CATALOGUE OF SELECTED ADAPTATION AND MITIGATION MEASURES

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More information on the DELIVER project can be found at the web page http://odolnesidliska.sk/.

CONTENTS

I. INTRODUCTION AND FOCUS OF THE CATALOGUE

Climate change and its negative effects on all areas of life have become a reality. Since the pre-industrial period, the temperature has risen by about 1.5 °C and according to various scenarios its increase could reach up to 4 °C by the end of the 21st century. The signatories of the UN Convention on Climate Change, including Slovakia, made a commitment in the 2005 Paris Agreement to adopt measures that will contribute to limit the temperature increase to 1.5 – 2 °C as maximum. However, in the current situation, reducing greenhouse gas emissions is not sufficient, but it is also necessary to adapt to the effects of climate change and to take measures to reduce its adverse effects.

Responding to climate change is becoming crucial in the process of city governance. Climate change and its effects must become a top item in the agenda to secure the life quality in our cities and should be taken into account in all other urban policies. In order to respond to climate change effectively and efficiently, it is necessary to reassess the current traditional approach to the planning and decision-making processes towards assessing the sensitivity of the city's development plans and goals, as well as routine climate change activities in the city.

The solution is the creation and implementation of urban climate policies, which will allow to take systematic and comprehensive actions by municipalities. The measures that cities are currently implementing to mitigate adverse effects of climate change are often unsystematic and represent only partial, short term solutions. Studies and practice from different cities show that separate approaches to adaptation and mitigation reduce, on one hand, the complexity of response to climate change and, on the other hand, reduce the efficiency of using the public sources. Climate management of a city is a process by which the developed climate policy is being formed and implemented, how it is integrated into other urban policies, and also which steps are taken directly to protect the climate and to increase the adaptability of the city.

A frequent problem in the planning and implementation of investment activities is the absence of sufficient knowledge on the current and expected impacts of climate change on urban environment, as well as on the impact of these activities on adaptation to climate change or greenhouse gas production. At the same time, it is appropriate to prefer measures that are positive from the point of view of mitigation, adaptation and biodiversity, which will increase the added value of the implemented measures.

This publication offers an overview of selected measures for urbanised environment (with emphasis on housing estates), which can provide help (not only) to local authorities to orientate themselves in possible measures, their adaptation, mitigation and biodiversity impact, and help them select a right measure at a right place.

The document offers a clear and brief description of the recommended measures that will contribute to better orientation in the area of mutual relations of mitigation, adaptation and biodiversity. Its aim is to present mainly synergic measures that have both adaptation and mitigation impacts (positive or negative) and help in this way local authorities to find appropriate solutions and measures for mitigation of or adaptation to climate change.

The unique feature of the publication is the inclusion and description of only those measures that simultaneously relate to both adaptation and mitigation in the urban environment, whether with positive or negative impact. Due to the importance of preserving and supporting biodiversity from the point of view of climate change and the provision of ecosystem services, the impact of relevant adaptation and mitigation measures on the development of biodiversity is also described. The overview includes only those measures that are implemented in the residential area of the city or have a direct impact on the territory of the residential part of the city.

Each measure mentioned in this publication contains a brief general description of the measure, a description of its mitigation impact (positive or negative), adaptation impact (positive or negative) and impact on biodiversity (if relevant).

Measures whose direct impact is neutral from the point of view of adaptation or mitigation (they have no direct effect) are not included in this publication (for example, building flood protection in the form of dams or walls has a positive adaptation impact, but from the point of view of mitigation it has no positive or negative impact, therefore it is not part of this publication).

The intensity of the impact of the measure on the adaptability of the environment, on the reduction of greenhouse gases, or biodiversity is determined through a method of expert estimation and is given in the scale:

- – => negative impact,
- 0 => neutral impact (only when impact on biodiversity is assessed),
- + => slightly positive impact,
- ++ => moderately positive impact,
- +++ => significantly positive impact.

Finally, for each measure, the additional information useful for the implementation of the measure is provided. There are recommendations and information which can be taken into account in the process of planning or implementing the measure, or which are appropriate to study before the implementation of the measure. We can speak about legislative limits, recommendations for appropriate maintenance and management, advantages and disadvantages of selected variants of implementation, the need for consultation with experts in the given area in a planning process, etc.

The objective of the publication is not to provide a detailed or technical description of measures, but to guide the reader and motivate him/her to prioritise complex measures with adaptation, mitigation and biodiversity impacts, to avoid the implementation of climate change adaptation measures causing the increase of emissions (if it is not necessary) and to study the facts and broader relationships in specialized literature or consulting with a sector specialist. The list of mentioned measures is not exhaustive, but it is a selection of measures usable in housing estates and based on the practice and experience of the authors of the publication.

The publication entitled „Overview of Adaptation and Mitigation Measures for Urbanised Environment“ was prepared by a team of experts within the international project DELIVER – DEveloping resilient, low-carbon and more LIVablE urban Residential area, which focuses on harmonising activities aimed at mitigation of climate change, adaptation to its effects and support of biodiversity in urbanised environment (more information on the project and other outputs is available at http://odolnesidliska.sk/).

II. OVERVIEW OF ADAPTATION AND MITIGATION MEASURES

A. SYNERGIC ADAPTATION AND MITIGATION MEASURES

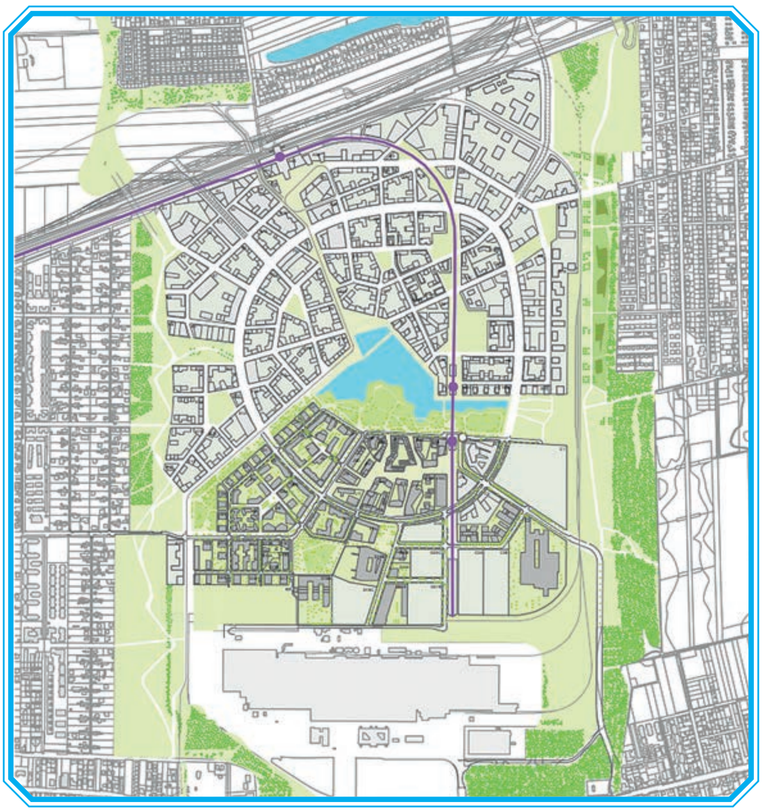
1 Use of climate resilient spatial planning

The systemic and most effective measures include climate-resilient spatial planning, which takes into account aspects of climate change when planning the composition of the city (or part of it). Through the application of various urban approaches and regulations, it is possible to considerably minimise the production of greenhouse gases on the territory of the city, or increase the city's resilience to the adverse impacts of climate change (heat waves, river floods, flash floods, etc.).

The measures in the area of spatial planning and urban design to minimise greenhouse gas emissions include, for example, polycentric city model, compact city model with short transport distances, preference of public transport, cycling and pedestrian transport at the expense of individual car transport, and others.

Measures to increase the resilience and adaptability of the city's territory to adverse impacts of climate change include, for example, maintaining corridors for ventilation and wind circulation in the city, creating a network of biocorridors, ensuring sufficient functional green spaces and their accessibility for the population, appropriate regulatory framework of the territory (e. g. coefficient of vegetation areas, surface impermeability ratio, ecoindex) and others.

Picture 1: Aspern Seestadt – a new part of Vienna with elements of climate-conscious spatial planning and a smart city



Picture source: Wien 3420 Aspern Development AG

Mitigation impact of the measure: ++

This is a complex issue which, when implemented properly and in time, can have a significant mitigation benefit in terms of the impact of settlements on climate change. A unifying element of these measures is that they must be planned in time, already during the elaboration of a spatial plan. Fundamental decisions which affect the structure of building development are taken when working on a spatial plan, regulatory plan and spatial studies, long before the individual buildings are designed.

Examples of these measures are described in a publication of e. g. Pavlečík et al., 2019. These are, for example, division of land and urban structure, which creates the conditions for saving and obtaining solar energy:

- the division of land allows for the predominant access from the north and large glazed areas on the south side of detached and terraced houses, which enables passive solar gains
- regulation prevents the shading of buildings, takes into account also the slope of the terrain, which allows the installation of photovoltaic panels on buildings, placement of new buildable areas so that the above mentioned actions could be easily secured (ideally, plain or southern slopes, without shading by conifers, deciduous trees, that in winter are without foliage and therefor do not shade, with access from the north).

Creating a „city of short distances“: the aim is to organise the city in such a way that as many services, infrastructure and attractions could be easily reached by walking or cycling and that residents do not have to travel far, and also that the maintained road network is as short as possible.

Support of natural ventilation and cooling of the city mitigates the effect of heat island and the need for active cooling in buildings.

Adaptation impact of the measure: +++

One of the most effective measures to reduce the impact of heat waves and urban heat island is to cool the area through good air circulation, which can be reached by a proper composition of buildings and public spaces in a city. The built-up lands with their density, height and structure affect the overall flow by roughness. It is advisable to consider building open corridors, green belts and the appropriate layout of the street network to ensure the inflow of cooler air from the areas outside a city into the built-up area. Such flow of cooler air mitigates the impact of summer heat in urban areas and improves air quality. The denser the built-up land is and if the orientation of the buildings is perpendicular to the wind flow direction, the ventilation of the built-up land is reduced.

Through suitable composition of buildings and their surroundings it is also possible to increase the thermal comfort in the adjacent public areas of buildings (e. g. inter-blocks – enclosed areas between houses) during heat waves. The solution can be, for example, planning of public space for rest and recreation in the (partial) shade of the buildings to minimise overheating of the space in the summer.

The impact of different forms of vegetation and water retention measures on increasing the adaptation of a city to changing climate conditions is described below for specific measures.

Impact of the measure on biodiversity: ++

Climate-resistant planning, which incorporates elements of green vegetation of various sizes and types, clearly helps not only people survive in cities under more difficult conditions, but also creates proper conditions for animals and plants to survive.

Additional information for implementation of the measure:

- The complex implementation of the measure is very demanding or even practically impossible under the current conditions with the existing urban structures. The measure is appropriate to be implemented in the planning and construction mainly of new city districts, or in individual major infrastructural reconstructions in a city.
- At present, it is not possible to define appropriate measures that are generally valid for all cities. When designing measures, it is necessary to take into account the natural conditions of individual cities, as well as the threat to particular cities by selected impacts of climate change.
- In practice, it is very difficult for a given city to find a suitable combination of measures which mitigate the climate change (mitigation) and adapt the area to the impacts of climate change (adaptation), as some of the measures and approaches contradict each other (for example, dense building of houses to reduce traffic distances and leaving enough public spaces for the development of green areas with a sufficient microclimatic effect). Therefore, it is appropriate to invite experts in the field of response to climate change to the spatial planning process.

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Pavelčík, P. - Klápště, P. - Lupač, M. – Třebický, V. 2019: Města a sídelní krajina ČR v době změny klimatu. Stručný přehled problematiky pro představitele veřejné správy. Rudná: CI2, o. p. s., 32 s.
Available at: <https://ci2.co.cz/sites/default/files/souboryredakce/brozura_mesta_a_sidelni_krajina_cr_a_zk_0.pdf>.

Karpatský rozvojový inštitút. 2015: Stratégia adaptácie mesta Trnava na dopady zmeny klímy – vlny horúčav.
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United Nations Economic Commission for Europe. 2011: Climate Neutral Cities, How to make cities less energy and carbon intensive and more resilient to climatic challenges, 98 p.

United Nations Economic Commission for Europe. 2011: Climate Neutral Cities, How to make cities less energy and carbon intensive and more resilient to climatic challenges, 98 s.

2 Planting of solitary trees and small tree groups in public spaces with local cooling effect

In our understanding, a solitary tree is a tree growing alone. It can also be a small group of two to four trees, which used to be planted in the past mainly near small sacral structures, or directly in the central areas of settlements, for instance during certain historical events. At present, solitary trees and smaller groups of trees in public spaces are mostly planted in paved surfaces (streets, public spaces near the structures of public services, such as schools, health services, social services, cultural facilities, parking lots, etc.). Solitary trees are often referred to as point elements of green infrastructure.

Picture 2: Solitary trees can also be planted in narrow streets of the city – an example from the city of Louvain (Belgium)

Photo by Zuzana Hudeková

Mitigation impact of the measure: +

The vegetation, as it is growing, retains carbon through a process which is called sequestration. There is long-term storage of atmospheric carbon dioxide in newly-formed biomass (in trunks, branches, leaves and roots of wooden plants). The extent of sequestration depends on the age of the tree, its species, season and habitat. In case of young trees, captures are low because the total volume of newly formed biomass is low. The highest captures are in case of long-living trees. In the next periods of tree growth, the sequestration rate increases, but subsequently in the adult phase and especially as the tree is dying, the sequestration rate is decreasing again.

From the point of view of climate change mitigation, there is an important factor how the wood is used after the felling of trees – if it is burned, the captured and stored carbon will be released into the atmosphere again. Even the dead wood is able to store carbon for decades, and that means that the forest soils usually have a higher carbon content than the non-forest ones, and this carbon can remains there for decades to hundreds of years, especially if nature-friendly forestry practices are used. If wooden plants are used as a raw material, e. g. for timber production, the length of the mitigation benefit is prolonged.

Applying this type of measures, when determining the level of carbon dioxide capture, it is therefore necessary to start from the specific wooden plant species and habitat.

For new biomass the average capture is: 1 ton of new biomass = 3.67 tons of absorbed CO_2.

At present, the so-called biochar is beginning to be used in tree planting practices in cities in cities (especially solitaire trees). Biochar can absorb CO_2 in addition to the supply of nutrients for the tree and water absorption (in fact, the process of pyrolyses is used,that means decomposition of wooden biomass into carbon under high temperatures without oxygen). In various studies, carbon sequestration with the use of biochar was calculated in the range of 0.7 – 1.8 Gt C per year (Smyth, 2016).

Adaptation impact of the measure: ++

Planted solitary trees are cooling during heats and strong sunlight, mainly with the help of smaller-scale shading of public spaces, providing so the space for short-term cooling of residents who are in the immediate vicinity. It is appropriate to supplement this measure with the installation of, for example, benches to create conditions for people to spend some time on public space.

Active cooling due to evapotranspiration, when trees evaporate water through their vents, which is converted into water vapour by absorbing thermal energy from the environment, takes place also under conditions of supplying the tree with moisture. However, the air flow causes that even very gentle breezes mix cooled air with hot surrounding air. The cooling effect is therefore only noticeable in the immediate vicinity of the trees. That means that such a form of tree planting does not have a significant microclimatic effect outside the area shaded by trees. However, the difference of temperatures under the tree (in the shade) and on lawn under the sun is more than 20 °C at noon. In the root area of a solitary tree, it is appropriate to plant bushes or perennials to increase the adaptive effect.

Impact of the measure on biodiversity: ++

Solitary trees attract especially birds, which hunt prey from these trees in the surrounding environment in the grass, but also on pavements and on asphalt areas. The tree provides them with shelter against a predator, as well as good position to look for a prey. At the same time, the insects on the tree are a food for small songbirds. The solitary tree also fulfils a function of a „stepping stone" for birds, insects and other animals, on which or under which these animals move between larger and more distant groups of trees within the settlement. When flowering, solitary trees provide a food habitat for pollinating insects.

Compared to grassed surface, in particular the group of trees, but solitary trees as well, together with bushes, are important to increase and maintain biodiversity, especially pollinating insects, beetles and birds. The grassed surfaces are regularly mowed and the grassland habitat is so regularly damaged. Trees and bushes contribute to the stabilization of the habitat from the point of view of biodiversity. At the time of mowing the grass area, the insects hide on the leaves, trunks and in the immediate vicinity of the tree.

It is important to maintain also long-living wooden plants, because their long life leads to the creation of many special environmental elements, such as cavities (in roots, trunks, crowns, closed or open ones, with water, dry...), small areas of exposed wood, various cracks and cleavages in the trunk, dead branches, etc. All these places in trees offer a specific environment to which whole communities of various beetles, secondary inhabitants of their corridors, their predators and parasites are linked. Old, surviving trees are solitary in most cases. A huge number of such trees can be found in cities, along roads, near churches, in parks and cemeteries.

Additional information for implementation of the measure:

- When choosing suitable wooden species, it is necessary to take into consideration the conditions of changing climate and to prefer domestic (and related) species.
- When planting solitary trees on places where residents are expected, shapes of tree trunk with a crown base set at the height of over 2.2 m are used; in the case of planting a tree near the road with bus traffic, the required height of the crown is 4.2 m.
- In order to create proper conditions for successful growth and further development of trees, the basic condition is to ensure sufficient space for roots (the space where the tree will develop its root system). This is possible, for example, by providing sufficient size of the planting pit, which also depends on the type of tree to be planted. Larger trees require up to 8 – 10 m^3 of planting pits, which is very problematic in conditions of limited space.
- In the space for the rooting of the tree, which should be then fully walkable, it is necessary to carry out a complete replacement of the soil with special tree substrate resistant to compaction (so-called structural substrate) and, if possible, to use mycorrhiza or biochar, which also has a mitigating effect. In case of paving, or occupation of the surface of the surrounding space by structures, it is necessary to use other technologies (rooting modules) enabling good development of the root system (e. g. DeepRoot, Silva Cells, aeration probes, so-called biochar and others). In case of maintaining the walkability, grids are installed, or other water-permeable surface materials are used.
- When planting solitary trees on parking lots, e. g. the Slovak Technical standard STN 73 6110 standard prescribes as minimum 1 tree for 4 parking boxes in the space between opposite stands. Areas for planting the trees must be at least 3.00 m wide to assure the natural development of underground and above-ground tree parts. Rooting modules must be installed in the entire area under the place for green vegetation, the dimensions of which (width 3 m, depth 0.5 m – 0.8 m) guarantee the natural development of the root system.
- Appropriate planting technology and providing quality care after planting with special focus on sufficient irrigation (especially during 3 years after planting it is necessary to ensure adequate irrigation – irrigation dose depends on the weather and is specified in the Arboristic Standard of Planting) – and mulching, if possible, by organic matter up to 10 cm of thickness. When planting a tree, it is necessary to proceed in accordance with the national planting standards, e.g in Slovakia ,

the Slovak Technical STN 83 7010 standard „Nature protection. Treatment, maintenance and protection of tree vegetation" and with sectoral standards, the standard of "Cutting of wooden plants", "Protection of wooden plants during construction activities" and "Planting of wooden plants".

- It is necessary to pay attention to operational safety of the tree, especially if it grows in public spaces and as a part of green vegetation. In the marginal areas, or after static protective measures also in parks and in areas of green vegetation, it is recommended to keep old trees with various cavities, which are biologically very valuable.
- Old (senescent) trees require a special type of care. This means a complex of measures including a special cutting of the tree-top to stabilise the tree and to support its regeneration, as well as colonisation of the individual tree by other organisms. For example, stable dead branches or parts thereof are left in the tree crown and the wood mass after cutting is left, if possible, close to the treated tree (in a whole, not as a chip) so as not to disturb the natural cycle of nutrients in the locality. It is especially beneficial to leave dead trees (or dead wood) in the number of 4 – 10 pieces per hectare.

Additional sources of information (links):

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Endlicher, W. 2012: Einführung in die Stadtökologie. Ulmer, Stuttgart.

Henninger, S. (Hrsg.). 2011: Stadtökologie. Bausteine des Ökosystems Stadt. Verlag Ferdinand Schöningh. Paderborn

Meyer, F. H. (Hrsg.). 1982: Bäume in der Stadt. Ulmer, Stuttgart.

Sources for selection of appropriate tree species to be planted:

- http://www.galk.de/index.php/arbeitskreise/stadtbaeume/themenuebersicht/strassenbaumlis,
- https://citree.de,
- www.willBAUMhaben.at,
- https://www.treebuilders.eu/products/structurail-soil-cells/,
- https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_04_2016_chancen_und_risiken_des_einsatzes_von_biokohle.pdf

3 Group planting of trees in public spaces with primary microclimatic function

Public spaces with group planting of trees, or multi-storey vegetation or tree lines can be supplemented with suitable furniture and elements of so-called small architecture to ensure the conditions for residents who wish to spend free time in this microclimatic favourable (thermally comfortable) space.

Mitigation impact of the measure: +

The direct mitigation impact of planting the trees in cities is similar to that of measures 2 and 4. It is the sequestration of atmospheric carbon and its storage in biomass of trees. New biomass has an average mitigation benefit: 1 ton of new biomass = 3.67 tons of absorbed CO_2.

From the point of view of total amount of greenhouse gas emissions produced by cities and their inhabitants, the sequestration potential of green areas (so-called „nature in the city"), including groups of trees, is relatively limited (EC, 2020). We can mention the city of Barcelona as an example, where the sequestration potential of urban vegetation was calculated at only 0.47% of the total annual carbon footprint of this city (Baro et al., 2014. 475). However, green infrastructure, green areas, have many other benefits (see adaptation benefits and impact on biodiversity below). The cited research has also confirmed that in the urban structure of settlements, certain types of land use in a city – especially green areas, low-density residential areas, residential areas with low houses surrounded by gardens, have the largest capacity to capture carbon (Table 1).

Picture 3: Group planting of trees – an example from Amsterdam (The Netherlands)

Photo by Zuzana Hudeková

Table 1: Average carbon sequestration from the point of view of different typologies of land use in cities with help of nature-based solutions (NBS)

Types of green infrastructure – area close to nature	***Score***	***Average carbon sequestration (kg C/m²)***
Parks and (semi)natural areas of urban greenery	*5*	*32.6*
Areas of urban greenery connected to grey infrastructure	*4*	*28.9*
Blue infrastructure	*5*	*36.1*
Residential greenery near buildings	*2*	*5.4*
Areas of urban agriculture and community gardens	*4*	*23.7*
Accompanying greenery of watercourses and water bodies	*2*	*12.5*

Source: Naturvation 2019a.

Note: The score is proposed so as to provide a scale of relative contribution of a given area of green infrastructure and a nature-based solution to carbon sequestration, while 5 is a relatively high contribution and 1 a relatively low contribution.

Adaptation impact of the measure: +++

Groups of trees and tree lines create a pleasant microclimate during heat in public spaces. Thanks to them, squares, streets or promenades can be properly designed as a refuge for residents (especially vulnerable groups) during summer months and heat waves.

The microclimatic effect of the measure and the effect on the surrounding area depend on the size of the area planted with trees. The tree with a crown diameter of 5 meters covers an area of approximately 20 m_2. At least 120 kWh of solar energy reaches such a crown during a clear summer day – 1% is used for photosynthesis, 5 – 10% is reflected in the form of light energy, 5 – 10% is reflected as heat and about the same percentage warms the soil. The largest part of the captured energy (about 80%) is put into the process of evaporation by the plant – transpiration. If a tree is sufficiently supplied with water, it evaporates 100 – 400 litres per day, which uses (or „recycles") 250 – 1000 MJ of solar energy (70 – 280 kWh). On average, during ten hours, the tree cools with an output of 7 – 28 kW. For comparison, air conditioners in luxury hotels have an output of about 2 kW. However, it should be emphasized that although air conditioners cool the interior, their engines increase the temperature of exterior and contribute to heating the environment.

The microclimatic effect of trees on the surrounding area depends on the size of the area planted with trees. Multi-storey greenery (including the level of bushes) fulfilled the microclimatic function much better also due to the reduction of the air flow, thus mitigating the mixing of the cooled air with the surrounding heated air.

Impact of the measure on biodiversity: ++

Any group of trees or bushes automatically increases the biodiversity of the environment, as it was described in the above-mentioned cases – thus attracting insects, birds and other small animals – squirrels, hedgehogs, lizards, blindworms. When planting, where possible due to conditions (suitable subsoil, less emissions from transport, etc.), native domestic tree species should be preferred, which support our native species of animals. Where our native tree species are not able to survive urban conditions, it is necessary to select non-native tree species without invasive potential.

The importance of domestic or native species is often underestimated when planting in city centres, especially in public spaces. Non-native and crossbred species are often more ornamental, more colourful or richer in blooming. Non-native trees are often better able to withstand the changing conditions of climate change (drought, summer heat). However, this poses a risk to biodiversity, as other species of fauna are linked to native species. For example, relatively often planted ginkgo (even in tree lines in cities) is linked with only 7 species of insects, while our domestic oak is linked with more than 500 species. Instead of our domestic small-leaved linden (*Tilia cordata*), a silver linden (*Tilia tomentosa*) is planted in some places, as it better tolerates drought and summer heat. However, it is not very known, that the nectar in the flowers of silver linden is toxic, especially to bumblebees and, to a lesser extent, to bees. Bees, wasps and bumblebees cannot digest this sugar because they do not have the enzyme to do so. Mannose-6-phosphate accumulates in the bodies of bees and in excessive amounts leads to paralysis and death.

Additional information for implementation of the measure:

- When choosing appropriate tree species, the conditions of the changing climate must be taken into account and domestic (and related) species have to be preferred.
- In order to create appropriate conditions for the successful growth and further development of trees, the basic condition is to ensure sufficient space for roots (the space where the tree will develop its root system, it means to root). This is possible to achieve for example by a sufficient size of the planting pit, which also depends on the type of tree to be planted. Larger trees require up to 8 – 10 m^3 of planting pits, which is very problematic in conditions of limited space.
- In the space for the rooting of the tree, which should then be fully walkable, it is necessary to carry out a complete replacement of the substrate with a special tree substrate resistant to compaction (so-called structural substrate) and possible use of mycorrhiza or biochar. In the case of paving, or building some structures on the surface of surrounding space, it is necessary to use also other technologies (rooting modules), enabling good development of the root system (for example DeepRoot, Silva Cells, aeration probes, or so-called biochar and others). Research of the growth of decorative pear, which was carried out in the British city of Manchester, showed that trees in unpaved terrain, or trees planted in a special „tree" substrate („Amsterdam soil") grew two times faster than the trees in paved areas and with compacted substrate, and their cooling effect was also approximately five times higher (Rahman et all, 2011).
- Appropriate planting technology and provision of quality post-planting care with special regard to sufficient irrigation (especially during 3 years after planting it is necessary to ensure adequate watering – irrigation dose depends on the weather and is specified in the Arboristic planting standard) – and mulching up to 10 cm thickness, if possible with organic mass. When planting a tree, it is necessary to proceed in accordance with the national planting standards,e.g in Slovakia STN 83 7010 standard „Nature protection. Care, maintenance and protection of tree vegetation" and with sectoral standards, the standard "Cutting of wooden plants", "Protection of wooden plants during construction activities" and "Planting of wooden plants".
- Emissions from vehicles can react with the products of gas exchange generated in physiological processes of urban trees and other plants, resulting in reduction of air quality in cities in summer (reducing so otherwise positive impact of urban vegetation). The study showed that during the July heat, 20% of ozone concentrations were caused by emissions of volatile

organic compounds (VOCs) from vegetation, which interacted with other air pollutants. Although VOCs from vegetation can contribute to air pollution during heat, it does not mean that green areas could be the main sources of ground-level ozone in the summer. The way how to reduce ozone levels is to reduce emissions from vehicles – the main source of NOX that reacts with VOCs from vegetation.

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4 Planting of trees and bushes with primarily hygienic, land reclamation and anti-erosion functions

Planting of groups of trees and bushes whose primary purpose is technical (for example stabilizing slopes against landslides, preventing wind erosion of the soil) or hygienic (for example absorbing small dust particles, barrier to noise such as road greenery). In addition to their primary function, however, they also have a positive impact from the point of view of reaction to climate change – they capture and sequester carbon, stabilize soils in extreme weather events and cool their close surroundings. Examples of implementation of the measure:

- vegetation dividing strips between roads with tree lines,
- zones of hygienic greenery in industrial zones and transport hubs,
- windbreaks,
- wooden plants with anti-erosion function (such as prevention and remediation of slope landslides).

Picture 4: Road greenery has isolation and hygienic functions – example from Bilbao (Spain)

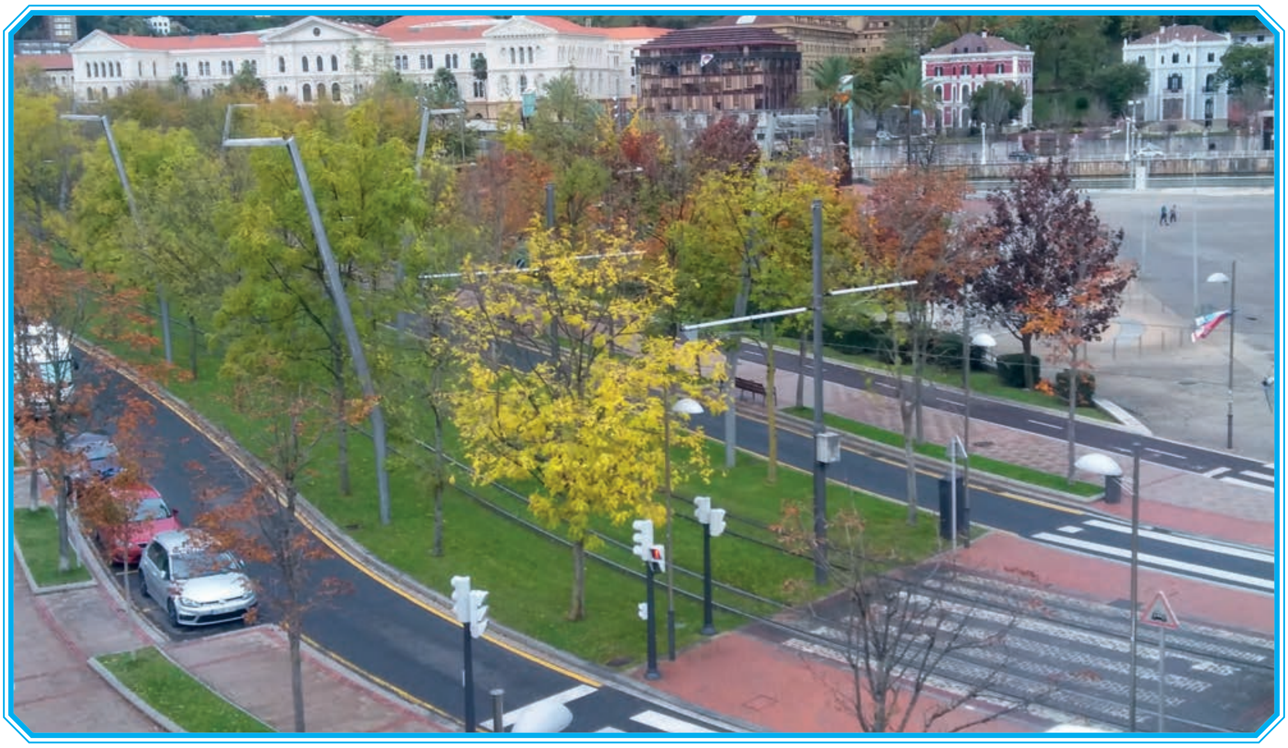

Photo by Zuzana Hudeková

Mitigation impact of the measure: +

The direct mitigation effect of tree planting in cities is similar to that of measure 3. It is the sequestration of atmospheric carbon and its storage in tree biomass. The average mitigation benefit of new biomass: 1 ton of new biomass = 3.67 tons of absorbed CO_2.

There are also indirect effects of greenery on reducing the impact of other sectors on climate, such as reducing individual car traffic in cities. Although green infrastructure alone cannot automatically reduce car traffic, there is a clear indirect impact of greenery on reducing car traffic: reducing parking plots and increasing green space and building pedestrian and bicycle infrastructure in city centres have a direct mitigation benefit.

Other mitigation benefits of greenery include shielding and cooling of the environment (for example, in case of road greenery it is shielding of vehicles), reducing the need for technical solutions of cooling in this way.

Adaptation impact of the measure: +++

Wooden plants with primarily hygienic, reclamation and anti-erosion functions have their role mainly in reducing noise, the amount of dust particles in the air, capturing rainwater, reducing wind intensity, etc.

Trees (depending on their size and species) capture rainfall very effectively. Studies mention that while huge trees catch 80% of the rainfall fallen on their crown, young trees only 15%. From the point of view of annual balance, coniferous trees are more effective in capturing precipitation, as deciduous trees in the state without leaves capture only 10 to 30%. Thanks to its root system, vegetation supports the infiltration of rainwater into the lower layers of the soil and into the groundwater.

The function of reducing the noise level in the urban environment, as well as reducing the wind speed, is also important. Noise reduction can reach 30 dB per 100 meters, a 10 m strip of continuous greenery with bushes reduces the noise intensity by about 1 dB.

As windstorms and storms are also expected as one of the impacts of climate change, wind speed can be reduced by appropriate planting of trees in the form of windbreaks. Semi-permeable windbreaks with an optimal permeability of 40 – 50% are the most efficient. If we denote h as the height of the windbreak, the efficiency on the windward side is 10 h and on the leeward side 20 – 25 h.

Green areas cool the surrounding areas and increase the humidity (by 5 to 7% as average) through evaporation. According to research, the amount of evaporated water from an adult deciduous tree can reach approximately 100 – 400 l per day.

Impact of the measure on biodiversity: ++

Tree lines and groups of trees in the middle of urban area act like a green oasis for all living things – they attract especially birds, which hunt prey from these trees in the surrounding environment in the grass, but also on pavements and on asphalt surfaces. The tree provides them with shelter against predators, as well as a good view of any prey. Alternatively, it can provide them with nesting space. At the same time, the insects found on the tree provide food for small songbirds. Tree lines also play a role of biocorridors for birds, but also insects and other animals, where they move between more distant groups of trees within a housing estate or industrial area. At the time of flowering, trees are a food habitat for pollinating insects (for example, fruit trees, lindens, hawthorns).

Compared to the grassed area, the group of trees supplemented with bushes is of great importance for increasing and maintaining biodiversity, especially of pollinating insects, beetles and birds. The grassed areas are regularly mowed and the grassland habitat is regularly damaged by this management. The same applies to trees along roads. Trees and bushes contribute to the stabilisation of biotope and surrounding landscape in terms of biodiversity. Insects hide on the leaves, trunks and in the immediate vicinity of the tree at the time of mowing the adjacent lawn or during road maintenance.

Additional information for implementation of the measure:

- When choosing suitable tree species, it is necessary to take into consideration the conditions of changing climate and domestic (and related) species must be preferred.
- In order to create appropriate conditions for the successful growth and further development of trees, the basic condition is to ensure sufficient space for rooting (the space where the tree will develop its root system, to root). This is possible, for example, by sufficient size of the planting pit, which also depends on the type of tree planted. Larger trees require up to 8-10 m3 of planting pits, which is very problematic in space-limited conditions.
- In the space for the rooting of the tree, which should be then fully walkable, it is necessary to carry out a complete replacement of the soil with special tree substrate resistant to compaction (so-called structural substrate) and, if possible, to use mycorrhiza or biochar. In case of paving, or occupation of the surface of the surrounding space by structures, it is necessary to use other technologies (rooting modules) enabling good development of the root system (e. g. DeepRoot, Silva Cells, aeration probes, so-called biochar and others).
- Appropriate planting technology and providing quality care after planting with special focus on sufficient irrigation (especially during 3 years after planting it is necessary to ensure adequate irrigation – irrigation dose depends on the weather and is specified in the Arboristic Standard of Planting) – and mulching, if possible, by organic matter up to 10 cm of thickness. When planting a tree, it is necessary to proceed in accordance with the national planting standards,e.g in Slovakia, , the Slovak Technical STN 83 7010 standard “Nature protection. Treatment, maintenance and protection of tree vegetation”

and with sectoral standards, the standard of "Cutting of wooden plants", "Protection of wooden plants during construction activities" and "Planting of wooden plants".

- In the past, there were tree species planted in public green spaces, which even under the influence of climate change behave invasively, invade plant communities, from where they remove native species and form monocultures (communities consisting mainly of one species). In Slovakia, the issue of non-native and invasive species is addressed by Act 543/2002 on nature and landscape protection as amended, in Article 7, as well as by Decree of the Ministry of the Environment of the Slovak Republic 158/2014. As the list of invasive plants is still being amended, it is appropriate to avoid planting even potentially invasive species.
- Greenery planted along the pedestrian promenades and cycling paths is attractive not only from the point of view of recreational purposes, but also for the use of bicycle and pedestrian transport, as a means of daily transport within the city itself, but also to connect the city with its recreational facilities through green infrastructure.
- Greenery has a positive impact on air quality, it serves as a filter of dust particles (the value of capturing 20 g of dust particles per m^2 of leaf area is mentioned). Researchers from Columbia University have found out that the rate of asthma in children was 4 to 5 times lower in urban areas with tree lines. Trees on the streets are able to remove sulphur dioxide and reduce the particulate matter content by up to 75%. The biggest effect of dust collection and absorption of extraneous substances was found in trees growing in two lines with a relatively high planting density. However, a separately growing tree is also capable to capture 15 – 20% of hazardous PM10 dust particles. A number of works deal with the efficiency of capturing biogenic volatile organic compounds and dust according to the type of trees and these were evaluated on the basis of a so-called urban tree air quality score (UTAQS).

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Hudeková, Z. et al. 2018: Zelena infraštruktúra – Príručka nielen pre samosprávy. Bratislava: Mestská časť Bratislava-Karlova Ves, 2018. ISBN 978-80-973076-8-4. Available at: <https://www.karlovaves.sk/wp-content/uploads/Zelena-infrastruktura-prirucka-nielen-pre-samospravy.pdf>.

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5 Inner courtyard greenery providing a pleasant microclimate for local residents

The inner courtyard greenery is perceived by the inhabitants of the immediate surroundings as semi-public, or specific greenery, which is publicly available but used mainly by locals. The inner courtyard greenery means all kinds of vegetation directly in the yards between residential buildings as well as greenery in the vicinity of residential buildings, which fulfils recreational and social functions for local residents. In order to ensure proper conditions for local people to spend time, the interior yards include suitable furniture with elements enabling short-term recreation.

Mitigation impact of the measure: ++

The direct mitigation impact of inner courtyard greenery is similar to the impact of measures 2, 3 and 4. It is the sequestration of atmospheric carbon and its storage in tree biomass. The average mitigation benefit of new biomass is: 1 ton of new biomass = 3.67 tons of absorbed CO_2. For a given type of vegetation, a relatively low intensity of carbon capture applies: 5.4 kg of carbon per m^2 (see Table 1).

The indirect mitigation effect of inner courtyard greenery can be seen in the form of energy savings. Based on the works from the USA and the UK, energy savings should come from the trees shading on buildings and reducing so heat loss due to

Picture 5: Example of inner courtyard greenery with blooming meadow in Bratislava – Karlova Ves

Photo by Lenka Nemcová

reduction of wind speed. Of course, it depends first of all on the position of the trees in relation to the building, on their type and size, distance from the building, etc. In general, it is recommended to plant deciduous trees on the southern sides of the facade, which, after loss of leaves, allows the use of heat gains from the sun during cold months.

Totally, there is estimated 3% energy saving for each residential building if there are trees within a distance of less than 10 meters (Nowak, 1994). According to some research, the reduction of energy consumption for heating and air conditioning is estimated at the level of 10% as a result of tree shading (Heisler, 1986; Jones, 2003). Thanks to the achieved energy savings, CO_2 emissions are also directly reduced.

However, in case of overgrown vegetation in the vicinity of buildings, especially with coniferous trees shading the surrounding houses so that all-day lighting is required, the requirements for energy supply are increasing.

Adaptation impact of the measure: +++

Even in smaller areas of greenery, which include inner courtyards, a cooling effect was demonstrated. This can spread up to a distance of 200 m from the green area itself, even with an inner courtyard area of 0.24 ha.

In addition, with a suitable combination of shading, active cooling with the help of vegetation and simultaneous sufficient ventilation of the inner courtyard space, these areas can serve as a space for spending time and cooling during summer heats.

The microclimatic effect of the planting itself on the surrounding buildings can be further underlined by the use of vertical greenery on the facades.

Impact of the measure on biodiversity: ++

Any group of trees or bushes automatically increases the biodiversity in the environment, as described in the above-mentioned cases – it attracts insects, birds and other small animals – squirrels, hedgehogs, lizards, blindworms. When planting, where it is possible due to conditions (suitable subsoil, less emissions from transport, etc.), native tree species should be preferred as they are more appropriate for our native animal species. Where our native tree species are not able to survive in urban conditions, it is necessary to select non-native tree species that do not have invasive potential.

Additional information for implementation of the measure:

- When choosing suitable tree species, it is necessary to take into consideration the conditions of the changing climate, to prefer domestic (and related) species and the distance of the planting place from the facade.
- Appropriate planting technology and provision of quality post-planting care with special regard to sufficient irrigation (especially during 3 years after planting it is necessary to ensure adequate watering – irrigation dose depends on the weather and is specified in the Arboristic Planting Standard) – and mulching up to 10 cm thickness, if possible with organic mass. When planting a tree, it is necessary to proceed in accordance with the national planting standards, e.g in Slovakia , the Slovak Technical STN 83 7010 standard "Nature protection. Care, maintenance and protection of tree vegetation" and with sectoral standards, the standard "Cutting of wooden plants", "Protection of wooden plants during construction activities" and "Planting of wooden plants".
- In the inner courtyards, as well as in the pre-entrance areas to residential houses, we can also see examples of inappropriately planted (mainly) tree vegetation. Already during planting, it is necessary to pay attention to ensuring proper conditions for successful growth and further development of trees – by ensuring not only sufficient space for rooting, but also sufficient space for growth and development of the tree crown.
- In case of overcrowded vegetation, especially in case of coniferous trees, which shade the surrounding houses too much all year round and during entire day, so that all-day lighting is required (multiplying so energy supply requirements) partial felling or cutting is required.
- In the inner courtyards, it is appropriate to support the active participation of the residents in designing and managing this space. The courtyard has a potential to support common activities of the community living here (for example, in the form of joint care for greenery or planting community flowerbeds).

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Hudeková, Z. 2019: Ako pripraviť akčný plán pre zelenej infraštruktúry so zohľadnením nových výziev, Bratislava: Mestská časť Bratislava-Karlova Ves, 2019. ISBN 978-80-570-1323-5.
Available at: <https://www.karlovaves.sk/wp-content/uploads/Akcny-plan_zelena-infrastruktura_web.pdf>.

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Available at: <https://op.europa.eu/en/publication-detail/-/publication/6dd4d571-cafe-11ea-adf7-01aa75ed71a1>.

NATURVATION (NATure-based URban innoVATION project): H2020, November 2016 – October 2020.
Available at: <https://naturvation.eu>.

6 Creation of new larger areas of greenery with functional tree vegetation

Large areas (at least 0.3 ha) of greenery in the city are areas covered by trees, where the trees crowns occupy occupy at least 40 – 60% of the territory. Such areas of greenery include, for example, urban parks, recreational areas on the territory of the city, economic and recreational forests near the built-up areas, etc.

Large-area greenery can be created in the urbanised environment, for example, by:

- creating new areas of greenery, parks, forest parks (transformation of unused areas into parks),
- revitalisation of brown areas to green areas,
- transformation of concrete and asphalt surfaces into areas of tree greenery,
- increasing the number of parks fulfilling the function of "cooler islands".

Mitigation impact of the measure: ++

The extent of mitigation benefit is given by the Forest Act and forestry management plans (originally forestry economic plans). The aim should be to increase the sequestration potential of forest vegetation, forestal parks and public greenery, for example by choosing an appropriate species composition. In forestal parks and suburban forests, it is important to respect the principles of sustainable forestry management (SFM).

It is estimated that during the life cycle (i. e. from planting to felling) of coniferous economic forest 2.5 tonnes of carbon per 1 hectare of vegetation is captured in 1 year. In our conditions, a 250-year natural deciduous forest (without economic activity) captures up to about 494 grams of carbon per m^2 (i. e. 49.4 tons of carbon per 1 hectare). The average values of carbon sequestration for specific types of nature friendly types of areas in cities are given in Table 1. In case of larger green areas, such as parks, forest parks, urban forests, etc., relatively high values of sequestration are reported here, namely 32.6 kg of carbon per m^2.

Adaptation impact of the measure: +++

According to the temperature simulation in Manchester, increasing the share of greenery by 10% would be able to keep the average temperature in densely populated areas of the city in 2080 at or even below the level of the 1961 – 1990 period (Gill et al, 2007).

Picture 6: Larger areas of greenery – an example from a new eco-district in Paris – Boulogne Billancourt

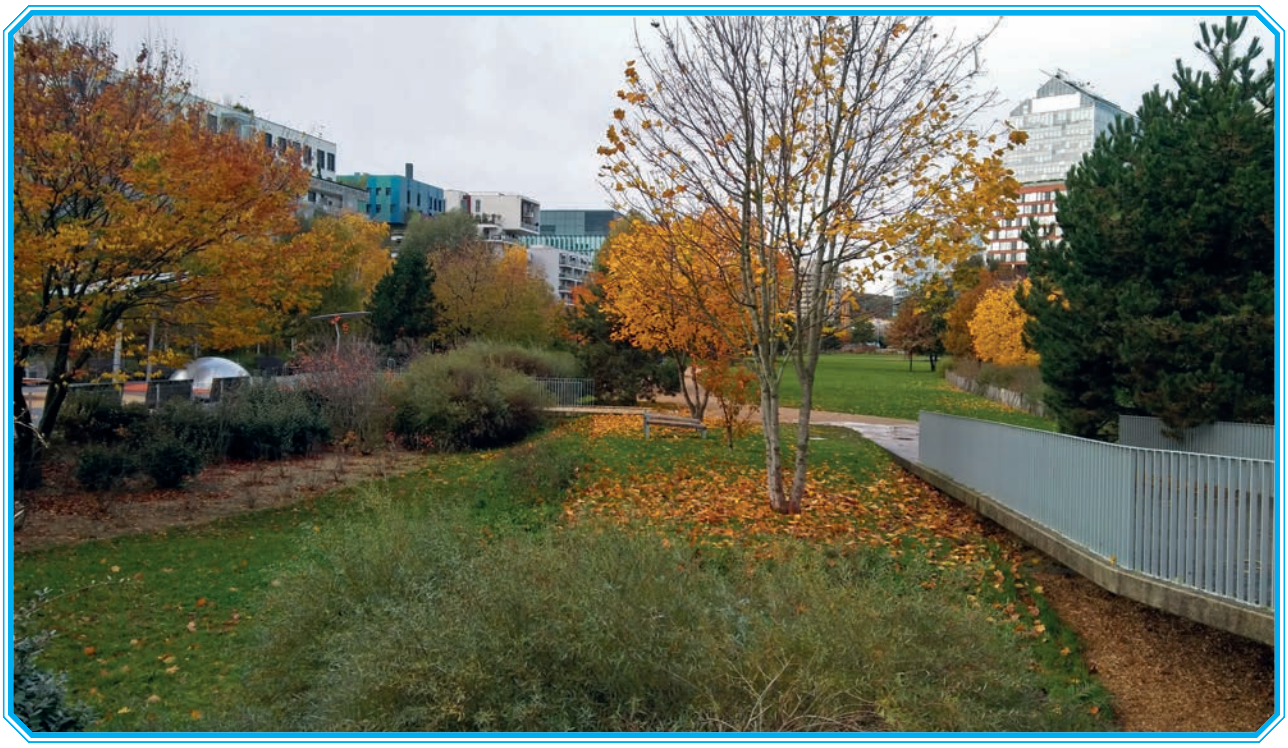

Photo by Zuzana Hudeková

The construction development on one hectare of quality soil with a high retention capacity of approximately 4,800 m^3 leads to a considerable decrease of evaporation from vegetation. The energy needed to evaporate such an amount of water corresponds to the energy consumed by about 9,000 freezers per year, which is about 2.5 million kWh.

However, the cooling effect depends not only on the ratio and quality of vegetation, but also on the location of greenspaces within the settlement, the nature of the surrounding buildings, the division of the terrain, etc. In general, based on several sources, it can be said that the difference in air temperatures, e. g. between the green and the built-up areas, was in the range 0.94 °C to 2.26 °C on average. Leizinger et al. measured temperatures near a group of trees from 24 – 29 °C, while the temperature on the street was 37 °C and on the roofs of buildings 45 °C.

A significant cooling effect of vegetation on its surroundings is manifested only in parks with a sufficiently large area. This effect is noticeable up to distance of 500 m depending on the size of the park and the nature of the surrounding development (buildings). For parks with area of more than 150 ha it can be up to distance of 1 km. Simply, large areas of greenery also cool their surroundings and this effect is noticeable from the edge of the park to the distance corresponding approximately to its area.

In the urbanised environment, areas of greenery are also important for retaining rainwater, they help percolation of water, reducing so the risk of drought. Not only the vegetation itself, but also the quality of the soil plays its roles. Fully functional soil can capture up to 3,750 tons of water per hectare or almost 400 mm of precipitation, or one cubic meter of porous soil can hold 100 to 300 litres of water.

Trees, depending on size and species, capture rainfall very effectively. Studies show that while large trees catch 80% of rainfall, young little trees only 15%. From the point of view of year-long comparison, coniferous trees are more effective in capturing precipitation, as deciduous trees, when without leaves, capture only 10 to 30% of precipitation.

By capturing rainwater, when it is still "above the surface" (by the trees crowns), the amount of water sinking into soil is reduced. Thanks to its root system, the vegetation helps the infiltration of rainwater down to the lower layers of the soil into groundwater. It is also important to slow down the runoff during heavy rainfall, alleviating so the rainfall-sewerage network. A study from Manchester shows that a 10% increase of urban greenery area can help reduce rainwater runoff by 5%.

Impact of the measure on biodiversity: +++

Large areas (0.3 ha as minimum) of greenery with large trees have an important ecostabilisation function for biodiversity in the city. They are not only a temporary refuge for animals, but also their permanent shelter. From these areas animals then go or fly to the surroundings and return. However, this only applies if the maintenance of such an element is carried out without chemical preparations and in a generally nature-friendly way. As early as 5 years after planting, this area can contain several times more species of plants and animals, when compared to intensively cultivated lawns. If these areas are older than 10 years, they can become a permanent home of songbirds and pollinating insects. Newly planted areas need to be equipped with shelters for hedgehogs and reptiles – piles of rocks or branches and leaves – if these animals are to be here on permanent basis. Birds need birdhouses and feeders, which have to be placed not on young growing trees but on stands next to trees.

Additional information for implementation of the measure:

- When choosing suitable tree species, it is necessary to take into consideration the conditions of the changing climate and to prefer domestic (and related) species.
- Appropriate planting technology and provision of quality post-planting care with special regard to sufficient irrigation (especially during 3 years after planting it is necessary to ensure adequate watering – irrigation dose depends on the weather and is specified in the Arboristic planting standard) – and mulching up to 10 cm thickness, if possible with organic mass. When planting a tree, it is necessary to proceed in accordance with the national planting standards,e.g in Slovakia , the Slovak Technical STN 83 7010 standard "Nature protection. Care, maintenance and protection of tree vegetation" and with sectoral standards, the standard "Cutting of wooden plants", "Protection of wooden plants during construction activities" and "Planting of wooden plants".
- When discussing the effectiveness of green areas, it is necessary to focus on quality, especially on the representation of wooden plants, which has a significant impact not only on the temperature of the area, but also on the possibility to cool their surroundings. Several studies (e. g. Potscher et al., 2006) have confirmed that in the parks with only a small proportion of trees, or only with low ornamental plants planted, the temperature is the same, or even slightly higher than in their surroundings.
- When managing forest parks and other forest vegetation, it is important to implement the principles of sustainable forest management.

Additional sources of information (links):

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7 Maintaining greenery in a manner close to nature, including, including reduced mowing frequency

Maintaining greenery in a manner close to nature comprehensively addresses all maintenance tasks, from natural methods of plant protection without the use of chemicals, weeding, through mowing with regard to the protection of insects and other animal species, and simultaneously allowing seed formation in annual herbs, thorough mulching of flower beds to limit the growth of unwanted herbs and weeds, but also to prevent undesirable drying of the soil, etc. Great attention is paid to the appropriate selection of species of vegetation (wooden plants and herbs), for example in the form of the use of perennial beds that do not require irrigation and tolerate the conditions of habitats in residential areas. Nature-friendly care is also applied to the care of trees, especially regarding the protection of species, hollow nesters and insects. Where it is possible and acceptable in a residential environment, dead wood is left on the natural surface.

An important area of cities is covered by grassy areas (lawns, meadows or pastures). These areas vary according to their purpose and related governance and maintenance. They can be frequently mowed and very poor in species with the need to irrigate regularly (such as golf turf or "English turf") or very rich in species, with a natural or semi-natural character, lower mowing frequency and minimum irrigation requirements. Mowing lawns is one of the basic tasks of greenery maintenance.

Mitigation impact of the measure: +

Meadows and lawns have the same mitigation characteristics as other types of green infrastructure and "green" measures. The rate of carbon sequestration is logically, due to the smaller volume of biomass, lower than that of wooden plants or other permanent crops. On the contrary, frequent mowing even contributes to the release of carbon back into the atmosphere and also contributes to the drying of lawns in the summer (summer dormancy). A very dry lawn or meadow will have very low carbon sequestration (if any, depending on the degree of drying) and, on the contrary, it can become a source of carbon in the city.

From the point of view of mitigation, it is not recommended to plant summer annuals and perennials, which are cultivated in remote horticultures and greenhouses, as this requires increased traffic, which again contributes to CO_2 emissions. Similarly, *Picture 7: An example of mosaic mowing in Zvolen*

Photo source: CEEV Živica

pesticides or chemical fertilisers for greenery maintenance, the production of which emits large amounts of greenhouse gases, also have a negative impact.

With less frequent mowing, financial resources will also be saved and greenhouse gas emissions will be reduced (if mowing with motor mowers). Motor mowers make a significant contribution to CO_2 emissions. They have very environmentally unfriendly engines, just for comparison – when calculated in terms of the same output, the mower emits 35 times more CO_2 than a car. The 5.5-horsepower mower, when mowing for 1 hour, emits twice as much CO_2 emissions than a 100-horsepower car riding 90 km.

Adaptation impact of the measure: ++

The higher the lawn, the better the microclimate. Hundreds of thousands of 10-centimeter grass stalks retain a significantly higher proportion of soil moisture than short-cut lawns. This lawn dries more easily and overheats in the heat. Low-cut lawns lose their cooling function in summer, as they heat up to 60 degrees Celsius. The temperature measured on the dry lawn in the summer months was very similar to the temperature of the overheated asphalt surface. On a dried lawn, the soil surface is so compacted and impermeable to water that percolation of rainwater is minimised. Rainwater drains away from the dried and compacted lawn as if it were a paved impermeable surface.

Impact of the measure on biodiversity: +++

„Permanent mowing – losing meadow" – *Ovid*.

As can be seen from Ovid's quote above, frequent mowing brings more harm than benefit. For the biodiversity of plants and insects, frequent mowing is devastating. With frequent mowing, which is repeated every week or every two weeks, the number of plant species in the lawn is eliminated to 2 – 5 species and the number of insects also to 2 – 3 species (ants – some species – are the most resistant).

Mowing every two months (in mosaic) or only twice a year multiplies the number of species of plants and animals, not only on meadows maintained in this way, but also on neighbouring areas with more intensive mowing (this is confirmed by monitoring carried out in Bratislava – Karlova Ves within the LIFE DELIVER project). The diversity of insect species is greater if there are different species of microbiotopes on the grass or meadow. For example, if there is a path through the meadow, or the meadow is on a slope that is disturbed by the birds burrowing, or the meadow is close to the twice mowed area, there is also area mowed every month, and also the area that is mowed only once a year – in summer, and then old grass is left for the wintering of larvae and insect individuals until the next spring. The presence of moles and mole hills also increases biodiversity. In mole hills, bees and bumblebees can find shelter to nest in the ground. If mown grass is not removed, this leads to nitrogen enrichment of the soil, which favours only nitrophilous species (such as nettle). This in turn increases the demands on frequency of mowing, as well as has a very adverse effect on the number of species and biodiversity.

When planting flower beds, we prefer perennials, especially those species that provide food and shelter for birds and honey producing plants. Flower beds belong to very attractive areas of greenery in cities. They are pleasure not only for eye, but also for pollinators. However, annuals require a lot of irrigation or even fertilisation. It appears that planting perennials is always more favourable and economically advantageous.

Dead wood in the form of a fallen trunk of a large tree, but also piles of branches, which also serve as shelters for lizards, blindworms and hedgehogs – these are centres of biodiversity. Because dead wood contains, along touchwood which is a source of nutrients, also water, which it absorbs from precipitation like a sponge, it attracts many rare animals. For example, those that lay eggs in the wood to develop their larvae (e. g. stag beetles, longhorn beetles), butterflies (e. g. common blue butterflies), to replenish minerals and water from wood, as well as solitary bees to find shelter for themselves and offspring.

Additional information for implementation of the measure:

- Greenery management and related maintenance must be adapted to the function – there are different requirements for the grass areas intended for picnics or games and different requirements for the less used grass areas along roads, etc.
- To maintain the lawns properly in times of climate change, the appropriate technique must be selected. Existing grass-mowers often do not allow to increase the cutting height. There is also a problem with the removal of biomass from higher mowed areas and this has an impact on the mitigation benefits of the measures. Companies, carrying out lawn maintenance, will have to invest in new equipment, or it will be necessary to replace the service provider with one that has appropriate equipment.
- When choosing, we try to prefer domestic species (preferably those which provide animals with food or shelter) and species that tolerate the extremes of the residential environment, especially with low requirements for irrigation (xeriscaping).
- The higher diversity, the lower risk of over-reproduction of individual species (including ticks).
- Flowering meadows as areas with reduced frequency of mowing are not suitable for walks. For walks around these areas, it is necessary to regularly mow the footpaths.
- Areas with reduced frequency of mowing better absorb dust particles from the air, which are carcinogenic and cause allergic reactions. Higher grass naturally filters fine particles of dust.
- In order to reduce occurrence and creation of grass pollen, which belongs to strong allergens, it is recommended to perform the first mowing before flowering (depending on the weather at the end of May) even on areas with reduced frequency of mowing.
- On areas mowed twice a year it is necessary to remove the invasive species (American and Canadian goldenrog (*Solidago, Stenactis annua, Aster novi-belgii*) and thistles.

Additional sources of information (links):

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Hudeková, Z. 2016: Prírode blízka údržba mestskej zelene – príručka pre samosprávy. Bratislava: Živica, 2016. ISBN: 78-80-968989-7-8. Available at: <https://zivica.sk/kniznica/prirucka-prirode-blizka-udrzba-mestskej-zelene/>.

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Kolektiv autorů. Principy tvorby veřejných prostranství. Kancelář architekta města Brna.

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Flandin, J. – Parisot, Chr. 2016: Guide de gestion écologique des espaces publics et privés. Natureparif, 188 s. Available at: <https://www.arb-idf.fr/sites/arb-idf/files/document/ressources/guide_gestion_ecologique_natureparif_2016.pdf>.

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8 Building wetlands in urban environment

Building new nature-friendly and protection of natural wetlands in the built-up area of the city or with a direct impact on the built-up area of the city. Wetlands are defined as natural or artificially created territories that are seasonally or permanently flooded.

Picture 8: Wetland Triangl at periphery of the Skalka residential district in Prague

Photo by Mirek Lupač

Mitigation impact of the measure: ++

Building wetlands in the urban environment meets the parameters to combine the adaptation and mitigation criteria. From the point of view of mitigation, it is important that wetlands have a huge capacity to absorb and retain one of the most important greenhouse gases – carbon dioxide. Restoration of artificially dried peatlands and wetlands can capture up to 25% of emissions from agricultural production. Peatland is a specific ecosystem capable of storing more carbon than forests. As much as a third of carbon in soil is captured in peatlands, even though they cover only 3% of global land (Bonn et al., 2016).

Holden (2005) emphasizes that the long-term ability of peatlands to absorb carbon dioxide depends on ongoing climate change and on the management of a particular habitat. These factors affect hydrological processes and the flow of water under the peat surface. They have a significant impact on the overall rate of carbon sequestration, because under unfavourable conditions peatlands can be a net source of other greenhouse gases, such as methane (Green et al. 2018).

The average values of carbon sequestration for individual types of close-to-nature types of areas in cities are given in Table 1. In case of blue and blue-green infrastructure, the highest values of carbon sequestration apply – 36.1 kg C/m^2. Areas of urban greenery linked to grey infrastructure have a similarly considerable contribution (28.9 g C/m^2).

Adaptation impact of the measure: +++

Wetlands contribute to water retention, reduce flow fluctuations in running water, replenish groundwater supplies, purify water and remove harmful substances from it. Their capability to accumulate a large amount of precipitation (similar effect to "sponge") can significantly reduce floods from storm rainfalls.

Research as well as practical experience prove that evaporation from wetland and other hygrophilous vegetation sufficiently supplied with water has a very favourable effect on microclimatic conditions. Moreover, as described in previous parts, this involves cooling by evaporation from the water surface, as water consumes 2500 kJ to evaporate 1 mm of water/m^2. At present, there is not much research known addressing the combined cooling effect of evaporation of water and evaporation from wetlands and other vegetation. Hammel et al. (2012) in their research pointed to a favourable state of humidity within the surrounding soil, which also has a positive effect on the cooling of the environment.

Impact of the measure on biodiversity: +++

The positive impact of the built wetlands on local biodiversity is high. After the construction of the water surface, it is immediately occupied by animals dependent on water – dragonflies, water beetles, frogs, etc., which cannot live without the existence of this water surface. Moreover, stable wetlands serve as source of water for insects, birds and smaller mammals – hedgehogs, squirrels from the surrounding area. Wetlands, with their existence, increase the chances of animals to survive in times of heat and drought. Built wetlands are used in many countries as green infrastructure to capture rainwater (including pre-treatment of wastewater), but they can also be biodiversity "hotspots". According to some studies, the number of plant species (including several protected ones) increased by more than 200%.

Additional information for implementation of the measure:

- The built wetlands serve as a cost-effective and multi-purpose rainwater management option in the urban landscape, offering flood protection as well as wildlife habitats.
- However, due to the existing requirements of potential evapotranspiration (evaporation from vegetation), lower parts of our region are shifting to the steppe climate zone. This is demonstrated in maps of climate zones shifts which applies mainly to the lowlands (in Slovakia, e. g. Podunajská nížina and Záhorská nížina), but also to areas with lower altitude in the south of central and eastern Slovakia (up to about 250 m above sea level). However, drying is also taking place elsewhere in Slovakia, however there it is not a change towards the steppe zone, but towards worsening conditions for several wooden plants (especially spruce). Wetlands at low altitudes, or in dry environment, consume a huge amount of water by evaporation (even more than 800 mm per year and m^2), which is by 50% to 100% more than the surrounding landscape with grassy or occasional non-irrigated vegetation. The result is that we should build wetlands only where there is naturally enough water, e. g. floodplain forests around the Danube river. Where there is a shortage of water (steppes and semi-deserts without rivers rich in water), the artificial construction of wetlands is undesirable due to loss of valuable water that is needed in the country for other purposes.
- Studies also show that if there is a polluting industry in the vicinity of a wetland, wetlands can accumulate high levels of pollution and be potentially toxic to wild animals.

Additional sources of information (links):

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Available at: <https://www.eurosite.org/wp-content/uploads/CAP-Policy-Brief-Peatlands-in-the-new-European-Union-Version-4.8.pdf?fbclid=IwAR2KdXy0QY68QLMNj8zwkHe4YX4MwMo_LP3kzdCJYnFnQCQyjux0FgbUqDw>.

EC (European Commission). 2016: Science for Environmental Policy. Constructed wetlands boost biodiversity: evidence from Italy.
Available at: <https://ec.europa.eu/environment/integration/research/newsalert/pdf/constructed_wetlands_boost_biodiversity_evidence_from_italy_457na2_en.pdf>.

9 Building productive urban gardens

Growing food directly in cities and establishing the so-called community gardens in cities are becoming increasingly popular. This is an opportunity to enhance public spaces and unused areas. Currently, the creation of community gardens responds to the lack of greenery in cities, the loss of public space at the expense of private spaces, the transformation of abandoned space, the creation of a more pleasant natural environment or the connection of the local community with urban agriculture. Grassy areas in residential areas, parks, abandoned land or even the roofs of buildings are an ideal place to establish them. Vegetables, fruits and herbs are grown here, as well as flowers and bushes. If enough space is available, trees are planted. Various dwellings and shelters for useful animals may be included.

Types of urban gardens:

- community gardens in public spaces and inner courtyards,
- gardens on the roofs of buildings,
- production gardens.

Picture 9: Community garden as a part of public greenery in Bratislava-Karlova Ves

Photo source: Municipality Bratislava-Karlova Ves

Mitigation impact of the measure: ++

Using good practices, urban agriculture can contribute to the reduction of greenhouse gas emissions directly through capturing (sequestration) and indirectly, by reducing transport distances for the transport of agricultural products or by reducing the use and production of pesticides and fertilizers.

In accordance with Table 1, the average sequestration of carbon in this type of functional use of territory is 23.7 kg C/m^2.

To more accurately determine the mitigation effect, a comprehensive analysis of the carbon footprint of a specific agricultural production (emissions related to agricultural production, fuels, energy and fertilizers, carbon stored in surface and underground biomass) would be needed. The same applies, though on a smaller scale, to private production or community gardens or other forms of urban gardening. Research shows that intensively cultivated European agricultural land is a net producer of greenhouse gas emissions (according to some sources, the agricultural sector accounts for one quarter of all greenhouse gases) and therefore does not contribute to carbon sequestration (Lugato et al. 2016).

Soil itself plays an important role in climate protection, since it can absorb and actively bind atmospheric carbon. Land use change, degradation processes and erosion often lead to release of soil organic carbon from the soil into the atmosphere, reducing so the capacity of soil to store CO_2.

Research has shown that approximately 86% of European agricultural areas demonstrated the loss of carbon (that means its transfer to the atmosphere) due to erosion (Pérez-Soba et al. 2018 : 44), with higher carbon losses linked with intensively cultivated systems (for instance vineyards or permanent crops).

Adaptation impact of the measure: +

Depending on the size of the community garden, as well as the form of planting, especially the proportion of fruit trees providing shading, the cooling effect of greenery is manifested. Community gardens often collect rainwater (for example from the roofs of surrounding buildings), which is then used for watering.

Along with the cultivation of food itself, which increases the food independence of the population, building and supporting the community is very important.

Impact of the measure on biodiversity: +

Contrary to the often-mowed lawns in residential areas, the urban garden with a diverse range of cultivated plants brings a revival of biodiversity, if chemicals are not used in cultivation. Pollinators can be deliberately attracted by a sound selection of flowering plants cultivated together in vegetable beds, which bloom step-by-step during the season from spring to autumn. It is recommended to prefer traditional undemanding varieties – tulips, snowdrops, lilies of the valley, primroses, phloxes, forget-me-nots, lupines, roses, oregano, thyme, wild-thyme, carnation, for sunny places also rock plants – rock roses, stonecrops, etc. A suitable combination with vegetables can prevent greater damage caused by pests.

Drinking fountains installed in the middle of gardens, which are regularly replenished with water, become in this city garden in the middle of the housing estate sought places for insects and birds, especially in summer.

Additional information for implementation of the measure:

- One of the possible obstacles is to find a suitable plot of land and to solve ownership issues, or to sign a long-term lease of land. Another obstacle in Slovakia is vandalism.
- There are already several positive examples abroad. The German city of Andernach today provides its inhabitants with an experience focused on changing the way of life in the city, from a classic urban model to a city with healthy food. A group of neighbours came up with the idea of growing fruit and vegetables in the urban parks in 2010, and began farming on 8,000 square meters of orchards and about 13 hectares of municipal lands, where the state administration cultivates vegetables which the inhabitants of Andernach can pick up for their own consumption from public greenery.
- The "Incredible edible" movement originated in the British town of Todmorden. Thanks to "guerrilla" gardening in public spaces in the framework of the "Incredible edible", up to 57% of the population have started to cultivate their own food and their goal is to become an independent town in the cultivation of food. The "Incredible edible" movement subsequently spread to other European countries.

Additional sources of information (links):

Incredible Edible Network initiative. Available at: <https://www.incredibleedible.org.uk/>.

Jedlé mesto: mestské záhradníctvo na zelených plochách Andernachu. Available at: <https://richtiggut.bauhaus.info/garten-freizeit/beet-balkon/andernach-essbare-stadt-urban-gardening>.

Gerber, P. J., et al. 2013: Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

Lugato, E., et al. 2016: Quantifying the erosion effect on current carbon budget of European agricultural soils at high spatial resolution. In Global Change Biology, 22(5), s. 1976 – 1984. 2016.

Pérez-Soba, M., et al. 2018: D2.3: Report on patterns and trends of Public Goods/Ecosystem Services in relation to land management systems, PEGASUS: Public Ecosystem Goods and Services from land management – Unlocking the Synergies, European Commission.

10 Building green roofs

Green roofs are an effective adaptation-mitigation measure in an intensively urbanised environment with lack of vacant areas. Green roofs can be built on buildings with a flat but also with a sloping roof.

Based on the species composition and related parameters (for example thickness of substrate), green roofs are divided into intensive and extensive ones. Intensive green roofs have most of the area covered with low to medium-high vegetation (most often various types of grasses, perennials or smaller bushes), under which there is a substrate thick a few tens of centimetres and insulating layers. In order to maintain prosperous conditions for roof vegetation, regular maintenance and regular watering are required according to the needs and selected species of vegetation. Extensive green roof is usually almost maintenance-free (maintenance needed 3-4 times per year) as it is covered with undemanding plant species (e. g. mosses, stonecrops, succulents, grasses and herbs) with a substrate thickness from cca 8 up to 20 – 25 cm and insulating layers.

Mitigation impact of the measure: +

Green roofs contribute to mitigating climate change and reducing greenhouse gas emissions in two ways. The first one is the absorption of carbon by roof vegetation itself, which uses it as a source during its own growth and binds it in its own body. Another way is to improve the thermal insulation parameters of the building roof and to prevent excessive overheating of the building during the summer heat waves, or its cooling. Thanks to the increased insulation, active machine cooling is not required to ensure thermal comfort in the building (for example by very widespread, but from the point of view of mitigation unfavourable, air-conditioning devices), which reduces the energy consumption to cool the interior.

Picture 10: Even on the extensive green roof, it is possible to combine stonecrops with undemanding rock perennials and grasses.

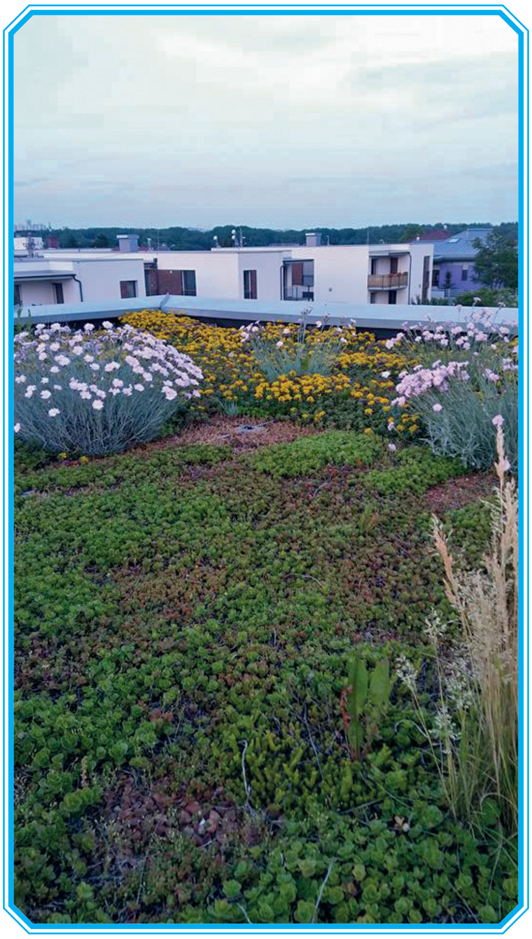

Photo by Zuzana Hudeková

A specific mitigation benefit will depend on the type of building on which the green roof is located, the location of the building itself, its cardinal direction and the method of heating. The effect of this measure must be assessed together with other measures implemented on the building, which also contribute to the reduction of greenhouse gas emissions. In general, the following gross mitigation benefit applies to new biomass on the green roof: 1 ton of new biomass = 3.67 tons of absorbed CO_2. In order to better thermally insulate the building through the green roof, the remarks on fuel savings for heating given in measure 17 apply. If the building is of a lower energy standard and heated by fossil fuels, the benefit will be higher than for an existing low-energy building. Published research shows that green roofs increase the thermal insulation of the roof system through shading, increased insulation and evapotranspiration, thus reducing the energy demand of the 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.

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

Adaptation impact of the measure: ++

Green roofs have a significant effect to prevent the overheating of the building during summer heat waves. Thanks to the shading effect of vegetation and additional insulation (soil substrate and technical insulation layers), they are able to maintain the building's inner temperature during sunny summer days up to several °C colder than in a comparable building with a traditional roof. Through the evaporation from the roof vegetation, they also contribute slightly to the cooling of their surroundings. Another adaptation effect of green roofs is to retain and slow down the runoff of rainwater, thus helping rainwater management in a city and reducing the risk of local floods. 1 m^2 of extensive green roof with a substrate thickness of 25 cm can catch about 137 litres of rainwater (which is a comparable amount of water in a bathtub). Maximum runoff coefficient of vegetation roofs is by 85 to 90% lower than in case of the impermeable surface. However, the intensity of the adaptation effect of vegetation roofs varies significantly depending on the type and implementation of the measure itself.

Impact of the measure on biodiversity: +

Green roofs provide a refuge and living space for many animals in a highly urbanised environment. Impact on biodiversity depends on the type of implementation of the green roof. Extensive green roofs with little species diversity and mostly low vegetation provide shelter mainly to invertebrates. Intensive green roofs with more diverse and richer vegetation provide space for life, food or relaxation to a wider range of animals, including birds, pollinators, etc. To increase the biodiversity effect, it is possible to add to the green roof a small water element to feed birds in times of drought, or various pieces of wood and plant material that serve as a refuge for insects and other invertebrates. In times of drought, it is necessary to add water to water pots.

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

To support biodiversity it is recommended:

- To preserve diversity (diversification of plant species and layers), that means to plant different species with different height. To prefer domestic species, in some cases it is possible to "transfer" a part of the flowering meadow onto the roof.
- If technically possible, to use a substrate with a thickness of more than 20 cm, if this is not possible at least 8 to 10 cm. It is recommended to use a local substrate with a quality close to natural soil (preferably local soil).
- To use elements supporting the biodiversity (rocks, dead wood, possibly a water element, or shelters on the roof), a water pot for birds and insects.
- Do not use automatic irrigation, not only to save water, but also to support natural processes.

The study, which collected knowledge from 31 green roofs (Grooves – Green ROOfs Verified Ecosystem), identified 200 plant species, of which 70% grew spontaneously. Simultaneously, more than 300 species of fauna were identified, including 250 species of insects. From this point of view, green roofs can also serve as "biocorridors" for various species as they provide the necessary shelter, food and also the possibility of nesting and reproduction for birds as well as other animal species.

Additional information for implementation of the measure:

- The technical parameters of the building are the basic condition and limit for the selection of a suitable type of green roof. Intensive roofs are significantly more demanding on the sufficient bearing capacity and statics of the roof cladding and can be implemented mainly on roofs with a low slope. Extensive roofs usually do not require increased roof bearing capacity and can also be implemented on roofs with a higher slope.
- The surface of roofs is exposed to extreme temperatures during the summer heat waves, so it is necessary to consider a proper species composition of vegetation (especially for maintenance-free extensive roofs) or an effective irrigation system in case of intensive vegetation roofs.

Additional sources of information (links):

Hudeková, Z. 2016: Prírode blízka údržba mestskej zelene – príručka pre samosprávy. Bratislava: Živica, 2016. ISBN: 78-80-968989-7-8. Available at: <https://zivica.sk/kniznica/prirucka-prirode-blizka-udrzba-mestskej-zelene/>.

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Hill J, Drake J, Sleep, B. 2016: Comparisons of extensive green roof media in Southern Ontario. In Ecological Engineering 94, s. 418 – 426. 2016.

Príklad technológie na realizáciu vegetačných striech na strechách s vyšším sklonom. Available at: <https://www.optigreen.com/system-solutions/pitched-roof/15-45-cable/>.

Karpatský rozvojový inštitút. 2016: Katalóg adaptačných opatrení miest a obcí BSK na nepriaznivé dôsledky zmeny klímy. Available at: <http://www.kri.sk/web_object/761.pdf>.

11 Building green walls

The term of "green walls" means the walls of buildings covered by vertical greenery of different technical design and with different species composition. The main types (categories) of green walls include vegetation facades and so-called living walls.

Green facades are created by climbing plants growing directly on the wall surface or on a supporting overhanging structure. The roots of the plants are in the ground near the wall and the plant gradually grows on the surface of the wall in a bottom-up direction.

Living walls are a more complex system with a supporting structure, which includes vegetation rooted in containers (for example with soil or aqueous solution) mounted on a supporting structure or directly on the wall and irrigation system. The whole system is often solved in the form of modular panels.

Picture 11: An example of a green façade on a residential building

Photo by Zuzana Hudeková

Mitigation impact of the measure: +

The specific mitigation benefit will depend on the type and location of the building, the type of green wall and the existing energy intensity of the building. Climbing plants significantly reduce the temperature of the wall, not only depending on climate zone, but mainly on the area they cover. The temperature reduction is thus in the range of 10 – 30 °C. It has been calculated that reduction of the wall temperature by 5.5 °C will save 50% of the electricity needed to air-condition the building. If we take into account that 1/3 of the energy for heating in winter is consumed for walls cooled by winds, climbing plants (especially evergreen ones such as ivy) bring energy gains even in winter.

Adaptation impact of the measure: ++

The cladding of buildings is exposed to the weather and sunlight during the entire year, which leads to relatively large fluctuations of temperature on its surface. Overheating of the cladding can be effectively prevented by shading it by vertical vegetation, which also has a positive impact on thermal comfort in the interior. Moreover, this vegetation cools its surroundings as well as the building through evaporation. It is recommended to install green walls a few centimetres from the wall to ensure air circulation between the vegetation and the wall. In this case, the positive cooling effects are maintained (by shielding and cooling through plant evaporation), the wall structure is protected (against mechanical damage, dirt, acid rain, etc.) and the possible negative impact of the green wall on the building wall surface is minimized (for example by excessive humidity, damaging the structure by plant tendrils, etc.).

The intensity of its effect depends on selected type and installation of the green facade.

Impact of the measure on biodiversity: +

The flowers blooming on a green wall attract insects at the time of flowering and during the winter they can also overwinter in the wall in the substrate. So obviously this measure increases biodiversity in the urbanised environment.

Additional information for implementation of the measure:

- In case of green walls, it is recommended to build an irrigation system to provide the plants with enough water.
- The lower parts of the green wall can also be used as a form of city garden and it is possible to cultivate herbs or selected vegetables on it.

Additional sources of information (links):

Yeh, Y. P. 2012: Green Wall – The Creative Solution in Response to the Urban Heat Island Effect. National Chung-Hsing University.

Basdogan, G. – Cig, A. 2016: Ecological-social-economical impacts of vertical gardens in the sustainable city model. Available at: <https://www.researchgate.net/publication/316505048_Ecological-social-economical_impacts_of_vertical_gardens_in_the_sustainable_city_model>.

12 Support of nature-based measures to capture and absorb rainwater

In an intensively urbanised environment, it is appropriate to support the creation of new water areas with elements of greenery. Such areas also include nature-based measures for the capture and infiltration of rainwater.

Collecting ponds and other retention bodies – little lakes and other small water bodies in the residential environment help to create an attractive environment for people in direct contact with water. Particularly advantageous are those water elements which use the captured rainwater, or water bodies, which also serve to capture rainwater or serve to temporarily catch extreme precipitation. An example can be Nový Lískovec lake in the city of Brno (Czech Republic), where rainwater is concentrated from the roofs of three apartment buildings (blocks of flats).

Terrain modelling with the aim to capture and slow down rainwater – these can be implemented in lawn areas in public greenery. It is extremely important to allow soaking from the paved area to the green area. At present, frequent obstacles are e. g. curbs, incorrect sloping of the paved surface, or the area of greenery is at a higher level than the paved area, which leads to the clogging and washing of parts of the soil on pavement or road, as the dried and compacted soil (to which we also contribute by intensive mowing of the lawn in the summer months) does not have a sufficient ability to capture rainwater.

Mitigation impact of the measure: +

Reduced demands on wastewater treatment, which lead to reduced energy consumption and related CO_2 emissions. Wastewater treatment generates greenhouse gas emissions mainly due to organic pollution and the release of methane into the atmosphere. This gas is 28 times stronger greenhouse gas than carbon dioxide. An indicative emission factor (converted to CO_2 equivalents) of 0.815 kg CO_2 e/m^3 applies to wastewater. Therefore, if we prevent the outflow of for example 100 m^3 of rainwater and its mixing with wastewater, mitigation benefit will be 81.5 kg CO_2e.

Picture 12: An example of terrain depression for capturing rainwater (Campus of University of Economics in Vienna)

Photo source: IEPD

According to the European Commission's Synthesis Report (Nature-based Solutions for Climate Mitigation. Analysis of EU-funded projects), the average mitigation benefit of "green areas for water management" is 12.5 kg CO_2/m^2. Additional information can be found in Table 1: Relative contribution of nature-based solutions (NBS) from the point of view of different types of land use in cities.

Adaptation impact of the measure: ++

During heavy rainfall, they capture part of the water and fulfil a role of storage tanks slowing down the outflow of water from the area. Subsequently, the captured water can be gradually soaked into the soil or kept in place and cooling so its surroundings by evaporation as well as directly from the water surface, thus helping to maintain a pleasant microclimate.

Sustainable management of rainwater in the form of nature-based measures to capture and soak rainwater reduces the risk of floods (their frequency as well as the extent of damage). It also contributes to drought prevention by helping to soak into lower layers of the soil, thus replenishing groundwater supplies.

Impact of the measure on biodiversity: +

Small rainwater surfaces and lakes, which temporarily accumulate water after rain, attract insects, frogs, reptiles, because they are a source of moisture and prey (insects for reptiles). If perennials of different species are planted in these rain lakes, this also increases the biodiversity of plants.

Additional information for implementation of the measure:

- The primary precondition for soaking is the determination of the infiltration coefficient, which characterises the infiltration capacity of the soil and rock environment of the investigated locality and is used in the calculations when designing the infiltration device.
- In case of rain gardens, a constant water level should not occur; rainwater, in case of correct design, shall soak within 48 hours.
- Another positive aspect of nature-based solutions is the improvement of the quality of groundwater, which is filtered through individual layers and harmful substances and pollution are removed in this way.

Additional sources of information (links):

Oborová norma TNV 75 9011 Hospodaření se srážkovými vodami.
Available at: <http://eagri.cz/public/web/file/209372/TNV_75_9011__brezen_2013.pdf>.

CEEV Živica. 2020: Klíma nás spája: Čo je to dažďová záhrada?
Available at: <https://www.klimaspaja.sk/co-je-to-dazdova-zahrada/>.

EC (European Commission). 2020: Nature-based Solutions for Climate Mitigation. Analysis of EU-funded projects.
Available at: <https://op.europa.eu/en/publication-detail/-/publication/6dd4d571-cafe-11ea-adf7-01aa75ed71a1>.

13 Use of permeable surfaces in public spaces

The measure consists in reducing the area of impermeable surfaces and building permeable surfaces wherever it is technologically and legislatively possible. The measure can be implemented by reconstructing existing impermeable surfaces to (semi)permeable, or by using (semi)permeable materials in the construction of new surfaces. In order to ensure the protection of soil and groundwater quality, it is appropriate in areas with a risk of harmful substances (e. g. parking lots) to supplement the measure with technologies for capturing and binding potential harmful substances through mechanical filtration or filtration with absorbent material (e. g. oil traps, oil separators, etc.). Suitable permeable surfaces in an urbanised environment include, for example:

- permeable concrete / asphalt,
- (semi)vegetation blocks,
- threshing surface,
- interlocking paving,
- special surfaces (resin-bonded systems).

Mitigation impact of the measure: +

The mitigation benefit of the measure is rather indirect and with less impact, but still positive. By reducing the surface runoff, the amount of drained rainwater will be reduced and less water will have to be treated, transported, cleaned, which results in savings of energy and resources. This especially applies when there is no separate sewerage networks for wastewater and rainwater in the city. Wastewater treatment generates greenhouse gas emissions mainly due to organic pollution and the release of methane into the atmosphere. This gas is 28 times stronger greenhouse gas than carbon dioxide. An indicative emission factor (calculated to CO_2 equivalents) of 0.815 kg CO_2e/m^3 applies to wastewater. Therefore, if we prevent the outflow e. g. 100 m^3 of rainwater and its mixing with wastewater, mitigation benefit will be 81.5 kg CO_2e.

A significant aspect of this measure is the carbon footprint, i. e. emissions associated with the production of for example grass tiles. It is advisable to prefer materials with a lower carbon footprint during production.

Adaptation impact of the measure: ++

Impermeable surfaces are a physical barrier to the infiltration of rainwater in urban environment, which can cause local floods and problems in drainage and sewerage systems in case of heavy rains. Increasing the proportion of permeable surfaces will contribute to the soaking of part of the rainwater at the place of rain and will reduce the volume of rapidly drained water and reduce any flood wave. Simultaneously, this reduces the load on sewerage network and wastewater treatment plants, which contributes to increasing effectiveness of water management in settlements.

Increasing the saturation of the soil with rainwater increases the short-term resilience of the territory to possible periods of drought, which may follow a period of intense precipitation, and through evaporation from the soil contributes to improving the microclimate in the area.

Impact of the measures on biodiversity: +

The measure has a positive impact on biodiversity, because rainwater captured among tiles and in a permeable surface provides conditions for soil animals to hide here. Such humid places are an attractive habitat for frogs and reptiles.

Additional information for implementation of the measure:

- When drafting the drainage or using the permeable surface of roads and car parking lots, it is necessary to know the degree of water pollution soaking through the surface and the degree of risk of accidental leakage of hazardous substances. The conditions for quality of water for soaking are regulated by e. g. Regulation of the Slovak Government 269/2010.
- To ensure systematic implementation of the measure, it is recommended that local authorities incorporate a coefficient of maximum impermeability of areas (ecoindex) into the regulations of spatial plans.

Picture 13: An example of the use of a permeable threshing surface in park greenery – an example from eco-district Boulogne Billancourt in France

Photo by Zuzana Hudeková

Additional sources of information (links):

Kováč, B. 2009: Regulácia na lokálnej úrovni.
Available at: <http://www.uzemneplany.sk/clanok/regulacia-na-lokalnej-urovni>.

Hudeková, Z. et al. 2012: Ekoindex: Stanovenie regulatívu pre metodiku spracovania ÚPD so zameraním na zadržiavanie dažďových vôd v urbanizovanom prostredí.
Available at: <http://recbratislava.sk/wp-content/uploads/2017/11/Eko_index.pdf>.

MDaV SR. 2019: Technické podmienky nakladania s dažďovými vodami odvádzanými z pozemných komunikácii a parkovísk.
Available at: <https://www.ssc.sk/files/documents/technicke-predpisy/tp/tp_112_2019.pdf>.

Institut plánování a rozvoje hlavního města Prahy. 2013: Manuál tvorby veřejných prostranství v Praze – D.1 materiály a povrchy.
Available at: <https://www.iprpraha.cz/uploads/assets/manual_tvorby_verejnych_prostranstvi/pdf/D.1.pdf>.

Mesto Benešov. 2016: Manuál městských povrchů pro město Benešov.
Available at: <https://www.benesov-city.cz/assets/File.ashx?id_org=219&id_dokumenty=49486>.

14 Construction of technical elements for infiltration and retention of rainwater from paved surfaces

Infiltration and retention areas are especially used in space-limited places (for example in case of rainwater infiltration on roads or in heavily urbanised environment).

Surface infiltration devices are shallow surface infiltration devices with grass or humus layer with vegetation. The infiltration channel is an excavated linear infiltration device filled with a permeable gravel material, with retention and soakage into more permeable soil and rock layers. The infiltration tank is a structure with a significant retention function together with infiltration through a grassed or humus layer with vegetation.

If infiltration is not possible in a given location, it is possible to use detention tanks, which in the urbanised environment can have the form of so-called water plazas.

The main goal of "water plazas" is to control intense storm activity, especially during extreme rainfall, and to protect so the surrounding infrastructure and buildings against local surface floods. Outside this period, "water plazas" can fulfil a social, gathering, recreational or sporting function similar to any other public space.

Picture 14: Use of infiltration channels in a residential area – an example from eco-district in Bottière-Chénaie in Nantes (France)

Photo by Zuzana Hudeková

Mitigation impact of the measure: +

The mitigation benefit is similar to measure 13 – reducing the surface runoff will reduce the amount of rainwater drained by the sewerage system. As a result, less amounts of this rainwater will have to be transported, modified and treated, saving energy and resources in this way. Attention must be paid to technical design and carbon footprint of the materials and equipment used.

Adaptation impact of the measure: +

Sustainable management of rainwater in the form of the construction of technical elements to retain and soak rainwater reduces the risk of floods (their frequency as well as the extent of damage). It also contributes to drought prevention by helping the soakage into the lower layers of the soil and replenishing groundwater supplies.

Impact of the measure on biodiversity: +

The measure has a positive impact on biodiversity, as rainwater captured among the tiles and along the grassy infiltration devices provides conditions for soil animals to hide in such an environment. Such moist places also attract frogs and reptiles.

In case of underground infiltration (infiltration blocks, shafts, etc.), there is only an indirect effect on biodiversity in the form of supplying the soil profile with infiltrated rainwater.

Additional information for implementation of the measure:

- The primary precondition for infiltration is the determination of the infiltration coefficient, which characterises the infiltration capacity of soil and rock environment of the investigated location and which is used in the calculations when designing the infiltration device.
- An example of detention can be the Water Plaza in Rotterdam. The Water Plaza in Rotterdam could be divided into two main parts: a part for sports and a playfield with a terrain modelling, which are simultaneously retention tanks. The sports ground is located 1 m below the terrain and access to it is possible through stairs, which can also serve as a possible point of view for spectators, watching sports matches taking place here. The playground with field modelling provides space for a picnic and various games for children. During intense rains, when an extreme amount of precipitation falls, the individual parts of the "water square" will gradually be filled with water. In total, the square is designed to hold 1000 m3 of rainwater. In the rainy season, streams will form here, as well as small islands and other nooks that can entice children to play with water. The volume of rainwater can be left here until the threat of local floods subsides. Then the accumulated rainwater is gradually discharged into the nearest water recipient.

Additional sources of information (links):

Regionálne ekologické centrum Bratislava. 2018: Keď neprší, ale leje – dôsledky zmeny klímy.
Available at: <http://recbratislava.sk/ked-neprsi-ale-leje-dosledky-zmeny-klimy/>.

MDaV SR. 2019: Technické podmienky nakladania s dažďovými vodami odvádzanými z pozemných komunikácii a parkovísk.
Available at: <https://www.ssc.sk/files/documents/technicke-predpisy/tp/tp_112_2019.pdf>.

SUSDrain: Flood risk management benefits.
Available at: <https://www.susdrain.org/delivering-suds/using-suds/benefits-of-suds/flood-risk-management.html>.

ČSN 75 9010 Vsakovací zařízení srážkových vod

Oborová norma TNV 75 9011 Hospodaření se srážkovými vodami.
Available at: <http://eagri.cz/public/web/file/209372/TNV_75_9011__brezen_2013.pdf>.

Vítek J. et al. 2018: Hospodaření se srážkovými vodami – cesta k modrozelené infrastruktuře. Olomouc: 2018.

15 Use of principles of sustainable architecture from the climate change point of view

A sustainable architecture from the point of view of climate change is one that has minimal negative impact on the environment. An effective tool to reduce the negative impact of buildings and their emission balance is first of all a conceptual proposal as early as in the design phase to minimise energy consumption of operation, especially the need for energy for heating, cooling and ventilation, hot water, energy consumption for lighting, but also water consumption, etc. When designing sustainable buildings, it is necessary to use the principles of integrated design. The shape of the building and its orientation, the use of suitable construction materials with the required technical parameters, location and size of transparent constructions, use of rainwater or grey water, smart planting of trees around the building to create shading, have a major impact on energy efficiency of the building and thermal comfort in the interior during entire year.

Great impact on the immediate surroundings of the building or group of buildings is made by the chosen source of heat and hot water (heat exchange station, gas boiler or heat pump), but especially by the energy carrier (natural gas, other fossil fuels, wooden chips or biomass or ambient energy used by heat pumps or solar energy in the form of solar thermal panels or photovoltaic panels).

Mitigation impact of the measure: +++

This measure combines several measures, which are described separately in this publication, so here you can find only a brief list of the most important ones:

- choice of materials and method of their transport to the construction site,
- conceptual solutions and layout of buildings,
- thermal insulation of buildings,
- use of highly reflective surfaces of buildings and surrounding public spaces,
- use of solar gains in buildings,
- use of radiant heat and cold from external walls,
- heat recovery from exhaust air,
- greening of the roof,

Picture 15: Residential building with elements of sustainable architecture
(Home for the elderly in a passive standard, Modřice pri Brne, Czech Republic)

Photo source: IEPD

- controlled ventilation with heat and cold recovery,
- heat and cold storage,
- shading of glazed surfaces of buildings,
- use of grey water,
- use of natural and recycled materials for the construction of buildings,
- use of flexible construction systems,
- use of materials and structures with a long service life.

Adaptation impact of the measure: +++

Because of growth of outdoor temperatures, it will be necessary to implement several measures at the level of buildings in terms of principles of sustainable architecture, so as to ensure effective shading, especially of south- and west-facing transparent structures, windows and doors in order to reduce overheating of the interior. In case of unfavourable shape, historical buildings protected by law, buildings in rows, it will be necessary to correct the quality of the indoor environment with the use of technical equipment (e. g. cooling devices, see measure 26), where it is possible to reduce the potential adverse mitigation effect by installing renewable energy sources (RES), e. g. photovoltaic panels. Increasing temperatures will bring a greater amount of intense precipitation and therefore the creation of surfaces with the possibility of water soaking will contribute to minimising the damage caused by floods and to improving the microclimatic conditions in the area.

Impact of the measure on biodiversity: +

A well-planned building that takes into account the animals and plants around it can increase biodiversity in the wider area. For example, incorporating shelters for pacific swifts on apartment buildings, or a vegetation wall, need not be expensive solutions that will revive architecture. Such a "green" building does not have to be a barrier to the movement of animals, but rather act as a stepping stone for animals passing through the urban environment.

Additional information for implementation of the measure:

- In the implementation of the proposed measures for existing buildings there is a frequent problem of incorrect technological process in implementation of the measures. In case of new buildings, the main obstacle is insufficient information of experts and residents, as well as insufficient support from the state administration.

Additional sources of information (links):

Keppl, J. et al. 2013: Rukoväť udržateľnej architektúry. Selce: Vydavateľstvo tlačovín Slovenskej komory architektov, 2013. 168 s. ISBN 978-80-971205-1-1. Available at: <https://www.fa.stuba.sk/ueea-na-stiahnutie.html?page_id=1749>.

Pavelčík, P.; Klápště, P.; Lupač, M.; Třebický, V. 2019: Města a sídelní krajina ČR v době změny klimatu. Stručný přehled problematiky pro představitele veřejné správy. Rudná: CI2, o. p. s., 32 s. Available at: <https://ci2.co.cz/sites/default/files/souboryredakce/brozura_mesta_a_sidelni_krajina_cr_a_zk_0.pdf>.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

Karpatský rozvojový inštitút. 2016: Katalóg adaptačných opatrení miest a obcí BSK na nepriaznivé dôsledky zmeny klímy. Available at: <http://www.kri.sk/web_object/761.pdf>.

16 Selection and use of construction materials

When choosing construction materials, it is important to take into account their impact in terms of mitigation and adaptation. For both new and renovated buildings, from 1 January 2021, it is required in the Slovak Republic to achieve the standard of buildings with almost zero energy demand, which is based on the European directive on energy performance of buildings which has been reflected in several regulations and standards in Slovakia. When designing structures and buildings, it is necessary to respect the current (2020) thermal-technical standard e. g. in Slovakia STN 73 0540, which defines the criteria of minimum thermal insulation properties of the building structure (values of the heat transfer coefficient of the structure – U), i. e. external walls of buildings, roofs, floors above unheated space. A building structure can therefore consist of a single-layer or multi-layer structure, if it meets the requirements defined by the standard and the relevant regulations for achieving the energy class of the building during certification. Various types of building materials have different accumulation capacity and thermal phase transition.

Picture 16: Ludesch Community Centre (Austria) in a passive energy standard and with a facade made of wood obtained from the surrounding forests

Photo source: IEPD

Mitigation impact of the measure: +/–

Contrary to other measures listed in this catalogue, the carbon footprint associated with the production of materials plays a key role in the selection and use of building materials. There are currently many sources of information where this information can be obtained (see additional sources of information). The production of some materials has a significant negative impact, especially if they are produced from primary and energy-intensive raw materials – e. g. aluminium, steel, but also concrete. For other, nature-based materials, such as wood or bamboo, the overall carbon balance may even be positive (due to the absorption of carbon during the growth of the tree or crop). Similarly, it is advantageous to use recycled materials.

The choice of materials, the method of construction or reconstruction fundamentally affect the mitigation aspects of the operation of the building. In the EU, buildings account for around 40% of energy consumption and 36% of greenhouse gas emissions. Buildings are also a significant source of emissions (carbon bound in building materials and energy used to erect buildings). The construction of new buildings with almost zero energy consumption and passive buildings can make a significant contribution to climate change mitigation by saving a large part of the CO_2 emissions associated with conventionally designed buildings.

At present, about 3/4 of European buildings are considered inefficient, with only 0.4 – 1.2% (depending on the country) of the building stock being renewed annually in order to increase energy efficiency. The EU taxonomy for sustainable financing (EC 2020) aims at achieving savings in "major renovations" in line with the requirements of the Directive on energy performance of buildings – in partial renovations to achieve a 30% reduction in primary energy consumption compared to the energy performance of buildings before renovation.

Adaptation impact of the measure: ++

Under the conditions of complying with the required parameters, technological procedures and regular maintenance, the construction material itself has a fundamental impact on the quality of the indoor environment, especially in terms of thermal stability, but also from the point of view of protection against the effects of other phenomena such as rain, storms, etc. Strict compliance with the current strong building requirements is therefore a key factor in terms of adaptation.

The use of massive building structures, due to better accumulation capacity, contributes to the stabilisation and maintenance of thermal comfort in the building both in winter and summer. When using a ventilation system with heat recovery and night ventilation, it is possible in most residential buildings to maintain the required quality of the indoor environment even without air conditioning equipment.

Impact of the measure on biodiversity: +

The measure may also have a partly impact on biodiversity, for example facades created with the aim of gradual colonisation of various species, such as the so-called living facade on the building of a grammar school focused on natural sciences and biodiversity in Paris eco-district Boulogne Billancourt.

Additional information for implementation of the measure:

- Low building culture is a common problem in the construction and renovation of buildings. Failure to comply with technological procedures, inconsistent elimination of thermal bridges, but also poor quality of building materials, can cause premature degradation of building structures and deterioration of the building. Another determinant is insufficient maintenance and renewal of building structures (the renewal of privately owned apartment buildings is decided by the community of owners with limited information as well as financial possibilities).

Additional sources of information (links):

EC (European Commission). 2020: Sustainable finance: TEG final report on the EU taxonomy.
Available at: <https://ec.europa.eu/knowledge4policy/publication/sustainable-finance-teg-final-report-eu-taxonomy_en>.

ČVUT: Envimat – katalog stavebních produktů a dopadů jejich výroby na životní prostředí.
Available at: <http://www.envimat.cz>.

17 Increasing the thermal protection of building structures

Renovation of apartment buildings and increasing their energy efficiency is, in addition to the construction of new apartment buildings and residential areas, one of the most important tasks that local self-governments must address in cooperation with apartment building owners.

In order to improve the energy efficiency of existing buildings, it is necessary to carry out several building modifications and measures, simultaneously with the use of modern technologies, such as ventilation system with heat recovery or the use of renewable energy sources. The most important measures include thermal insulation of the external and roof, if possible also insulation of floors in contact with the terrain, using thermal insulation materials with consistent elimination of thermal bridges. The elimination of thermal bridges is one of the most important measures in the design of structures or when restoring and insulating buildings. The thermal bridge is a place in the cladding structure of a building, where significantly more heat leaks than through other parts. In a well-insulated building, such leaks can form a significant part of heat losses and the surroundings of a thermal bridge can be cooled to such an extent that water vapour condenses there. It depends on the expertise of a designer and the implementation company, how they can solve these weak points of the construction in mutual cooperation (that is also why it is necessary for the architect to monitor his work from the first draft to the final approval). Typical examples of thermal bridges are the joints of walls with foundations, the balcony cantilever, the installation of windows and window frames, the transitions of cables through structures and corners of rooms.

Compliance with stricter requirements on thermal protection requires to design a greater thickness of thermal insulation layer when insulating buildings, which affects the design and construction of building insulation from the point of view of fire safety.

Picture 17: Increasing thermal insulation of external cladding of an apartment building (P. Horova street, Bratislava, Slovakia)

Photo source: IEPD

Mitigation impact of the measure: +++

The construction industry, buildings and heating energy consumption contribute significantly to greenhouse gas emissions (estimated at 36% of global greenhouse gas emissions). The insulation of the external walls of building therefore has a significant positive mitigation effect, especially on the energy consumption for heating. The second benefit is the reduction of the absorption of solar radiation by external walls of building during the summer months (reduction of energy consumption for air conditioning). Specific mitigation benefits will depend on the current energy consumption, energy consumption after the implementation of the measure in the building and especially from the energy source for heating. For energy sources with a higher proportion of carbon (e. g. coal, heating oils but also natural gas), the absolute mitigation benefit will be higher than for example in case of biomass or heat pump. The insulation material used is also an important aspect – higher carbon generation during the production (e. g. mineral wool) reduces the overall mitigation benefit.

The application of thermal insulation material depends on the shape of the building (e. g. the structure of the building, loggias, balconies, windows, doors, etc.). At the same time, it is possible to use a large amount of thermal insulation materials (insulation thickness 15 – 30 cm). However, the total wall thickness and insulation should not exceed 60 cm, so it is advisable to use highly effective thin insulation on older houses. Recommended value of the heat transfer coefficient is min. 0.15 W/m^2K (for passive houses). Uninsulated or insufficiently insulated external walls of building usually has a value of 0.5 – 1.5 W/m^2K. If the building reaches the recommended value, it is not necessary (or effective) to implement these measures from the point of view of reducing greenhouse gas emissions.

Adaptation impact of the measure: ++

Insulation of the external walls of building, especially the roof constructions, reduces the heat transfer through the structures and contributes to a more stable temperature inside the building even in summer. When designing the thermal insulation, whether in the form of a ventilated facade or a contact thermal insulation system, the use of vegetation roofs for the roof, it is important to comply with the required values specified in the thermal technical standard STN EN 73 0540, taking into account the relevant structure and building category. At present, the thickness of thermal insulation during reconstructions usually does not exceed 80 mm (regardless the type of thermal insulation material used). The recommended thickness for buildings with almost zero energy demand is 200 mm of thermal insulation, with a thermal conductivity coefficient lambda of 0.04 W/m^2K, the roof cladding requires as minimum 300 mm thermal insulation. With such thicknesses of thermal insulation materials, it is possible to improve the temperature stability in the interior of the building during the entire year.

Impact of the measure on biodiversity: –

Insulation of the external walls of building has a negative impact on biodiversity if there are nests of species of animals protected by law in the façade (in the joints between the panels) before the insulation – pacific swifts and bats. Hundreds of such active nests with nestlings or their parents are destroyed in Slovakia every year during thermal insulation (they are immured alive), violating so the Nature Protection Act. Therefore, before insulation, it is necessary to make a thorough inspection of the facade and joints by experts and adjust the insulation work so that these openings are closed only when the nestlings of pacific swifts fly out (early August), in case of bats it is necessary to provide an opening in autumn. Then it is necessary to install booths for bats and pacific swifts on the same sides of the building as the original nests before installation of insulation on the facade (e. g. https://www.bat-man.sk/Budky-na-budovy-c11_0_1.htm) to create shelters for them. If this is possible (e. g. with attic openings under the roof), these must be left without a grid so that pacific swifts can use them again even after installation.

There can be another negative effect of insulation on common house martins, which make their nests just under the roof of apartment buildings, where the roof protrudes. After insulation, this edge is eliminated and common house martins can no longer make nests there. They then make them in the corners of the windows, as the space in the corner increases after insulation. However, people do not like it, as birds make their windows dirty, and so they demolish their nests. In doing so, they also violate the Act on nature protection, and prevent common house martins from nesting, thus reducing biodiversity in the residential area.

This could be avoided if the needs of nesting were already taken into account when designing the roof and insulation, and the roof was designed with an edge under which a nest could be placed after insulation (up to 10 cm from the edge of the wall).

Additional information for implementation of the measure:

- Based on 30 years of experience with the implementation of thermal insulation, the most common problems include, for example, incorrect technological procedure, which can bring gradual degradation of thermal insulation material used, failure to address the thermal bridges brings mould on internal surfaces due to condensation of air humidity at low temperatures (occurring at surface temperature of about 16 °C in place where there is insufficient thickness or insulation or no insulation).
- When choosing construction and insulation materials, it is recommended to take into account the life cycle of products and their carbon footprint.

Additional sources of information (links):

ČSN 73 0540-2 (730540): Tepelná ochrana budov.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec.
Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

18 Shading of transparent parts of buildings by technical elements

During the summers, the interior of buildings receives up to 40% of heat through transparent parts of the external cladding (e. g. windows, glazed walls, light wells, glazed interspaces). In order to reduce unwanted overheating and to increase thermal comfort in the interior, it is appropriate to prevent the passage of sunlight through transparent constructions with various technical elements. To prevent the interior from overheating, it is recommended to install mainly exterior technical elements, such as:

- exterior blinds and window shades,
- pergolas,
- sunblinds,
- specially modified glasses and shielding foils,
- window shutters,
- architectural solution of the building composition (e. g. balconies, loggias, where the balcony board overlaps over transparent structures, a roof with an overlap that provides shading in the summer months, etc.), applying especially to new buildings.

Picture 18: Shading of windows by a solid structure in Manchester

Photo by Michal Schvalb and Ladislav Hegyi

Mitigation impact of the measure: ++

The mitigation benefit should be based on an assessment of the temperature stability in the room during the summer. There is a requirement for a maximum rise in indoor air temperature in the residential buildings (according to STN 73540 standard) up to 28 °C as maximum. An important aspect is whether the building uses an active cooling system with air conditioning. This increases energy consumption (also possible refrigerant-HFC leaks) and has a negative mitigation effect. External shading will then have a greater benefit in reducing greenhouse gas emissions than in buildings without air conditioning or with a passive cooling system.

A man is a very important element in terms of this measure. For passive shading elements, the key element is the person who manipulates them. If good practice is not followed, the mitigation benefit is easily zeroised. Active shading elements are automatically controlled and regulate the shading of sunlight depending on the preset values and the current weather. After taking into account the impact of the use, the real efficiency of heat load reduction is in the range of 50 – 80%. The market provides a large number of solutions with various ways of installation (directly on the facade of the building, hidden within the thermal insulation system, etc.). Shading elements should be applied especially on the south and west facades of the building.

Internal shading elements are not recommended because they achieve very low shading efficiency (5 – 25%) – Malý et al., 2019.

Adaptation impact of the measure: ++

Shading of windows, glazed facades and external entrances is a basic measure to adapt to heat waves, which can be applied with immediate results even when renovating existing buildings. Interior shading is significantly less effective in reducing interior overheating than building exterior shading. Shading can be solved with blinds, shutters, shades and sunblinds. The aim of the shading is permanent protection against sunlight, while this protection can be easily operated manually or automatically as required.

Impact of the measure on biodiversity: +

The measure has a positive impact on biodiversity, because collisions of birds and insects with the glass are eliminated by shading the glass openings with these elements. Birds avoid these glass openings and are not injured or killed by impact with the glass.

Additional information for implementation of the measure:

- Financial aspects can be problematic, varying according to the type of shading as well as the method of control – the manual version is less expensive, but more laborious to operate.
- The current Slovak legislation in the area of energy efficiency of buildings does not deal with cooling of residential buildings, so designers do not address the need for cooling which results in insufficiently protected buildings against summer overheating and increasing requirements for installation of air conditioners that contribute to CO_2 emissions.

Additional sources of information (links):

ČSN 73 0540-2 (730540): Tepelná ochrana budov.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

19 Use of reflective surfaces in buildings and public spaces

Different types of materials used for roofs and facades of buildings, as well as paved surfaces of public spaces, have different heat gains from solar radiation. The ability of a surface to reflect solar radiation with a small increase of temperature (i. e. reflectivity and infrared emission at the same time) is expressed by the SRI (solar reflectance index). This is the ability of the material to resist solar thermal radiation manifested by slow growth of material temperature. Simply said, reflective surfaces of bright colours have a higher SRI coefficient (and accumulate less heat) and low-reflective dark-coloured surfaces have a lower SRI coefficient (and accumulate more heat). If it is not possible to apply a bright colour (e. g. due to monument protection by law), it is possible to use a material with suitable physical properties ensuring high reflectivity of sunlight.

Mitigation impact of the measure: +

The mitigation benefit is positive and similar to the measure 18, but less intense. Implementation of the measure contributes to the reduction of overheating of the building interior during summer months. Various types of building surfaces (facades, roofs) have various heat gains from solar radiation. Some studies have shown that the differences in surface temperature between black and white roofs can range from 30 – 40 °C in summer. Surfaces with high reflectivity can have a positive effect on the ambient temperature and lead to cooling of buildings. On the contrary, low-reflective surfaces absorb, store and gradually release significantly more heat.

Higher reflectivity of the roof and increase of the mitigation benefit can be achieved by using reflective coatings on the roof during reconstructions, or by using bright gravel on flat roofs. Coatings not only increase the reflectivity, but also increase the life of the roof and act as waterproofing (liquid silver foils). It is optimal to apply the coating as part of a complex renovation – cleaning the surfaces, undercoating of all parts of the surface and after perfect drying to perform the final reflective coating.

Picture 19: The use of bright paving and building facades to reduce overheating of materials and the environment is common in subtropical and tropical countries – an example of Dubai

Photo by Pavol Stano

Adaptation impact of the measure: ++

Roofs and facades of buildings, as well as paved surfaces in public spaces (e. g. pavements, parking lots) with a high SRI coefficient (high reflectivity) absorb a small amount of thermal radiation and minimise overheating of the building cladding or public space. Due to the smaller accumulation of heat of walls, roofs of buildings and paved surfaces in public spaces, their subsequent secondary heat radiation to their surroundings is also reduced, which is noticeable especially at night. In this way the measure also contributes to reducing the effect of the urban heat island and reduces the overall overheating of the urban environment. By reducing the overheating of the building external cladding, the measure also has a positive effect on maintaining thermal comfort in the interior during summer heats.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- Reflected sunlight from glass structures, highly reflective facades or public spaces can negatively affect the surrounding buildings and increase their exposure to sunlight, thus negatively contributing to their higher overheating.
- In colder climates (e. g. foots of mountains, etc.) with milder temperatures in summer and longer heating seasons, it may be beneficial to use materials and colours with a lower SRI index (e. g. darker colours of roofs) to ensure greater heat gains during the heating season.

Additional sources of information (links):

Muscio, A. 2018: The Solar Reflectance Index as a Tool to Forecast the Heat Released to the Urban Environment: Potentiality and Assessment Issues. In Climate 2018, 6, 12. s. 1 – 22.
Available at: <https://www.mdpi.com/2225-1154/6/1/12/htm>.

Cambridge Science Park. 2020: Solar Reflectance Index in the built environment.
Available at: <https://www.designingbuildings.co.uk/wiki/Solar_Reflectance_Index_in_the_built_environment>.

Abdelwahab, S. et al. 2018: The Negative Impact of Solar Reflections Caused by Reflective Buildings' Facades: Case Study of the Nasher Museum in Texas. Available at: <https://oaktrust.library.tamu.edu/handle/1969.1/175386>.

ČSN 73 0540-2 (730540): Tepelná ochrana budov.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec.
Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

20 Controlled ventilation with heat recovery

An effective technical solution to ensure fresh interior air and to minimise heat loss through air exchange 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 level of CO_2 in the interior, depending on the number of persons present. Controlled ventilation with recovery of heat from the exhaust air can improve thermal comfort at relatively low cost. The system of controlled ventilation with heat recovery can be also combined with the cooling function to ensure reduction of indoor temperature. Controlled ventilation with heat recovery first of all helps to ensure a higher quality of the indoor environment and also helps to reduce the cost of heating in the winter as well as the cost of cooling in time of heats.

Mitigation impact of the measure: +

The overall mitigation benefit of the measure is positive, despite the fact that controlled ventilation with recuperation requires energy for its operation. The basis of the mitigation benefit is in the supply of fresh heated air in winter (cooled air in summer) into the interior of the building. The recuperator ensures that the warm air discharged in the winter heats the supplied cold air, reducing so the energy consumption for heating (Malý et al., 2019).

Adaptation impact of the measure: ++

During the heat, the interior of the buildings is overheated also due to thermally inefficient ventilation through the windows, which is necessary to have fresh air in the room. Controlled ventilation with heat recovery is a more effective tool to reduce heat loss and to ensure thermal comfort in the interior during heat waves. In the period of summer months, it helps maintain thermal comfort in the interior by using cooler night air, removing warm exhaust air from warmer rooms and cooling the air supplied to the rooms. During nights, air exchange through the windows is sufficient for ventilation and cooling of the interior.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- An important requirement for air conditioning is the volume of air which the unit is able to replace and adjust to the required quality. Depending on the size of the building and the number of rooms, local or central units with outputs from 15 m^3 to 1000 m^3/hour can be installed. The system is so limited by the amount of air that can be replaced, as well as its requirements for space. In a 20 m^2 room it is necessary to exchange 20 – 30 m^3 of air per hour (depending on the use of the room and the number of persons). If a cooling device is also connected to the air conditioning system, it is important to take into account the cardinal orientation of the room, especially if we want to ensure the required temperature even during hot summer days. Then it is necessary to take into account larger amount of supplied cooled air.
- A frequent solution is the ventilation of houses by underpressure ventilation using a ventilation unit with automatic regulation, which ensures a constant underpressure to exchange the air (Malý et al., 2019).
- The recovery unit also reduces interior air humidity (also proper for older houses after reconstruction).
- The disadvantage of heat recovery units is their limited operation at low temperatures (–5 °C and less). The number of such frosty days is (and will be) decreasing in the Slovak and the Czech Republics due to climate change.
- The implementation of the measure is often necessary in case of new constructions or significant renovations of buildings to comply with current thermal standards (since 2021 buildings with almost zero consumption).

Picture 20: Installation of ventilation control module with heat recovery and bypass

Photo by Zuzana Hudeková

Additional sources of information (links):

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

21 Production of energy from renewable sources

Producing energy (heat or electricity) from renewable energy sources means various technologies for producing energy in a sustainable way without the use of fossil fuels. Such production is more environmentally friendly, supports the decentralisation of energy production and is generally closer to the place of consumption. For the purposes of this publication, the installation of facilities for the production of energy from renewable sources means their installation in order to cover primarily individual consumption, whether by households, schools, social facilities, municipal authorities, companies, etc.

Energy from renewable sources is energy produced by:

- photovoltaic panels,
- wind turbines,
- photothermic panels,
- heat pumps,
- boreholes for the use of geothermal energy,
- biomass boilers (using wooden waste and energy crops),
- devices for the combustion of landfill gases, gases from wastewater treatment plants and biogas

The advantage of these sources is also their possible combination within one installation or building.

Picture 21: Use of photothermic panels on a vegetation roof

Photo by Zuzana Hudeková

Mitigation impact of the measure: +++

The production of 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 Slovak Republic 0.161 kg/kWh. The carbon footprint of the production of electricity from renewables is about 0.04 kg/kWh, depending on the type of renewable source.

Biomass usable for energy production, which can take several forms, is also considered a renewable resource (see additional sources of information). When energy is produced from biomass, carbon is released into the air, similarly to the combustion of fossil fuels. However, its overall emission balance is considered to be zero or close to zero because it is carbon that was assimilated in previous life stages of a given biomass source, that means relatively recently when compared to fossil fuels. The European Court has decided that biomass can be considered a renewable energy source. For the future, second-generation biofuels or combined biomass processing are subject of discussion because biomass should be used primarily for non-energy purposes. Biofuel is just one of the end products. There are efforts to use for example pure cellulose.

Photothermic panels use the same principle as PV panels, but use the energy of solar radiation to heat hot water, not to generate electricity. The set-up costs of photothermic panels are lower than those of PV panels. A detailed comparison is e. g. in this article (http://www.solarnispolecnost.cz/cz/fotovoltaika-a-fototermika-porovnani). Photothermic panels can be installed on roofs and in gardens of houses. The mitigation benefit is similar to that of PV panels – their use for heating water will reduce electricity production from sources with a higher carbon content. In the conditions of the Czech Republic and the Slovak Republic, electricity (boilers) or coal and natural gas are most often used for the preparation of hot water.

The use of ambient heat with the help of heat pumps and related technologies also have a mitigating benefit. Once again, it reduces the consumption of fossil fuels, the consumption of which for heating in Europe is considerably high (40% of total energy consumption). Their disadvantages are high starting costs, the relative complexity of the technology and the need for revisions and repairs, as well as the need to use HFC gases as cooling medium. These are strong greenhouse gases, if they are released into the environment, the mitigation benefit of the technology is "zeroed". Measures to reduce energy consumption by using the principles of energy-efficient buildings should therefore become the primary measure in buildings, and use of a heat pump instead of e. g. natural gas boilers should be secondary measure.

The use of geothermal energy (e. g. through deep boreholes) for central heat supply can have a large mitigation benefit. The disadvantages are again high investment costs as well as complicated technical solutions in complicated geological conditions.

Adaptation impact of the measure: +

The installation of renewable energy sources is neutral from the point of view of adaptation, but in some forms of energy production from renewable sources it is possible to identify a slightly positive adaptation effect. When photovoltaic or photothermic panels are installed on the roof or external cladding of buildings, their area are shading the structure of the building, thus contributing to reduction of overheating of the building and maintaining thermal comfort in the interior of the building. The installation of devices using renewable sources also diversifies energy sources, increases self-sufficiency and reduces the dependence on central supply networks, thus increasing resilience in cases of failures of central distribution networks caused, for example, by extreme weather.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity, except for wind turbines with negative impact, which are however not situated in residential areas.

Additional information for implementation of the measure:

- Higher installation costs and economic return in the long run, often on the edge of equipment life (without the use of subsidies) – for example in case of household heat pumps.
- In case of photovoltaic panels, a permit is required for connection to the public electricity grid.
- In the production of electricity from photovoltaic panels in households, energy is obtained mainly at time when consumption is low (during the day) and excess energy goes to the central grid. In times of high electricity consumption (evening and morning), it is necessary to take electricity from the central network. This effect can be reduced by using an accumulator (battery) to store energy, or by partially adapting the operation of the household (turning on appliances such as washing machine, dishwasher, etc. in times of excessive electricity production).

Additional sources of information (links):

MacKay, D. J. C. 2013: Obnoviteľné zdroje energie – s chladnou hlavou; Slovenská inovačná a energetická agentúra, Bratislava, 2013. Available at: <https://www.siea.sk/wp-content/uploads/files/poradenstvo/publikacie/kniha_oze/EnergiaSChladnouHlavou_web_102013.pdf>.

Bezplatné energetické poradenstvo SIEA: https://www.siea.sk/bezplatne-poradenstvo/

TZB-info: Bechník, B. 2009: Biomasa – definice a členění. Available at: <https://oze.tzb-info.cz/biomasa/5641-biomasa-definice-a-cleneni>.

Energie-portal.sk: Rojko, M. 2020: Drevná biomasa je naďalej obnoviteľným zdrojom, rozhodol európsky súd. Available at: <https://www.energie-portal.sk/Dokument/drevna-biomasa-je-nadalej-obnovitelnym-zdrojom-rozhodol-europsky-sud-106119.aspx>.

TZB.info: Matuška et al. 2014: Porovnání solárního fototermického a fotovoltaického ohřevu vody. Available at: <https://oze.tzb-info.cz/solarni-kolektory/11103-porovnani-solarniho-fototermickeho-a-fotovoltaickeho-ohrevu-vody>.

TZB.info: séria článkov o geotermálnej energii. Available at: <https://oze.tzb-info.cz/geotermalni-energie>.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.
Evans, S. 2017: Building solar, wind or nuclear plants creates an insignificant carbon footprint compared with savings from avoiding fossil fuels, a new study suggests. Available at: <https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints>.

22 Capture and use of rainwater in buildings

Collection of rainwater is a process of collecting and storing rainwater that falls onto a surface (usually a roof, and almost any external surface), regardless the source of water.

Rainwater is a relatively clean source of water that requires only minimal treatment (usually UV filtration). The collected water is used for non-drinking purposes, e. g. flushing the toilets and urinals, washing machines, irrigation systems, car wash, sprinklers, etc. Some sources state that in this way it is possible to replace up to 50% of domestic and 85% of distributed tap water for households.

Rainwater collection is usually carried out in three ways. The water is collected in storage tanks and pumped directly to the place of use or, where possible, brought by gravity. Another way is that the water is pumped from the storage tanks to an elevated tank and then brought back to the point of consumption by gravity. The first method is appropriate for detached houses, because water does not have to be pumped over long distances. For larger buildings, the second or third options are more effective.

Depending on the area of the roof belonging to an apartment unit, it is possible to consider different intensities of the use of rainwater. With a roof area of up to 20 m^2 for washing, over 30 m^2 partly for flushing toilets and washing, over 80 m^2 for flushing toilets and washing or watering greenery.

In addition to the use of rainwater in buildings, it can also be used in exterior to water greenery, supply the bioretention collection ponds, rain gardens, etc.

Picture 22: Example of collecting rainwater in collection containers for watering in Bratislava-Karlova Ves

Photo by Lenka Nemcová

Mitigation impact of the measure: +

The measure belongs to a larger group of "water management" with a similar mitigation benefit. Drinking water is saved, which is replaced by rainwater, and this is associated with saving energy consumption for pumping, treatment and distribution of drinking water. According to data from distribution companies (for example Veolia CZ), the carbon footprint of the production and distribution of 1 m^3 of drinking water is 0.394 kg of CO_2. One person usually consumes 150 litres of drinking water per day, the annual consumption of a four-member household is more than 200 m^3. If 50% of drinking water consumption can be saved thanks to the use of rainwater, the mitigation effect will be about 40 kg CO_2/year.

Adaptation impact of the measure: ++

The collection and drainage of water from surface runoff can also mitigate the flood risk and regulate runoff as a part of a sustainable drainage system. Sustainable drainage systems in the urban environment are similar to "natural" drainage systems, capturing and treating surface water at the local level, which they then gradually release back into the surrounding environment.

Rainwater can also be collected from green roofs, even if its volume is significantly reduced (less intense rains do not even drain away, but soak into the substrate). Some materials may be more suitable for rainwater collection, e. g. materials with a high mineral content.

When using rainwater to irrigate the surrounding greenery, it contributes to making microclimate more pleasant.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- In case of green roofs, it is important to take into account that leached nutrients, vegetation mass, sediments and organic matter (including bacteria) mean that the quality of this water is lower than the quality of water collected from a "normal" roof. Therefore, it is not advisable to use fertilisers that can cause contamination. However, the main problem is the colouration of the water to brown, which the rainwater gets from the green roof, and therefore it is recommended that the rainwater obtained in this way be used for instance for irrigation, where colouration is not as big problem as when used in buildings.
- The main disadvantages include, in particular, concerns about health risks. It is important to ensure that all distribution lines of water, which is not intended for drinking purposes, are clearly marked.
- The systems require regular maintenance: cleaning the filters every few months, cleaning the roofs annually.
- The economic return is often more than 5 years.

Additional sources of information (links):

Happold, B. 2020: Rainwater harvesting.
Available at: <https://www.designingbuildings.co.uk/wiki/Rainwater_harvesting>.

EC (European Commission). 2020: Sustainable finance: TEG final report on the EU taxonomy.
Available at: <https://ec.europa.eu/knowledge4policy/publication/sustainable-finance-teg-final-report-eu-taxonomy_en>.

Státní fond životního prostředí ČR: Dotační program Dešťovka.
Available at: <https://www.dotacedestovka.cz>.

23 Capture and use of waste "grey" water in buildings

Grey water is used water that comes from sinks, showers, bathtubs and washing machines. Grey water may contain traces of dirt, food, grease, hair and household cleaners.

In households, drinking water is used unnecessarily to flush toilets or water the greenery around the house, and for this purpose it is possible to use effectively the grey water, which is slightly polluted. The solution is to recycle greywater or rainwater. Recycled water (both drinking and waste water) is thus another cost item that can be saved. Saving water is saving energy. Grey water recycling is one of the effective tools to improve the efficiency of water use in buildings and urban environments.

Mitigation impact of the measure: +

The use of grey water is one of the measures that contribute to the saving of drinking water and thus have a similar mitigation benefit. The system is similar to the use of rainwater, but it means the installation of an additional treatment system, higher investment costs and a certain decrease of mitigation benefits. The average volume of grey water produced in a detached house is between 55 – 112 l/PE.day. In large facilities, such as hotels, swimming pools or wellness centres, the consumption of hot water is up to 400 l/PE.day. Of this amount, according to the type of house, residential complex, etc., it is possible to reuse

Picture 23: Example of use of waste water in household

Picture provided by CI2

40 to 70% of the water. This will have a positive effect on energy savings for pumping, treatment and distribution of drinking water.

Like any other source of water, grey water can be purified to the extent that it is suitable to the desired end use. For instance, raw grey water could also be used to irrigate the garden, but only if it is used very quickly (according to many regulations within 24 hours of capture). The organic load does not harm plants, it can even supply them with nutrients. However, in the remaining unused grey water, bacteria multiply rapidly and this water rapidly becomes black water and the mitigation positives turn into negatives (a source of methane in case of more intensive purification process).

An integrated approach, such as combining greywater recycling with recovery of heat from grey water, would further increase the efficiency of the whole system. The thermal energy obtained from greywater can be used to preheat drinking water to produce hot water in the building, saving so energy and increasing the overall efficiency of the system.

Adaptation impact of the measure: +

Lack of drinking water is becoming a problem in all countries; Slovakia is no exception. Excessive consumption, less rainfall and intensive land management are causing growing water shortages. Climate change, increasing water scarcity, population growth, demographic changes and urbanisation are challenges for water supply systems already today. By 2025, half of the world's population will live in areas suffering from water scarcity. The reuse of grey water is therefore becoming an important strategy, it helps to save drinking water, while reducing the amount of sewage water by almost 50%.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- Additional water distribution pipelines in the buildings are necessary for the use of grey water. It is ideal to plan the use of grey water when designing a building, or during the reconstruction of distribution networks in existing apartment buildings.
- The advantage of this water management is the saving of water and sewage. The disadvantage is the need to build two pipelines – for drinking water and grey water.
- We assume that water prices will grow and the reuse of wastewater will become more important in our country as well. The reuse of grey water is now technologically possible and economically justifiable.

Additional sources of information (links):

World Health Organisation (WHO). 2019: Drinking-water.
Available at: <https://www.who.int/news-room/fact-sheets/detail/drinking-water>.

Nolde, E. 2020: Greywater Recycling in Buildings.
Available at: <https://www.watefnetwork.co.uk/58-261>.

TZB.info: Biela, R. 2011: Kvalita šedých vod a možnost jejich využití.
Available at: <https://voda.tzb-info.cz/8097-kvalita-sedych-vod-a-moznost-jejich-vyuziti>.
EC (European Commission). 2020: Sustainable finance: TEG final report on the EU taxonomy.
Available at: <https://ec.europa.eu/knowledge4policy/publication/sustainable-finance-teg-final-report-eu-taxonomy_en>.
Vodavdomě.sk. 2020: Recyklace šedé vody – nevyužitý zdroj uvnitř budovy.
Available at: <https://www.vodavdome.cz/recyklace-sede-vody-nevyuzity-zdroj-uvnitr-budovy/>.

B. ADAPTATION MEASURES WITH POSSIBLE ADVERSE MITIGATION IMPACT

24 Cooling of the environment by water elements with water circulation

The measure can be implemented in the form of various technical facilities, such as fountains, artificial streams or so-called water mist sprayers. In general, these are technical elements using the flow of water or water vapour. The implementation of these measures usually requires the involvement of a pumping system ensuring the circulation of water.

Picture 24: Cooling the street with a system of fountains in Brussels

Photo by Pavol Stano

Mitigation impact of the measure: –

In case of this measure, the positive adaptation effect prevails over the negative mitigation effect. The measure would have a positive mitigation effect only if it were located inside the building and would replace active technical cooling. When used outdoors, it is necessary to ensure the circulation of water, which means to use a pump and electricity. Although the input costs are higher, it is advisable to prefer modern pumps with higher efficiency, lower consumption and longer operation life. A suitable option to minimise the production of greenhouse gases is the use of renewable energy sources and solar pumps, which reduce the amount of emissions produced during the operation of the system.

Adaptation impact of the measure: ++

Water from fountains, artificial streams and water vapour sprayers create a pleasant microclimate and effectively cools the surrounding area during the summer heat, especially in the areas where it is not possible to provide sufficient shading or cooling by other more environmentally friendly measures. Elements with water circulation (flow) have a significantly higher cooling effect than non-circulating water elements (e. g. ponds). A very effective solution is mainly the use of water vapour sprayers, which combine the cooling of the environment by evaporation of water in air, the cooling effect of small droplets on human skin and the cooling of a paved surface after the fall of water droplets and subsequent evaporation.

Cooling with the aid of water element is given by adiabatic cooling (cooling through evaporation). From a water area of 1 m^2, water evaporates depending on the temperature between 1 – 2 litres of water per day, but the amount of evaporated water may increase proportionally with increasing temperature. The energy needed for evaporation is obtained from the ambient air and from the water itself. According to the literature, if 1 litre of water evaporates from the water surface, the temperature of 540 litres of water is reduced by 1 °C.

The cooling effect of the evaporation is thus not only proportional to the amount of evaporated water, but is also based on the principle of compensating for the different temperatures of the cooling water and the ambient air. In case of a water element with water circulation, the cooling effect is based on combination of water evaporation, small cooling droplets of water (water aerosol) in contact with human skin, as well as water vapour falling on a paved surface. According to some research, the temperature on the leeward side of the fountains decreases on average by 3 °C and the cooling effect is noticeable up to 35 m from the water element.

Impact of the measure on biodiversity: +

The measure has a positive impact on biodiversity if this measure is designed so as to be used for drinking by birds, insects and other animals.

Additional information for implementation of the measure:

- The implementation of the measure requires the consumption of water, therefore in times of drought it is appropriate to consider the cooling effect of the measure and the need to use water supplies for other necessary purposes.
- It is advantageous in the framework of the measure to use captured rainwater and to minimise the consumption of treated drinking water.

Additional sources of information (links):

DG CLIMA project Adaptation Strategy of European Cities. 2016: Climate Adapt: Water uses to cope with heat waves in cities. Available at: <https://climate-adapt.eea.europa.eu/metadata/adaptation-options/water-uses-to-cope-with-heat-waves-in-cities>.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

25 Modernisation of public transport vehicles

Public transport vehicles must ensure, in addition to transport, also the comfort and health of passengers in changing climate conditions. The most vulnerable groups of the population, that are particularly sensitive to extreme weather and heat waves, are a significant proportion of public transport passengers. During the summer heat, the air temperature in a non-adapted vehicle can rise significantly and pose a health risk to passengers. Therefore, it is necessary to ensure a safe temperature in vehicles with technical elements, e. g. by shielding transparent parts of the vehicle (e. g. with attached shielding foils) or by cooling with air conditioning units.

Mitigation impact of the measure: –

The measure focuses on equipping the public transport vehicles so that they are less overheated during heat waves (e. g. cooling by air conditioning or window shading), which has a positive adaptation but negative mitigation effect (increased energy consumption for air conditioning).

Another negative aspect of active air conditioning systems in public transport is the need to use coolants that are based on fluorinated hydrocarbons (HFC gases). Although F-gases do not have the potential to damage the ozone layer of Earth, they have global warming potential (GWP). Emissions of these substances therefore have a negative impact on Earth's climate system in terms of its warming. The GWP potential is related to a CO_2 molecule for which the potential is set to 1. Some F -gases have a potential up to a thousand times higher than just one molecule of CO_2. It means that if the substance has GWP = 1430, one molecule released into the atmosphere has the same effect as 1430 released CO_2 molecules. Moreover, these substances are very stable, and their emissions persist in the atmosphere for several decades (Ministry of the Environment of the Czech Republic, 2020). It is recommended to use substitutes for these coolants or alternative coolants with the lowest possible GWP (up to 500), if the equipment allows it.

Adaptation impact of the measure: ++

The use of active cooling of the interior of public transport vehicles by means of air-conditioning devices has a significant adaptation effect to ensure a pleasant (not hazardous to health) interior temperature of the vehicle, especially during periods of heat waves and during the summer months. A supporting measure to ensure internal thermal comfort in public transport vehicles is the shading of transparent parts of the vehicle (windows), e. g. by special shading or reflective foils from the outside of the windows. The installation of the foil reduces the amount of sunlight passing into the vehicle and reduces

Picture 25: Air-conditioned vehicles of public transport with reflective coating on windows in Bratislava, Slovakia

Photo by Pavol Stano

the overheating of the vehicle structure as well as the interior. The measure is particularly important for the protection of vulnerable groups of the population who are frequent users of public transport – e. g. seniors and mothers with small preschool children, handicapped inhabitants.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- In case of improper operation of air conditioning devices (e. g. excessive temperature difference between interior and exterior, insufficient service and cleaning of filters) or excessive use, their operation may cause adverse health effects for passengers.

Additional sources of information (links):

Regionálny úrad verejného zdravotníctva SR: Rovný I. 2009: Klimatizácia.
Available at: <http://www.uvzsr.sk/index.php?option=com_content&view=article&id=1497:klimatizacia&catid=101:ovzduie-a-zdravie&Itemid=92>.

MŽP ČR. 2020: Fluorované skleníkové plyny.
Available at: <https://www.mzp.cz/cz/fluorovane_sklenikove_plyny>.

26 Cooling building interiors

The quality of building interior is necessarily linked to the temperature, either in summer or during the heating season. The first and most important procedure to ensure the required indoor temperature during summers is to reduce the heat gains, especially through transparent structures, as well as to minimise the impact of internal heat sources. To reduce the heat load, it is necessary to provide external shading, especially shading of windows oriented to west and south. The internal shading of the windows has a significantly lower effect. When seriously applying the measures to reduce the solar load, as well as the elimination of internal heat sources, the need to reduce the temperature in the interior, i. e. cooling, can be minimal.

The ideal way is to use low-temperature heating systems all year round, also for cooling. In buildings with low energy requirements, such as the passive standard, the need for heat and cold is provided by low-temperature distribution systems located in the cladding walls. Due to the low need for energy supply both for heating or cooling, the installed area of heat exchange systems is relatively small.

Cooling by supplied air has its limits in the form of the need to thermally insulate air distribution systems, but especially due to the fact that air is not an ideal energy carrier (specific heat capacity 0.33 Wh/K.m^3).

Picture 26: Low temperature heating and cooling in a passive house (Hviezdoslavov) before plastering (Slovakia)

Photo source: IEPD

Mitigation impact of the measure: –

Contrary to the above-mentioned passive cooling systems, the active systems mean increase of energy consumption and a negative mitigation effect. The use of central cooling is more advantageous in terms of energy consumption and mitigation. By installing central cooling (air conditioning) it is possible to reduce the heat load (temperature in °C) in the building. However, the installation of the system must always be preceded by construction modifications (shading elements, insulation, windows, etc.) so that the required power of the unit can be as small as possible. Cooling can be distributed in the building by air (air ducts, which is the most common method in the Slovak Republic and the Czech Republic), water (water pipes), coolants (cooling pipes – the simplest method for building renovation) or their combination. In terms of space requirements, air systems are the most demanding, the coolant distribution systems are least demanding (Malý et al., 2019).

Adaptation impact of the measure: +++

Air conditioning systems help to ensure a comfortable indoor temperature in the summers, especially during extreme heat waves. Air conditioning installation should be a priority especially in buildings where the groups of persons most vulnerable by heat waves are (especially the elderly over 75 years, young children under 4 years, disabled citizens and patients with chronic respiratory or cardiovascular diseases).

At the same time, however, air conditioning systems can increase the outside air temperature, for example in adjacent streets, by up to 1 – 2 °C (Munck, C. et al., 2013), while the temperature difference is even higher at night. All air conditioning systems that operate on the basis of heat transportation from one place to another (thanks to the cooling circuit) would increase the air temperature in the streets in the most urbanised parts of central Paris by 0.5 °C to 2 °C (depending on the type of air conditioner) .

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- It can cause adverse health effects in case of improper operation (e. g. excessive temperature difference between interior and exterior, insufficient service and filter cleaning) or excessive use.
- The advantage (not mitigation one) of the local cooling system is smaller building modifications, the disadvantage is the need to remove heat directly from the room (either the condenser, compressor and evaporator are located together in one device, or the evaporator is inside the building and condenser unit outside (most often on the facade)). Local cooling systems use coolants to remove heat, but the outdoor units are often noisy. The disadvantages of fluorocarbon coolants in terms of climate change have been mentioned elsewhere in this publication (see also the Ministry of the Environment of the Czech Republic, 2020). In case of apartment buildings, the installation of local units is a simpler variant, but often with a limited technical possibility of placing the condenser on the facade.
- Additional restrictions result from local regulations or possible monument protection.

Additional sources of information (links):

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec.
Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

MŽP ČR. 2020: Fluorované skleníkové plyny.
Available at: <https://www.mzp.cz/cz/fluorovane_sklenikove_plyny>.

Munck, C. et all (2013) : How much can air conditioning increase air temperatures for a city like Paris, France? In International Journal Of Climatology, Int. J. Climatol. 33: s. 210–227.
Available at: <https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/joc.3415>.

27 Publicly accessible indoor cooled areas

The measure is to provide public and free interior spaces with a pleasant indoor temperature, where residents could spend time free of charge during heat waves. The premises should provide the possibility of short-term leisure time and basic equipment (e. g. seating areas, sanitary facilities, drinking water, etc.). They can be provided for example by a local government in the form of access to a part of municipal buildings (e. g. meeting rooms, cultural or social facilities...) or by private institutions.

Ensuring a pleasant indoor temperature can be ensured by cooling with air conditioning equipment, or by other technical or architectural elements to prevent overheating of the building without the need to increase energy consumption (building shielding, good thermal insulation of the cladding, etc.), or their combination.

Mitigation impact of the measure: –/+

Mitigation benefit or negative impact depend on the specific technical solution of cooling the publicly accessible space. If an active cooling system is applied using an air conditioning unit, the measure has a negative impact on greenhouse gas emissions, which is described in more detail for previous measures. Contrary, when using passive elements of cooling the indoor environment, the impact of the measure can be positive. The architectural and technical solution also affects the internal carbon footprint, i. e. emissions generated during the production of used building materials. Preference should be given to natural and nature-based materials, such as wood or other raw materials, which absorb CO_2 during their growth. On the contrary, concrete, steel, aluminium and other similar materials are accompanied by high emissions during their production.

Picture 27: Seniors spending free time in the air-conditioned meeting room of the Bratislava Self-Governing Region authority during the heat

Photo source: Office of Bratislava Self-Governing Region

Adaptation impact of the measure: ++

In times of heat wave, it is necessary to provide public and free accessible interior spaces to cool the local population (especially vulnerable groups such as the elderly, mothers with children, people with health problems), that does not have the means to provide their own space with a comfortable temperature to spend free time. The implementation of the measure increases the adaptation capacity of the locality and reduces the risk of occurrence and severity of health problems (e. g. collapses) of the local population due to the negative effects of heat waves.

Impact of the measure on biodiversity: 0

The measure does not have any impact on biodiversity.

Additional information for implementation of the measure:

- Sufficient spatial and technical capacities of the municipality, or provider of the premises, are necessary.
- If the municipality does not have suitable premises, it can address other relevant institutions on its territory (e. g. state or regional institutions, universities, private social or health care facilities, private enterprises) with a request for cooperation and making the premises available to the public.

Additional sources of information (links):

Karpatský rozvojový inštitút. 2016: Katalóg adaptačných opatrení miest a obcí BSK na nepriaznivé dôsledky zmeny klímy. Available at: <http://www.kri.sk/web_object/761.pdf>.

Pavelčík, P. – Klápště, P. – Lupač, M. – Třebický, V. 2019: Města a sídelní krajina ČR v době změny klimatu. Stručný přehled problematiky pro představitele veřejné správy. Rudná: CI2, o. p. s., 32 s. Available at: <https://ci2.co.cz/sites/default/files/souboryredakce/brozura_mesta_a_sidelni_krajina_cr_a_zk_0.pdf>.

Malý, V. et al. 2019: Adaptace domů na změnu klimatu. Agentura Koniklec. Available at: <http://www.poradme.se/adaptacedomu/publikace.pdf>.

Poznámky:

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