected from part of two surrounding apartment buildings (from roofs and terraces).

The construction of wetland habitats in an urban environment fulfills the requirements for integrating adaptation and mitigation measures.. From a mitigation perspective, wetlands play a crucial role in absorbing and storing carbon dioxide, a significant greenhouse gas.

Blue-green infrastructure

The blue-green infrastructure on this public space is composed of 2 wetlands with a water habitat of 39.71 m^2 and 48 m^2, newly constructed rainwater infiltration basins or depressions with a total area of 34 m^2 and 85 m^2.

Bioretention wetland beds are designed as separate elements of blue-green infrastructure in an elliptical shape with plantings of suitable plants in the littoral and sublittoral zones. They are located behind underground storage tanks (the overflow from the underground tanks into the wetland bed is a PVC sewer pipe with an outlet into the wetland). The littoral zone serves the function of supporting biodiversity and the vitality of the aquatic ecosystem. In the sublittoral zone, rainwater is temporarily accumulated. The introduction of water from two vertical rainwater drains through underground storage tanks ensures the calming of the flow and sedimentation of pollutants.

The wetland provides suitable conditions for a variety of animals and pollinators even in times of extreme drought and supports biodiversity. The evaporation from the reservoir cools the urban surrounding microclimate. The infiltration time will be 12.5 hours.

Infiltration areas – bowl-shaped rain gardens are created as flowering retention areas that are seeded with communities of flowering meadows. They will provide a more vital biotope in times of drought and height differentiation of public space. After rain, they can fill with rainwater and after about 2 days they will empty by infiltration into the subsoil.

A total of 21 trees and 84 shrubs were planted on the public space, to which irrigation is supplied from underground tanks (see text below). Domestic species and species that tolerate drought and adverse conditions of the urban environment were used for planting: 8 pieces of field maple (*Acer campestre*), 6 pieces of manna ash (Fraxinus ornus), 3 pieces of oak (*Quercus frainneto „Trump*"), 4 pieces of Turkish hazel (*Corylus colurna*), which protects 84 bushes of barberry (*Berberis thunbergii*).

Picture No. 20: Wetland bed in the upper part of the park (source: archive of the Municipality of Bratislava-Karlova Ves)

Picture No. 21: Terrain modeling, tree planting with irrigation from captured water, retention bowl areas with planted meadow mix (source: archive of the Municipality of Bratislava-Karlova Ves)

The following species were planted in the wetland beds – common reed (*Hippuris vulgaris*), yellow iris (*Iris pseudoacorus*), water cattail (*Sagittaria sagittifolia*), river horsetail (*Equisetum fluviatile*), forest rush (*Scirpus sylvaticus),* spreading sedge (*Juncus effusus*), purple loosestrife (*Lythrum salicaria*), iris sibirica, iris Kaempfer`s (*Iris kaempferi*), marsh marigold (*Caltha palustris*), pennywort buttercup (*Lysimachia nummularia*), slender sedge (*Carex gracilis*), (*Myosotis palustris*).

Picture No. 22: Planting a flowering meadow mix in bowl-shaped gardens for water retention (source: archive of the Municipality of Bratislava-Karlova Ves)

Grey infrastructure – Underground storage rainwater-tanks

In this case, two underground PE storage tanks with a volume of 7.5 m^3 each are used to collect rainwater from two vertical rainwater – drains from two adjacent apartment buildings. The flat-shaped storage tank contains a coarse sediment filter and an electric submersible pump with a float switch. The captured water is used for irrigation. Irrigation of planted trees and lawns is controlled by a drip irrigation unit into two separate drip irrigation branches.

Picture No. 23: Underground retention tanks for rainwater capturing (source: archive of the Municipality of Bratisla-va-Karlova Ves)

Measures taken in this area were implemented to improve climatic conditions in the area, support biodiversity in a densely built-up urban area by creating wetland habitats and planting native species of tree and shrub vegetation. By revitalizing the park and building nature-friendly solutions and elements of sustainable management of rainwater, it was possible to make the public space intended for short-term relaxation more attractive.

By capturing rainwater, it was possible to ensure enough moisture for vegetation and by modeling the terrain, it was ensured that rainwater would soak into rain gardens.

The planting of plants was aimed not only at increasing the aesthetic effect of the solved space, but also at preserving the natural character of the locality and supporting biodiversity. For this reason, domestic species as well as species that fill the space not only with smells and colours, but are also important in the food chain, were preferred when selecting plant material. The aim of the planting was mainly to improve the microclimate in the park for residents and visitors. Based on the rainfall-runoff model, this public space belonged to the most problematic localities in the residence called Dlhé Diely in Bratislava. The measures taken have managed to eliminate the negative impacts of improper accumulation of rainwater and improve the availability of public green areas in this area, which is one of the factors in increasing adaptive capacity in assessing the vulnerability of the population to the negative impacts of climate change.

Picture No. 24: Wetland – bed in the lower part of the park (source: archive of the Municipality of Bratislava-Karlova Ves)

In 2023, the third phase of the project will be implemented, which will again mitigate the negative impacts of climate change. An artificial stream will flow through the area, which will pleasantly cool the microclimate of the environment. In addition, two more underground storage tanks will be built to collect rainwater from roofs, residential terraces, and lawns. The artificial stream will use the collected rainwater.

In addition, the following will be implemented:

- Bioretention systems – a wetland bed with a retention space and ornamental plants (1 unit).
- A small water playground – with a hand pump, small water-mill, sluices and a wooden barrel.
- A fountain – with an underground reservoir, using captured rainwater.
- Above-ground decorative storage tanks – for manual watering (2 units)
- Irrigation – sprinkler irrigation of lawns
- Planting of greenery – planting of trees (5 pieces) and shrubs (5 pieces)
- Vegetative wall – staircase structures with climbing plants, beds and drip irrigation (1 unit)

Picture No. 25: Visualization of phase 3 – water retention measures Kaskády (source: archive of the Municipality of Bratislava-Karlova Ves)

Picture No. 26: Phase 3 – construction of a artificial stream using retained rainwater (source: archive of the Municipality of Bratislava-Karlova Ves)

Funding of measures

- 1st and 2nd phase: project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EU – LIFE program, Climate protection (implementation)
- 1st and 2nd phase: project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financing from State`s budget of Slovak republic – Department of environmental protection of SR (implementation)
- 1st and 2nd phase: project PERFECT: Planning for Environmental Resource eFficiency in European Cities and Towns, EU, Interreg Europe program (project documentation, implementation)
- 3rd phase: project "Kaskády – model pilot solution for rainwater on public spaces (3rd phase)", IROP-PO7-SC73-2021-87, priority axis: 7 – REACT-EU, investment priority: 7.1 – Support for the mitigation of the effects of the crisis in the context of the COVID-19 pandemic and the preparation of a green, digital and resilient economic recovery, Specific target: 7.3. – Improvement of environmental aspects in cities and urban areas.

4. Counseling, Education, Communication

4.1. Non-investment "soft" adaptation measures

Measures that include, for example, education, counselling, awareness raising and communication, or other behavior-influencing activities, are just as important as those that take into account existing and projected climate change in a given area. For example, educating citizens on how to behave in the event of heat waves or floods, raising awareness, etc., such activities also develop social capital, and therefore allow for increased resilience at the level of individual residents as well as at the level of the entire neighbourhood.

4.2. Lectures and workshops held in Karlova Ves

The Bratislava-Karlova Ves Municiplaity is preparing various activities in the areas of counselling, education, and communication as part of its projects. In the frame of the DELIVER project, partners of the project from the Bratislava Regional Environmental Protection Association (BROZ) held lectures and workshops for primary school students. The children were actively involved in the lectures to jointly find solutions and answers to questions about the negative impacts of climate change and the promotion of biodiversity in urban environments. Basic concepts such as the greenhouse effect, accumulation and radiation of heat from surfaces, and evaporation of water from vegetation were explained in the lectures, with the help of graphic representations. Lectures were also held in the form of games focused on food chains, in which the students could acquire new knowledge from nature / biology and quickly understand the importance of the existence of all organisms, including plants and the often-misunderstood importance of insects. Through workshops, students also learned how to practically implement measures to mitigate the negative impacts of climate change or to support biodiversity. Plants were planted together in the school grounds, and children were also involved in caring for greenery, as well as building shelters for wildlife such as hedgehogs, reptiles, birds, or insects.

In addition to events and work with children, public lectures were also organized for residents on hot topics, such as limited mowing regime, tolerance of birdhouses on windows, creation of water retention measures, or planting trees, especially native species. The topics of allergens, ticks, and mosquitoes are particularly interesting. It is necessary to talk about the possible risks, prevention, and at the same time provide practical advice. Based on the discussions, practical tips and instructions on how to promote and increase biodiversity in the city are a popular part. Environmental education and lecture activities are part of an innovative comprehensive approach to increasing climate resilience in Karlova Ves.

Picture No. 27: Seminar Summer without air conditioning – the impact of architectural design on reducing the need for building cooling – consulting session, July 2023 (source: archive of the Municipality of Bratislava-Karlova Ves)

Funding of the measures

- project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EU, LIFE program, from the subprogram "Climate protection" (implementation of workshops for schools and events in the frame of counselling for residents)
- project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financing from the State`s budget of Slovak republic (implementation of workshops in cooperation with the Norwegian partner).

4.3. Community Education Centre for Climate and Biodiversity

A major accomplishment during the deep renovation of the A. Dubček Elementary School building at Majerníkova 62 was the conversion of part of the heat exchanger station into the Community Education Center for Climate and Biodiversity (KVC). The centre has been opened since October 2022 for schools and public as a space for environmental education focused on climate change. This is both as part of regular teaching (nature studies, practical classes) and as supplementary education. It also serves the interested public as an consultancy and educational centre for the implementation of the renovation of residential buildings, public buildings, and public spaces. It also serves the professional community and municipalities as a space for professional workshops and lectures to share knowledge and experience. Last but not least, it is available to the local community: for informal groups of citizens, civic associations / NGOs – as a space for meeting and exchanging experiences in community activities, primarily focused on environmental issues. More information about the centre and the possibility of registering an event is available on the website of the Bratislava-Karlova Ves Municipality [12]

The centre is divided into several zones both indoors and outdoors.

The presentation room with a capacity of 20-30 people is used to organize educational lectures, workshops, and seminars on ecology and the issue of climate change. It is located in the building of the A. Dubček Primary school, and has a separate barrier-free entrance from Ľ. Fullu street. After registering the event and approving its focus by the KVC – manager, it is currently offered for free.

The outdoor exhibition in the school's interior atriums consists of information panels and functional prototypes of interactive 3D – models that illustrate the effects of climate change in residential areas and show measures to mitigate and adapt to it (i.e., adaptation and mitigation measures). It also includes a space dedicated to promoting biodiversity, cultivating edible plants and herbs, and a demonstration of sustainable rainwater management. Access to the exhibition is possible only after registering with the KVC – manager.

Picture No. 28: Visualization of the renovated interior – atrium of A. Dubček Primary school with interactive models (source: Hlina s.r.o.)

12 https://www.karlovaves.sk/zivotne-prostredie-a-projekty/komunitne-centrum-pre-klimu-a-biodiverzitu/

An **educational information trail** dedicated to biodiversity has been built in the sports and recreation area Majerníkova 60-62 near A. Dubček Primary school. The trail features a variety of examples of how to support biodiversity – diversity of animal and plant species.

There is also a **gazebo for outdoor educational activities** with a demonstration of rainwater – capturing with a soakaway pond and drinking fountains for insects and birds. A community school herb garden has been built next to the gazebo.

The trail is accessible to the general public without restrictions. In case of interest in a guided tour of the trail, it is necessary to contact the manager of the KVC.

Picture No. 29: Presentation of the interactive models, workshop: How can we contribute to mitigating the impacts of climate change, with students of A. Dubček Primary school and Tilgnerova Primary and Secondary school, September 2023 (source: archive of the Bratislava-Karlova Ves Municipality)

With the help of children, various simple **shelters for animals** have been built in the area, such as hedgehog houses for hedgehogs, which are very useful insectivores. A suitable place for a snake pit, a shelter for reptiles (snakes and lizards), is a gentle slope that is exposed to the sun for as long as possible. Under a large pile of stones, there are tree branches and a wooden box inserted into a dug hole. A simpler and equally effective version of the shelter is also a stacked pile of stones next to a wall. As part of the educational trail, so-called **dead wood** was also left, which is the basis of life after the death of a tree. Various organisms decompose it into small chips, which provide nutrients for young, germinating trees and plants.

Together with children, quite small or larger **insect hotels** have also been built. Endangered species of insects will find a safe place to lay their eggs and survive the winter in them. **Bird-houses** with various seeds, cereals, or nuts have also been installed in the area, which help birds survive the winter when they cannot enjoy natural food sources.

In the more difficult-to-access sloping terrain, areas with limited mowing, approximately twice a year, have been left in the area. With a limited mowing regime on selected sites, a natural meadow vegetation is created, which supports plant and animal diversity, captures harmful dust and retains more moisture.

Picture No. 30: Orientation map of the Community Education Centre for Climate and Biodiversity (source: BROZ)

Funding of the measures

- project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financing from the State`s budget of SR (implementation of the reconstruction of the room from the original heat exchanger station)
- project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EU, LIFE programme, Climate protection (implementation of the interior measures and equipment, education and measures to support biodiversity in the exterior).

IV. ANNEX

1. Climate-resilient public buildings – a comprehensive approach

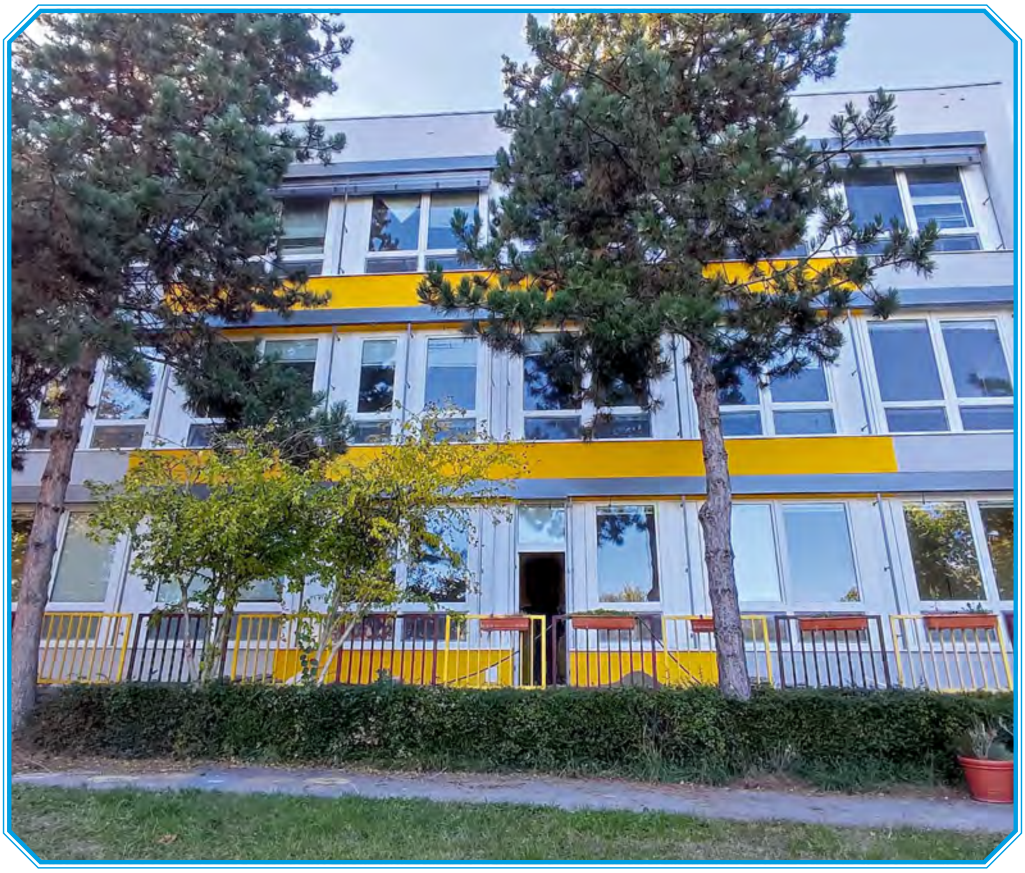
In today's world, it is undeniable that cities and municipalities need to respond systematically and effectively in order to increase the climate security of their residents. However, in Slovakia, there is still a lack of adequate technical and financial support for cities in the process of selecting and implementing adequate measures to mitigate or adapt to the impacts of climate change. In order to help local governments navigate and assist in selecting the right measure in the right place, a team of experts from the DELIVER project has compiled a Catalogue of selected adaptation and mitigation measures for urban areas13 .

In Slovakia, there is currently no example of a comprehensive renovation of a public building that includes both energy efficiency improvements and green measures and measures to support biodiversity. The deep renovations of two selected public buildings in the Bratislava-Karlova Ves Municipality – the Kolískova 14 Kindergarten and the A.Dubček Primary school on Majerníkova 62 – should serve as exemplary deep renovations. This could be a model approach for other municipalities, including all information and dissemination activities that raise awareness of the importance of comprehensive deep renovations of public buildings. Partial solutions, such as the frequently implemented insulation, do not bring the desired effect, on the contrary, it often only preserves the undesirable technical condition or construction defects in the renovated building.

In any case, without the possibility of obtaining additional external resources from various national and international grant schemes, municipalities cannot be able to implement renovations in the full complex scope.

1.1. Deep green renovation of Kolískova 14 Kindergarten, Bratislava-Karlova Ves

The kindergarten building underwent a deep green renovation from December 2020 to April 2022. The goal was to not only significantly reduce energy consumption, but also to ensure the quality of the indoor environment, improve the surrounding microclimate, conserve natural resources by using rainwater, and increase the diversity of plants and animals in the kindergarten grounds. The comprehensive renovation of the kindergarten should serve as a prototype model for the renovation of similar public buildings in Slovakia.



Picture No. 31a: Kolískova 14 Kindergarten (source: archive of the Bratislava-Karlova Ves Municipality)

13 https://odolnesidliska.sk/wp-content/uploads/2021/03/Katalog-AM-opatreni.indd-slabe-rozlisenie_FINAL_FINAL.pdf

Picture No. 31b: Solar thermal panels on the roof of a building (source: archive of the Municipality of Bratislava-Karlova Ves)

The building uses renewable energy sources through **solar panels** located on the insulated roof. Solar energy is used to heat domestic hot water for use in the bathrooms and kitchen.

In addition to high-quality insulation of the roof and facade, **effective shading of windows** with external lamellar blinds, three **vegetation walls** made of stainless-steel mesh with climbing plants, and fifteen **vertical cable systems with winding plants** prevent overheating of the building. Green walls cool the surface of the building envelope by shading the leaves, improve the microclimate by evaporating moisture from the leaves, and improve the aesthetic appearance of the building. Climbing plants, in addition to the cooling effect, add variety to the space for children with their distinctive ornamental flowers and some even with edible fruits.

Picture No. 31c: Kolískova 14 kindergarten: three vegetation walls made of stainless-steel mesh with climbing plants, and fifteen vertical cable systems with winding plants (source: archive of the Bratislava-Karlova Ves Municipality)

Ventilation is provided by **controlled ventilation with heat recovery**, which recovers heat from the exhaust air. It also prevents dust and pollen from entering the interior and the formation of excessive humidity, thus preventing the growth of various fungal and mold organisms. This significantly improves the environment for living and sleeping for young allergy sufferers, as it is ventilated without dust and pollen. A unique solution is the intake of clean air from restored internal atria with planted greenery, which supports biodiversity and also serves as a natural air purifier. The temperature in the internal atria does not reach even in summer as high a temperature as the surrounding terrain, thanks to the shading by the walls of the object.

Picture No. 32 and 33: Controlled ventilation with heat recovery in classrooms, bedrooms and in the kitchen (source: archive of the Municipality of Bratislava-Karlova Ves)

Abundant greenery and a water feature in the form of two **cooling ponds in the atria** provide children with a more pleasant aesthetic environment and a better microclimate. The ponds are designed as natural biotopes without chemical treatment or filtration. Water is cleaned by planting aquatic plants and aerated by a fountain pump. The planting in the atria was carefully selected to respect climatic conditions, promote biodiversity, and diversify the space of the atria. Climbing plants are planted, which beautify the walls and also reduce temperature and increase air humidity. The pond level is monitored by a person responsible for monitoring the occurrence of mosquitoes during the egg-laying period, and the larvicide BTI is applied to the water preventively at the time when the larvae hatch from the eggs, but have not yet pupated.

Picture No. 34 and 35: Cooling climate – ponds in two inner atria of the kindergarten (source: archive of the Municipality of Bratislava-Karlova Ves)

Rainwater is used to fill the ponds, and if necessary, they are supplemented with water from a **retention tank**. Rainwater from the roof of the building does not flow into the sewer system, but is collected in a 33 m^3 underground retention tank located in the kindergarten grounds between two playgrounds.

Captured water is used for sanitary purposes, such as flushing toilets, for irrigating planted greenery in atria and for replenishing the water level in ponds. Rainwater is used primarily, and a switch to drinking water in case of insufficient rainwater will occur automatically, no maintenance is required. Rainwater is treated using an ultraviolet disinfection unit.

Picture No. 36: Underground retention tank for rainwater collection in kindergarten ground (source: archive of the Bratislava-Karlova Ves Municipality)

Their natural predators – bats and common swifts (Apus apus) – also help effectively eliminate unpleasant stinging insects in residential areas. One bat can collect up to 5 000 small insects per night, and one pair of common swifts can catch up to 20 000 mosquitoes per day. That is why inconspicuous **nesting boxes** are placed on the facade of the kindergarten for these useful co-tenants of the building.

Picture No. 37: Bat and swift nesting – boxes on the facade of the kindergarten (source: archive of the Bratislava-Karlova Ves Municipality)

One of the adaptation measures against the effects of climate change is to reduce temperatures by shading. Therefore, **shade sails** have been installed over the children's sandboxes in the kindergarten grounds to shade the most exposed areas where children play. In addition to reducing environmental overheating, shading protects children from direct sunlight and its potential harmful effects. The advantage of such shading is mainly a significantly lower perceived temperature, which can be around 10 degrees Celsius lower than the ambient temperature on direct sunlight.

Pictures No. 38 and 39: Exterior shade sails in the Kolískova kindergarten grounds (source: archive of the Bratislava-Karlova Ves Municipality)

As part of measures to reduce environmental overheating and preserve biodiversity, smaller **areas with differentiated mowing mode** are also marked out in the lower part of the kindergarten grounds. These areas serve to create different types of environments for various plant species, as well as to ensure a sufficient supply of flowering and nectar-bearing plants for pollinators. They also serve as a catcher of carcinogenic dust and serve to retain water in the area. Last but not least, their significance for children also lies in highlighting diversity through colours and smells that express a connection with nature.

Picture No. 40: Hedgehog wintering place in the Kolískova kindergarten grounds (source: archive of the Bratislava-Karlova Ves Municipality)

As part of measures to support biodiversity, a **shelter for animals** – hedgehogs – has been built in the lower part of the kindergarten grounds. Hedgehogs are common inhabitants of urban environments. They find enough food here, but they have nowhere to hibernate for the winter. Fallen leaves and fallen branches from trees are dug out of the lawns in the fall, and bushes are cleared and trimmed from the bottom. Such a man-made shelter provides a suitable place for hedgehogs to hibernate. In addition to hedgehogs, the shelter is also used by many other organisms and insects, such as spiders, centipedes, millipedes, woodlouse, earwigs, ladybirds, etc.

Funding for deep renovation

- project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financing from the State`s budget of Slovak republic (implementation of the reconstruction of the room from the original heat exchanger station)
- project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EU, LIFE program, from the subprogram "Climate protection" (implementation of the interior solution and equipment)
- Bratislava-Karlova Ves Municipality took out a loan for this purpose

1.2 Deep green renovation of A. Dubčeka Primary school, Majerníkova 62, Bratislava-Karlova Ves

The deep green renovation of A.Dubček Elementary School on Majerníkova 62 in Bratislava, Slovakia, was focused on reducing the energy intensity of the building and significantly improving the quality of the school's indoor environment. The deep green renovation is an example of several innovative and green solutions, using rainwater collection, renewable energy sources, and planting greenery to support biodiversity, which will contribute to mitigating and adapting to the impacts of climate change.

Due to the need to pool financial resources, the renovation works were divided into stages from autumn 2021 to October 2023.

Construction activities began in autumn 2021 with the **reconstruction and insulation of the roof**. In 2022, work continued in such a way as to allow uninterrupted operation of the school facility: the **exterior facade and inner atria were insulated**, and the previously unreplaced **facade windows were replaced**. The renovation took into account the importance of biodiversity and therefore the inconspicuous **nest boxes for the black swift, bats, and house martin** were also built on the facades during insulation.

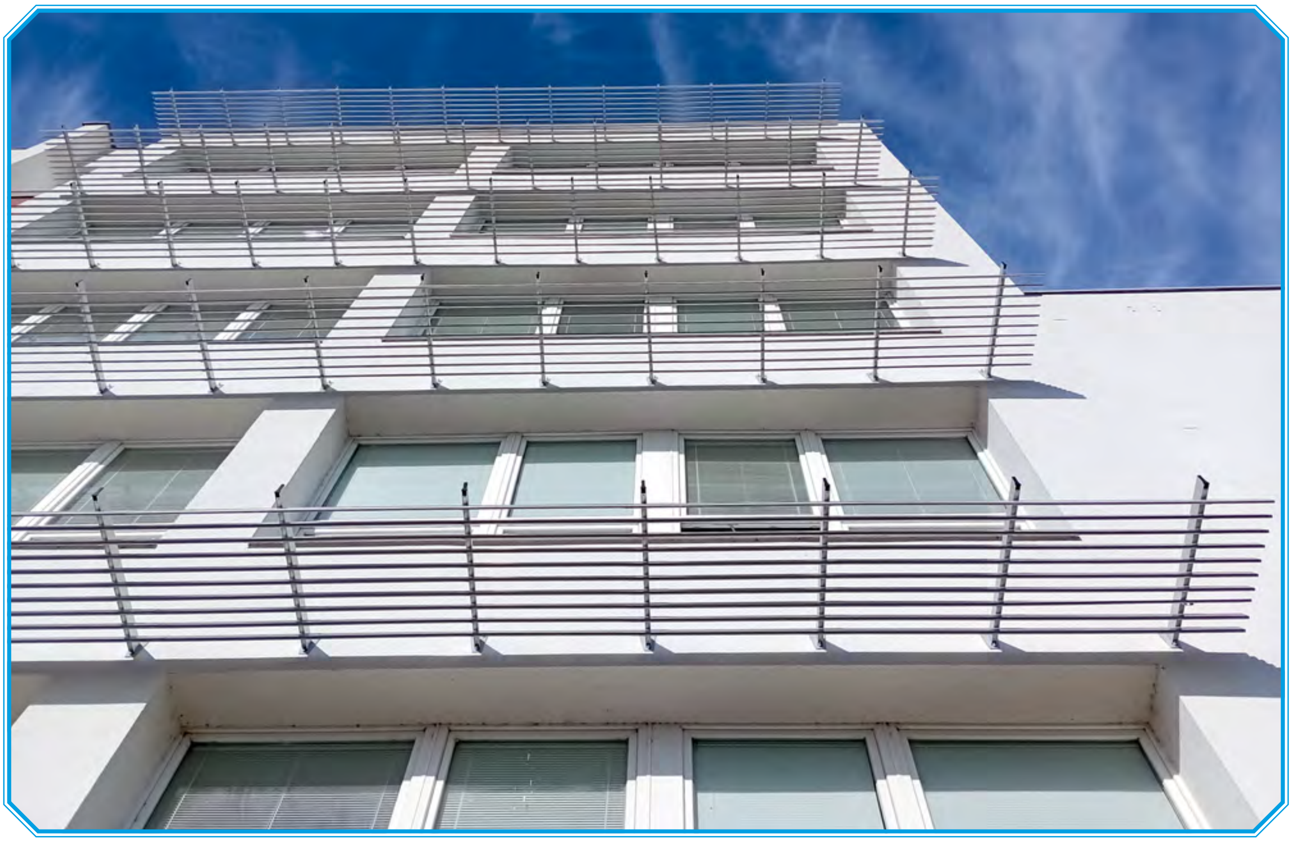
Picture No. 41: A. Dubček Primary school in Majerníkova street 62 (source: archive of the Bratislava-Karlova Ves Municipality)

As part of the interior works, the installation of **ventilation in the form of heat recovery**, i.e. controlled ventilation with air exchange, was carried out, along with the associated electrical installation and necessary construction modifications. The main principle of heat recovery is the recovery of heat from waste air. Thanks to the heat exchanger, heat is transferred to the fresh air, which is already preheated and supplied to the designated areas. Ventilation using heat recovery units will significantly improve the quality of the indoor environment, save energy thanks to the recovery of heat, and prevent the formation of excessive humidity in the interior. This method of air exchange prevents the proliferation of various fungal and mold organisms that are caused by insufficient air circulation, high humidity, and high levels of carbon dioxide. The environment for teaching and for people with allergies will be significantly improved, as we will be ventilating without dust and pollen.

A unique solution for controlled ventilation proposes the intake of clean air from those parts of the building that are not exposed to strong sunlight, near to installed vegetation green walls and from the Majerníkova area. The planted greenery will support the preservation of biodiversity and will also serve as a natural air purifier to improve the microclimate of the school's surroundings.

In the summer of 2022, field work was carried out on measures to use **rainwater collected in an underground retention tank**, which is used for sanitary purposes – flushing toilets in gyms.

Since an important part of adaptation to climate change is reducing the temperature in buildings by effective shading, **exterior electrically operated louver blinds** were installed on the windows of the entire main facade of the building facing south. **Horizontal sunshades with fixed slats** were installed on the windows on the west and east sides.



Picture No. 42: Horizontal sunshades with fixed slats on the A. Dubček Primary school building (source: archive of the Bratislava-Karlova Ves Municipality)

In 2023, **solar panels (50 units) and photovoltaic panels (86 units)** were installed on the roof of the building. These renewable energy sources are used primarily to reduce energy consumption for the heating of domestic hot water in both buildings, Majerníkova 62 and Majerníkova 60, especially in the school – kitchen, showers, and for heating pool – water. The system is set up so that the hot water that is not used in the school kitchen, showers, and sanitary facilities is used in the pool technology to heat the water in the pool.

Picture No. 43: Solar and photovoltaic panels are located on the roof of A. Dubček Primary school (source: archive of the Bratislava-Karlova Ves Municipality)

The renovation placed a strong emphasis on the design of the greenery and **garden architecture in the inner courtyards** of the school. One of the goals of the deep green renovation of the building was to maximize the use of rainwater and return it to the water cycle in the greatest possible volume. As the area of the atria consisted of a large part of concrete paths, this impermeable layer had to be removed first and then soil was brought in so that planting work could begin.

The concept of the atria – **public spaces for students and potential visitors to the Climate and Biodiversity Community Centre** – is spatially divided according to the function of use.

In the right atrium, emphasis is placed on the **cultivation of various plants in raised beds, in an herb garden, and on a green vertical wall.** In addition to the rain garden, the remaining vegetation areas are designed as ornamental semi-shaded beds and self-climbing climbing plants. The spaces were complemented with **rain water tanks, wooden composters, and benches**.

In the left atrium, **climbing vegetation** is planted, which climbs onto the structures using steel cables. The spaces are complemented with benches, and a column with a water tap. An important part of the left atrium is the creation of a school and public space for the **presentation of interactive models to showcase the implementation of possible measures to mitigate and adapt to the impacts of climate change.** These models are installed and made accessible to the public as part of the activities of the Climate and Biodiversity Community Centre.

Due to the static assessment of the roofs, the requirement for main green roofs had to be abandoned. The only roof that met the static assessment is a small flat roof above the main entrance, which is made using an **extensive green roof system** with minimal surface loading. For this reason, great attention was paid to **vertical greenery**. Climbing plants are planted on two facades, thanks to a steel mesh, which will improve the climatic, aesthetic, and biodiversity environment. Two concrete containers with graphic design are placed in front of the school building. New perennial vegetation will be planted in these containers together with a **climbing plant system.**

All of these measures have a significant positive impact on improving the quality of the school's indoor and outdoor environment, as well as on the environment in Karlova Ves, as many of the proposed prototype solutions aim to reduce the carbon footprint by more than 30 percent (CO_2 t/year) and the energy consumption of the Primary school by 70 percent (kWh/year).

Picture No. 44: Green roof over the entrance to A. Dubček Primary school (source: archive of the Bratislava-Karlova Ves Municipality)

Funding for deep renovation

- project MITADAPT: Low-carbon Bratislava-Karlova Ves resilient to climate change – adaptation and mitigation measures, ACC02P02, Norwegian grants and co-financing from the Slovak Republic (implementation of the reconstruction of the room from the original heat exchanger station)
- project DELIVER: DEveloping resilient, low-carbon and more LIVablE urban Residential area, LIFE17 CCA/SK/000126 – LIFE DELIVER, EC, LIFE programme, Climate protection (implementation of the interior solution and equipment)
- grant from the SK-Environmental fund
- grant in the form of a loan from the SK-Environmental fund.

Notes

ISBN 978-80-570-4933-3