ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

FAKULTA ŽIVOTNÍHO PROSTŘEDÍ

KATEDRA APLIKOVANÉ EKOLOGIE

GREEN INFRASTRUCTURE AND THEIR ECOSYSTEM SERVICES

ZELENÁ INFRASTRUKTURA A JEJÍ EKOSYSTÉMOVÉ SLUŽBY

BAKALÁŘSKÁ PRÁCE

Vedoucí práce: prof. RNDr. Dana Komínková, Ph.D.

Bakalant: Anna Wehrenberg

2022

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS ASSIGNMENT

Anna Wehrenberg

Landscape Technical and Administration Services in Environment

Thesis title

Green infrastructure and their ecosystem services

Objectives of thesis

The main aim of the thesis is to describe the techniques used in green infrastructure (GI) in the Czech Republic and foreign countries. Identify possible improvements in the usage of GI in the Czech Republic.
The thesis looks at these main research questions:
- What are the benefits and barriers to implementing green infrastructure in urban areas?

- How is GI used by other countries? Is it possible to change the way GI is used in the Czech Republic to make it more effective?

Methodology

Literary research summarizing the benefits and barriers of green infrastructure. The portal of spatial planning, the Center for Architecture and Metropolitan Planning and other sources will be used to summarize the usage of GI in the future building projects in the Czech Republic. Case studies and examples of foreign practice will be applied to compare the usage of GI in different countries. Possible improvements in the usage of GI will be identified.

The proposed extent of the thesis

40 stran

Keywords

Ecosystem services, spatial planning, climate regulation, Prague

Recommended information sources

Barič K. et al., 2020: Principy a řešení udržitelné architektury, Rethink Architecture

Bolund P., Hunhammar S. 1999: Ecosystem services in urban areas, Ecological Economics 29 (2). P. 293-301

Bucur D. et al., 2019: Advanced Evapotranspiration Methods and Applications. IntechOpen, London, UK. ISBN: 978-1-78985-812-9

Marino M. et al., 2019: Integrating green infrastructure and ecosystem services in land use planning. Results from two Finnish case studies. Land Use Policy 82. P. 643-656

Oliveira S. et al., 2011: The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon. Building and Environment 46 (11). P.2186-2194

Expected date of thesis defence

2021/22 SS – FES

The Bachelor Thesis Supervisor

prof. RNDr. Dana Komínková, Ph.D.

Supervising department

Department of Applied Ecology

Electronic approval: 20. 8. 2021
prof. Ing. Jan Vymazal, CSc.
Head of department

Electronic approval: 2. 9. 2021
prof. RNDr. Vladimír Bejček, CSc.
Dean

Prague on 03. 03. 2022

Prohlášení

Prohlašuji, že jsem bakalářskou práci na téma:
Zelená infrastruktura a její ekosystémové služby vypracovala samostatně a citovala jsem všechny informační zdroje, které jsem v práci použila, a které jsem rovněž uvedla na konci práce v seznamu použitých informačních zdrojů.
Jsem si vědoma, že na moji bakalářskou práci se plně vztahuje zákon č. 121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů, ve znění pozdějších předpisů, především ustanovení § 35 odst. 3 tohoto zákona, tj. o užití tohoto díla.
Jsem si vědoma, že odevzdáním bakalářské práce souhlasím s jejím zveřejněním podle zákona č. 111/1998 Sb., o vysokých školách a o změně a doplnění dalších zákonů, ve znění pozdějších předpisů, a to i bez ohledu na výsledek její obhajoby.
Svým podpisem rovněž prohlašuji, že elektronická verze práce je totožná s verzí tištěnou, a že s údaji uvedenými v práci bylo nakládáno v souvislosti s GDPR.

V Praze dne…………….   Podpis: …………………………………

Poděkování

Ráda bych v první řadě poděkovala mé vedoucí práceprof. RNDr. Daně Komínkové, Ph.D. za věcné připomínky a detailní časový harmonogram, díky kterému jsem bakalářskou práci mohla napsat s časovou rezervou. Dále chci poděkovat rodině a příteli, Štěpánu Staniekovi, za rady, podporu a trpělivost.

Abstrakt

Cílem této bakalářské práce je zkoumat využívání zelené infrastruktury v Praze. Dalším záměrem je identifikovat způsoby, jak zelenou infrastrukturu využívat více a efektivněji. Tato bakalářská práce se zaměřuje na projekty v měřítku lokálním i regionálním. Existující a plánované projekty jsou popsány a analyzovány. Dále jsou identifikovány ekosystémové služby. V práci je studována závislost měřítka a množství ekosystémových služeb, které projekt poskytuje. Jako příklady zemí úspěšných ve využívání zelené infrastruktury jsou uvedeny projekty Dánska a Rakouska. Přístupy k zelené infrastruktuře a její implementaci jsou porovnány na základě literární rešerše. V České republice je implementace zelené infrastruktury identifikována jako komplexní problém, který propojuje několik oblastí zájmu. Proto je třeba hledat řešení, která jsou stejná – komplexní a propojená. Dále je nutné upravit strategie plánování a legislativu tak, aby umožnovaly jednodušší implementaci zelené infrastruktury. Ze stejného důvodu by měly být využity úspěšné strategie z vyspělých zemí – Dánska a Rakouska. Konečně, vzdělávání široké veřejnosti a stejně tak i politických představitelů je klíčové pro porozumění významu zelené infrastruktury.

Tato bakalářská práce přináší přehled využívání zelené infrastruktury a přístupu k ní v Praze, České republice. Přináší vhled do problematiky, která, jak už bylo zmíněno, je velice komplexní a propojená skrze různé oblasti. Tato práce nepřináší detailní přehled jedné problematiky. Naopak, studuje více dotčených oblastí a ukazuje, jak se navzájem překrývají a ovlivňují. Budoucí výzkum by se mohl detailněji zaměřit na jednu problematickou oblast, která je v práci zmíněná, jako je legislativa, implementace zelené infrastruktury ve specifických oblastech, na příklad v lokálním a regionálním měřítku nebo sbíráním dat z určitého prvku zelené infrastruktury.

Klíčová slova

územní plánování, regulace klimatu, Praha

Abstract

The aim of the thesis is to study green infrastructure (GI) usage and ways to implement it more in Prague, Czech Republic. It focuses on urban green infrastructure projects on local and regional scale. Existing projects and future projects are described and analysed. Furthermore, ecosystem services are identified. The thesis focuses on if and how ecosystem services are connected to the scale of the project. Green infrastructure projects in European countries such as Denmark and Austria are provided as examples of GI – developed countries. The approaches towards green infrastructure and its implementation are compared based on the literary research. The thesis identifies the problem of GI implementation in the Czech Republic as complex and interconnected throughout different fields, therefore needing a complex and interconnected solution. Furthermore, planning and legislation strategies need to be altered to allow easier GI implementation. Also, strategies from GI – developed countries should be adopted for the same reason. Finally, education of the general public as well as of political representatives is key in order to understand the need for GI usage.

The thesis brings an overview of green infrastructure management in the Czech Republic. It provides an insight into the problematic that is very complex and interconnected throughout different fields. It is not in-depth research into one type of problematic but it dives into several different areas and shows how these overlap and affect each other. Further research could focus more deeply on one type of problematic identified in this thesis such as legislation, implementation of GI in different areas, for example public and private, or collecting data from specific GI elements.

Key words

spatial planning, climate regulation, Prague

LIST OF ABBREVIATIONS:

GI – green infrastructure

ET – evapotranspiration

UHI – urban heat island

BGI – blue green infrastructure

LIST OF PICTURES:

LIST OF TABLES:

1. Introduction

In 2020, 56.2% of the world's population lived in urban areas (WE Forum, 2020). United Nations (2018) predicted this number to increase to 68% by 2050. These numbers show that over half of the world's population is living in cities and this number is going to be increasing in the future. Although the rate at which urbanization will happen can vary amongst more and less developed countries, the direction of change is definite.

Simultaneously, with the increasing urbanization rate, the effects of climate change are more visible these days. These changes could be seen in urban as well as in rural environments. In rural environments, climate change causes periods of drought, extreme rainfall events, extreme fluctuations of temperatures and more (Nelson G.C. et al., 2009). One of the results are altered agricultural conditions causing uneven food production. (Nelson G.C. et al., 2009). In urban environments, climate changes are sensed as heat islands or floods for instance. The results are negative effects on human health or elevated energy costs (Rosenzweig et al., 2010; McCarthy et al., 2010; Hassan et al., 2015). As climate change affects planet Earth negatively, fighting against it and trying to lower its effects is one of the areas that demand attention today. The reason for the topic of this bachelor thesis is the need to find ways to alternate microclimate in urban areas, which are more and more densely inhabited. One of the possible solutions is green infrastructure.

Green infrastructure (GI) is defined as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation" (European Commission, 2020). GI consists of different elements that work on the basis of evapotranspiration. Green infrastructure elements have many different benefits depending on their size and the scale they are used at. These benefits could be categorized into four groups of ecosystem services. Ecosystem services could be defined in several ways. A simple definition that is favourable for this area of research is the one by FAO (2022) defining ecosystem services as the multitude of benefits that nature provides to society. These categories are provisioning, regulating, cultural and supporting services. Although each category consists of specific benefits, these are usually interconnected.

Examples of provisioning services are raw materials and food; regulating services provide water regulation or air quality; cultural services contribute with recreational areas or historical heritage; finally, supporting services maintain biodiversity and ecosystems. Thus, in one project, it is possible to find more than one of these ecosystem services.

Nonetheless, awareness of the general public of these benefits is rather low. That is due to insufficient education in this field. Of course, there are countries that are ahead in battling the effects of climate change. For example, Copenhagen, Denmark states in its Climate Adaptation Plan (2011) that it looks at climate change as an opportunity to improve the city. And even though it uses the green infrastructure elements mainly because of its regulating services, it uses them to improve the quality of life of its citizens as well (Copenhagen Climate Adaptation Plan, 2011). Prague, Czech Republic, also presented its Climate Change Adaptation Plan (2021), in which it binds to lower CO_2 emissions by 45% by 2030. The document also declares to try to modify the city to make it environmentally friendly and thus attractive to live in. The city of Prague has also prepared a document called Adaptative Strategy for Climate Change. Part of it is an implementation plan for the years 2020 to 2024, which present different projects that should help mitigate the effects of climate change and adapt the city to be resistant to it.

GI implementation is a process that is country-specific. It depends on current legislation, planning of future projects, responsibilities of different departments, funding, expertise in the field, experience of institutions and politicians, understanding of the process and its benefits, proper education, and there are more. To combat the barriers to GI implementation, ways to overcome these need to be found. It is clear that countries that have little or no experience with GI implementation are not going to find these ways. Or, if so, it would be much more difficult and lengthier for them than for countries that have this process already incorporated. Therefore, research has to be done to collect information from GI-developed countries about their beginnings. The question asked could simply be: Where to start? The areas that need to be working together to effectively implement green infrastructure, on private and public spaces, are many. That can also be a barrier for countries that would be willing to use GI, but do not know how. The argument against general GI implementation could be the specificity of individual countries, their geographical location, legislation system and so on. Nonetheless, if there are more countries using green infrastructure at least on some level, it will be easier to research strategies for specific - GI barriers.

Therefore, the more countries use GI on a basic level, the more specific data could be collected and used to develop GI implementation on a higher level.

In this research, I focus on integrating regulating services in cities. I focus on the city of Prague to find out how green infrastructure is being used here and if and how its usage could be improved. I compare the GI usage in Prague with other foreign cities. The criteria on which the selection has been based are as follows. Firstly, the city of Prague is the main area of research as it is a city where I have been raised and where I live my whole life. Due to this personal connection, I have a strong interest in the future of this city and the quality-of-life citizens of Prague have now and may have in the future. Secondly, the cities Prague is compared to are mainly European. If not, they have similar climate conditions. This way, the results of the research should be more reliable and solid then if GI techniques used in a city from central Europe would be compared to GI techniques used in arid areas or extremely wet areas. Nonetheless, some examples that do not copy the criteria stated above are used.

2. Aim of the thesis

The aim of the thesis is to describe the techniques used in green infrastructure in the Czech Republic and foreign countries. Identify possible improvements in the usage of GI in the Czech Republic. The thesis looks at these main research questions:

- What are the benefits and barriers to implementing green infrastructure in urban areas?
- How is GI used by other countries? Is it possible to change the way GI is used in the Czech Republic to make it more effective?

3. Theoretical foundation

3.1. Green infrastructure

Green infrastructure could be described as a tool. It is a “strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation” (European Commission, 2020). Another definition of GI by Benedict and McMahon (2002) is “an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations”. It is a “framework needed for environmental, social and economic sustainability – our nation’s natural life support system” (Benedict, McMahon, 2002). The function of this tool is crucial to ensure functioning ecosystems for future generations as well as for us, living on planet Earth today. As described by the European Commission, GI ensures ecosystems will cultivate their biodiversity and provide ecosystem services such as clean air, water and many more (European Commission, 2020). The term green infrastructure might seem like it is easy to understand. But what does an average citizen imagine when this term is mentioned? It might be green roofs, city parks, green walls or even nothing at all. What is green infrastructure really made up of? GI has many different parts and some of these might not come to a person’s mind at all when thinking about this term. As stated by the European Commission (2020), a functional network of green infrastructure should include core areas of biodiversity such as protected areas Natura 2000 – these have the function of hubs for the GI. Areas of healthy functioning ecosystems, restored habitats, natural features such as woodland strips or ponds, artificial areas such as eco-ducts, fish ladders, green roofs and walls as well as multifunctional zones that can be used for instance as recreational zones as well as food production areas. GI can even be enhanced by individual gestures such as collecting rainwater or leaving parts of a garden untouched to provide a home for wildlife and protect biodiversity. A huge benefit of GI is its multifunctionality. These are some of the main parts that make up the functional network of green infrastructure. To narrow the area of GI, this researched is focused on the urban areas and how green infrastructure is incorporated in them. As it was mentioned earlier, for example the core areas of GI would not be found in cities. Oppositely, the smaller elements that make up the GI are incorporated in the urban spaces.

These include green walls and roofs, parks, ponds or water streams, ecoducts, permeable pavements, downspout disconnection, bioswales or planter boxes, alleys and many more (EPA, 2017). Benefits of green infrastructure are many. These include increase in stormwater infiltration and storage capacity, therefore less stormwater runoff, less erosion and flooding. The greenery and trees provide benefits such as a physical barrier to noise pollution. The leaves can trap air pollutants, decrease the temperatures of urban areas by creating shade as well as increasing air humidity by evapotranspiration. As mentioned earlier, green infrastructure also supports biodiversity and the proper functioning of ecosystems. To summarize, it improves the conditions people live in on planet Earth that have a direct effect on their health (EPA, 2017).

In 2019, research was done to address the planning of GI at a municipal level in Scandinavia. The research analysed plans of 24 cities in Scandinavia, focusing mainly on the scope of the plans, the goals and strategies, the terminology and the measures for access to green spaces (Nordh, Olafsson, 2020). Altogether, the plans included 20 different goals or strategies. These were divided into ecological and social functions. Two goals were identified as having a planning function. Ecological functions that were identified in most of the plans were for example protection of green spaces, support of biodiversity, and ecology or focus on climate, sustainability and rainwater. Only seven plans included compensation for loss of GI. Mostly identified social functions were health and recreation, access to green space, access to rivers, lakes and the sea. 14 times out of the 24 cities were mentioned functions of GI such as identity and attraction and as spaces for children and youth. Less than that, functions were mentioned of GI being green cultural heritage, providing variety of green spaces, user participation, universally designed GI, safe GI and facilitating quiet green areas. Out of the two identified planning functions, map and value available GI were mentioned 5 times. The second planning function was to increase knowledge among inhabitants. Based on this summary of GI functions that were included in municipal plans of GI inclusion, it can be deduced what the most important functions are – protection of green spaces, support of biodiversity, health and recreation, when talking from the viewpoint of the city. The study provides some evidence on the values of green infrastructure, that are perceived in the urban environment. The individual benefits of GI can be further divided into subsections. These are called the ecosystem services.

3.2. Ecosystem services

“Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life” (La Greca et al., 2011). There are four categories that make up ecosystem services. These are - provisioning services, regulating services, cultural services and supporting services (FAO, 2020).

Provisioning services are the products directly obtained from the ecosystem such as timber, raw materials or food. Many of these are traded in markets and in rural areas people are dependent on these for their livelihoods. Regulating services are the benefits obtained by regulating the ecosystem processes, for example local climate air quality, carbon sequestration and storage, regulation of water flow or waste-water management. Other examples include pollination, flood and disease control or erosion prevention. Cultural services are the non-material benefits we obtain from ecosystems. Aesthetics, cultural identity or spiritual experience are all connected to the natural environment. Recreational use and tourism are also included in the cultural services. Supporting services provide living spaces for plants and animals and the maintenance for genetic diversity. These are the basis of all ecosystems and their services (FAO, 2020). All of these services are fundamental for us. As the global climate changes and we are experiencing new weather patterns, we will be in bigger need of the benefits these ecosystem services provide.

3.3. Ecosystem services by evapotranspiration

3.3.1. Evapotranspiration

To understand the benefits that GI creates, firstly it is important to understand the process of evapotranspiration. Evapotranspiration (ET) is one of the processes of the water cycle and it causes loss of water or retrieval of water into the atmosphere (USGS, 2020). It is a “combined process of evaporation from soil and plant surfaces and transpiration through plant canopies” (Irmak, Haman, 2021). ET is a sum of evaporation and transpiration (USGS, 2020). Transpiration is the loss of water vapour from stems and leaves of plants. Water is absorbed from soil through roots and delivered to leaves. There it converts into water vapour and diffuses into the atmosphere (Cornell, 2016). Evapotranspiration can be affected by several factors. These include wind, air temperature, solar radiation, air humidity or soil type and its capacity to hold water (Arboleda, 2015). Evapotranspiration is a process occurring in all parts of GI.

3.3.2. Urban heat island (UHI) relief

Urban areas are made of impervious materials, usually of dark colour, which trap heat and therefore the average temperature of an urban area is higher than that of a suburban area. This is called the urban heat island effect (Feng, 2018). The UHI effect increases building's energy consumption (Jim, 2015). Also, drought periods, when irrigation in cities is decreased, cause UHI effect to augment (Coutts et al., 2013). Green and blue infrastructure, via evapotranspiration, presents a strategy that is cost-effective and helps to lower the UHI effect. "The ET process is able to transfer a large portion of incoming solar radiation into latent heat leaving from the urban surface" (Zhou et al., 2010; Lehmann, 2014; Zhao et al., 2017). "Latent heat of vaporization is a physical property of a substance. It is defined as the heat required to change one mole of liquid at its boiling point under standard atmospheric pressure" (Datt, 2011). Thus, when solar radiation reaches the leaves of a plant, the thermal energy is used to convert water into vapour, which then dissolves into the atmosphere. "The energy absorbed in the process is called heat of vaporization" (Datt, 2011). This way of decreasing the UHI is called active cooling. That can be realized via either vegetated layers such as green roofs or non-vegetated GI such as water bodies or permeable pavements, where water evaporates from the surface. Both of these techniques cause an increase in air humidity (Völker et al., 2013; Wong et al., 2017; Wu et al., 2018).

GI in urban areas benefits from the spaces that would not be used otherwise such as rooftops or external walls. Even though these areas, when used on its own, have little effect, when used in higher numbers, the network of GI causes the urban heat island effect to lower (Feng, 2018).

3.3.3. Base flow regulation

Base flow regulation means affecting the regime of urban baseflow in terms of its peak discharge, lag time, recession coefficient, and water yield (Jefferson et al., 2017; Lim et al., 2017). To explain these terms - peak discharge is the time when a river reaches its highest flow after a storm. It does not occur during or instantly after a storm, but it takes some time as it includes water coming from neighbouring areas such as woodlands or from streams that connect to the river. The time taken for the peak discharge to occur is called *lag time.* (BBC Bitesize, 2021). Water yield is defined as the average amount of fresh water that runs off in an unregulated watershed (Kienzle, 2013).

In urban areas, water runoff tends to be higher than in suburban areas due to impermeable materials. These do not allow water to infiltrate into the surface so it runs off either into a drainage system or it infiltrates when a permeable surface is reached. During extreme precipitation, flooding can occur - causing damage. In the case of base flow regulation, green infrastructure is used to create a sink at the source of rainfall to decrease the excessive surface runoff (Brandăo et al., 2017; Zölch et al. 2017; Garcia-Cuerva et al., 2018). Evapotranspiration – focused GI is used so water absorbed during a rainfall can be later transformed into vapour by ET. Some examples of such GI elements are lined bioretention or green roofs (Jones et al., 2009; Stovin et al., 2013; Bhaskar et al., 2016; Feng et al., 2016). To explain, bioretention is a system consisting of a soil bed and a suitable vegetation cover. When stormwater enters the bioretention system, it is filtered through the soil bed. Then it is either absorbed by the subsoil under the soil bed or it runs off downstream. The vegetation cover uptakes the pollutants from the stormwater and maintains the pores of the soil (Bioretention systems, 2009).

3.3.4. Water budget reestablishment

The term water budget can be explained as a "hydrological tool used to quantify the flow of water in and out of a system" (Trenchlesspedia, 2017). It includes all water from the surface, subsurface and atmosphere within its exchanges. Some examples are water from rivers and lakes, groundwater, precipitation and evaporation. The role of a water budget is important for water-resource sustainability, environmental planning and management. Also, the way a water budget differs in a specific area over time can be used to assess the effects of human activities and climate change on water resources. There are also several factors affecting the water budget. Examples are vegetation or soil conditions. It is crucial for engineers to be able to calculate how much water is needed for human and environmental needs. At the same time, water budget is used when planning hydrological projects such as dams or water reservoirs. All the benefits as well as disadvantages of these projects have to be taken into account as these may affect groundwater, water dependent ecosystems or the quality of water after the project is finished and much more (Trenchlesspedia, 2017).

The water budget reestablishment is closely connected with the base flow regulation. A green infrastructure model can regulate not only a base flow, but also have an effect on the water budget of an area (Eger et al., 2014, Eger et al., 2017). Therefore, a GI unit needs to be designed with a thought of larger scale impact.

Respectively, a GI unit can be used to change climate conditions on a local-scale, for example a city square, but has a potential to affect much larger areas, such as an urban ecosystem or urban watershed. “Urban ecosystem is an ecosystem located within a city area” (Pickett, 2011). Then, a base flow regulation can be changed into a water budget re-establishment (Göbel et al., 2004, Feng et al., 2016, Walsh et al., 2016).

To summarize, evapotranspiration is a powerful process that can be used effectively to lower the impacts of climate on urban areas. These areas may not withstand the effects the climate has on them or it may be lowering the living conditions of the people in the area. At the same time, the impacts cause health issues and sometimes even endanger human life. Some examples of these impacts are floods in cities that are an outcome of mal-regulated water flows. These then cause unnecessary costs for the city and its citizens. Within the topic of costs, it is suitable to mention the expenses that have to be paid over the limit due to the urban heat island effect and its increase in the building’s energies consumption.

On the opposite end of the economy lies human health which is also affected by the impacts of climate on man -made areas. Health effects may be respiratory problems due to pollutants in the air, hearing problems due to excessive noise in the city, hypertension or stress and sleep disturbance (EPA, 2017). Of course, there are many more health issues connected with the urban environment.

As living in cities or densely populated areas will be even more common in the near future than it is now, it is necessary to find ways that will allow healthy and safe living within these environments. As it has been indicated, green infrastructure is one of the methods that has been found to lower the impacts of climate change in urban environments. Nonetheless, it still is a new technology that is only beginning to be seen across the world. Even though, today we are able to find many different areas within the topic of green infrastructure that are being researched.

Worldwide, it is possible to find GI used on different scales. The smallest scale could be called a local scale. By local, a single area within a city or an urban environment is meant. This area is affected by a GI unit such as green roof, wall, city park, alley or planter box. A larger scale could be described as a regional scale. This scale would include not only the built-in area of the city but also the outer area such as agricultural or forest areas surrounding the city. It is always upon the decision of the researcher how each scale will be described and identified as to the best of my knowledge, there is no normalized scale used for the area of green infrastructure.

Throughout this bachelor thesis, the term local scale is used to describe a single GI unit or more interconnected GI units within an area of an urban environment. It is always described how large area of GI is being discussed. The larger – regional scale is used to describe an urban ecosystem, urban watershed or simply a larger area integrating several parts of green infrastructure into one bigger system.

On a larger scale, it is necessary to use multi-objectives from different perspectives (Coutts et al., 2013, Johannessen et al., 2017). An equilibrium needs to be found to satisfy the human need of the ecosystem and the ecosystem's need for functionality. This is what we can imagine behind the term multi objectives. There are many areas that are affected by GI. Since man is the one affecting most of the processes that happen on planet Earth today, he may prioritize himself to be able to thrive. Nonetheless, the natural environment needs to prosper primarily, in order for man to be able to live on planet Earth. Thus, we need to implement several areas of interest into the understanding of how green infrastructure should be planned and projected. Only then it can fulfil its task (Feng et al., 2016).

As suggested before, green infrastructure is an area with huge potential as it could improve the living conditions not only of people but it could also help augment the levels of biodiversity, which are decreasing due to excessive human impacts. Human impacts such as destruction, degradation and fragmentation of habitats and pollution or exploitation of individual species are meant (Natural History Museum, 2021). For the reasons outlined earlier, GI is an area which needs more in-depth research for people to be able to use it to its full potential.

4. Green infrastructure practices in Prague, Czech Republic

4.1. Current green infrastructure practices/projects

At the moment, the Czech Republic is at the beginning of GI implementation. Although it may seem the topic of GI is more frequent today, the realization of GI projects is still quite low. Today, it is possible to find individual projects which are incorporating some elements of GI, but it is not a trend yet. Usually, it is either individual owners who decide to incorporate green elements into their housing or gardens, or it is larger project groups such as Skanska or companies that want to show their values using the green infrastructure as a tool. Detailed examples are in the following section. Larger scale projects, such as recreation of parks or bigger areas usually have to be done by the city or the owner.

The problem is that the larger the area, the more people are involved and more interests have to be taken into consideration. However, the reasons for low GI implementation might be speculative. It certainly is not an easy area to implement. Nonetheless, the factors affecting GI implementation are many. Some examples are insufficient legislation system, low understanding of the topic of general population or low investments into green technologies. And there are more.

An example of GI implementation is the housing estate in Prague - Čakovice. The project manages to connect housing with nature, which promotes healthy lifestyle of its citizens. At the same time, it includes elements of GI that help with rainwater infiltration and retention or urban heat island.

The green infrastructure system used at this location is described in more detail below. The system is made up of five different elements. These are land sags and trenches, drainage systems, water bodies, an emergency water tank and a water runoff body. There are two main trenches at the northern and southern side of the housing estate.

The trench bed is grass with the underneath layers consolidated with stone. Also, the areas where water is flowing into the trench from other drainage systems, are reinforced with a top stone layer. That should prevent erosion. Lower parts of the trenches are used as water retention areas, if needed during heavier rainfalls. Drainage systems are used as a combination of surface and interflow runoff. In most cases, a trench with a grass floor is used with a drainage pipeline underneath. Water that percolates into green roofs of parking lots is pointed into the direction of drainage. The roofs have a slope of 1% in the requested direction to achieve that. Another element is a small lake. Its function is mainly aesthetic, but it also works as a retention water body when needed. The floor of the lake is tilted by 0.31% in the direction of water runoff. The emergency water tanks' floor is also tilted by 1.25% in the direction of water runoff. The walls of the water tank reach 40 cm above the constant water surface. The slopes around the water tank are covered with greenery. Finally, the water runoff body is used to regulate water runoff into the recipient. Water can be directed into the emergency water tank if needed as well (Kuk, 2007).

Picture 1 and Picture 2 show examples of two different GI elements, that aid in water retention. That is helpful during heavier rain pours as it slows down water runoff and thus prevents overloading of the sewer system. Also, during periods of drought, retained water is used back by plants.

Picture 1: *showing a land sag which allows for water infiltration and retention as well as slower water outfall into the recipient.*

Picture 2: *showing a land sag which allows for water infiltration and retention as well as slower water outfall into the recipient.*

Trees with large crowns aid with shading and cooling the space as well as with air circulation. The ground of the playground in Picture 3 has a permeable surface, which again, allows for water infiltration if needed. Also, the area with trees covers an underground parking lot, which has a green roof and is effectively used as a public green space.

Picture 3*: showing several GI elements – green underground parking lot roof, large-crowned trees, permeable surfaces, which combine ecological function with social function.*

Retention reservoirs also help with rainfall retention, mainly during heavier events. Rainwater from the hills eventually flows into the reservoir.

In the case of extreme down pours, water can spill from the reservoir into the basin and percolate into the ground or, if needed, into the recipient. Another function of the body of water is to cool the air in hot summer days as do the trees.

Picture 4:*showing a water reservoir for rainwater retention surrounded by trees and other vegetation.*

All the GI elements presented above show a good example of GI implementation in practice. The multifunctionality of green infrastructure works well in urban areas. It creates more comfortable living spaces for the citizens; thus, it may promote physical exercise, community activities or individual leisure activities outside.

At the same time, open green spaces, that are adapted for climate change, such as water basins, land sags, green roofs and so on, may develop the understanding of the citizens and thus improve their behaviour and change the level of acceptance of the changes in urban environment.

Another example of a GI project is the apartment housing Botanica that was finished in 2018. It focuses mainly on water management as it aims at saving drinking water and reusing grey water. Grey water is water from showers, bathtubs, sinks or washing machines. As it is not extremely polluted, it is recycled and used again for flushing or watering plants. Based on the data, 26% of drinking water ca be saved due to grey water recycling. Rainwater is also collected into underground tanks as a 'deposit' and can be used as a substitute for grey water if needed. Green roofs are installed over the area of 350 m^2 and used for rainwater retention and evaporation. That helps to cool the microclimate of the building. Furthermore, the building is energy efficient. It is 28% more effective than was required. That is achieved by high-quality windows, LED lighting, energy efficient elevators or high-quality insulation layer. Moreover, water is heated using solar energy from panels situated on the roof. The building has won the BREEAM Excellent certification, which looks at environmental, social and economic aspects. The investment return time for the project is 10 to 15 years.

The data show that in the first year, there were saved over 130 000 Czech crowns. An important barrier in this project's realization were the regulations and norms that do not yet count with the grey water technologies.

Thus, it is more difficult to use these along with today's laws. The ecosystem services provided by this project are rainwater management, microclimate regulation, air and water quality, water runoff, biodiversity, property value (Nadace Partnerství a, 2022).

The ČSOB company headquarters can provide an example of how green infrastructure can be used as a tool to show the company's values to its clients. The headquarters are made up of two buildings, where the first one was built in 2007 and the second one in 2019. In 2020, it won an award in category Work environment. The aim of the project was mainly to create a comfortable working environment that would be environmentally friendly and sustainable. The building has both, intensive and extensive green roofs which are watered using drip irrigation to save water. Rainwater is collected using green roofs and is accumulated in tanks. This water is then used for irrigation of green roofs as well as of greenery around the building. Green spaces that surround the building also decrease surface runoff and support water infiltration. Both of the buildings have LEED certification, declaring their sustainability. The older building can save 13,9% of drinking water, having LEED Gold certificate, while the new one can save 47.06% with its LEED Platinum certificate. Furthermore, the building has a very unique system of heating and cooling. It has its own geothermal wells which are used as a source of energy. There is so much energy produced that it is sufficient for both of the buildings. The buildings also have automatic air conditioning, which opens windows at night to cool the building. Green roofs also add to temperature regulation of the building as the green layer functions as an insulation layer. Moreover, green roofs and greenery around the building provide habitat for insects, birds or even mushrooms. The ecosystem services are recreation and aesthetics, water management, air quality, biotope and biodiversity support (Nadace Partnerství b, 2022).

Picture 5: *showing part of the ČSOB headquarters in Prague – Radlice Visible is a green roof as well as green permeable surfaces around the building (Nadace Partnerství b, 2022).*

Fourth example of existing green infrastructure projects situated in Prague is the so-called House in the strait. It was prepared and realized between the years 2009 and 2014 and in 2014 it was awarded by Building Efficiency Awards. That is because the house's energy efficiency falls into category A. That is one of the highest possible categories, the higher categories being A+ and A++ which are passive buildings (Škvor, 2014). The house is mainly made up of wood as materials with low CO_2 production were chosen. The roof is green and extensive and is used for filtering rainwater which is then stored in tanks and used for flushing without any other stabilization. Rainwater that is not accumulated in the water tank is infiltrated. The green roof, as mentioned in the other projects as well, helps to regulate the temperature inside the building and regulates the microclimate. It also supports biodiversity. Furthermore, there is a tree planted in the courtyard which helps to regulate the temperature inside the house as well. The ecosystem services supplied are microclimate regulation, air and water quality, recreation, aesthetics, biodiversity support, water runoff and management (Nadace Partnerství c, 2022).

One more example of local scale GI is a house situated in Prague with a wetland roof. It is a family house situated in Prague 7 – Letná in the courtyard of apartment buildings. It was finalised in 2016 and it is a passive house. The wetland green roof functions as a wastewater treatment plant. Recycled water is reused for flushing as well as irrigation. In this case, water recycling saves up to 40% of drinking water. The wetland has the size of 80 m^2 and at 30° Celsius, 300 litres of water evaporate per day. Furthermore, during hot summer days the wetland plants keep their temperature at about 24° Celsius. That means the urban heat island is effectively lowered and so is the microclimate of this area.

Other benefits are regulation of surface runoff and biotope support for insects, butterflies, bees and other organisms. Part of the roof is also covered by solar panels. These are used for heating the water for the house. Furthermore, the house has a ground heat exchanger that is 40 metres long. In summer, it cools down the air while in winter, it warms it up. The air is then transferred to the house where it creates more humid microclimate. Oppositely, warm, dry air is used for example for drying clothes. It has been analysed that the return rate of the investment is about 20 years, while the longevity is twice as long. Yearly, the house saves 15000 Czech crowns due to all the green technologies (Nadace Partnerství d, 2022).

Picture 6: *a bird's view on the roof of the house. Visible are solar panels as well as the wetland roof (Nadace Partnerství d, 2022).*

Picture 7: *a closer look on the wetland roof showing different types of plants and a permeable ground (Centrum Pasivního Domu, 2022).*

The above examples show the level of green infrastructure implementation in the city of Prague. It could be concluded that GI development is beginning to expand. Nonetheless, it is not that easy. These days, green infrastructure projects are usually heard of more than the grey ones. And although that is a good sign showing it is something attractive, it does not mean there is more green than grey infrastructure being constructed. The benefits of GI are known though and some elements of GI are being added to existing grey infrastructure or to public spaces to help with climate change adaptation. Nonetheless, the more interconnected green infrastructure is throughout the city, the higher effect it has.

4.2. Future green infrastructure projects

Currently, there are several larger projects in Prague that include in their interest the ecological value of the space they are working with. The scales if these projects are different, some are local, some regional. Projects working with city parks, city districts or squares that cover a larger area provide examples of green infrastructure on a regional scale. The definition of local and regional scale was described earlier.

First example is Vyšehrad. It is a UNESCO castle, which stands on a hill in a large park. A study was done on the Vyšehrad park, because of its future development. As it is a project on a regional scale, it has more objectives. One objective is the information and navigation system around the park. Another focuses on the outer area of the hills – historically, there were vineyards and orchards which could be renewed again. Last objective, from the environmental point of view the most important one, is the ecological value of the park and its ability to adapt to the situation of climate change. It should focus on the composition of plant species, rainwater management and also light pollution (CAMP, 2020).

Picture 8: *Vyšehrad park with rainwater management features such as a pond and different types of plant species. Nonetheless, it comprises a space for leisure activities and nature protection (CAMP, 2020).*

Second example is Císařský/Emperor's Island. The Troja basin stretches over the area of 800 hectares and thus the area spans over 4 city districts – Prague 6, Prague 7, Prague 8 and Prague – Troja. Therefore, one of the challenges when preparing the project was the communication and decision-making processes amongst the owners and administrators, whose interests could have differed. To manage this issue, an organization was set up - the Troja Basin Suburban Park and a management plan was prepared (CAMP, 2020). The project was prepared by an interdisciplinary team of architects, landscape architects, water management and transport engineers (IPR Praha). The reason for the revitalisation was to recreate this huge area to become more attractive not only for leisure activities, but also biodiversity enhancement, nature and land protection and many more (CAMP, 2020). The aims that should be achieved via this project are improvement of microclimate in the city of Prague as well as decreasing extreme temperatures and UHI. That should be achieved through green infrastructure. Also, ecological stability should be enhanced. Furthermore, extreme hydrological events should decrease through increasing number of permeable surfaces, revitalization of water courses and water bodies. Environmental education, monitoring and research should be supported as well (INCONEX, a.s.,2021). In more detail, some planned revitalisations are for example renewal of river along the Emperor's island or improving flood protection. That should be achieved by creating a flood 'park' in the Troja basin. To improve connection between the citizens and the area, new leisure opportunities should be created. These should also fulfil educational purposes.

Furthermore, new connections and better conditions for pedestrians and cyclists should be constructed (IPR Praha). The ecosystem services provided by this project are water and air quality, microclimate regulation, biotope formation, noise reduction, recreation and education (INCONEX, a.s.,2021).

Picture 9: *Troja basin with infrastructure-related projects as well as nature and landscape protection* features *(CAMP, 2020).*

Third example is a city district - Rohan Island. It has an area of 88 hectares. These will be divided into two parts, Rohan City and Rohan Park. The Rohan city will provide housing, offices, restaurants and different services. Many smaller development projects will be included. Rohan Park will take up the largest area of the island.

Apart from the park's function as a place for leisure activities, its most important function will be flood protection. It will be one of the most important flood protection areas for the city of Prague (CAMP, 2020). The project aims to improve microclimate condition inf the city to lower the effects of urban heat island and heat waves on its citizens. That should be achieved via green infrastructure, by renewing old vegetation elements and creating new ones. Moreover, extreme hydrological events such as rainfall, floods or droughts should be lowered. Rainwater management should be improved, impermeable surfaces should be changed for semi-permeable or fully-permeable ones. The project also aims to protect the city from floods from the Vltava and Berounka river as well as decreasing surface runoff, that also affects levels of erosion.

The ecosystem services supplied are water runoff and microclimate regulation, air and water quality, noise reduction, recreation and aesthetic function (INCONEX, a.s., 2021).

Picture 10: *Rohan park situated as a flood protection area (CAMP, 2020).*

A more detailed example of blue-green infrastructure in Prague is the new project called Modřanský cukrovar. It is the first example of a residential area that is going to be built sustainably in the Czech Republic (Skanska, 2021). It has the BREEM certification, which is a sustainability assessment method (BREEM, 2021). Some examples of sustainable elements of the project are described in the following part.

Firstly, the new residential area will be situated in a brownfield area of the old sugar factory. Secondly, recycled materials will be used as the building materials. An example can be the material from demolition of the brownfield buildings. It will be separated and crushed. The crushed sand-like material will be used to make recycled concrete. Up to 20% of conventional concrete will be replaced with the recycled one. Thirdly, green energy will sustain the building. There will be 1144 m^2 of solar panels, which will save up to 650 MWh of non-renewable energy per year. All the sources of energy that will be used should come from non-fossil resources. Using green roofs that will cover 14000 m^2 will help with cooling the building in summer and keeping it warm in winter months. To help save energy, buildings will have a heat cover, which should save energy for heating the space. On the opposite side, the exterior window blinds should protect the building from overheating, and thus save energy that would be otherwise needed for cooling the spaces.

The buildings will have a PENB B certification (Energy Performance Certificate) – classifying them as energy efficient (Skanska, 2021). Water management is a large issue and thus it will be solved by several different practises. Firstly, green roofs will be used for rainwater retention. 1 m^2 of a green roof can retain up to 35 litres of rainwater at one moment. Retained rainwater will be stored in accumulation tanks, that will have capacity of 190 000 litres. When needed, this water will be used for watering the gardens and green elements in the complex. Also, the gardens will be constructed so that rainwater can be absorbed effectively during rainfalls. That means uneven gardens with little hills and sags. Another example of water management is the usage of low flow bathroom fittings such as a bathroom faucet or a shower. These will save up to 14% of drinking water. What's more, water from the bathroom will be cleaned and recycled using an in-built wastewater treatment. This water will be used for flushing as well as for washing machines to wash clothes. The usage of recycled water will save up to 31% of drinking water. Nature protection and the support of biodiversity are an integral part of the project. Thus, elements such as trees, birdhouses, lizard walls or bee willows will be included. To support insects, there will be over 7000 m^2 of flower fields instead of classical grass fields (Skanska, 2021).

Picture 11: Visualization of the residential area showing green roofs, solar panels, green infiltration surfaces and many public green areas (Skanska, 2021).

The above examples show regional scale projects. Following are smaller, local scale projects. First project is located in the historical city centre at Jungmann square which is a part of the UNESCO reservation. The plan is to plant two trees in the location to improve the microclimate of the urban area such as urban heat island or heat waves. The difference should be visible as at the moment, there is no greenery in the square. The ecosystem services of this local scale project are better air quality, noise reduction, surface runoff regulation, aesthetic and recreation function.

Second local scale project is located in Prague 6 – Královka park and concerns underground rainwater tanks. Rainwater should be collected into the tanks and then reused for watering greenery in the park. The main aim is to lower extreme hydrological events and improve rainwater management. The ecosystem services provided are water runoff regulation, flood risk reduction, water and air quality, CO_2 reduction, microclimate improvement or recreation and aesthetics. In Prague 8, another project is prepared to create trenches for water retention. Again, the aim is to lower and slow down surface runoff and support water infiltration. Thus, the ecosystem services supplied are runoff regulation, flood risk reduction, air and water quality, microclimate regulation and aesthetics. The fourth project is located in Prague 10 and aims to lower the urban heat island during hot summer days. That should be achieved by setting up a nebula, which is a fog making 'machine'. Due to that, air would become more humid and the temperature in the area would lower. Among with that, water elements such as small water bodies, drinking fountains for people as well as for birds would be set up. Thus, the ecosystem services provided are air quality, microclimate regulation, recreation and aesthetics, biotope formation, and also increase in property values. Finally, last example of a local scale GI project is recreation of courtyards in the apartment buildings. The aim is to renew old greenery in courtyards of the houses that were built in the 70s and 80s of the 20th century. That is because the greenery was planted randomly, with little interest of the species composition. Furthermore, the recreation function of the courtyards should be supported and renewed. Ecosystem services are noise reduction, air quality, microclimate regulation, biotope formation, property value increase, recreation and aesthetics (INCONEX, a.s., 2021).

The listed examples show that the Czech Republic plans on using green infrastructure more, both, on local and regional scale. However, these projects are all Prague-based, as is most of this research. Thus, it should be taken into consideration that the studied sample does not have to be reliable nationally, for the whole of Czech Republic. Nonetheless, it does provide a reliable sample for the area of Prague.

4.3. Barriers to GI implementation

A case study of Pilsen focused on the trends of ecohydrological management of cities. It did not look at specific projects, but rather at ecohydrological problems and their solutions. “The aim of the study was to find the level of implementation of new ecohydrological management trends in cities in the Czech environment” (Kopp, 2016). It was found that “the city administration provides water management to the level required to quality of life, is aware of the risks (e.g., an accident on the main source of water or flood risk) and is trying to respond to the global challenge of adaptation to climate change” (Kopp, 2016).

During Kopp’s case study, there were identified barriers that limit the implementation of new trends into practice. The importance of how limiting these barriers is for the development of the city’s ecohydrological management was also assessed.

One barrier that has been identified is the political representation of the city, which is changing. Due to this, not all planned projects are finished on time. There is also a debate about new trends in rainwater management. Nonetheless, even though the city is willing to work with different projects which focus on climate change, it is not putting them in between the main political priorities.

Another barrier in the process of realization of the ecohydrological projects is the city’s administration. The competences in the area of water protection and management are divided into different departments that do not have to work together necessarily. To explain in more detail, on the level of the country, the competences of water management are divided between the Ministry of the Environment and the Ministry of Agriculture. On regional level, competences are divided to regional authorities with independent competence and with transferred competence. Authorities with independent competence take care of flood protection and prepare plans for water and sewer supplies for its region. Authorities with transferred competence have many different competences. An example can be discharging of wastewaters into surface waters or deciding the area of floodplains.

It also makes decisions during exceptional situations such as emergency water events (Středočeský kraj, 2021). On a city level, competences are further divided into water management and management of watercourses. Furthermore, there are usually more organizations managing the area of water management. These can be water and sewer supplies, inspection of the environment, the sanitary station and many more (Portál ŽP HMP, 2005).

Thus, it is complicated to enforce integrated approaches towards the water management question, as there is not enough space for finding solutions together in between the responsible departments.

Technological development in the field of rainwater management is an important part of improving the ecohydrological management. In the Czech Republic, insufficient advertisement of new technologies is limiting development of green infrastructure and its usage. There is a rising offer with new technologies, mainly from western Europe. Unfortunately, the demand of Czech market is low. Most probably because of low financial motivation, inadequate propagation and uncertainties in between the customers as these technologies are not widely accepted and used yet (Kopp, 2016).

The so-called ‘heritage of the past’ is another barrier limiting the advancement of the ecohydrological management. It is one the most important and limiting barriers. The complicated city administration and competence distribution, the need to ensure a compensatory water source or the need to renew old or degrading city infrastructure are all parts of the heritage of the past that need to be dealt with. Heritage of the past functions as an emotional barrier too. The need to accept new ideas and new thought processes slows down the process of advancing in the field of GI. The multifunctionality of water in the urban environment is one field which has not been appreciated for its real value yet (Kopp, 2016).

Another study looked at stakeholder engagement and institutional context features of the ecosystem-based approaches in urban adaptation planning (Lorencová et al., 2021). One of the aims of the study was to “identify involved stakeholders and their preferences to define the institutional setting for the implementation of ecosystem-based adaptation measures” (Lorencová et al., 2021). The research was done in three Czech cities – Prague, Pilsen and Brno. The five most often mentioned problems by all three cities were heavy rains and storms, urban heat island, heat waves, insufficient water retention and floods. Each city prioritizes differently these problems. For example, in Prague, heat waves and UHI were the two most mentioned problems.

In Brno, insufficient water retention and heat waves were mentioned and Pilsen indicated water related issues – floods, heavy rains and insufficient water retention. Preferred climate-adaptation measures were also discussed. These differed in each city as well. Prague favoured “GI solutions such as urban greenspace, green roofs, permeable surfaces or vegetation belts” (Lorencová et al., 2021) the most.

Brno preferred urban agriculture and gardening the most, while Pilsen selected green walls and roofs, following with sustainable drainage systems (Lorencová et al., 2021). The climate adaptation measures correlate with the problems identified as most urgent by each city.

Following was the evaluation of implementation difficulty of each climate-adaptation measure. For example, all three cities assessed blue infrastructure as "highly cost demanding" (Lorencová et al., 2021). On the other hand, permeable surfaces were evaluated as "technically demanding by Brno", while Prague and Pilsen assessed these as "least time, cost and technically demanding" (Lorencová et al., 2021). These results show, that each city has in some cases different perspectives on the same problems. The question is why is that? What makes the difference?

The mentioned study by Lorencová et al. (2021) also looked at this problematic. It found that on the institutional level, there are very few differences amongst the three cities. Usually, the management of city greenery or water is below the competence of the City Hall. In Prague it is the Prague City Hall that has most financial resources for GI projects or climate-adaptation measures. Therefore, although the responsibilities are divided between the City Hall and city districts, the city districts can usually do very little to go through with potential projects. "We need to convince City Hall about large projects, since they can apply for EU grants. Municipal districts are rather poor" (interview No. P1) (Lorencová et al., 2021). This citation proves that funding is one barrier to GI implementation (Deely et al., 2020; Hoyle et al., 2017; Li et al., 2020). Secondly, as mentioned by Kopp (2016), the division of responsibilities is making it difficult to go through with new projects that could mitigate climate-related problems. In Prague, responsibilities are divided amongst several publicly owned organisations such as Technical Administration of Roadways of the Capital of Prague, Prague Forests or Prague Institute of Planning and Development (Lorencová et al., 2021). In Brno, the public greenspace is managed by Public Greenery of Brno, and in Pilsen, by Pilsen Public Property Management Company (Lorencová et al., 2021). Another problem identified by Lorencová et al. (2021) is lack of strategic plans for the city's development. In Brno, the Strategy for Brno should be developing a document addressing future climate-related problems.

So does Pilsen whose Planning Department of the City Hall "has been developing the Strategic Plan of Pilsen City that should cover some environmental topics" (Lorencová et al., 2021). Nonetheless, it can be concluded, based on the citations above, that none of the cities has the strategic planning section deeply integrated.

All of the cities are rather learning about the benefits and beginning to do so based on positive past experiences as mentioned by the city of Brno (Lorencová et al., 2021). Concluding based on the two above Czech studies, it can be said that the problems identified are similar across the Czech Republic. Be it the funding, division of responsibilities or lack of strategic planning documents with the focus on climate-related problems.

4.3.1. Overcoming the barriers

In the case study of Pilsen, there are several ways to overcome the barriers that were identified above. Integrating ecological values into economical calculations (Seják, 2005) is one of them. Another way is to use economic analysis. Based on those, new economic tools should be created to support the integration of ecohydrological measures into practice (Kopp, 2016). Also, the city of Pilsen has direct influence on the operator of water supply and sewage systems for the whole city. Therefore, it can directly affect the economy of water management and introduce new economic tools (Kopp, 2016).

Another solution, discussed in the case study of Pilsen, was a private decentralized rainwater system. Today, it is already a functioning system. It is a grant program. Its goal is to support citizens to store and use rainwater for personal usage in gardens. Furthermore, Lorencová et al. (2020) suggest, that climate-related problems should not only be pointed out, but possible solutions should be presented with them as well, so that decision-makers can get closer to actually solving the problem, not only knowing about it. "The City Hall of Prague needs to set up specific climate change adaptation priorities, provide guidance and support to planners, municipality districts and investors in order to implement a variety of EbA (ecosystem-based approaches) measures" (Lorencová et al., 2020). And so do other cities. Nonetheless, implementation of GI is individual in every city or region.

In support of the statement of Lorencová et al. (2020) is the case study of Brno – Nový Lískovec. This case study focused on possible ways to support planning and implementation of climate adaptation measures in urban areas (Macháč et al., 2018).

The results found that "stakeholders lack sufficient awareness of all the possible benefits of nature-based measures…prefer information of a quantitative nature for their decisions" (Macháč et al., 2018).

To solve this issue, proper economic tools should be used, such as "monetisation of costs and benefits, which quantify net benefits of a specific measure", although not all benefits can be expressed well through economic analysis, it still provides "an argument for gaining support to a project…" (Macháč et al., 2018).

Economic tools were used in this case study, to show that carrying out a GI projects will "bring many times over more benefits that the amount of the investment and operation costs". Nonetheless, the need to present information appropriately to the target group is key as it can affect, in case of GI implementation, whether a project will be carried out or not. That implies to citizens of the urban area as well, as understanding of GI benefits is low by general population as well as by political representatives. It is important to stress to the 'audience', that although the results of GI projects are presented as monetary values, it does not mean the benefits will provide financial resources to the municipal or family budget. "The value expresses improvement of the quality of the life, well-being and environment in this district, explain Macháč et al. (2018).

Additionally, they propose the need for long - term measurements to obtain needed data for further analysis. At the moment, these are not usually carried out, which is also mentioned by Li et al. (2020). Next, assessment process should be done by specialists from different fields, such as biologists, hydrologists or climatologists (Macháč et al., 2018).

To summarize possible ways to overcome the barriers to GI implementation in the Czech Republic, presentation of GI benefits needs to be improved or altered. That implies to political representatives as well as inhabitants of the discussed area. As mentioned by Seják (2005), Kopp (2016) or Macháč et al. (2018), it should be done through economic tools, that best represent the value of GI benefits to the target groups, although these tools may not be able to measure all benefits well. If the presentation of the GI projects is done appropriately and understood well by the target groups, the probability of carrying those out increases.

4.3.2. Strategies to overcome the barriers

Based on the research already reviewed in this thesis, it is clear and it was already mentioned that the problem is interconnected in between several areas – political, social, technical, financial. For this reason, it has to be dealt with that in mind. The issue has to be divided into smaller parts and layers so that solutions can be found from more different perspectives. Such as from individual – citizen perspective, from city perspective, national perspective and finally, international – global perspective. The scale of green infrastructure usage could be compared to this division of perspectives. Both of these start from the smallest part, the individual – individual components of GI such as green roofs, walls, permeable surfaces and so on. Then these develop into more complicated systems.

Cities and countries - interconnected systems, such as whole cities that have integrated green infrastructure, stormwater management strategies and many more. Using this comparison, the importance of developing GI usage to the most complex level can be shown. As when complex GI structures will be put into place, these will have the biggest effect. Equally, when global perspective will be used, the integration of GI into urban environments will become quicker.

There are some initiatives, that try to deal with implementing green infrastructure into urban areas. One of these is the Covenant of Mayors for Climate and Energy. It was founded in 2008 in Europe “with the ambition to gather local governments voluntarily committed to achieving and exceeding the EU climate and energy targets” (Covenant of Mayors, 2021). Today, there is over nine thousand local and regional authorities from over 57 countries. The objective of the Covenant of Mayors initiative is to “accelerate the decarbonisation of their territories, strengthen their capacity to adapt to unavoidable climate change impacts, and allow their citizens to access secure, sustainable and affordable energy” by 2050 (Covenant of Mayors, 2021). Also, signature cities are committed to “implement the EU 40% greenhouse gas-reduction target by 2030” (Covenant of Mayors, 2021). To adhere to this commitment, practical measures are set up. The signature cities commit to make a Sustainable Energy and Climate Action Plan (SECAP). This plan will be “outlining the key actions they plan to undertake. The plan will feature a Baseline Emission Inventory to track mitigation actions and a Climate Risks and Vulnerability Assessment” (Covenant of Mayors, 2021). From the beginning of this process, the cities will have to report their implementation progress every two years.

Prague joined the Covenant of Mayors initiative in 2018. As a result, in 2021 the city has presented a document called Climate Plan for Prague 2030. This document “presents 69 specific steps which lead towards fulfilling the Climate Pledge” (Green European Foundation, 2021). One of the main goals is to lower CO_2 emissions by 45% compared to the levels in 2010. This document also has the function of SECAP (Sustainable Energy and Climate Action Plan). The Climate Plan is divided into six main categories.

These are Sustainable Energy and Buildings, Sustainable Transport, Circular Economy, Adaptation Measures, Implementation and Monitoring and Financing of the plan. The relevant categories for this thesis are Sustainable Energy and Buildings and Adaptation Measures (MHMP, 2021).

Green infrastructure is a key tool in future city development. One priority of Sustainable Energy and Buildings category focuses on renewal of buildings to the standard of the 21st century metropolis. When put into practise, that means using energy management to monitor energy usage by buildings and finding different ways to lower their energy consumption. Potentially, total energy savings in the city of Prague could make 51105 MWh and CO_2 savings would make up 56% per year. Second priority of Sustainable Energy and Buildings category is the city of short distances and carbon neutrality. The main principles to create such a city are as follows.

- For new development use brownfields instead of green areas.
- Big development projects should be well connected to public transport as well as to non-motorized pathways such as cycle lanes.
- The ratio of residential and non-residential areas has to be well planned sothat all needs of future residents can be fulfilled.
- Use renewable and green energy resources.
- Implement blue-green infrastructure (BGI), including water management.

The aim of adaptation measures is to improve the quality of life of the citizens even during climate change. The main priorities are improving microclimate in the urban environment, lowering the effects of extreme hydrological events, adaptation measures of buildings and of public spaces and finally improving crisis management. Adaptation measures are described in the following tables (MHMP, 2021).

Table 1: *summarizing adaptation measures for microclimate improvement that are planned in the city of Prague (MHMP, 2021).*

Microclimate improvement	
Revitalization of parks, green spaces, non-permeable surfaces	• Setting up new and renewing old parks • Exchanging some non-permeable surfaces for semi or fully permeable ones • Irrigation systems • Planting new trees and care-taking of existing ones
Forests	• Continue city forests management with certification FSC and PEFC • Setting up new forest areas • Renewing old forest areas • Buy back forests areas that have private owners
Water bodies, wetlands	• Decreasing surface runoff • Protection of urban areas from flooding

	• Restore rivers into their natural shape with meanders and pools, where possible • Creating a cascade of small water bodies • Planting flower fields, forest stripes • network of roads
Water management: recycle and reuse	• grey water recycling and usage • usage for irrigation of green elements in the urban environment • evaporation cools the urban microclimate
Impermeable to semi/fully permeable surfaces	• exchanging impermeable surfaces for semi or fully permeable ones • grass pavement, grass tiles • gravel pavement • parks, parking lots, playgrounds

***Table 2**: summarizing adaptation measures concerning extreme hydrological events in Prague (MHMP, 2021).*

Extreme hydrological events	
Rainwater management	• document Standards of rainwater management is being prepared • binding document for all new development projects in the city of Prague as well as for all sides concerned • aims to use green, nature-based solutions to lower surface runoff and rainwater collections • reusing rainwater

***Table 3**: summarizing adaptation measures concerning buildings and public spaces in Prague (MHMP, 2021).*

Adaptation measures – buildings, public spaces	
Technical measures, green roofs	• energy saving elements – green roofs, solar panels, heat exchangers

	• insulation, materials, colours, roofs, greening of roofs and walls → temperature optimization inside the building as well as outside of it • aims to lower CO_2 footprint, use renewable energy instead
Vertical greening – green walls, mobile greenery	• lowers absorption of solar heatwaves by buildings • drinking fountains, fog-making machines, artificial wetlands • courtyards renewal • improves microclimate in urban environment • increases ecological value of the city • noise regulation, air quality, temperature regulation, aesthetics
Community gardens, ecological and sustainable agriculture	• support of community gardens • increase of green infrastructure element in urban environment • supports biodiversity •
Planting, renewing and maintenance of alleys	• Principles for planting new trees – spatial situation, species, maintenance • Private, public, development groups
Brownfields – evaluation, management and development	• Evaluation of brownfield areas • Possibilities for their usage • Aims to save up as many natural, green areas from being used for urban development

Land consolidation	• Tool for realization of adaptation measures • Aims to organize land by function and area to make its usage beneficial and positively affects land functions such as erosion, or biodiversity

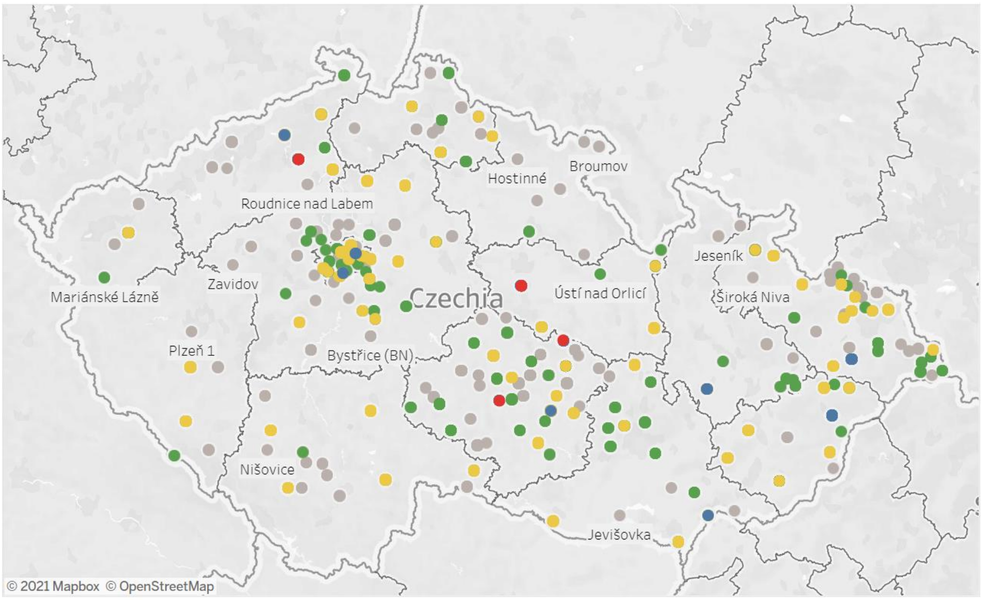
Table 4: *summarizing measures for crisis management such as prevention but also safety during extreme meteorological events (MHMP, 2021).*

Crisis management	
Data collections, analysis, mapping and methodology of adaptation measures usage	• Continue to collect data • Analyse effects of adaptation measures • Create new methodologies
City safety	• Protection of citizens and the city due to natural catastrophes • In Prague it is mainly floods • Flood plains • Mechanical protection • Measures on the water course • Mapping of potential drinking water sources in case of emergency – wells
Environmental education	• To create a population that understands the importance of air quality, climate protection • Educational programmes for school children • Community support of environmentally friendly activities – renewal of courtyards, community gardens etc.
Participation	• support public and individual initiatives willing to go through with different adaptation

	measures - grant programmes, methodological support, realization support etc. • having one space to share adaptation projects, public and individual, together • a centre collecting the best possible practices and solutions

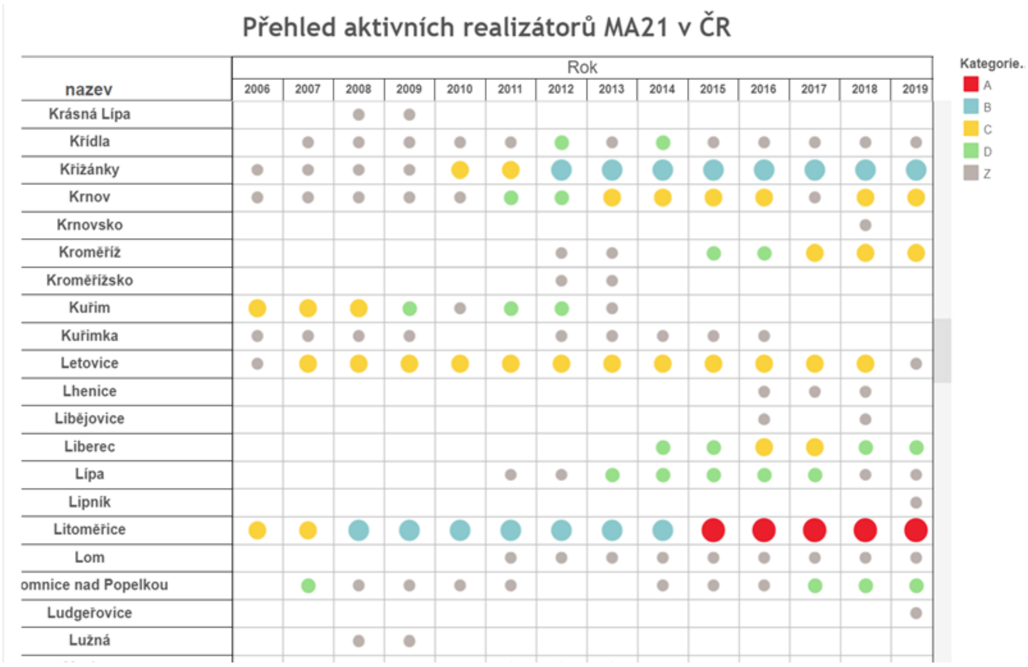
Another project is called Local Agenda 21 – LA21. It is “a voluntary process of local community consultation with the aim to create local policies and programs that work towards achieving sustainable development” (Srinivus, 2015). It puts together community participation, raising of awareness and capacity building. It was created in 1992 at the OSN summit in Rio and adopted by 178 governments, including the government of Czech Republic. “The Agenda 21 objectives require local governments to consult with the local community; minority groups; business and industrial organisations to create a shared vision for future sustainable development and to develop integrated local environmental plans, policies and programs targeted at achieving sustainable development” (Srinivus, 2015). In the Czech Republic, LA 21 is adopted by municipalities, from the smallest ones to the city of Prague. In the capital, LA21 is integrated by city districts. The level of integration of the municipality or the city district is divided into subcategories labelled A-D with one extra category of “interested” cities or city districts. Category “interested” registers the new city districts. Category D is the starting one after registration. It includes mainly the process of preparing for the whole LA21 project. Category C, called “stabilization”, should engage the public into the process and manage the political side of the project. Category B counts with using the system of LA21 and its values and principles.

Category A is the highest one. It is a long-term process during which the city district should be strategically developed. It should engage the public and lead to improving the standard of living of the citizens (CENIA, 2021).



Picture 12: *shows all municipalities signed up to the programme in the Czech Republic between years 2006 and 2020. Grey points represent the "interested" group of municipalities. Green points are category D, yellow points category C, blue points category B and red points category A (Místní Agenda 21a, 2021).*

To this day, there are 146 municipalities (Místní Agenda 21, 2021). Based on the statistics showed on the map (Picture 12), it can be deduced that most municipalities are in the category "interested". At the first sight, that would be judged as a positive thing - the fact that there are so many municipalities willing to make changes. Nonetheless, if more detailed study of these municipalities would be done, it would find that some of these are in the "interested" category for several years already. That can be shown on the example of the city of Bezděkov. It was signed up in the "interested" category since 2009 until 2016 (Místní Agenda 21b, 2021). During this time period, the municipality did nothing or very little to move up to category D. After 2016, it declined its membership in LA 21. This example shows, that the higher number of municipalities signed up to the programme does not necessarily mean more municipalities working towards sustainable development.



***Picture 13**: shows how individual municipalities develop from one category to another throughout the years on a selection of cities (Místní Agenda 21b, 2021).*

This sample - Picture 13, shows several different possible attitudes towards the membership in LA 21. The example of Kuřimka shows a municipality, which stays in the interested section for several years in a row, but nothing changes. Municipality Lípa shows quite rapid development from category "interested" to category D, but after 5 years, it goes back to "interested". Letovice show the example of moving from the "interested" category to C category in one year. The city of Litoměřice improved steadily throughout the years and has reached the highest category – A.

These examples show that membership in LA 21 does not ensure improvement of a municipality towards sustainable development necessarily. Nonetheless, there are many positive examples of municipalities, that do want to improve and put in the work, to actively advance from one category to another. The question is, what makes the difference between municipalities that do advance from one category to another and those who do not. One possible answer could be the governance of the municipality. As Kopp (2016) mentions, changing of the political representation of the city can result in not being able to advance in LA 21, as different political representations can have different priorities.

Another tool used in the Czech Republic since 2015 is the so called “Adaptive strategy” (Adaptační strategie ČR). It is a national document that not only evaluates the changes that will come with climate change, it also presents strategies and measures that will need to be taken. What more, it prepares the analysis of the legislation and the economy of the Czech Republic. The document identifies areas that should be of the highest interest with regards to climate change. Some of these are agriculture, forestry, water management, biodiversity, ecosystem services, urban landscape, health and many more. In the document, the risks of climate change in these areas are discussed as well as the measures that need to be taken. As it was already mentioned, economic analysis was made. Based on that, the financial complexity of the adaptive measures could be calculated. Using the analysis of legislation, changes to the legislation have been suggested – that would allow easier realization of future projects.

Some of the adaptive strategies that were prepared are listed in the following part. In the area of forestry, strategies such as cultivating spatially and species-diverse forests or stabilization of forest-bound carbon were suggested. In the area of agriculture, strategies such ecological farming, lowering of soil erosion as well as of soil drought, biodiversity protection or diversification of agriculture were proposed. Water management measures focused on stabilizing water flow in natural landscape, managing stormwater in urban areas, flood protection and risks connected with it. Other areas of interest were revitalization of water bodies, water dams, as well as of river basins. In urban areas, topics such as minimalizing surface runoff and reducing the pollution of surface runoff were discussed. The greenery in urban areas and its stability in the urban environment, the variability of the urban landscape or the strategies to lower the air pollution and heat waves in the urban environment are also areas that were prepared (MŽP, 2015).

The adaptive strategy is a tool used to prepare the Czech Republic and other EU countries. for climate change that is already changing some aspects of our lives. It will inevitably change many more in not-so-distant future. The above-mentioned measures are just some examples of adaptations to the changes that are about to come.

5. Green infrastructure implementation strategies in foreign countries

5.1. Austria

The approach to green infrastructure of the city of Vienna was studied. The city of Vienna was chosen as it is the capital of Austria and therefore can be compared well to the city of Prague. Vienna has created a document called STEP 2025, which is an Urban Development Plan. A part of STEP 2025 is a thematic concept Green and Open Spaces, which aims to maintain and develop the green and open spaces of Vienna. Challenges for green and open space planning on a global and regional level were identified. These include population development – meaning open space and green infrastructure needs to count with growing population. Demographic change, that will equal the number of the elderly (65+ years) to the number of under 19-year-olds by 2035. That is another challenge as it demands open spaces that will satisfy the needs of both groups. Furthermore, climate and energy are crucial objectives that need attention. Open spaces can create a connected network across the city enabling the citizens to use non-motorised transport, which would decrease energy consumption as well as greenhouse gas production and it has a lot of potential within this area of interest (Urban Development Vienna, 2015). The importance of green spaces in an urban environment can be divided into three sub-groups - ecological, economic and social. Ecological group includes the effect of green spaces on urban climate. That can positively affect the quality of air of an urban area. Leaves of plants help to cool an area due to evapotranspiration – making the air more humid as water evaporates from them. Trees provide shade and create a wind barrier when needed. Nature conservation is also included in the ecological group as open green spaces provide spaces for species that have restricted their habitats to the urban areas. Last but not least, water cycle and rainwater management are positively affected by green spaces. Retention of water increases in open green spaces including green roofs, and thus reduces the need for drainage systems mainly during heavy rainfall. This retention capacity plays a role in decreasing flood damage as it is a part of flood protection. Also, green areas contribute to higher air humidity, which improves temperature and air quality (Urban Development Vienna, 2015). The economic importance plays a role in real-estate industry as well as in tourism and farming. The real-estate industry benefits from integrating green spaces and green elements into its projects as it increases the interest of potential buyers. Not only does it add to the ecological value and improve the living conditions of the people, but it also has an aesthetic value.

Green spaces and tourism go together hand in hand as green open spaces often characterise the city and can attract many tourists. Example of GI and tourism in Vienna can be the Danube Island festival or the Rathausplatz (Urban Development Vienna, 2015).

Social importance includes leisure and recreation, everyday life, health and urban structure. Green spaces provide space for leisure activities of all the age groups as well as space for sports. Everyday life activities are also connected to open spaces, as we might use them for transport – linear green structures, as well as for community activities. Green spaces influence our health by providing spaces for physical activities as well as for recreation and relaxation. It has been proven that green spaces improve concentration, mental health and well-being. They create cleaner environment and improve the urban climate. Last but not least, urban structure is positively affected by green spaces. These break down the built-up structure of the city and create a visible difference within the urban area. The green spaces also provide historical evidence of the area and can make up the image of the city (Urban Development Vienna, 2015). Thus, it can be concluded that open green spaces have many functions and are valuable to the individual as well as to the city.

Finally, types of open space areas used in the city of Vienna are summarized. There are twelve different types of open spaces. These are divided into linear and wide-open spaces, and rural and urban open spaces. Linear urban spaces are most relevant to this research. Linear urban spaces are lively streetscapes and pedestrian zones, greened streets and streets with adjacent green spaces. Wide urban spaces are open spaces with restricted access, semi-public green spaces and parks. Rural open spaces then include green axes, green ways and corridors as part of the linear section, and multi-purpose land, module green space and protected areas as part of the wide-open spaces (Urban Development Vienna, 2015).

5.2. Denmark

The capital of Denmark, Copenhagen, is often called the world’s greenest city. It is because of its attitude towards ecological solutions that the city implements wherever possible. The best example of how green the city aims to be is its goal to become carbon neutral by the year 2025. If Copenhagen achieves its goal, it would be the first city ever.

To achieve that goal, Copenhagen has created a Climate Adaptation Plan which describes the effects of climate change on the city, the challenges it faces due to these effects and it outlines possible ways to overcome these.

At the moment, Copenhagen uses green infrastructure because of its regulating services. For example, after a severe event of cloudbursts which resulted in more than $910 million in repairs in 2011, the city council has adopted a Cloudburst Management Plan a year after. The plan included 300 cloudburst projects over the next 20 years, that will focus on catchment areas across the city. The GI areas such as parks will provide water retention spots, that should not only work as flood protection, but should also address the urban heat islands in the city (C40, 2015).

In the following part, some parts of the Climate Adaptation Plan of Copenhagen are shortly summarized. Firstly, challenges that the city is counting with in the future are explained and summarized. These are more and heavier downpours, higher sea levels, higher temperatures and urban heat islands, or climate change and its effect on groundwater. Heavier rainfall means the city will experience more flooding because of low capacity of sewer systems. Thus, spaces that will be least damaged have to be prepared and water will be directed into those spaces. These can be parks, sports grounds or open spaces. It is expected that the seas around Copenhagen will rise by up to 1 metre in the next 100 years. The problem of higher sea levels is also connected to heavier rainfall. The city tries to prepare for both, floods caused by rainfall as well as floods from the sea. It tries to build protection against these floods as value of buildings and other infrastructure that lie in the flooding area has already been affected. Urban heat island is a cause of increased air temperatures. These will affect mainly the microclimate of urban areas as temperature in a grey city will be higher than in green areas, and thus will cause higher expenditures on energy consumption. At the same time, it will lower the quality of life of the residents in these areas. Green areas providing shade, air circulation and cooling will be therefore preferred. It is expected that less groundwater will be formed.

That will be caused by higher temperatures and higher evaporation, so more water will evaporate instead of percolating into the ground. Also, less infiltration will occur due to more intense but shorter rainfalls, so water will flow away instead of percolating into the ground (Copenhagen Climate Adaptation Plan, 2011).

The city of Copenhagen sees the needed solutions as opportunities.

At the same time, Copenhagen works with the multifunctionality of green infrastructure and so plans on using it not only to adapt to climate change, but also to improve the quality of life of its citizens and develop the city.

As it was already said, Copenhagen is called the greenest city of the world. Therefore, it has a lot of green infrastructure already developed and its main aim, as stated in the Adaptation plan, is to safeguard the GI that is in place and continue developing it where it is the most needed. That means focusing on areas that are developing, being renewed or modified as well as areas that are in risk of floods or other problems as a result of climate change and so are in need of safety measures, for example in the way of different GI elements. In the Adaptation Plan, measures and plans are divided into several different parts. Firstly, as it was already mentioned, it is preserving and looking after existing green spaces. Existing green spaces such as parks or housing areas, should not only “assist in climate-adapting the city” but also “emphasize the individual identity of the individual places” (C40, 2015). Secondly, it is supplementing with more green and blue spaces in the city. For example, it can be renewing car parks, school yards, institutions and many more into more climate-adapted spaces as well as into spaces that will bring new opportunities into the area. Another take can be on green roofs and walls as these do not take up any additional space and so can be used in densely populated areas. As it was already mentioned, these have many benefits not only to the microclimate of that space but also to the economy of the building as these GI elements save costs on energies. Oppositely, trees with large crowns should be planted along roads, in courtyards, squares or parks as these make shade and thus can help in cooling the city. Third part focuses on creating continuous green networks in the city. As this includes green network across the city such as parks, green courtyards, trees, gardens, green walls and roofs and many more, it also brings with it the opportunity to involve citizens. This way, each person can help add some element of GI into his own garden or courtyard. That will even help to raise awareness and make the GI elements more understood by the citizens as well as more accepted. It should be a project on several levels – individual, in the neighbourhood, in the city district or in the whole city or even region.

This way, it can also offer multifunctionality as one space can provide rainwater infiltration, space for leisure activities as well as space for urban infrastructure (C40, 2015). Some of the existing and planned projects in Denmark and Austria are summarized in Table 21, Table 22, Table 23, Table 24 and Table 25.

5.3. Barriers to GI implementation

Green infrastructure is perceived as a beneficial tool all over the world. Nonetheless, it is not a technique that would be used on a larger scale. Mostly, it can be found on small scale projects such as buildings, streets etc. A comparative analysis by Li et al. (2020) was done on the theme of barriers and enablers to the implementation of GI in the UK and China. It was based on semi-structured interviews with professionals from fields such as water and flood management techniques, urban planning and some others. There were twelve interviewees in total, six from each country.

In the following part, barriers, identified in the interview, to implement green infrastructure are stated and further discussed.

In both countries, the lack of funding of GI was identified as one of the main barriers. “In the UK, developers are concerned about the high upfront investment costs…. In China, financial resources come mainly from government grants at this stage because GI does not directly generate economic benefits to attract private investment” (Li, 2020). Another problem connected to lack of funding is the maintenance of GI as it is dependent on financial support. Other related issues are design, engineering techniques or long-term monitoring and management. In the UK, many projects are not monitored after they are put into practice because of the limited financial support. Thus, green infrastructure has little data to be able to develop new GI techniques based on those.

As mentioned earlier, monitoring of the project is crucial for future development. “In China, pilot sites require monitoring to be included in the initial aims of the project…the projects are mainly maintained by the municipal administration, while if it is a private project, the responsibility would be on the housing compound, which finds it harder to monitor outcomes. The short-term funds for maintenance are reserved and need time to test in China” (Li, 2020).

Oppositely, in the UK, “maintenance is the responsibility of a more diverse group, which includes local authorities, landowners, local communities and private contractors” (Li, 2020).

Another barrier identified by both countries is socio-political. “The absence of political leadership and the developers’ role at the planning stage; the insufficient power of GI in regulations and policies; and weak governance and unclear responsibilities due to several institutions being involved” (Li, 2020). Limitations such as the legislative system and appropriate policies were identified.

Education, expertise and awareness in the field of GI of the local authorities as well as understanding of the general public are missing. All of these barriers are obviously limiting the usage and development of GI worldwide.

Another example to support the above statement is the study by Deely et al. (2020), which created a framework to identify barriers for the implementation of blue and green infrastructures. The method of this paper was a literature review, which consisted of 383 papers in total. These were found by searching for key-words such as ‘green infrastructure’, ‘blue infrastructure’, ‘blue-green infrastructure’, ‘barrier’, ‘obstacle’, ‘challenge’ and so on. Out of the literature review, 56 barriers, which could limit the development of GI, were identified. The barriers were further divided into five categories – institutional and governance, social-cultural, knowledge, technical and biophysical and funding and markets. The individual categories are described in detail.

Institutional and governance category listed barriers such as lacking clear leadership, long term vision, legislation and regulation, competing priorities, lack of climate change policies or interagency and interinstitutional cooperation. These barriers are very similar to those identified by Li (2020) as socio-political. Unclear leadership links to poorly defined roles, resulting in responsibility issues in the area of GI. Interagency also limits implementation. That is due to lack of communication in between specific disciplines needed to GI planning. That can be due to “discipline-specific language, and poor knowledge sharing between groups” (Johns, 2019). Also, the larger the project, the more needed the interdisciplinary communication and the more difficult (Deely et al., 2020).

Socio – cultural group included barriers such as culture and behaviour, societal perception of GI, community empowerment and impacts on future land use. These barriers show the perception of GI of different stakeholder groups. As such, each stakeholder group can view each barrier differently as it has different impact on it. An example can be private landowners, who are not willing to allow recreation of other residents on their GI property or landowners not willing to change their known practises to “take part in new BGI establishing programmes” (Johns, 2019). Similarly, it can be managers unwilling to change old methods for new ones to allow BGI development. In this case, the provisioning ecosystem services do not fulfil its function. Furthermore, community empowerment is strongly connected to institutional and governance issues.

If a community is not well supported and represented by its advocate, although it would be willing to become part of the BGI process, it cannot receive the benefits from the BGI it potentially could (Finewood et al., 2019).

Knowledge category included these barriers – lack of general knowledge on BGI, institutional experience, lack of technical guidance, lack of successful stories, negative past experiences and lack of clear cause-effect relationships. Lack of general knowledge is “one of the most commonly cited barriers to the implementation of a BGI” (Deely et al., 2020). That has a different effect on each level. If there is no or very limited knowledge on political level, BGI is often not proposed as a solution at all. That has of course the most profound effect. Technical guidance is also lacking. That is, as mentioned by Li (2020), linked to insufficient education. Low number of individuals with “a proficient level of expertise” (Keeley et al., 2013) limits the development of BGI. If these barriers – lack of education, lack of technical guidance and institutional inexperience add up, the result is a very limited number of BGI examples. That directly leads to low usage of BGI among stakeholders as it is very little seen as a representative example among others (Deely et al., 2020).

Technical and biophysical category listed – onsite limitations, design challenges, construction challenges, maintenance and performance challenges. Onsite limitations include the physical characteristics of a site – soil type, climate, terrain slope (Chaffin et al., 2016), lack of available space – needing more space than traditional methods (Liu and Jensen, 2018) or urban morphology (Brudermann and Sangkakool, 2017). Design characteristics combine not only the visible design, but also structural design. That links to the low level of expertise again, as to design a green roof, the strength of supports and many other variables need to be known in order to design it (Angelstam et al., 2017). Thus, many of these technical uncertainties lower the development of BGI. Furthermore, as mentioned by Li (2020), performance of BGI is also unknown.

That is due to lack of data (Li, 2020), “uncertainties over future climate change events” (Matthews et al., 2015), and “lack of environmental and climate change science in policy development” (Bissonnette et al., 2018).

Maintenance of BGI is also very poorly known (Connop et al., 2016). Moreover, it is more demanding than grey infrastructure maintenance, which again lowers the possibilities of BGI development (Deely et al., 2020).

Funding and market category comprised of barriers such as lack of funding, estimating benefits and costs and linking providers and users. Within the literature review, “funding related problems were the most common barrier cited” (Hoyle et al., 2017). The financial barrier again differs for different groups of stakeholders. For the landowners, it can be beneficial as BGI is often funded, although it is important to note, that funding can differ between countries as mentioned earlier by Li (2020). Oppositely, for the residents, it can be more costly, as green living is usually more valued and so more expensive due to the ecosystem services it provides (Deely et al., 2020). Nonetheless, landowners still perceive BGI as more costly than grey infrastructure, as it requires more land and staff with “expertise in BGI”. Another barrier is estimating benefits and costs as that is a very difficult process. BGI benefits such as improved water quality, flood protection, scenic value or carbon sequestration require “different econometric analysis to estimate their value” (Deely et al., 2020).

Another study, that focused on barriers and policy solutions for green infrastructure application was done in the US. It aimed on urban stormwater management. The objective of this paper was to “explore the barriers to GI, and suggest policies that can both overcome these barriers and expedite implementation” (Dhakal, 2017). During the research, ten US cities were surveyed and assessed based on the status of implementation of GI as well as federal and state policies. Twenty-nine barriers were identified and grouped. The outcome of the study was that most of the barriers result from cognitive limitations and socio-institutional arrangements. Based on these findings, thirty-three strategies and policies were suggested (Dhakal, 2017).

The studies summarized and compared above should provide sufficient evidence, that similar barriers to GI development and implementation are identified worldwide.

5.4. Strategies to overcome the barriers

As proposed in the UK / China comparative study, a more general strategy is to “raise understanding and awareness” (Li, 2020), engage the community and communicate with it. To this strategy connect practices such as “improving media reporting and education” (Li, 2020). A cultural shift needs to happen in order for “the public to understand the value and benefits of GI” (Li, 2020).

Change of “legislation, regulation and planning guidelines” (Li, 2020) was also stated as a beneficial strategy. Another strategy described the need for pilot and experimental studies.

To solve the economic problem, new financial resources and mechanisms could be found. These would be invested into technical innovations (Li, 2020). A strategy for solving the maintenance issue would be designing new low-maintenance GI elements. To summarize the UK-China comparative study, it is obvious that although the two are very different countries regarding location, climate or culture, both countries do find similar limitations to GI as well as strategies to overcome those.

Table 5: *summarizes the barriers identified by Dhakal (2017).*

Barrier:	Description:
Federal and state	• Constitutional protections of private property – forbids enforcement of GI on private property • Responsibility versus authority dilemma – cities have no control over private properties and its rainwater, but have to manage it
City	• Use restriction - which prevents the usage of free spaces for the purpose of GI • pavement material requirement - traditional pavement material has to be used, even if semi-permeable material would be beneficial • Lack of financial incentives - prevents the support of private parcel owners to implement GI
Governance	• Fragmented governance - causes fragmented spatial and functional jurisdiction • Lack of public engagement - prevents general public from having any role in the final decision making
Resource	• lack of financial resources from public or private investors into GI - harder to implement GI • data on costs and performance are missing - no historical performance data available or very limited amount of them • the shortage of workforce trained on GI
Cognitive	• Pro-grey mindset - people are used to grey infrastructure • Unawareness about GI, its benefits and limitations of grey infrastructure - cause lower usage of GI • risk aversion • reluctance to change • hesitation to take maintenance responsibility

The policies proposed by Dhakal (2017) who studied barriers and policy solutions for GI in the US are described below in Table 6.

“By policy we mean constitutions, laws, statutes, regulations, court decisions, andagency or leadership decisions. Governance is an inevitable aspect of policy, since it provides a platform for the political process required for policy making and plays a leadership role for policy implementation” (Dhakal, 2017). The proposed solutions were divided into five categories.

Table 6: *summarizing policy solutions supporting green infrastructure implementation in the US by Dhakal (2017).*

Category:	Description:
Federal and state	• Statutory provision • Allows cities to enforce flow control regulations on private properties
City	• allow GI usage in spaces where it is technically achievable • get rid of requirements to use non-permeable materials in drive ways • tax exclusions on GI materials and works • shared responsibility in between surface runoff ‘producers‘
Governance	• build a functional mechanism of communication, coordination and interaction • use this mechanism within government agencies as well as stakeholders outside.
Resource	• innovative funding mechanisms • create municipal green bonds • qualification programmes to educate staff working in stormwater management as well as other related areas • supporting universities to offer research opportunities in GI and courses for civil engineering students
Cognitive	• educational and outreach programmes about GI, its benefits and limitations of grey infrastructure should be established to raise awareness in public interest • courses on GI and ecosystem services from primary education, to build a solid population of GI educated people • programme to encourage individual and social capital

Based on information in Table 6, it can be deduced that all of the barriers are inter-connected and as it was already mentioned, the solutions should be thought of and prepared in the exactly same way, interconnectedly.

5.4.1. Planning and legislation strategies – example of Scandinavia

If the strategies to implement GI more effectively were studied more precisely, Copenhagen could be taken as a good example. Except from it having The Adaptation Plan, it has a set planning and legislation system. That is to allow cooperation of different fields for easier GI implementation. Copenhagen has two main legislation documents, the Planning Act and the Building Act. The Planning Act sets "the most important instruments for steering long-term development…including climate development" (C40, 2015). Planning Act is a superior document, which lays the main frameworks and regulations. The Municipal plan then develops regulations and frameworks for the topics mentioned in the Planning Act, such as homes, transport or recreational spaces. Finally, there is a local plan which is legally binding on the individual landowner. Local plans create frameworks for development and land use for the Municipal plan. Nonetheless, all the possible conditions that a local plan can regulate are defined by the Planning Act. Thus, it can be difficult to affect urban areas in the way the local would like to, but at the same time, "the local plan can go a long way towards ensuring that climate adaptation is taken into account in the development of the city" (C40, 2015). The Building Act's purpose is to "ensure that buildings are safe and healthy, and that they can withstand external effects" (C40, 2015). That means the municipality can set up the requirements that have to be fulfilled by new or renovated buildings. These requirements should make sure that buildings have optimal function as well as maintenance in the future climate. This puts more pressure on the buildings being stable in strong winds, being protected from floods and moisture as well as having good air circulation and indoor climate. However, these are just the requirements, which means these can be achieved through various ways. In case of adaptation to climate change, some areas of regulation are defined by special legislation. These areas are for example drainage of water, rescue preparedness or floods. It is clear that Copenhagen has a legislation structure which allows to incorporate GI into urban areas, although maybe not as easily as it would be desired.

The example of Scandinavian approach, particularly Denmark's, can be inspirational for other countries, such as China, the UK or the Czech Republic. These, as it was mentioned earlier, among other barriers indicate "the absence of political leadership and the developers' role at the planning stage; ….and weak governance and unclear responsibilities due to several institutions being involved" (Li, 2020) as a problem which does not allow them to incorporate GI into as many projects as would be possible. The idea of having some kind of a GI plan or a document summarizing all the plans, goals and strategies on how to achieve those, can help in the total number of realized GI projects. Copenhagen is a great example of this practise with its Climate Adaptation Plan. Apart from describing all the challenges and opportunities the city sees in climate change, it also presents its future plans on how to improve the local climate of the city. For instance, it has a green and blue structural plan, which specifies measures to encounter wastewater, recreation and other concerns. Another plan focuses at sustainable watering systems, developing rainwater collectors around the city to water trees, green paths or green spaces. The city also has a planting strategy, which prepares new spots where green elements such as trees or even parks will be created in the future (C40, 2015). At the same time, legislation system of the country is allowing the incorporation of GI. That makes it much easier to realize those projects than in countries where such legislation is missing.

What's more, Copenhagen looks at climate change and all the challenges it brings with it as an opportunity to develop the city into a city that is more climate-adapted and thus increases the quality of life of its citizens. On top of that, it plans on using the challenge of creating a climate-adapted city as an opportunity to become a leader in green urban solutions. These will be of high interest to many countries in the upcoming years as climate-adaptation will be an inevitable part of the future city development. That means that because of climate-adaptation, the city might be able to "generate new jobs and knowledge" (C40,2015).

In summary, the approach of Denmark and Scandinavia overall is much more positive as it sees opportunities in climate change adaptation. Thus, it is willing to adapt its legislation and planning system. It is a leading example of how other countries could achieve higher GI implementation. Nonetheless, firstly, the problem has to be understood not only by scientists, but also by general population and political leaders and representatives. That will allow the change of approach to this problem and thus, hopefully, the change of legislation.

6. Comparison of European green infrastructure projects: benefits and ecosystem services provided

The following part summarizes GI projects in the Czech Republic, in Austria and in Denmark. The tables summarize the project, identify its scale, GI elements included and ecosystem services provided. The idea of this part is to demonstrate, that no matter the size of the GI project or its primary purpose, every time, there are more functions as a result. Table 7 to

Table ***25*** summarize GI projects, existing and planned, their scale, benefits and ecosystem services. This summary provides evidence for the argument that green infrastructure is multifunctional, whether it is intended or not.

Table 7: *summarizing the project of Čakovice housing estate (Kuk, 2007).*

Project name	Čakovice housing estate
Project realization	Done
Scale	local
Description	Housing estate connecting city life with nature.
GI elements	• Land sags • Trenches • Drainage systems • Water bodies • Emergency water tank • Water runoff body
Ecosystem services	Regulating • water management, surface runoff regulation • Air quality • Microclimate regulation Cultural • Recreation • Sports • Aesthetics • Education Supporting • Biodiversity • Natural habitat

***Table 8**: summarizing the project of Botanica housing apartments (Nadace Partnerství a, 2022).*

Project name	Botanica housing apartments
Project realization	Done - 2018
Scale	local
Description	BREEM certified apartment housing focusing on water management.
GI elements	• Green roofs • Grey water recycling • Rainwater collection • Solar panels
Ecosystem services	Regulating • Rainwater management • Microclimate regulation • Air quality • Water quality • Surface runoff Cultural • Property value • Aesthetics Supporting • Biodiversity

***Table 9**: summarizing the project of ČSOB headquarters (Nadace Partnerství b, 2022).*

Project name	ČSOB headquarters
Project realization	Done
Scale	Local
Description	Company headquarters using GI as a representation of the company's values.
GI elements	• Green roofs • Rainwater accumulation tanks • Greenery
Ecosystem services	Regulating • Rainwater management • Surface runoff • Micro climate regulation • Water and air quality Cultural • Well-being • Aesthetics • Property value Supporting • Biodiversity • Natural habitat

Table 10: *summarizing the project of House in the strait (Nadace Partnerství c, 2022).*

Project name	House in the strait
Project realization	Done
Scale	Local
Description	A private house built from sustainable materials.
GI elements	• Green extensive roof • Sustainable materials – wood • Rainwater accumulation tanks • Greenery
Ecosystem services	Regulating • Microclimate regulation • Surface runoff • Water management • Air and water quality • Pollination Cultural • Aesthetics • Property value • Well-being Supporting • habitat

Table 11*: summarizing project of the house with a wetland roof (Nadace Partnerství d, 2022).*

Project name	House with a wetland roof
Project realization	Done
Scale	Local
Description	A private house using a wetland roof for rainwater filtration and recycling.
GI elements	• Green wetland roof • Greenery • Heat exchanger
Ecosystem services	Regulating • Microclimate regulation • Water management • Surface runoff • Air and water quality Cultural • Well-being • Aesthetics • Recreation Supporting • Natural habitat • Biodiversity • Ecosystem process maintenance

Table 12: *summarizing the project of Vyšehrad (CAMP, 2020).*

<table>
<tr><td>Project name</td><td>Vyšehrad</td></tr>
<tr><td>Project realization</td><td>Planned</td></tr>
<tr><td>Scale</td><td>Regional</td></tr>
<tr><td>Description</td><td>Improving the Vyšehrad park as a public space but also in terms of climate regulation and water management.</td></tr>
<tr><td>GI elements</td><td>Pond: Enhancing biodiversity
Rainwater management
Recreating the original, natural habitats – orchards and vineyards</td></tr>
<tr><td>Ecosystem services</td><td>Regulating
climate regulation due to large green areas
pollination areas,
air purification
water management
Cultural
leisure activities
aesthetic value
mental wellbeing
health
cultural heritage
Provisioning
food from orchards, vineyards
Supporting:
biodiversity maintenance
Nature protection</td></tr>
</table>

Table 13*: summarizing the project of Emperor's island (CAMP, 2020).*

<table>
<tr><td>Project name</td><td>Emperor's Island</td></tr>
<tr><td>Project realization</td><td>planned</td></tr>
<tr><td>Scale</td><td>regional</td></tr>
<tr><td>Description</td><td>Revitalisation of the Troja basin area on the level of landscape, water management and transport.</td></tr>
<tr><td>GI elements</td><td>Water management – river renewal, flood protection
Renewal of natural habitats</td></tr>
<tr><td>Ecosystem services</td><td>Regulating
climate regulation
natural hazards regulation – floods
pollination
water flow management
Cultural
recreation
tourism
aesthetic value
mental well-being</td></tr>
</table>

	• health • Information for education and research Supporting • biodiversity maintenance and protection • ecosystem process maintenance

***Table 14**: summarizing the project of Rohan Island (CAMP, 2020).*

Project name	Rohan Island
Project realization	planned
Scale	Regional
Description	Project of new residential area – Rohan City and a park – Rohan Island.
GI elements	• Large vegetation area
Ecosystem services	Regulating • climate regulation • natural hazards – floods • pollination • air quality Cultural • recreation • aesthetic value • mental well-being • health Supporting • biodiversity • ecosystem process maintenance • protection

***Table 15**: summarizing the project pf Modřanský cukrovar (Skanska, 2021).*

Project name	Modřanský cukrovar
Project realization	Planned
Scale	Local
Description	First sustainably built residential area in the Czech republic.
GI elements	• Brownfield area • Green roofs • Partially renewable energy - solar panels • Grey water recycling • Fragmented gardens • Biodiversity support - trees, beehives, flower fields, lizard walls
Ecosystem services	Regulating • purification and detoxification of water • climate regulation • pollination

	Cultural • recreation • aesthetic value • mental well-being • health Supporting • biodiversity • protection

Table 16: *summarizing the project at Jungmann square (INCONEX, a.s., 2021).*

Project name	Jungmann square
Project realization	Planned
Scale	Local
Description	Planning trees in the UNESCO historical area.
GI elements	• vegetation - trees
Ecosystem services	Regulating • Microclimate regulation • UHI • Heatwaves • Air quality • Noise reduction • Surface runoff regulation Cultural • Aesthetics • Recreation Supporting • biodiversity

Table 17: *summarizing the project at Královka park (INCONEX, a.s., 2021).*

Project name	Královka park - Prague 6
Project realization	Planned
Scale	Local
Description	Installing underground tanks for rainwater.
GI elements	• greenery • rainwater tanks
Ecosystem services	Regulating • water management • surface runoff • extreme hydrological events regulated • water quality • air quality Cultural • aesthetics • recreation

Table 18: *summarizing the project of trenches at Prague 8 (INCONEX, a.s., 2021).*

Project name	Prague 8 – trenches
Project realization	Planned
Scale	Local
Description	Create trenches along a road to aid in water retention during heavy rainfalls.
GI elements	• trenches • greenery
Ecosystem services	Regulating • water management • surface runoff • water infiltration • air quality • microclimate regulation Cultural • aesthetics

Table 19: *summarizing the project of nebula at Prague 10 (INCONEX, a.s., 2021).*

Project name	Prague 10 - nebula
Project realization	Planned
Scale	Local
Description	Set up a nebula, water elements and drinking fountains to lower UHI
GI elements	• nebula • small water elements • drinking fountains for people and birds
Ecosystem services	Regulating • air quality • microclimate regulation Cultural • aesthetics • recreation • property value Supporting • biodiversity

Table 20: *summarizing the project if courtyards' renewal (INCONEX, a.s., 2021).*

Project name	Renewal of courtyards
Project realization	planned
Scale	Local
Description	Renewing old Prague courtyards in apartment buildings built in the 70s of the 20th century.
GI elements	• Greenery
Ecosystem services	Regulating • Microclimate regulation • air quality • noise reduction Cultural • recreation • aesthetics • property value Supporting • biodiversity

Table 21 to

Table ***25*** summarize GI projects, realized and planned in Denmark and Austria.

Table 21: *summarizing the project of Sigmund – Freud Park in Austria (Urban Development Vienna, 2015).*

Project name	Sigmund-Freud-Park: Austria
Project realization	Done
Scale	Regional
Description	Park in Vienna representing a wide urban open space.
GI elements	• Greenery - trees, vegetation • Permeable surfaces
Ecosystem services	Regulating • climate regulation • water flow regulation • pollination Cultural • aesthetic • wellbeing • health • recreation • tourism Supporting • biodiversity • life cycle maintenance

Table 22: *summarizing the project at Wagramer Strasse (Urban Development Vienna, 2015).*

Project name	Wagramer Strasse: Austria
Project realization	Done
Scale	Local
Description	Green street in Vienna representing a linear urban open space in a built-up area.
GI elements	• vegetation - trees
Ecosystem services	Regulating • climate regulation – microclimate • air purification Cultural • aesthetic • wellbeing • health

Table 23: *summarizing the project of Prater (Urban Development Vienna, 2015).*

Project name	Prater - Austria
Project realization	Done
Scale	Regional
Description	Vienna's protected green space which is a historical area as well as a recreational space.
GI elements	• Large green space • Vegetation • Water bodies
Ecosystem services	Regulating • climate regulation • purification of water • air quality • pollination • pest regulation Cultural • aesthetic • tourism • recreation • cultural heritage • mental wellbeing • health • education Supporting • ecosystem process maintenance • life cycle maintenance • biodiversity maintenance and protection

Table 24: *summarizing the project of in Denmark (Tredje Natur, 2022).*

Project name	Climate Tile: Denmark
Project realization	Planned
Scale	Local
Description	A new concept developed in Denmark to prevent street flooding during extreme rainfall events. Tiles with holes throughout them allow water to infiltrate 'into' the pavement. Water is collected under the pavement and used up by vegetation in the streets.
GI elements	• permeable surface
Ecosystem services	Regulating • natural hazards – flooding • water flow regulation, • air purification Cultural • aesthetics

Table 25: *summarizing the project of Stok Meadow Storkeengen in Dennmark (CF Moller Architects, 2021).*

Project name	Stork Meadow Storkeengen: Denmark
Project realization	Planned
Scale	Regional
Description	Recreating a nature area into a public nature park. It integrates "climate resilience strategies", mainly to adapt to increased rainfall events. Rainwater accumulated from roofs, car parks and roads in the Vorup city is led to Stork meadow. Water is collected and purified using natural wet meadow areas. Purified water is led into the Gudena stream. A dyke was created to protect low-lying parts of Vorup from flooding. Pathways created to encourage recreation in the area.
GI elements	• Meadow areas created • Flora and fauna enhanced
Ecosystem services	Regulating • climate regulation • natural hazards regulation – floods • purification and detoxication of water • water flow regulation Cultural • recreation • tourism • aesthetics • education • health • mental wellbeing Supporting • biodiversity maintenance and protection • ecosystem process maintenance

The tables above summarize information about projects in the Czech Republic, Denmark and Austria. These projects are either local or regional scale projects. Regardless of the scale, each project always provides more than one type of ecosystem service. There is always a regulating service, usually a cultural service and then additionally a supporting service. In urban areas, it is unusual to find provisioning services. More information on this topic in chapter 3.2. Multifunctionality is a feature that all GI projects have in common. Although the scale of the project does not affect the amount of ecosystem services provided, it affects the area affected by those. Generally, it could be said that the larger the project, the bigger the effect. That applies not only to affecting citizens, but mainly to environmental benefits that enlarge with the area. Furthermore, the aim of the project varies from one project to another. Some projects have one individual goal while some already use the knowledge of multifunctionality of green infrastructure and design the project to 'get the most out of it'. No matter the primary aim, the project always brings more with it. For example, the Jungmann park project in Prague, that mainly aims to improve the microclimate in the city centre (regulating ecosystem service), will most probably also improve the wellbeing of people working in the area. That might promote spending more time outside of the buildings, which could lead to more physical activity and so improved health conditions (cultural ecosystem service). This is only one example of a GI project aiming at one group of objectives (climate regulation) that can be achieved by green infrastructure. It is possible to say that green infrastructure has an incalculable number of benefits that are not all possible to list before the project is realized. Unfortunately, this fact also lowers the number of possible GI projects, as often many developers do not have enough real-life evidence of GI benefits to persuade them to use green infrastructure in their projects.

7. Discussion

The first question given in the aims focused on benefits and barriers to GI implementation. Table 26 and Table 27 were created to summarize this answer clearly.

The second question aimed at GI usage in foreign countries. Further, it focused on possible improvements of Czech approach towards GI implementation. To help answer the second question, the literary research studied GI practises in Europe as well as in other countries. In Europe, countries such as Austria or Denmark could be called GI - developed. Their green infrastructure projects are carried out in large numbers, as well as on larger scales. These are often connected throughout a city for example, to elevate its positive effect. On the other hand, there are other countries worldwide, such as China, the US or the UK, that fight the same battles as the Czech Republic.

Therefore, to make GI implementation more effective in the Czech Republic, strategies used by GI - developed countries should be adopted. These are for example the planning and legislation systems that are often limiting Czech municipalities to carry out possible GI projects. In the Czech Republic, legislation and planning documents are being developed, but the division of responsibilities in between departments is slowing the process down. However, as it was also mentioned by Li et al. (2020) or Deely et al. (2020), it can be concluded that ineffective legislation and planning processes are not solely a problem in the Czech Republic. This fact just strengthens the importance to learn from those who already have functioning systems.

Nonetheless, to make the planning system effective and functioning, change in understanding and education towards GI has to occur first. On the same level, cognitive barriers need to be eliminated step by step to allow stakeholders to trust and believe in green infrastructure measures. The difference, in this case, between the Czech Republic and other GI developed countries is the level of understanding of general public as well as of political representatives. Therefore, in my opinion, the change, as any other national change, has to happen from the bottom – using education and positive examples.

In the future, research could be broadened in the area of GI measurements and monetary values. That would mean measuring different values concerning GI on green as well as on grey infrastructure to allow comparison.

For instance, these values would include temperature inside and outside of the building, humidity of the air outside of the building as well as air quality, noise pollution and so on. The results could then be either presented as such or transformed, using economic analysis, to show monetary values of green and grey infrastructure. These would then be used to persuade developers, city counsellors and even the general public, about the benefits of GI and hopefully, increase the implementation of GI projects into practise.

Table 26: *summarizing the ecosystem services by green infrastructure.*

Ecosystem service:	Ecosystem service functions:
Provisioning	• Food and water • Raw materials • In case of this literary research, very limited amount of provisioning services was identified. One example could be honey from bees that are breaded using GI.
Regulating	• climate regulation – UHI relief • water management – baseflow regulation • natural hazards protection – floods • purification of water and air • pollination • pest and disease regulation • carbon sequestration
Cultural	• recreation and tourism • aesthetic value • education and research • mental wellbeing, health • cultural heritage, historical value
Supporting	• biodiversity maintenance, support and protection • ecosystem process maintenance • life cycle maintenance

Table 27: *summarizing the barriers to GI implementation.*

Barrier to GI implementation: name	Barrier description
Funding/ governance/ legislation	• Weak leadership - Unclear roles and responsibilities • Lack of funding • Cost and benefits analysis difficult • Linking providers and users • Maintenance difficult with low financial resources
Monitoring / evidence for usage	• Long-term monitoring • Weak advertisements, successful stories
Technical and biophysical	• Design challenges • Onsite limitations • Construction challenges • Maintenance and performance inexperience
Education/expertise	• Lack of general knowledge on GI • Understanding of general public • Institutional inexperience • Lack of technical guidance • Lack of clear cause-effect relationships
Socio-cultural/ education	• Societal perception of GI • Perception of different stakeholder groups • Community empowerment • Culture • Behaviour • Impacts on future land use

8. Conclusion

As it was mentioned at the end of Part 1 – by the criteria set, countries or areas with similar climate were supposed to be compared to each other. In the case of the studies discussed above, the UK does fulfil the set criteria, but China does not. However, as the UK-China study shows, there is no essential difference when talking about barriers except from the socio-political ones. These would differ between every country because they are not dependent on climate conditions. This argument can be based on the US study as well. Derived from the findings, Dhakal (2017) says that although GI features can vary significantly from one location to another, adopting GI faces similar cognitive and socio-institutional challenges of implementation regardless of location. Based on this statement, it can be concluded that research into barriers to implement GI and the strategies to overcome those can be universal for countries worldwide. Last but not least, the above-mentioned international studies clearly suggest that countries worldwide can work together in order to develop new strategies to overcome barriers to implement GI no matter their geographical location.

To summarize the results of this literary research, benefits of green infrastructure, in the form of ecosystem services were identified and represented. The number of ecosystem services was shown from the perspective of local and regional scale projects. That proved that the scale does not affect the number of ES, but it does affect the area influenced by that. Alongside, barriers to GI implementation were described not only in the Czech Republic, but also in foreign countries. These were then compared to each other and discussed as often, same barriers were named. The second part of the review looked at possible improvements to augment GI implementation in the Czech Republic. Areas identified as needing attention are mostly education, planning and legislation as well as solving the division of responsibilities in between concerned departments. The complexity of the problem and the need for understanding of the problem as a whole is an important area requiring attention. There are many different fields that need to be taken into account in order to find a solution. Based on my own experience, the general public knows very little about green infrastructure. Often, people have no idea what to imagine behind this term. Therefore, education might require the most attention, in order to change how GI is perceived.

The benefit of this research is that it summarizes more fields that are affected by GI, such as UHI or base flow regulation, and it shows their interconnectedness. Furthermore, the usability of the results is mainly in making a clearer picture of the situation in the Czech Republic.

On the other side, the thesis is very shallow because of its complexity. The area requires in-depth research on specific topics. Nonetheless, it can be a stepping stone for further research as well as for first steps and decisions where to start in order to augment the implementation of GI. Surely, as it was mentioned several times already, education, understanding and perception of GI is key. Hand in hand with it goes change of thinking, which, although maybe not visible, it is a limiting factor for putting GI into practise. Finally, the change has to be complex and communal. Putting more attention to one area identified as problematic will not solve the problem and it will most probably not even help in increasing GI implementation. As responsibilities are divided, more departments have to work together to create the desired change. As it was said, implementation of green infrastructure is an interconnected and complex problem that seeks the same solutions.

9. Sources and literature overview

9.1. Scientific publications:

Angelstam, Barnes, Elbakidze, Marais, Marsh, Polonsky, Richardson, Rivers, Shackleton, Stafford, 2017: Collaborative learning to unlock investments for functional ecological infrastructure: Bridging barriers in social-ecological systems in South Africa. Ecosystem Services 27 (B). P. 291-304.

Benedict, McMahon, 2002: Green Infrastructure: Smart Conservation for the 21st century. Renewable Resources Journal 20 (3). P.12-17.

Bhaskar, Hogan, Archfield, 2016: Urban base flow with low impact development. Hydrological Processes 30(18). P.3156-3171.

Bissonnette, Dupras, Messier, Lechowicz, Dagenais, Paquette, Jaeger, Gonzalez, 2018: Moving forward in implementing green infrastructures: Stakeholder perceptions of opportunities ad obstacles in a major North American metropolitan area. Cities 81. P. 61-70.

Brandǎo, Cameira, Valente, Cruz de Carvalho, Afonso do Paco,2017: Wet season hydrological performance of green roofs using native species under Mediterranean climate. Ecological Engineering 102. P.596-611.

Brudermann, Sangkakool, 2017: Green roofs in temperature climate cities in Europe – An analysis of key decision factors. Urban Forestry and Urban Greening 21. P. 224 - 234.

Chaffin, Shuster, Garmestani, Furio, Albro, Gardiner, Spring, Green, 2016: A tale of two rain gardens: Barriers and bridges to adaptive management of urban stormwater in Cleveland, Ohio. Journal of Environmental Management. 183 (2). P.431- 441.

Connop, Vandergert, Eisenberg, Collier, Nash, Clough, Newport, 2016: Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. Environmental Science and Policy 62. P. 99 - 11.

Coutts, Tapper, Beringer, Loughnan, Demuzere, 2013: Watering our cities: The capacity for water sensitive urban design to support urban cooling and improve human thermal comfort in the Australian context. Progress in Physical Geography. 37(1). P.2-28.

Deely, Hynes, Barquín, Burgess, Finney, Silió, Álvarez-Martínez, Bailly, Ballé-Béganton, 2020: Barrier identification framework for the implementation of blue and green infrastructures. Land Use Policy. 99 (105108).

Dhakal, Chevalier, 2017: Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management 203, Part 1. P. 171-181.

Eger, Chandler, Kasaee Roodsari, Davidson, 2014: Water budget triangle: A new conceptual framework for comparison of green and gray infrastructure. In: 2014 International Conference on Sustainable Infrastructure: Creating Infrastructure for a Sustainable World, ICSI 2014.

Eger, Chandler, Driscoll, 2017: Hydrologic processes that govern stormwater infrastructure behaviour. Hydrological Processes 31(25). P.4492-4506.

Feng, Burian, Pomeroy, 2016: Potential of green infrastructure to restore predevelopment water budget of a semi-arid urban catchment. Journal of Hydrology. 542. P.744-755.

Feng, 2018: Evaporation from Green Infrastructure: Benefit, Measurement, and Simulation.

Finewood, Matsler, Zivkovich, 2019: Green infrastructure and the hidden politics of urban stormwater governance in a Postindustrial City. Annal of the American Association of Geographers. 109 (3). P.909-925.

Garcia-Cuerva, Zechman Berglund, Rivers III, 2018: An integrated approach to place green infrastructure strategies in marginalized communities and evaluate stormwater mitigation. Journal of Hydrology 559. P.648-660.

Göbel, Stubbe, Weinert, Zimmermann, Fach, Dierkes, Kories, Messer, Mertsch, Geiger, Coldewey, 2004: Near-natural stormwater management and its effects on the water budget and groundwater surface in urban areas taking account of the hydrogeological conditions. Journal of Hydrology 299(3). P.267-283.

Hassan, Hashim, Hisham Hashim, 2015: Impact of Climate Change on Air Quality and Public Health in Urban Areas. Asia Pacific Journal of Public Health 28 (2), P. 38 - 48.

Hoyle, Jorgensen, Warren, Dunnett, Evans, 2017: “Not in their front yard” The opportunities and challenges of introducing perennial urban meadows: A local authority stakeholder perspective. Urban Forestry and Urban Greening 25. P. 139- 149.

Irmak, Haman, 2021: Evapotranspiration: Potential or Refeference? University of Florida – Department of Agricultural and Biological Engineering (ABE) 343.

Jefferson, Bhaskar, Hopkins, Fanelli, Avallaneda, McMillan, 2017: Stormwater management network effectiveness and implications for urban watershed function: A critical review. Hydrological Processes. 31(23). P.4056-4080.

Jim, 2015: Assessing climate adaptation effect of extensive tropical green roofs in cities. Landscape and Urban Planning. 138. P.54-70.

Johannessen, Hanslin, Muthanna, 2017: Green roof performance potential in cold and wet regions. Ecological Engineering 106. P.436-447.

Johns, 2019: Understanding barriers to green infrastructure policy and stormwater management in the City of Toronto: a shift from grey to green or policy layering and conversion? Journal of Environmental Planning and Management 62 (8). P. 1377-1401.

Jones, Jha, 2009: Green infrastructure: Assessing the benefits of bioretention over traditional stormwater management. Environmental Science and Sustainability. 2nd World Scientific and Engineering Academic and Society (WSEAS) International Conference on Natural Hazards, Morgan State University, Baltimore, MD. P.134-141.

Keeley, Koburger, Dolowitz, Medearis, Nickel, Shuster, 2013: Perspectives on the use of green infrastructure for stormwater management in Cleveland and Milwaukee. Environmental Management 51. P.1093-1108.

Kopp, 2016: The current trends of the ecohydrological management of cites: a case study of Pilsen. Business trends 6. P. 51-62.

La Greca, La Rosa, Martinico, Privitera, 2011: Agricultural and green infrastructures: The role of non-urbanised areas for ecosustainable planning in a metropolitan region. Environmental Pollution. 159(8-9). P.2193-2202.

Lehmann S., 2014: Low carbon districts: Mitigating the urban heat island with green roof infrastructure. City, Culture and Society. 5(1) P.1-8.

Li, Collins, Cheshmehzangi, Chan, 2020: Identifying enablers and barriers to the implementation of the Green Infrastructure for urban flood management: A comparative analysis of the UK and China. Urban Forestry & Urban Greening 54.

Liu, Li, Jensen, Bergen, 2018: Green infrastructure for sustainable urban management: Practices of five forerunner cities. Cities 74. P. 126-133.

Lorencová, Slavíková, Emmer, Vejchodská, Rybová, Vačkářová, 2020: Stakeholder engagement and institutional context features of the ecosystem-based approaches in urban adaptation planning in the Czech Republic. Urban Forestry and urban Greening 58. ISSN: 1618-8667.

Lim, Welty, 2017: Effects of spatial configuration of imperviousness and green infrastructure networks on hydrologic response in a residential sewershed. Water Resources Research. 53(9). P.8084-8104.

Macháč, Rybová, Louda, Dubová, 2018: How to support planning and implementation of climate adaptation measures in urban areas? Case study of Brno – Nový Lískovec. Smart Cities Symposium Prague.

Matthews, Lo, Byrne, 2015: Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landscape and Urban Planning 138. P. 155-163.

McCarthy, Best, Betts, 2010: Climate change in cities due to global warming and urban effects. Geophysical Research Letters 37 (9).

Nelson, Rosegrant, Koo, Robertson, Sulser, Zhu, Ringler, Msangi, Palazzo, Batka, Magalhaes, Valmonte-Santos, Ewing, Lee, 2009: Climate Change – Impact on Agriculture and Costs of Adaptation. International Food Policy Research Institute, Washington D.C. ISBN: 978-0-89629-535-3.

Nordh, Olafsson, 2020: Plans for urban green infrastructure in Scandinavia. Journal of Environmental Planning and Management 64 (5). P.883-904.

Rosenzweig, Solecki, Hammer, Mehrotra, 2010: Cities lead the way in climate-change action. Nature 467, P, 909-911.

Seják, 2005: Základy udržitelné ekonomie přírodních zdrojů a životního prostředí. Ústí nad Labem: Univerzita Jana Evangelisty Purkyně.

Stovin, Poë, Berretta, 2013: A modelling study of long term green roof retention performance. Journal of Environmental Management 131. P.206-215.

Völker, Baumeister, Claßen, Hornberg, Kistemann, 2013: Evidence for the temperature-mitigating capacity of urban blue space—A health geographic perspective. Erdkunde. 67(04). P.355-371.

Walsh, Booth, Burns, Fletcher, Hale, Hoang, Livingston, Rippy, Roy, Scoggins, Wallace, 2016: Principles for urban stormwater management to protect stream ecosystems. Freshwater Science 35(1). P.398-411.

Wong, Jiang, Bohn, Lee, Lettenmaier, Ma, Ouyang, 2017: Lake and wetland ecosystem services measuring water storage and local climate regulation. Water Resources Research. 53(4). P.3197-3223.

Wu, Wang, Fan, Xia, 2018: Thermal environment effects and interactions of reservoirs and forests as urban blue-green infrastructures. Ecological Indicators. 91. P.657-663.

Zhao, Fong, 2017: Characterization of different heat mitigation strategies in landscape to fight against heat island and improve thermal comfort in hot– humid climate (Part I): Measurement and modelling. Sustainable Cities and Society. 32. P.523-531.

Zhou, Shepherd, 2010: Atlanta's urban heat island under extreme heat conditions and potential mitigation strategies. Natural Hazards. 52(3). P.639-668.

Zölch, Henze, Keilholz, Pauleit, 2017: Regulating urban surface runoff through nature-based solutions–An assessment at the micro-scale. Environmental Research. 157. P.135-144.

9.2. Online sources:

Arboleda A., 2015: Evapotranspiration product (online) [citated: 2021.01.17] from URL:https://www.wmo.int/pages/prog/wcp/agm/meetings/sat2015/documents/LSASAF_evapotranspiration.pdf.

BBC Bitesize, 2021: Interpretation of Hydrographs (online) [citated: 2021.01.18.] from URL: https://www.bbc.co.uk/bitesize/guides/zpqwwmn/revision/1.

Bioretention systems, 2009 - New Jersey Stormwater Best Management Practices Manual. (online) [citated:2021.01.18.] from URL: https://njstormwater.org/bmp_manual/NJ_SWBMP_9.1%20print.pdf .

BREEM, 2021: What is BREEM? (online) [citated: 2021.10.16.] from URL:https://www.breeam.com/.

C40 – Cities Climate Leadership Group, 2015: Cities100: Copenhagen – Green Infrastructure Prevents Flooding (online) [citated:2021.10.17] from URL: https://www.c40.org/case_studies/cities100-copenhagen-green-infrastructure-prevents-flooding.

CAMP, 2020: Praha zítra (online) [citated: 2021.08.07] from URL: https://www.campuj.online/expo/.

CENIA, 2021: Kritéria MA21 a jejich zavádění do praxe (online) [citated: 2021.08.22] from URL: http://m.muhb.cz/assets/File.ashx?id_org=3782&id_dokumenty=840911.

Cornell B., 2016: Transpiration (online)[citated: 2021.01.17] from URL: https://ib.bioninja.com.au/higher-level/topic-9-plant-biology/untitled-6/transpiration.html.

Covenant of Mayors, 2021: Objective and scope (online) [citated: 2021.08.22.] from URL: https://www.covenantofmayors.eu/about/covenant-initiative/objectives-and-scope.html.

Datt, 2011: Latent Heat of Vaporization/Condensation. Encyclopedia of Snow, Ice and Glaciers. Encyclopedia of Earth Sciences Series. Springer, Dordrecht. (online) [citated: 2021.01.18] from URL: https://link.springer.com/referenceworkentry/10.1007%2F978-90-481-2642-2_327.

EPA, 2017: Healthy Benefits of Green Infrastructure in Communities (online) [citated: 2021.01.17] from URL: https://www.epa.gov/sites/production/files/2017-11/documents/greeninfrastructure_healthy_communities_factsheet.pdf.

EPA, 2020: What is green infrastructure? (online) [citated: 2020.11.18.] from URL: https://www.epa.gov/green-infrastructure/what-green-infrastructure.

European Commission, 2020: Environment: The forms and functions of green infrastructure (online) [citated: 2020.11.18.] from URL: https://ec.europa.eu/environment/nature/ecosystems/benefits/index_en.htm.

FAO, 2020: Ecosystems and Biodiversity (online) [citated: 2020.11.18.] from URL: http://www.fao.org/ecosystem-services-biodiversity/background/supporting-services/en/.

FAO, 2022: Ecosystems Services and Biodiversity (online) [citated: 2022.02.11.] from URL: https://www.fao.org/ecosystem-services-biodiversity/en/.

Green European Foundation, 2021: Prague Goes Green: Ambitious Climate Plan and Call for Partnership (online) [citated: 2022.02.23.] from URL: https://gef.eu/sessions/prague-goes-green-ambitious-climate-plan-and-call-for-partnership/.

IPR Praha, 2021: Císařský ostrov (Trojská kotlina) (online) [citated: 2021.12.11.] from URL: https://iprpraha.cz/projekt/15/cisarsky-ostrov-trojska-kotlina.

Místní Agenda 21, 2021: Průběžné přehledy zapojení do MA21 k dnešnímu dni (online) [citated: 2021.12.14.] from URL: MA21 dnes (cenia.cz)

Nadace Partnerství a, 2022: Systém recyklace šedé vody v bytovém době Botanica (online) [citated:2022.02.17.] from URL: Databaze - Jak na klimatickou změnu – LIFE TreeCheck.

Nadace Partnerství b, 2022: ČSOB Kampus (online) [citated:2022.02.17.] from URL: https://www.lifetreecheck.eu/cs/Databaze/2020/CSOB-Kampus.

Nadace Partnerství c, 2022: Dům v úžině (online) [citated:2022.02.17.] from URL: Databaze - Jak na klimatickou změnu – LIFE TreeCheck.

Nadace Partnerství d, 2022: Dům s mokřadní střechou v Praze (online) [citated:2022.02.17.] from URL: Databaze - Jak na klimatickou změnu – LIFE TreeCheck.

Natural History Museum, 2021: Human Impacts on Biodiversity (online) [citated: 2021.01.20.] from URL: https://www.nhm.ac.uk/our-science/our-work/biodiversity/human-impacts-biodiversity.html.

Pickett, 2011: Urban Ecosystem, Britannica (online) [citated: 2021.01.20.] from URL: https://www.britannica.com/science/urban-ecosystem.

Portál ŽP HMP, 2005: Orgány veřejné správy a organizace jejich působnosti v oblasti vodního hospodářství s působností na území hl.m. Prahy (online) [citated:2021.12.01] from URL: http://portalzp.praha.eu/jnp/cz/voda/organy_ve_vodnim_hospodarstvi/index.html.

Skanska, 2021: Modřanský cukrovar (online) [citated: 2021.10.16.] from URL: https://reality.skanska.cz/prodej-bytu-praha-12/modransky-cukrovar-1.

Srinivus, 2015: Local Agenda 21 (online) [citated: 2021.08.22.] from URL: https://www.gdrc.org/sustdev/concepts/18-la21.html.

Středočeský kraj, 2021: Kompetence krajského úřadu v oblasti vodního hospodářství (online) [citated:2021.12.01.] from URL: https://www.kr-stredocesky.cz/web/zivotni-prostredi/voda-kompetence.

Škvor, 2014: Kategorie RD podle energetické náročnosti (online) [citated:2022.02.17.] from URL: Kategorie RD podle energetické náročnosti – PRECIZNí DřEVOSTAVBY (precizni-drevostavby.cz).

Tredje Natur, 2022: Climate tile. (online) [citated:2022:03.04.] from URL: https://www.tredjenatur.dk/portfolio/klimaflisen/.

Trenchlesspedia, 2017: Water Budget (online) [citated: 2021.01.20.] from URL: https://www.trenchlesspedia.com/definition/3144/water-budget.

UN - United Nations, 2018: 68% of the world population projected to live in urban areas by 2050, says UN (online) [citated: 2021.12.17.] from URL: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.

USGS, 2020: Evaporation and the Water Cycle (online) [citated 2020.11.27.] from URL: USGS.gov | Science for a changing world

9.3. Other sources

Copenhagen Climate Adaptation Plan, 2011: (online) [citated:2021.10.17.] from URL: https://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf.

INCONEX, a.s., 2021: Implementační plán 2020-2024: Zásobník projektů a záměrů (online) [citated:2022.02.17.] from URL: Microsoft Word - Příloha k MZ č. 1.docx (adaptacepraha.cz).

Kuk, 2007: PROVOZNÍ ŘÁD – ODVODŇOVACÍ SYSTÉM OBYTNÉHO SYSTÉMU U ZÁMECKÉHO PARKU. ING Real Estate Development, Praha, P.47.

MHMP, 2021: Klimatický plán hlavního města Prahy do roku 2030 (online) [citated:2022.02.21] from URL: https://klima.praha.eu/DATA/Dokumenty/klimaplan_cz_4_1_2022.pdf.

MŽP, 2015: Strategie přizpůsobení se změně klimatu v podmínkách ČR (online) [citated: 2021.08.22.] from URL: https://www.mzp.cz/C1257458002F0DC7/cz/zmena_klimatu_adaptacni_strategie/$FILE/OEOK-Adaptacni_strategie-20151029.pdf

Urban Development Vienna, 2015: STEP 2025. Thematic concept – Green and Open Spaces (online) [citated:2021.10.17.] from URL: https://www.wien.gv.at/stadtentwicklung/studien/pdf/b008440.pdf.

9.3.1. Pictures, tables:

Centrum Pasivního Domu, 2022: Dům se zelenou mokřadní střechou – kořenovou čističkou na střeše (online) [citated:2022.02.18.] from URL: https://www.pasivnidomy.cz/domy/dum-se-zelenou-mokradni-strechou-korenovou-cistickou-na-strese-517#zucastneni.

CF Moller Architects, 2021: Storkeengen (Stork Meadow) (online) [citated: 2021.12.12.] from URL: https://www.cfmoller.com/p/Storkeengen-Stork-Meadow-i3327.html.

Místní Agenda 21 a, 2021: MA 21 v mapách (online) [citated: 2021.12.14.] from URL: https://ma21.cenia.cz/cs-cz/ma21vdatech/ma21vmap%c3%a1ch.aspx.

Místní Agenda 21b, 2021: Přehledy realizátorů (online) [citated: 2021.12.14.] from URL: https://ma21.cenia.cz/cscz/%c3%bavod/prove%c5%99ejnost/p%c5%99ehledy realiz%c3%a1tor%c5%af.aspx.