

# High on Greenery

The Potential of Green Roofs for Supporting Accelerated Climate  
Transition Goals in Järfälla Municipality

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### Summary:

This assignment aims to investigate the potential use of green roofs as green infrastructure (GI) to mitigate climate change, including consideration for social factors such as perspectives of stakeholders and citizens, and recommendations for how the municipality can go about with further information and implementation.

### Sammanfattning:

Den här uppgiften har som mål att visa upp den potentiella användning av takträdgårdar för att mitigera klimatförändringar och hur aktörer går tillväga med att informera personer om det, involvera dem och hur de slut implementerar dem.

### Abbreviations:

GYF: Grönytefaktor/ Green space factor, The green space factor is a planning tool used to ensure a certain amount of vegetation or water in a built environment both on neighbourhood land and on public land

Sedum: Sedum or as it's known in Latin Sedeo, is a family of plants in the greasewood family.

A.I: Artificial intelligence refers to the simulation or approximation of human intelligence in machines.

KTH: Kungliga Tekniska högskolan or, as it is known in English, Royal Institute of Technology

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## 1. Introduction

Green infrastructure (GI) is defined by the European Commission (EC) as a strategically planned “*network of natural and semi-natural areas*” (EC, 2019) with the purpose of communities benefitting from ecosystem services that the areas may produce. Several studies have indicated the ecosystem services that may arise from GI planning, include cost savings (Bobbins & Culwick 2015) and health benefits (Zoppi 2020, Wang et al. 2014, Lovell & Taylor 2013), biodiversity, climate mitigation, and food insecurity (Lovell & Taylor 2013) among others, which are all aligned to several of the UN’s Sustainable Development Goals (SDGs). One distinguishable characteristic of having this “green” approach to infrastructure is GI’s common orientation towards the larger scale climate change-related ecosystem service benefit. At GI’s core, the ecosystem-based approach to planning becomes one of “*the most widely applicable, economically viable and effective tools to combat the impacts of climate change*” (EC, 2019). The impacts of climate change is the main issue addressed by SDG 13: Climate Action, wherein GI can further delve into making SDG Targets 13.1, that states that all countries need to strengthen their adaptive capacity to natural disasters and climate-related hazards and 13.2 that states that there is a need to develop policies, strategies, and plans to address climate change according to the United Nations (2015), creating a reality with its potential in influencing measures in national policies, strategies, and planning.

To maximize potential benefits, GI planning revolving around multiple functions is possible, however challenging. According to Lovell and Taylor (2013), the planning and implementation of GI can benefit from diverse stakeholder feedback through introducing multifunctionality at various development phases within planned areas. Multiple and diverse functions may be able to serve a diverse community, which more realistically reflects the composition and demographic characteristics of current societies. Questions of appropriate timing and method of ecosystem service availability may be able to address potential societal issues relevant to SDG 10: Reduced Inequalities.

### 1.1 Green Roofs as Multi-functional GI

Green roofs boast a rich history that spans centuries and is deeply rooted in various global cultures. One of the earliest instances dates back to the Hanging Gardens of Babylon, constructed around 600 BCE in present-day Iraq, showcasing the practice of cultivating plants on elevated structures (Metych, 2023, Accessed 15 Dec. 2023). This history underscores humanity's enduring desire to connect with nature in urban settings (Spirn,2014). Over time, rooftop gardening has served both practical and aesthetic purposes. In medieval Europe, monasteries used rooftop gardens to cultivate medicinal herbs, while 19th-century New York featured rooftop gardens as urban escapes from congestion and pollution (Spirn,2014). For example, the prominent urban planner Le Corbusier talks about rooftop gardens in his Five Points of Architecture in 1923 (Oechslin & Wang, 1987), mentioning that rooftop gardens should be placed on large square roofs.

Today, green roofs are experiencing a revival, driven by environmental sustainability, the need for urban green spaces, and efforts to combat the urban heat island effect among other urban challenge. Green roofs, also known as rooftop gardens, vegetated roofs, living roofs, and eco roofs (Shafique et al., 2018), are gaining popularity in temperate and cool-temperate climates, particularly in Europe and North America, as a type of GI that can serve multiple functions. A green roof, as defined by Shafique et al. (ibid.), is the general term for a roof with planned vegetation planted on top of a medium or substrate for the purpose of extracting multiple social, economic, and environmental benefits. They have become integral components of sustainable

urban design, offering recreation, relaxation, and solutions to contemporary urban challenges (Beatley, 2016). From stormwater management and temperature regulation to improved air quality and higher well-being for urban residents, green roofs offer not only aesthetic appeal but also the potential to mitigate a multitude of urban challenges (Orsini et al., 2017).

## 1.2 Problem Statement and Case in Study

In the summer of 2018, Sweden had experienced a record high of mortality cases affiliated to extreme temperatures with over 635 deaths resulting from a heatwave occurrence (Åstrom et al., 2019). In consideration of the vulnerability of the varying socioeconomic profiles (SCB, 2021) to heat stress (Rohat et al., 2019), the relevance of addressing goals of SDG 13 becomes of importance on the local, as well as global, scale.

The Climate City Contract (CCC) is a tool used by municipalities to directly contribute to SDG 13 by participating in the European Commission's target of 100 climate neutral cities by 2030. To orient municipal actions towards this target, the Swedish government has collaborated with academia and industry to formulate Viable Cities, a strategic innovation programme for supporting Swedish cities in standardizing, developing and implementing their own CCCs. Järfälla is one municipality that has been actively involved in this programme and using the city as a testbed (Schabb & McCormick 2023) for experimentation with new projects, research and initiatives towards the climate transition.

One of Järfälla's testbed projects towards climate transition goals is called "IOTak" which has been labeled as a smart green roof project to develop a streamlined process for planning and evaluation of further green roof implementation on municipality buildings (Barkarby Science, n.d. Accessed 15 Dec. 2023), as well as future households (Järfälla Kommun Climate Contract Information Kit, n.d. Accessed 21 Nov. 2023). With the increasing population and population diversity in Järfälla (Järfälla Kommun, n.d. Accessed 15 Dec. 2023), a quick pace of planning and implementation of GI such as green roofs may increase risk in terms of unequal access to ecosystem services (Razzaghi, 2023) and benefits that these provide, as well as challenges in the long-term sustenance when it comes to cost, maintenance, and general interest (Razzaghi, 2023).

## 1.3 Aim and Research Questions (RQ)

Thus, this research project aims to investigate opportunities for accelerated climate transition in Järfälla municipality through a review of green roof implementation conditions and practices through selected green roof case studies in parallel to insights from IOTak project stakeholders as well as citizens of the municipality. This investigation will address the following research questions:

- What are green roofs according to experts, and what are their benefits, drawbacks, and methods in their implementation?
- What insights can be identified from other green roof implementation projects that are relevant to Järfälla municipality?
- What are the perspectives of citizens with regards to green roofs and GI planning of the municipality, and how can these be used in the future green roof planning in Järfälla?

## 2. Method

To investigate the research questions, the study design was used. Identification of potential data sources was made by the researchers, which included consultants and actors in the private and public sector, educational podcasts, videos and online resources about green roofs, and scientific articles. Furthermore, support from the municipality was initially requested for developing a target citizen group to gather citizen perspectives. As the feasibility of the exhaustive list of resources was studied, challenges to the project became evident, which supported the researchers in defining the scope and limitations of the research.

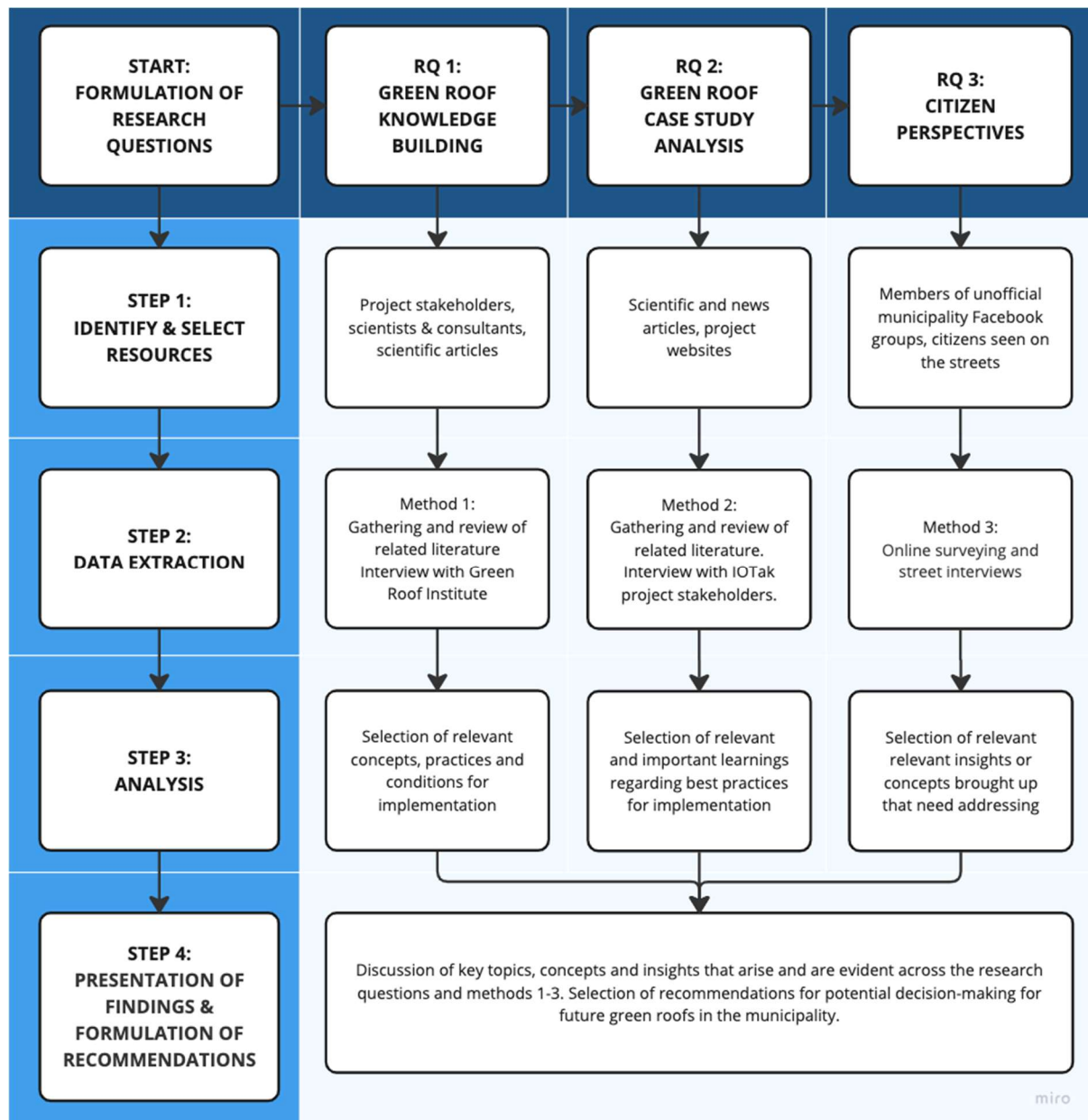


Figure 1. 4-step framework for conducting this study

### 2.1 Scope and Limitations

The scope of the research project includes identification of a few essential concepts, cases, and insights regarding green roofs for the purpose of identifying key areas for consideration when furthering green roofs in Järfälla municipality. All data gathered for this purpose were

qualitative to focus on in-depth understanding of citizens' perspectives (Halcomb, 2016) and describing multifaceted phenomenon (Bailey, 2008) using methods such as interviews, observation and text analysis to collect data (Bryman & Nilsson, 2018).

Limitations to the research project have mainly arisen through the availability of data sources. Selected cases were made based on convenience and availability of online information, knowledge-building interviews were made with the only project stakeholders and green roof consultants that were available within the time frame, and only a limited number of citizens were surveyed and interviewed within the same time frame. Although recommendations backed up by quantitative evidence are not made in this research, the qualitative data is used to answer the selected research questions that attempt to approach the research aim by the consideration of a social dimension in decision-making. With the advantage of qualitative data in answering “what” and “why” questions (Obono & Obono, 2008), the intersection between environmental goals and social aspects of green roof projects is discussed in order to help Järfälla municipality in identifying future opportunities.

## 2.2 Data Gathering and Analyses

### 2.2.1 Literature review

Literature review can serve as a basis for future research and theory (Mustafa et al. 2021). In addition to providing evidence of an effect and developing knowledge, the practice can serve as a basis for developing policy and practice, as well as generating new ideas and directions.

For this research project, key themes within the topic of rooftop gardens were identified for gaining in-depth knowledge on the GI for Method 1 (figure 1). Keywords such as “green roof”, “sedum roof”, and “green roof maintenance” have been used with Scopus and Google Scholar search engines for identifying and selecting related literature. Furthermore, terms taken from interviews with consultants and stakeholders such as “biotope roof” and “green roof substrate” have also been used for reviewing literature on green roofs.

The initial phase involved meticulous exploration of pertinent literature, employing search criteria like rooftop gardens, green infrastructure, urban gardens, and urban greenery. Diverse scholarly articles, books, and various sources were gathered to compile a comprehensive understanding. Subsequently, discerning patterns and themes within this wealth of information became pivotal, unraveling recurrent motifs, contrasting viewpoints, and notable gaps in the existing literature. Following this rigorous analysis, key insights were meticulously extracted, emphasizing pivotal findings and arguments that surfaced from the synthesis, culminating in a distilled understanding of the subject.

Additionally, literature has also been identified and selected for the purpose of a case study analysis in Method 2 (figure 1) for identifying best practices for implementation in varying areas. For this case study search, keywords such as “green roof household case” and “green roof policy” have been used. Furthermore, literature involving specific cases within Sweden have been used upon recommendations garnered from interviews with consultants.

### 2.2.2 Surveys

Surveys are a widely used community-based approach for collecting data to gain local knowledge, understand local conditions, and practice direct democracy (Carr & Halvorsen, 2001), offering a structured approach to gathering information from a broad audience. They allow researchers to collect large amounts of data quickly and cost-effectively. Surveys can

target specific demographics or be designed for general populations, providing valuable insights into opinions, preferences, behaviors, and trends (Ponto J.2015). In the case of this study, two online surveys were conducted to seek future insights stemming from citizens' perspectives as mentioned in this study's third research question. The surveys were made to collect data anonymously with minimal demographic data collected such as age, type of residence, and duration in residence, for the purpose of qualifying potential bias brought about by the method of survey.

The first online survey was made through Google Forms and released to an online Facebook group called "Vad händer i Jakobsberg", which consisted of 3 900 members as of the posting date. The intention of this initial survey was to directly scope out citizen knowledge and interest on green roofs through 'yes' or 'no' and multiple choice type of questions that directly involve green roof-related topics. Questions about awareness of and access to existing green roofs in Järfälla were included. All survey 1 questions may be found in the appendix section (7.2).

The second online survey was also made through Google Forms and released to an online Facebook group called "Händelser i Järfälla", which consisted of 20 100 members as of the posting date. This second survey was made to scope out opportunities that can lead to higher citizens' preferences for, and acceptance of, green roofs through questions categorized into three categories: environmental values, perceptions, and attitudes. A study by Du Plessis and Brandon (2015) explains how positive environmental values can promote co-creation in planning for the built environment. Additionally, Larson et al. (2009) indicate socio-cognitive factors such as perceptions and attitudes influence public willingness to adopt and accept green infrastructure. In these studies, as well as in this research project, the definitions given by Dietz et al. (2005) and used by Turner (2016) for these socio-cognitive factors are used, wherein values are referred to worldviews or beliefs that one holds about the environment, perceptions are referred to personal observations about the subject matter such as the natural environment and the municipality, and attitudes are referred to as judgments, stances, or opinions coming after personal observations. To seek values, perceptions and attitudes in this survey, respondents were asked to agree or disagree with statements on a scale of 1-5. Statements utilized for determining values have been adapted from the New Environmental Paradigm (NEP) scale, which was originally developed by Dunlap and Van Liere (1978) to measure general environmental concern and has been utilized and known to be one of the most effective predictors (Xiao et al. 2017) for a given sample population's level of environmental concern, which may affect success of GI implementation in terms of community acceptance. Other statements used to identify perceptions and attitudes were formulated by the researchers with the context of Järfälla municipality. All survey 2 questions may be found in the appendices (section 7.2).

Mean likert scale scores and outliers were considered in the analysis of data from these two surveys. Conclusive positive or negative scores were used to highlight potential opportunities, while neutral or inconclusively mixed scores were unutilized for this study.

### 2.2.3 Interviews

As stated by Jaure et al. (2008), open-ended questions are asked during one-to-one interviews to encourage participants to address issues pertinent to the question. To investigate topics suggested by the respondent, the interviewer may reword, reorder, or clarify the questions. Interviews serve as a powerful tool for gathering data, offering a dynamic avenue to delve into subjects' thoughts, experiences, and perspectives. These conversations enable researchers to explore nuanced details, diving beyond quantitative data into the qualitative realm. They foster



a rich understanding of motivations, emotions, and contexts that numbers alone might not capture (ibid).

For seeking answers to the first research question, we interviewed Barkarby Science and the IOTak project manager from the Järfälla municipality who are both major actors in the municipality. The interviewees were selected on the grounds of being able to give answers about relevant projects, and how the projects made use of rooftop gardens. However, due to the limitation of time, some relevant stakeholders were unable to participate for an interview. Assessment of interview data with project stakeholders has been done with possible the following bias in consideration: First, the information on progress and output received may have been managed to depict only positive aspects since the IOTAK-project is still ongoing with the hopes of future funding for expansion, and second, design and planning decisions by the project management may have been defended and relayed without a critical point of view. Thus, to be able to gain a critical perspective, a third interview with an external green roof consultancy in Sweden, Green Roof Institute, was made.

Furthermore, the interview method was also utilized to aid seeking answers for the third research question, wherein brief 3-question street interviews were made to gather citizens' perspectives, in consideration of the timeframe of the project. The questions asked revolved around (1) the citizens' knowledge of green infrastructure projects of the municipality, (2) their perspective of the municipality's efforts for community participation in planning, and (3) their possible suggestions to the municipality for better community involvement. In addition to surveys, Carr & Halvorsen (2001) indicate direct community conversations such as these are good methods for gaining local knowledge.

### **3. Results and Analysis**

#### **3.1 Knowledge Building for the inhabitants of Järfälla Municipality**

##### **3.1.1 Findings from Green Roof Literature**

The terminology associated with the cultivation and maintenance of rooftop gardens in urban areas varies depending on the context in which they are used. While urban agriculture and urban gardening are often used interchangeably, it should be noted that urban gardening does not necessarily focus on the production of food (Sutton, (Ed), 2015). Literature review and stakeholder interviews resulted in key concepts that were identified as important in the consideration of green roof implementation in Järfälla Municipality, but also other locations across the globe.

#### **The Potential Role of Green Roofs in the Urban Context**

Järfälla Municipality is growing at a rapid rate. Rooftop gardens could be one of the most important ways in which residents of the municipal area can get access to green spaces in their urban environment, whether it is through parks and allotments, as a result of the rapid growth of the population and at the same time give the inhabitants proximity to nature (Järfälla,2023 Accessed 15 Dec. 2023).

A solution to the mentioned challenge of Järfälla Municipality is to design the potential roofs with annual seeds, bulbs, or other cryptophytes (living plants below ground, which are invisible during certain seasons) that only emerge under favourable conditions. Plant selection for green

roofs in temperate regions has focused mainly on shallow-rooted, succulent plants that are native to temperate regions (Sutton, (Ed), 2015). Roof systems can still benefit from natural soils even if they are no longer biologically active by mimicking the mineral-based properties of a particular plant palette's habitat to grow and reproduce successfully.



*Figure 2: An example of “rooftop gardens” in Texas (Sutton,(Ed), 2015).*



*Figure 3: An example of “rooftop gardens” in Texas from another angle (Sutton,(Ed), 2015).*

Even though some Sedum roofs or as they are called in some other parts of the world, brown roofs may not be the most attractive in terms of aesthetics or even in terms of performance, they do demonstrate that they are worth investigating in even if they aren't the most attractive in the aesthetics of the potential rooftop garden (Sutton,(Ed), 2015), as they are uncomplicated to install and offer a green solution to the rooftops across Järfälla Municipality.

Moreover, increased temperatures and precipitation anomalies will alter certain parameters regarding building designs (Sutton,(Ed), 2015). Common or shared space can be essential to the development of a sense of community within and around the garden. Research has shown that levels of social capital tend to be higher in gardens that reserve some area for communal space (Christensen, Søren, 2017). The space can also be used for several different activities like gardening for donation, classes, or community events (Christensen, Søren, 2017).

### **Key Ecosystem Services that Green Roofs Provide**

There is a wide range of ecosystem services that are associated with urban areas, the most commonly studied of which are regulatory services (Tan & Jim,2017). Depending on how they are designed, temperate green roofs may be able to provide stormwater management, climate control, and habitat benefits, all of which can be greatly enhanced by incorporating green roofs (Bengtsson et al,2006).

## Stormwater Management

Water scarcity is a severe problem facing many cities worldwide, particularly within cities characterized by a drier climate (Tan & Jim,2017). While the generation of storm water within cities is beginning to be seen as a valuable resource, urban water bodies, urban vegetation, and associated soil's capability of stormwater retention, storage, and groundwater recharge (Tan & Jim,2017) would contribute to meeting local water “needs”. Using green rooftops in urban areas reduces runoff and flooding by absorbing the water that falls on them. As a result of the structure of the system, stormwater can be managed and reduced in volume, which reduces the stress on drainage systems as a result (Tan & Jim,2017). One example of this is to fit the new or already existing roof with a sort of foam layer, the foam absorbs the storm water, and at the same time provides the greenery on the roof with water (Tan & Jim,2017).



*Figure. 4: Experimental hydroponic foam layer beneath the growing greenery, providing plant-available water while retaining stormwater (Sutton, R. K. (Ed.). 2015).*

## Mitigation of Urban Heat Island Effect

Rooftop gardens can mitigate the urban heat island effect by absorbing heat and providing shade, making cities cooler and more comfortable during hot weather (Lehmann,2014). Both North America and Europe have developed and adopted the concept of rooftop gardens to prepare themselves for the cool-temperate climates found in the respective regions (Sutton,(Ed), 2015).

Even with all these factors in place, these regions can experience both freezing and warm weather throughout the year, but they are generally not subject to climatic extremes such as high temperatures, prolonged droughts, or intense rainfall, which are more common in tropical and subtropical regions in the world (Sutton,(Ed), 2015). For green roof designs, this poses a variety of challenges as they need to not only provide adequate conditions for plant growth but also improve roof performance in terms of their ability to provide intrinsic cooling for the building as well as reduce the effects of heat islands in their surroundings (Sutton,(Ed), 2015).

## Support to Urban Biodiversity

Green roofs, are integral to urban biodiversity within GI planning, act as habitat connectors in the larger green infrastructure. These elevated green spaces atop buildings offer sanctuaries for diverse species, serving as corridors that link habitats across urban landscapes. By providing interconnected greenery, they facilitate wildlife movement, contributing significantly to urban biodiversity by bridging fragmented habitats and supporting diverse wildlife populations.

By providing habitat opportunities to birds, insects, and even small mammals on green roofs, green roofs are contributing to the biodiversity of cities in general (Wang Et al., 2022). Although typically avoided in favor of engineered substrate, natural soils can provide an important ecological benefit for green roof systems in terms of jump-starting a viable habitat. They can act as fungal and microbial inoculants and can serve as an additional source of plants, and they attract pollinators, supporting these diverse pollinator communities at the urban scale of insects (through seed banks, eggs, and larvae), or presumably of species that naturally coexist (Brown, Et al. , 2016).

Urbanization tends to decrease biodiversity, lead to habitat loss, and negatively impact the environment in cities around the world as soil seals and is impermeability, green spaces disappear, and habitat fragments become more fragmented (Beatley, 2016). With green roofs, conditions are created for biodiversity establishment, habitat creation, and enhancement of urban ecology, allowing natural colonization of plants, birds, insects, and small animals and spots for feeding and nesting.

Green roofs differ from natural ecosystems in that they are highly manufactured, human constructs. In natural ecosystems, ecological dynamics are complex, which may not transfer directly to green roofs. However, experimental manipulations of diversity in systems ranging from mosses to algae to forest trees generally find positive effects of increasing diversity (Sutton, (Ed), 2015), suggesting that green roofs too may share similar dynamics as biodiversity found in “natural” parts of the environment (Beatley, 2016).

### 3.1.2 Findings from Interviews with Green Roof Experts

After conducting the three different interviews, the researchers can begin to see certain patterns, trends, and statements that the interviewees agree with after they have conducted the three different interviews.

The first thing that all three agree on is that roofs are unused surfaces, which have the potential to be so much more than just a surface on which to place a Sedum roof to make the building “green” in the eyes of the public (Johansson,2023 15 November). Whether it's one of the four most used ecosystem services or putting sensors on the roofs, all three interviewees saw the potential of the roof, and not just a trend to be used for promotion.

To achieve this, all three of the interviews spoke about the importance of knowledge and highlighted that it will help with the need for a better understanding of the roof as an asset, as well as the need for improved collaboration across stakeholders (Sundberg,2023 21 November). They concluded that with the right knowledge and collaboration, the roof can be leveraged for a wide range of ecosystem services (Johansson,2023 15 November).

According to two of the three interviews, the Grönytefaktor, or Green Space factor, is an outdated concept and a new system is required to ensure green qualities are achieved in the construction of new buildings and areas, while the third interview talked about the importance of creating a framework for rooftop gardens and green infrastructure for future use of Järfälla Municipality (Lindberg,2023 December 5).

And finally, they all agree on the part of the maintenance is something that is an important part of the planning of the green rooftop gardens. Regular maintenance and monitoring should be conducted to ensure that the garden is functioning properly (Johansson, 2023 15 November). It is also important to consider the impact of the roof on the environment, such as the potential for runoff, and to design the garden accordingly (Sundberg,2023 21 November).

However, some answers were different from the different interviewees. Firstly, The Green Roof Institute, on the other hand, was more open about the fact that knowledge can always be improved to increase understanding among all the potential actors and stakeholders who want to get involved with green roofs in the future (Johansson,2023 15 November). At the same time, interviewees involved with IOTAK were more defensive in tone regarding the question of what could be done better, as the project was still ongoing, and we would just have to wait and see what could be improved in the future (Sundberg,2023 21 November).

Secondly, all the interviewees answered the question of what a green rooftop was to them, their answers all differed from each other. One definition was “vegetation that does not have any connection with groundwater”, while a second was “It is a roof that is optimized for the best use, so you have to find out what type of roof it should be” (Sundberg,2023 21 November), and the final answer was “It is something that is as broad as it sounds” (Lindberg,2023 December 5).

This means the defining of what a green rooftop garden is, might not be as easy as the interviewees made it sound.

### 3.1.3 Summary of Key Findings

After gathering data from both literature analysis and interviews with stakeholders and consultants, a few key concepts have been identified to be crucial in planning green roofs.

#### **The framework and hindrance of the Grönytefaktor/ Green space factor**

The concept of "Grönytefaktor," encapsulating the measurement of green spaces within urban landscapes, can play a pivotal role in assessing the ecological balance and livability of a municipality like in this case Järfälla (Boverket ,2020 Accessed 15 Dec. 2023).

However, its sole emphasis on quantifying green areas might inadvertently hinder the evolution of comprehensive green infrastructure. While it acknowledges the presence of green spaces, it might overlook the quality, diversity, and connectivity of these areas crucial for effective green infrastructure development. By focusing solely on quantity, there's a risk of neglecting strategic planning for integrating various forms of green infrastructure, such as green roofs, permeable surfaces, and biodiversity corridors.

This narrow emphasis might impede the holistic evolution of green infrastructure that fosters resilient, sustainable, and interconnected urban environments, as the interviews from both Green Roof Institute and Barkarby Science pointed out. Integrating a qualitative aspect into the Green space factor framework could better facilitate a more robust and diversified green infrastructure development strategy within urban settings.

### **The equality aspect of a rooftop garden, and how they might benefit the socio-economical challenged:**

It is also necessary to take into consideration the equality component when discussing green roofs in the country, since socioeconomic areas in the country tend to have less green space and more paved roads in their neighborhood/area (Development, 2023 Accessed 16 Nov. 2023) The result of this phenomenon is that these areas become warmer during periods of higher temperatures as a result of this process.

There may be overcrowding in this area, the residents may not have proper air conditioning, and some of these residents may not have the financial capability to leave their homes since they do not have the finance to do so (Development, 2023 Accessed 16 Nov. 2023) This situation can lead to a variety of health risks, including heat stroke, dehydration, and other heat-related illnesses as previously mentioned in the assignment. It also puts a strain on public services, such as healthcare, water, and electricity.

### **A “Rooftop garden” or just a “Sedum Roof”**

The most interesting observation the researchers have made is that with the results and what is said in the podcast The IoT Public Sector Podcast and what was learned during the interview with Barkarby Science is that several areas in the municipality are surrounded by asphalt, which in turn is affected by the increasing heat during the summer and there is a risk that those who live in those apartments do not have the opportunity to travel away to cooler climates during heat waves (Sundberg,2023).

During the interview with Green Roof Institute, they told the researches that although heat stress mitigation is one of the four major benefits of green roofs, heat stress is often left in the background when deciding what to implement on the roof (Johansson,2023). With this information, we can conclude that with the current changes in the climate and the context of urban density, heat stress should not be in the background of the decision phase.

## **3.2 Case Analysis of Green Roofs**

Across Europe, some countries are already at the forefront of green roofs and by proxy smart roofs. In Basel, Switzerland, there is a requirement for newly built flat roofs to be green and, in Paris, there is a law that new commercial roofs must be partially green, in Copenhagen new roofs must be covered in green as long as they do not slope more than 30% (Interlace Hub, 2022). London has trees, gardens, and recreation as part of the requirement for new buildings that are being built (Development, Podcast. 2023). Therefore, the researchers have listed some examples, upon receiving recommendation and referral from stakeholder interviews, of cases with relevance in terms of policy implementation and planning.

### 3.2.1 Identification and Selection of Cases

#### **Wollishofen, Moos, Switzerland**

Seewasserwerk Moos, or Moos Water Filtration Plant, is a prominent water treatment facility located in Moos, near Zurich, Switzerland. By utilizing advanced technologies and processes for water purification, this plant provides clean and potable water to the surrounding region (Green Roofs, n.d. Accessed 15 Dec. 2023). The case of Moos was chosen because we got a tip from the Green Roof Institute to look at it since it is one of the oldest green roofs in Europe and also a unique case of Green Roof that has flora that is unique to the roof and thereby created an ecosystem of plants that do not grow anywhere else in the region (Johansson, H, 2023 15 November).

The roof meadow contains a large community of rare green-winged orchids, including a large meadow with surprisingly diverse flora. Despite not being designed as a green roof, plants have naturally colonized the roof. There are approximately 175 different plant species living on the three oldest green roofs (from 1914), including nine orchid species (Green Roofs, n.d. Accessed 15 Dec. 2023).



*Figure 5: A still of the roof of Seewasserwerk Moos, with its unique ecosystem that houses plants that only grows at its roof (Green Roofs, n.d. Accessed 15 Dec. 2023.).*

#### **Hamburg, Germany**

The historic World War II bunker known today as St. Pauli Bunker in Hamburg, Germany, has been repurposed as an multi-functional events facility and urban roofdeck park. Neighborhood residents, together with a local association for collaborative planning called Project Hildegarden, have planned for the public space which includes 8 250 sqm. of green urban gardens and a ramp from the ground to ensure public access. Furthermore, the city of Hamburg has implemented a policy in 2015 for mandatory green roofs for applicable new construction and renovation projects. With this policy the Hamburg Ministry for Urban Development and Environment has allotted financial subsidies to encourage and support residents in their own implementation of green roofs. Subsidies can be given to property owners that have plans for a minimum of 20 sqm of green roof space with 8 cm of green roof soil thickness (Hamburg Municipality, n.d. [website accessed: 14/01/2024]).



*Figure 6: Visualization of the planned St Pauli Bunker in Hamburg, Germany (Hamburg Municipality, PlanungsbüroBunker, [website accessed: 14/01/2024]: hamburg.com)*

### **ØsterGro, Copenhagen, Denmark**

Since Denmark is one of the leading countries in the world with it comes to green roofs, rooftop gardens, and green infrastructure (Johansson, H, 2023). It was quite clear for us to find a case that highlighted the best of the best of the tips we got from the interviewees such as urban greenery , a palace for recreation and a community of people working together. So the choice fell on ØsterGro located in Copenhagen.





*Figure 7: ØsterGro garden, located in the center of Copenhagen, Denmark (ØsterGRO,2014 Accessed 27 Nov. 2023).*

ØsterGro was established on top of Copenhagen's Climate Resilience Neighborhood's old car auction house, Nellesmannhuset, as Denmark's first rooftop farm. It has 600 m<sup>2</sup> of organically grown vegetables, fruits, greens, herbs, edible flowers, a greenhouse, a henhouse, and three beehives. ØsterGro is organized as a community-supported agriculture (CSA) and sells its produce. Members pay for their weekly harvest share in advance of the harvest season (ØsterGRO,2014 Accessed 27 Nov. 2023).

It is hopefully only a matter of time before Sweden also imposes these requirements. Malmö is currently at the forefront, but the other parts of Sweden can also reach the same level as Malmö and the other countries in Europe (Johansson, H, 2023 15 November). To do that, there is a need for adaptation with more climate-adapted plants for the future, but also for the present that are part of the local flora (Alizadeh, & Hitchmough, 2020).

## **Sergelhuset, Stockholm, Sweden**

Located in the heart of Stockholm's city center, Sergelhuset features a roof landscape of Urban Green installed on four of its floors, with a unique view of Sergel's torg. In addition to the construction of water-retaining structures and the construction of carpentry, there are over 2,000 planted spring-flowering bulbs, 400 shrubs, and more than 3,000 perennials throughout Stockholm, the roof is also fitted with Sedum carpets and meadow carpets that are filled with poppies and chicory (Urban Green A. n.d Accessed 27 Nov. 2023.).

There are also planters with stonecrop, red coneflower, lovewort, bridal veil, silver grass, silver shrubs, and Icelandic vine. Clematis and honeysuckle climb on expanded metal, and on the terrace at the top of the building that on all the other sides is surrounded by concrete and asphalt (Urban Green A. n.d Accessed 27 Nov. 2023.).



*Figure 8: The roof of Sergelhuset located in the heart of Stockholm, fitted with Urban Green own Sedum roof (Urban Green A. n.d. Accessed 27 Nov. 2023)*

## **Campus Albano, Stockholm, Sweden**

Campus Albano stands as a scientific nucleus, uniting Stockholm University and KTH Royal Institute of Technology alongside the city itself. This innovative space embodies a sustainable campus, housing educational facilities, offices, and laboratories tailored for students, educators, and researchers.



*Figure 9: The public rooftop garden located at Campus Albano, located just a few minutes from KTH main campus.*

During a three-year construction phase led by Skanska on behalf of Akademiska hus, Urban Green served as a subcontractor. The project aimed to set a precedent for sustainable urban development. Notably, it prioritized biodiversity and various facets of sustainability, such as social and environmental (Urban Green B,n.d Accessed 27 Nov. 2023).

It is also important for the researchers to emphasize that the Albano campus currently actively engages with its sustainability program, which is available in both comprehensive and concise formats. Albano's sustainability objectives are articulated in this program, aligned with Citylab's overarching sustainability objectives. Furthermore, it also outlines the methodology for implementing sustainability measures across all subprojects within the Albano campus as well as the reasons for doing so (Akademiska Hus.n.d. Accessed 15 Dec. 2023).

### **Greenhouse, Malmö, Sweden**

One case that stood out during the interview with the Green Roof Institute was the Greenhouse in Malmö, this was because the building and its shared rooftop garden embodied the potential future projects that will make use of rooftop gardens, and at the same time how it connected the inhabitants of the building (MKB,n.d Accessed 27 Nov. 2023.). There, the apartment building is partly equipped with balconies that are made to facilitate the care of plants where the balcony is divided into two climate zones - one part is glazed to extend the growing season while another part is open. The balcony is also equipped with a water ejector and a floor drain to collect any water that may be spilled during irrigation (MKB,n.d. Accessed 27 Nov. 2023).

In addition, there is a public roof garden on the roof of the building with the possibility of cultivation and recreation. Here, the recurring issue of green roof management has been resolved, with the residents of the building taking care of it (MKB,n.d.Accessed 27 Nov. 2023). Especially through the cultivation in a common area, have helped to bring people in the building together



*Figure 10: The rooftop gardens located on the building Greenhouse in Malmö, which has solved the question of maintenance with the residents taking care of the garden (MKB,n.d.).*

What's worth highlighting in this case is the extra dimension that the roof adds, the creation of a community for the residents of the house. This also highlights the social sustainability that the roof provides in connection with the sustainability that has previously been linked to green roofs.

### **Barkarby, Järfälla, Sweden**

Perhaps the most recent and local case in this assignment of rooftop gardens, since it is located in Barkarby in Järfälla Municipality, is the case of IOTAK by Barkarby Science.



*Figure 11 and 12: The IOTAKs project group site visit in Barkarby on the roof that will serve as the test bed for the project. 7/12-2023.*

Many municipalities like Järfälla does have untapped resources in the case of roofs that can both smart and roofs, and the idea behind this project is to capitalize on these resources. Since many areas of Järfälla Municipality are already densely populated, so many perspectives and wills that want to move different projects forward. Sadly, too often, the green areas are the ones that suffer and become overlooked during times of recession and other economic recessions. Rooftops have a huge untapped potential, and that is where you find their untapped potential.

By integrating IoT technology with green roofs as a way of providing ecosystem services, it would be possible to make green roofs smart (Barkarby Science,n.d. Accessed 15 Dec. 2023). By using solar cells, the temperatures can be reduced on the roof, meaning that the potential vegetation will be protected from the heat and potentially drying up, the roofs will also be able to collect and use storm and rain water, as well as the potential number of pollinators can increase due to increased water availability. Secondly, there is a reduction in the level of noise as well as a cooling effect (Barkarby Science, n.d. Accessed 15 Dec. 2023). Smart green roofs can also provide data regarding air quality, soil moisture, and other environmental factors (Barkarby Science, n.d. Accessed 15 Dec. 2023). This data can then be used to optimize the use of resources and plan for future infrastructure. Finally, smart green roofs can help reduce carbon emissions by having a sort of foam that absorbs the carbon emissions from the surrounding traffic (Sundberg,2023 21 November).

### 3.2.2 Summary of Case Findings

A summary of key findings are found in the table \_ below. In the cases of countries in Switzerland, Germany and Denmark, policies mandating the development of green roofs on new projects and retrofitting projects are supported by financial subsidies and lowered material costs for installation. In the case found in Germany, aspects related to the stormwater management ecosystem service of green roofs are utilized as a financial incentive through potential lowering of rainwater runoff fees. Key features of local cases in Stockholm and Malmö include green roofs being accessible to the public, or to stakeholders at minimum. Among the cases, only the municipality buildings of Project IOTak in Järfälla utilizes artificial intelligence as a testbed project.

RQ 2: What insights can be identified from other green roof implementation projects that are relevant to Järfälla municipality?		
Case	Project Characteristics	Notable Incentives or Policies
<b>Filtration Plant, Wollishofen, Moos, Switzerland</b>	Creation of ecosystem on green roofs with flora non-endemic to the region (175 plant species) One layer insulation membrane, 12-15 cm thick soil.	Driven by energy saving and biodiversity conservation. Mandatory green roofs for all new developments with flat roofs. Began with subsidies 20-30 CHF/sqm in the 90s, and now lowered overall costs of green roof without subsidies to 23 CHF/sqm.
<b>St. Pauli Bunker, Hamburg, Germany</b>	Public access via a ramp from the ground. Historical green public site.  140 ha of green roofs across residential and non-residential buildings (city of Hamburg)	Public roof garden that integrates neighbors in planning process. Regular workshops and meetings held by foundation owner with neighborhood for decision-making.  Subsidies up to 60% for green roofing for both residential and non-residential projects via Hamburg IFB Bank, with minimum 20 sqm of green roof space and 8cm thick soil layer planned. 50% reduction on rainwater fees
<b>Denmark</b>	Old car auction house. Rooftop farm, including henhouse and beehives	Mandatory green roofs for new developments with roofs < 30% slope. Incentive for building occupants (commercial) in terms of harvesting. Detailed requirements for green roofs are still in development.
<b>Sergelhuset, Stockholm</b>	Green and sedum roofs. 3000 perennials, 2000 spring-flowering bulbs, 400 shrubs	Retrofitting project with the goal of adding multifunctionality to areas with few greenery.
<b>Campus Albano, Stockholm</b>	Solar panels for energy harvesting. Choice of resilient species. Seating areas. Bee hotels.	Public access for recreation. Prioritization on resiliency and biodiversity. Maintained by Stockholm University
<b>Greenhouse, Malmö</b>	Integrated with residences. Balconies with two climate zones to take advantage of growing season.	Public access for recreation and cultivation. Maintained by residents through community-building recreational activities.
<b>Barkarby, Järfälla</b>	IoT roof with solar panels that serve as heat protection as well as for energy harvesting.	Utilization of artificial intelligence to detect environmental factors that helps decision-making on planning  <span style="float: right;">miro</span>

Table 2: Summary table of key findings from case studies.

### 3.3 Citizen Perspectives

Following the methods described in chapter 2 of this report, 2 online surveys were conducted after identifying Facebook groups dedicated to citizens in Järfälla. Additionally, 6 street interviews were acquired in a site visit to Jakobsberg Centrum.

#### 3.3.1 Survey Respondent Demographics

Respondents Profile	Survey 1 (N = 65)		Survey 2 (N = 15)	
	Total	%	Total	%
<b>Age</b>				
18-24	1	2%	1	8%
25-34	6	9%	0	0%
35-44	19	29%	1	8%
45-54	19	29%	4	33%
55-64	14	22%	2	17%
65+	6	9%	4	33%
<b>Type of Residence</b>				
Single Family Home	36	55%	6	40%
Apartment Rental	7	11%	2	13%
Apartment Homeowner	19	29%	7	47%
Other	3	5%	0	0%
<b>Duration in Residence</b>				
< 1 year	1	2%	0	0%
1-5 years	6	9%	1	7%
5-10 years	8	12%	0	0%
10-20 years	17	26%	4	27%
20+ years	31	48%	10	67%
Other	2	3%	0	0%

*Table 3: Survey Respondent Demographics*

As shown in the table above, a total of 65 survey responses were gathered for survey 1 and 15 survey responses for survey 2. The composition of both randomized survey sample groups yielded in majority of respondents being of middle-age to elderly citizens (89% and 91% above 35 years for each survey, respectively), being owners of single family homes or apartment units (84% and 87% for each survey, respectively), and having been occupants of their current residences for 10 years or more (77% and 94% for each survey, respectively). In consideration of studies that indicate middle-age to elderly persons being the most vulnerable to heat stress in Sweden (Åström et al., 2020), and the likelihood that homeowners and long-time residents of Järfälla are to continue residing in Järfälla within the time frame of the climate city contract goals (goals for 2030), the resulting responses have been deemed relevant by the researchers for the main aim of this study, which includes identifying existing and valid perspectives that may give insight into future strategy, plans, or policies for green roofs in Järfälla. In consideration of the resulting sample sizes, this study does not involve characterizing the whole population of Järfälla municipality, which may be a further recommendation for the municipality to acquire in the future.

### 3.3.2 Key Perspectives

RQ 3: What are the perspectives of citizens with regards to green roofs and GI planning of the municipality, and how can these be used in the future green roof planning in Järfälla?			
Category	Survey 1 (N=65)	Survey 2 (N=15)	Street Interviews (N=6)
<b>Environmental Values</b>	<ul style="list-style-type: none"> <li>Natural areas should be nurtured</li> <li>Recreation, aesthetics, and accessibility are important aspects regarding GI and natural areas</li> </ul>	<ul style="list-style-type: none"> <li>Ecocentric views towards climate change and it's consequences.</li> <li>Believe that access to nature is important for human health</li> </ul>	<ul style="list-style-type: none"> <li>Satisfied with their current environmental conditions and think it is important to take care of this</li> </ul>
<b>Perceptions</b>	<ul style="list-style-type: none"> <li>lack awareness of and access to any real-life example of GI such as green roofs</li> <li>lack an understanding of ecosystem benefits of green roofs according to science</li> </ul>	<ul style="list-style-type: none"> <li>Lack of communication and collaboration between municipality and citizens.</li> <li>Lack of knowledge on climate change, GI and ecosystem services.</li> </ul>	<ul style="list-style-type: none"> <li>Lack of effective means of communication and collaboration of municipality towards the citizens and the context of living conditions in Järfälla (languages, accessibility, etc.)</li> <li>Private businesses care more about the environment than the municipality</li> <li>Unequal access to nature can be correlated with socio-economic status of the area</li> </ul>
<b>Attitudes</b>	<ul style="list-style-type: none"> <li>private green roofs are of low interest in terms of preferences for new projects: majority are unwilling to pay nor maintain them</li> <li>potential interest in green roofs if there is overall reduction in household expenses</li> </ul>	<ul style="list-style-type: none"> <li>Inconclusive preferences over green roofs due to lack of knowledge on maintenance and costs</li> <li>There is hesitation on investing time to community involvement and municipality collaboration.</li> </ul>	<ul style="list-style-type: none"> <li>Willingness to listen and collaborate with municipality if better communication is in place</li> </ul>

*Table 4: Summary of Findings in regard to Citizens' Perspectives*

Table 4 above shows a summary of key findings across the two surveys and street interviews. Common values that were evident included a general care towards the natural environment. Common perceptions or observations made by citizens included a lack of knowledge on green roofs, ecosystem services, and lack of communication and efforts from the municipality towards reaching out to citizens for environmental-related concerns. Prevailing attitudes among persons were their willingness to listen and reciprocate environmental efforts, as well as give suggestions, to the municipality.

#### Survey 1 Results

Results from the initial scoping survey (N=65) are shown in the table 5 below. A general openness to GI such as expansion of park space and use of flowerbeds are existent in the sample group, however practical knowledge of benefits, costs and real-life examples of newer forms of GI are potential barriers for green roofs.



QUESTIONS	REPOSSES	
"What is important to you regarding green spaces and infrastructure (GI)? (multiple answers allowed)"	Recreation (40) Aesthetics (35) Accessibility (35) Cleanliness (34) Biodiversity (31) Climate-friendly (29)	
"Would you like there to be more implementation of nature based solutions (or GI) close to you? If yes, which types consider (multiple answers allowed)?"	78% Yes (51) 22% No (14)	Parks (35) Flowerbeds (31) Trees (28) Green Roofs (15) Sedum Roofs (12) Allotment Gardens (12)
"Are you aware of the existence of rooftop gardens or green roofs in your area?"	9% Yes (6) 8% Maybe (5) 83% No (54)	
"If you are aware of rooftop gardens or green roofs, have you ever visited or utilized one?"	3% Yes (2) 97% No or N/A (63)	
"What benefits do you think are associated with rooftop gardens and green roofs?" (multiple answers allowed)	Air Quality (37) Biodiversity (32) Aesthetics (29) Energy Efficiency (23) Recreation (22) Food Production (12) Increased Property Value (8) Stormwater Management (2)	
"Would you be willing to pay more every month to have easy access to a green roof in your building?"	26% Yes (17) 74% No (48)	
"Would you be more interested to living in a residence with access to green roof if you could affect your rent by helping out with the maintenance of the garden?"	58% Yes (38) 42% No (27)	
"Would you be willing to take care of other green infrastructure like allotment gardens if they are easily accessible?"	43% Yes (28) 57% No (37)	

Table 5: Summary of Responses from Survey 1

## Survey 2 Results

Questions seeking environmental values of respondents of survey 2 were met with an overall positive response with all respondents agreeing to ecocentric leaning statements while disagreeing with anthropocentric leaning statements according to the NEP scale. It is also noted that general agreement was made with the statement "Climate change is a real and important global issue", which is not part of the NEP scale and has been included by the researchers as shown in table 6.

VALUES	N number of respondents			Mean (Median)
	Negative (-)	Neutral	Positive (+)	
"Humans have the right to modify the environment to suit their needs"	5	9	1	2.67(3)
"When humans interfere with nature, it often produces disastrous consequences"	0	3	12	4.2(4)
"Climate change is a real and important global issue"	1	2	12	4.47(5)
"Despite our special abilities, humans are still subject to the laws of nature"	0	1	14	4.67(5)
"Plants and animals have as much right as humans to exist"	1	2	12	4.27(5)
"Human ingenuity will ensure that we do not make the Earth unlivable"	7	6	2	2.67(3)
"If things continue in their present course, we will soon experience a major catastrophe"	1	2	12	4.13(4)

Table 6: Summary of Value Responses from Survey 2

Questions seeking to identify respondents' perceptions on the municipality and municipality-led public space planning, as well as concepts of green roofs, GI and private property, have

been met with mixed views as shown in table 7. While majority agree on the importance of climate transition (N=13) and preparedness (N=10), majority are not aware (N=10) of the common goals of the municipality and the EU through the climate city contract nor believe that the municipality has been effectively communicating about these issues (N=11). Furthermore, majority (N=9) also believe that the municipality does not take effort into listening to the community in terms of societal needs and wants for the purpose of integrating into the community planning process.

PERCEPTIONS	N number of respondents			Mean (Median)
	Negative (-)	Neutral	Positive (+)	
<b>Municipality and Public Space</b>				
"Access to public parks, wildlife, green spaces are important to my health"	0	0	15	4.8(5)
"I think I am aware of green roof projects in my area"	9	2	4	2.47(2)
"The municipality has effectively and sufficiently communicated to me about climate change and climate preparedness"	11	3	1	2(2)
"The municipality's communication on climate change and climate preparedness is very important"	4	1	10	3.87(4)
"I am well aware of Järfälla's "Climate City Contract 2030"	10	3	2	2(1)
"Heat stress is a real important issue in Järfälla"	2	7	6	3.4(3)
"Climate change is an important issue for Järfälla"	0	2	13	4.4(5)
"I am aware of how the municipality involves the community in the planning process"	8	5	2	2.27(2)
"The municipality listens to the community in terms of what we need and want"	9	4	2	2.4(2)
<b>Green Infrastructure and Private Space</b>				
"It is important to have my own private green space"	1	7	7	3.47(3)
"Heat stress has personally affected me in my residence"	7	4	4	2.53(3)
"Cost is the main barrier from implementing green roofs in my home"	9	5	1	2(1)
"I think my house is physically incapable of implementation of a rooftop garden"	3	3	9	3.67(4)
"A rooftop garden is important for improving my house's air quality"	7	6	2	2.27(3)
"A rooftop garden is important for improving my self-sufficiency in food and harvest"	7	6	2	2.2(3)
"A rooftop garden is important for improving the aesthetics of my house"	9	5	1	1.93(1)
"A rooftop garden is important for improving the economic value of my house"	9	3	3	2.2(2)
"A rooftop garden is important for heat regulation of my house"	10	3	2	2.07(2)
"A rooftop garden is important for improving the recreational value (having a place to do hobbies) of my house"	10	4	1	2(2)
"A rooftop garden is important for improving the biodiversity of plants and animals surrounding my house"	4	4	7	3.13(3)
"A rooftop garden is important for improving the rainwater management of my house"	5	6	4	2.73(3)

Table 7: Summary of Perception Responses from Survey 2

Despite respondents showing agreement to the importance of developing public (N=15) and private (N=7) green spaces, green roofs garnered low ratings in terms of their importance. A lack in perceived benefits was evident in the majority of responses, wherein only the benefit of increased biodiversity garnered a slightly positive mean score (3.13). This lack of perceived benefits may have correlation with the lack of real-life access and experience of green roofs as shown previously in responses of survey 1. However, this potential correlation shall not be further studied in the scope of this research project.

ATTITUDES	N number of respondents			Mean (Median)
	Negative (-)	Neutral	Positive (+)	
<b>Municipality and Public Space</b>				
"There is little one can do to solve heat stress"	8	7	0	2.27(2)
"I am satisfied with the municipality projects and initiatives so far"	6	9	0	2.47(3)
"I try to actively involve myself by giving suggestions and participating in municipality initiatives and projects"	5	4	6	3.13(3)
"My actions have too small of an effect to actually contribute to climate change"	6	4	5	2.87(3)
"I regularly visit public parks and green spaces"	1	3	11	4.13(4)
"I engage in community gardening, share gardening hobbies with neighbors"	9	2	4	2.47(2)
<b>Green Infrastructure and Private Space</b>				
"I would like to have a rooftop garden in my home"	6	3	6	3(3)
"I would rather have a rooftop garden that can have multiple benefits rather than just one benefit"	3	3	9	3.4(4)
"I do not like to have animals or insects within or near my house"	11	1	3	2.07(2)
"Rooftop gardens are difficult to maintain"	2	10	3	3.07(3)
"I would be willing to pay for adding a rooftop garden to my house"	9	3	3	2.4(2)
"I like maintaining my own garden"	1	6	8	3.8(4)
"I would like to learn more about gardening technology and rooftop gardens"	8	4	3	2.47(2)

Table 8: Summary of Attitude Responses from Survey 2

Responses to questions under attitudes, which aim to identify citizen preferences and judgments that can lead to how they act and react to stimuli, were met with majority negative or mixed views. Although there are positive agreements on traditional green infrastructure such as the eagerness to maintain their own gardens (N=8) and to visit and benefit from public parks and green spaces (N=11), the lack of eagerness to learn more about new GI such as green roofs (N=8) and to engage in community gardening (N=9) have been met with disagreement. Furthermore, wanting a green roof garnered mixed responses with some agreeing (N=6), disagreeing (N=6), or having no opinion (N=3). The lack of perceived individual ecosystem benefits of green roofs as shown earlier in earlier questions is also manifested in the desire for multi-functionality of green roofs (N=9).

#### Citizen Interview Results

Although a variety of responses were collected from the 6 street interviews with some interviewees not having answers, opinions, nor suggestions, a few repetitive responses were found to be worth highlighting for this study.

On awareness of municipality's planning projects geared towards the environment:
<p>"Yes, I've seen some things, but only because I've intentionally searched for it."            "Not the municipality (having such environmental projects). Some businesses, some construction businesses who build environmentally friendly do have these. I live in such an environmentally friendly building."            "They don't send so much information."</p>
Judgement on municipality's effectiveness in collaboration and communication with citizens:
<p>"Maybe on their webpage, but otherwise I'd have no idea"            "(Lack of effort for) ...multiple languages. Many in Järfälla don't know Swedish."            "It used be that we read about things in the local newspaper. But now there is nothing."</p>
Suggestions or advice for the municipality in terms of collaboration and planning?
<p>"Have some meetings, open doors.."            "Pay attention to how the people behave.. and listen to us when we want something done or something green (in terms of planning of public spaces)."            "..do small simple things that don't cost and are not advanced."            "Be physically present and talk to people, just like you do now."            "To not only reach people through the internet. There are posters and physical mail, such things....(About education for the environment) It could go through the landlords as a mini course. There are many who live here who don't know Swedish, who can't throw plastic in plastic, metal in metal, etc. Go out with information and courses."            "Go out and talk to people, to talk as we talk now. You could hand out information in town squares, to talk and hand out pictures. Many people don't know the language so it might be better to show pictures." <span style="float: right;">miro</span></p>

*Table 9: Summary of street interview response highlights*

As shown in table 9, all 6 street interview respondents either had no opinion or had negative responses towards the efforts of the municipality on environmental projects and planning, as well as communication and collaboration for these. Furthermore, suggestions given by these interviewees heavily involved increasing methods and frequency of citizen engagement. The researchers have also noted the recurring interviewees' preference on simpler and more straightforward means of communication, such as face-to-face conversations for surveys and data gathering, rather than sole digital methods. Additionally other relevant findings from individual interviews included buildings or areas in Järfälla with concentrations of Swedish immigrants that have not adapted to reading material in the Swedish language (or in some cases even the English language), as well as perceived geographical grouping according to socio-economic status. For the first additional finding, it was noted that some immigrants do not understand, nor take effort to fully understand, communication material sent to them in a language that they have difficulty in reading comprehension. For the second additional finding, it was noted that a perception of segregation of groups according to socio-economic status is a perceived reason for having unequal access to municipality planning projects.

## 4. Discussion and Recommendations

Within the Järfälla municipality, there exists a palpable awareness among its populace regarding the concepts of green rooftops and the implementation of green infrastructure. However, despite this awareness and acknowledgment, there is a prevailing sentiment among the community that their voices and perspectives on these sustainable initiatives are not adequately acknowledged or integrated into decision-making processes. This perception underscores a perceived gap between public sentiment and the mechanisms for community engagement and inclusion in matters pertaining to sustainable urban development within the municipality. Stemming from the results garnered from the 3 main research questions, table 10 shows a summary of recommended opportunities for better policy-making and planning for the future of green roofs in Järfälla municipality.

Future Policies	Future Planning
<ol style="list-style-type: none"> <li>1. Incentives that are custom-fit to population               <ol style="list-style-type: none"> <li>a. care for natural environment</li> <li>b. disinterest for maintenance</li> <li>c. Interest for multifunctional benefits (recreation, food sourcing, etc)</li> </ol> </li> <li>2. Communication by getting to know population:               <ol style="list-style-type: none"> <li>a. Language</li> <li>b. Frequency of communication</li> <li>c. Medium of communication</li> </ol> </li> <li>3. Increasing likelihood of public acceptance               <ol style="list-style-type: none"> <li>a. Education/nudging citizens and stakeholders on benefits</li> <li>b. Increasing accessibility to benefits for experiential learning</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>1. Prioritization of heat stress, climate transition, resource sustainability, and energy efficiency as factors for decision-making</li> <li>2. Consideration of social factors together with Green Space Factor, as indicator for decision-making</li> <li>3. AI to aid efficiency in calculation of environmental factors, but should not replace traditional means of communication to determine social factors.</li> <li>4. Consideration of socio-economic status of population</li> <li>5. Follow-up and operations feedback, including proper knowledge transfer for long-term maintenance</li> </ol>

Table 10: Summary of recommended opportunities for future green roof policy-making and planning

### 4.1 Future Policies for Green Roofs

As shown through the case study comparison in section 3.2 of this research project, countries in the EU have already been implementing more detailed policies and mandates on green roofs for new construction or renovation projects. As indicated in consultant interviews in section 3.1 of this research project, stakeholders in the GI industry in Sweden are looking forward to implementation of further policies and mandates for green roofs in the country in the years to come. In consideration of potential tensions or policy-barriers arising from citizens' perspectives in section 3.3 of this research project, key insights and recommendations have been made, which may be useful for the Järfälla municipality upon completion of the IOTak project and utilizing project findings for furthering local green roof policy.

#### Incentivizing Homeowners

As shown through the international cases in section 3.2, financial subsidies may be able to support a gradual introduction and implementation of green roof mandates for new construction and renovation projects. However, as shown in section 3.3, implementation costs aren't the main barrier for current citizens to want green roofs on their properties. It would be crucial for Järfälla municipality to create custom-fit incentives for green roofs through knowledge of what

Järfälla citizens value, and improving what they perceive to be beneficial and important. In the Hamburg, Germany case, a reduction in rainwater fees proved to be a successful add-on incentive to decrease overall household expenses, which also exposed citizens to the benefit of green roofs for stormwater management. In this case, added maintenance for green roofs becomes beneficial to lowering maintenance for stormwater. In several of the cases in section 3.2, public access to green roofs allowed for citizens to realize practical benefits in terms of added recreation and potential food supply, on top of benefits that may be observed at a distance or without direct access such as increased aesthetics and increased perceived biodiversity. Survey respondents in section 3.3 showed that they value recreation, aesthetics, and accessibility when it comes to public GI, which may not be the same result for the entire Järfälla population today nor in the future. Thus, it would be ideal for the municipality to create incentives based on knowledge on wants and needs of the population, which may involve future in-depth surveys and other means of communication.

### **Appropriate Communication**

With Project IOTak serving as a testbed for the use of artificial intelligence in planning and decision-making for green roofs according to interviews in section 3.1, tensions may arise with decisions and policies made in consideration of voices of multiple stakeholders. It is notable that the citizens are direct stakeholders of the project as well, and ensuring that they receive equal and just benefits would mean that they remain included in the decision-making process for green roofs. As shown in survey results and interviews in section 3.3, current citizens desire and are willing to collaborate when approached with more traditional and frequent modes of collaboration. Section 3.3 results show that the sample group desire understandable language as well as face-to-face meetings, which may not be the case for the majority of the Järfälla population today nor in the future. Thus, it would be crucial to custom-fit the municipality's collaboration process with citizens through knowledge of how the citizens prefer to collaborate.

### **Increasing Public Acceptance**

As presented in interviews in section 3.1 of this study, consultants encourage further education on green roofs and GI, as well as their benefits, to citizens to increase likelihood of public acceptance in future policy and planning scenarios. It is also evident through citizen surveys in section 3.3 that current knowledge is lacking, especially when it comes to the benefits that green roofs provide. However, according to the interview results with the Project IOTak manager, as shown in section 3.1, a main barrier to green roof education in Järfälla is the lack of investment and funding for such projects. Thus, together with the recommended increase of green roof accessibility to citizens for hands-on learning on benefits of green roofs, it would also be ideal to strategize for multiple methods to nudge potential stakeholders and investors for furthering green roofs in the municipality. As noted in the case studies, financial incentives were made possible due to investments of the national government and other stakeholders for green roofing. Methods for nudging potential investors can include ensuring maximum and equally just benefits achieved for Project IOTak, effective communication and public access to these projects or other successful green roof projects.

## **4.2 Future Planning for Green Roofs**

### **Key Knowledge when Designing and Retrofitting a Green Roof**

After interviewing three different actors and stakeholders regarding rooftop gardens and their implementation, it can be deduced from their responses that increasing green roof knowledge and awareness is a root cause for succeeding in furthering green roof implementation. Above all, the level of knowledge should be raised at all levels on how to think about the construction of a roof and its surroundings. By giving the flora and fauna that is based on the nearby ground a lift, both the flora and fauna that are located in the neighborhood or area of implementation will work perfectly for the biodiversity without needing to relocate it, while at the same time tapping into the unused potential of the roof (Development, Podcast. 2023 Accessed 16 Nov. 2023).

However, not all actors that are constructing new buildings with potential for green roofs reason in this way. Instead, they argue for themselves that "If we put a Sedum roof on the roof of the building, we don't have to look after it while it is still green"(Johansson,2023 15 November). Unfortunately, this current attitude towards Sedum roofs is still all too common in Sweden, especially in the central and northern parts. The problem with that attitude is that Sedum roofs in Sweden are only around 3 centimeters high compared to the international standard of 10-15 cm and have a life expectation of 3 to 5 years (Johansson,2023 15 November), and since Sedum roofs are a cheap solution to implement and to promote as a "green option" for the building, and company. It becomes the "natural" selection for the buildings, especially in the central and northern parts of Sweden.

This in conjunction with the regulations of GYF (Green Space Factor) can create a potential vicious circle of green wasting. Although the green space factor formula can adapt factors to an eco-efficiency perspective or surfaces provides flexibility in the planning of construction projects such as Sedum roofs with room for both creativity and efficient construction (Boverket ,2020 Accessed 15 Dec. 2023). However, the green space factor formula also has the disadvantage of that it lacks the quality aspect, as it does not require any results or follow-up after the construction and implementation are complete, which means that the recurring replanting of Sedum roofs on buildings is not affected once they have been approved, nor does it result on any penalties or complements for owners of the building.

Finally, with this current attitude towards Sedum roofs in Sweden, there is also the question of the maintenance of the roof. One of the most common issues of green roofs is who going to maintain it?(Johansson,2023 15 November). And since the attitude toward Sedum roofs is as previously mentioned that they can maintain themselves, some buildings are constructed without any way to access the roof itself for maintenance. Leaving the Sedum roof with no options other than slowly wither and die, before finally being replaced and the circle starts anew (Johansson,2023 15 November).

This shows the importance of knowledge surrounding rooftop gardens, and at the same the risks of it becoming just another trend in sustainable urban planning. So why does it still occur? Maintenance companies already know what they should do to maintain the rooftop gardens, but there needs to be more of them so that rogue companies don't get a foothold in the market and add to the unfortunate trend of green wasting (Johansson,2023 15 November). At the same time, automation increases, which in turn can be beneficial for the maintenance and the potential of the roof in the future depending on how it develops (Development, Podcast. 2023 Accessed 16 Nov. 2023).

In the end, the clients of the roofs, which can be anyone from clients, municipalities, developers or construction companies, need to learn how to design the buildings in a more sustainable and

green way (Johansson,2023 15 November). That's the way we have to go and educate ourselves and then educate the others involved in the planning process. Even if it's a bit more expensive, it won't last long. So you don't think short-term and affordable and instead think long-term and sustainable to prevent green wasting. Then the management of the potential roof is done.

As much as it's easy to critique the Green Growth Factor and talk about how knowledge might enable us to develop a better alternative in terms of managing and implementing green growth, a better framework hasn't yet been developed despite the importance of the Green Space Factor (Boverket ,2020 Accessed 15 Dec. 2023.).

### **Potential Barriers to Consider During Green Roof Planning**

Among the most prominent issues in the literature regarding rooftop gardens is who should be responsible for them and what practices should be followed as a means of ensuring their preservation in the long run. (Bravo, E,2021).

It is important to note that the local authorities are required to act as stakeholders and public actors in this case, Järfälla Municipality. It has been expressed in some cases that it is questionable whether the people who live in the buildings with the gardens should run and maintain something that is on the border of their responsibility, especially if they did not agree to it in the first place when that has been the case (Green Roofers ,2016Accessed 15 Dec. 2023). There is an issue of whether private building rooftops should be used for these kinds of gardens if the tenets of the building cannot ensure that maintenance is done. The municipalities should instead use the roofs on their public buildings for rooftop gardens.

It's also worth noting that rooftop gardens face the dilemma of limited plant selection, as the plants have to survive the climate in Sweden all year. Secondly, the water usage of these gardens may also affect the efficiency of storm water collection. Finally, the long ROI (Return Of interest) for rooftop gardens might hinder the overall incentive to construct/establish/retrofit buildings with them. When considering the installation of a planted roof, it is important to take into account various factors such as the structure, location, ownership, technology, climate, and more (U.S. General Services Administration.,2011). Despite the higher installation cost compared to conventional roofs, a life cycle analysis can help justify this investment. Although maintenance costs may increase, the longevity of a planted roof can offset the added expense (U.S. General Services Administration.,2011).

The process that is carried out today when a green roof is to be built is often a decision on how the roof is to be designed taken long before those with the knowledge today are involved in the process, to be able to make their voice heard. Once they are involved, the decision is more about whether the roof can handle the weight, whether the slope is too steep or not, and whether it is possible to get onto the roof. While these are important decisions, they can leave little room for sustainable discussion and use of the roof. As a result, it is important to consider the long-term effects of rooftop gardens design when it comes to factors such as climate change, resource sustainability, and energy efficiency (Wong,2003). These factors should be taken into account during the decision-making process in order to make an informed decision.

### **The Use of Artificial Intelligence on Green Roofs**

As the researchers already have mentioned in the text, both the potential and usage of rooftop gardens are present in Järfälla Municipality and with the options of the four most common



types of ecosystem services. However, there are also many other ecosystem services and green solutions that have the potential to be implemented on the roof. The only question is, who knows what is the best usage of the roof in question? What if the roof knew it by itself, what if the roof was a smart green roof?

As the case with IOTAK by Barkarby Science shows by fitting roofs with sensors that communicate both to the users and also with each other through A.I. This means that the roof fitted with the sensors is a roof that is optimized for the best use, so you have to find out what type of roof it should be. Not just the most four common usages of rooftop gardens, but so much more (Sundberg,2023 21 November). When people have to decide what is best for a roof where they will live or work, it leads to several options that can prolong the process and decisions. Using data-driven optimization to help with the decision, a decision can be made and adopted much more efficiently and quickly.

For example, whether it should only have solar cells on the roof, or whether it should be adapted for large amounts of rain. It can also be a combined roof, for example, a combination of greenery and solar cells. But also to get the roofs to communicate with each other using the sensors, an example of this could be that a sensor on a roof at KTH can tell a roof in Barkarby about incoming rain (Sundberg,2023 21 November).

This means that the roofs with rainwater adaptation can be prepared in good time. 'We want the work to be proactive rather than reactive. The roofs and sensors also can measure carbon dioxide emissions. There also needs to be an investigation on both Sedum roofs and Meadow roofs to get a better understanding of them as well, as to see their potential. We will also place growing boxes if the possibility exists, then measure the number of pollinators in a neighborhood is something that the roofs should be able to do. In other words, it will be a data-driven decision-making model (Vinnova,2023 Accessed 15 Dec. 2023).

This is where GYF could come in and will help with its point system and of various kinds depending on how much green you have in the project, but how do you calculate it with all the roofs? This is where AI comes in and helps, for example, with climate and socio-economic issues. Questions of socio-economic nature are difficult to calculate in the planning process of today, where many different voices want to get heard at the same time. This is where AI comes in and makes the difficult decisions with help of the data that has been collected through the sensors (Sundberg,2023).

There is a hope that the different ecosystem services that can be offered by a roof will be able to be combined to make a good result, for example, the services of cultivation and solar cells can be combined to make a good result (Vinnova,2023 Accessed 15 Dec. 2023). It deals with calculating how the climate will be affected by the action. Also, the socio-economic factors can have an impact on the development of a neighborhood, such as recreation facilities with parks and places for social gatherings where people want to live in.

However, without a robust and sustainable funding strategy, realizing the vision of smart green roofs as detailed in the text could prove challenging, potentially limiting its accessibility and widespread. The assumption that roofs could autonomously determine their optimal use based on sensor data overlooks practical considerations, such as the dynamic nature of urban environments and diverse stakeholder needs. Moreover, the reliance on AI for decision-making raises ethical concerns regarding data privacy, algorithm biases, and the accountability of automated systems in shaping urban landscapes (Miller,2023).

## 5. Conclusion

After concluding the data collection through literature reviews, interviews, case studies and surveys, then analyzing the results, the researches have come to the conclusion that Järfälla Municipality should take the following recommendations into consideration for future projects that involves rooftop gardens and green infrastructure.

**Suggest that Järfälla Municipality holds fast with their plan of being a leading municipality with green and smart infrastructure.**

Järfälla Municipality's commitment to becoming a pioneering municipality with an emphasis on green and smart infrastructure can be seen as both commendable and forward-thinking. By upholding this vision that has been set will not only showcase Järfälla Municipality's dedication to achieve environmental sustainability, but also positions them as a beacon for other regions and municipality's across Sweden aspiring to integrate eco-friendly practices and innovative technological solutions into their infrastructure as well.

Secondly, by steadfastly pursuing this vision of the future, Järfälla Municipality can set an impressive example, by fostering a community that values and prioritizes the harmonious coexistence of modern development with the preservation of nature with their work and development of projects like IOTAK and future projects that will make use of the framework set for implementation green infrastructure solutions like rooftop gardens.

Järfälla Municipality should allocate the required funds for green roofs, this can ensure that Järfälla Municipality don't fall into a cycle of investing in Sedum roofs that might not fulfill long-term green objectives. While Sedum roofs are a popular choice for their low maintenance, solely relying on them could lead to a limited scope of ecological benefits. By diversifying investments to incorporate various types of green roofs that align with broader sustainability goals, the municipality can maximize environmental advantages and avoid being trapped in a repetitive cycle of insufficient green solutions. Investing upfront in a range of green roof options may entail higher initial costs, but offers a more robust and effective approach towards sustainable infrastructure in the long run.

**Suggest that they spend the necessary costs on green roofs, so they don't get stuck in a loop of green wasting with Sedum roofs.**

To continue on from the first recommendation regarding rooftop gardens, currently, within Järfälla Municipality, existing green roofs predominantly consist of Sedum Roofs, implemented in a rather ad hoc manner without a structured implementation plan or comprehensive understanding of green roof specifics (Lindberg,2023 December 5). This approach has led to a lack of the extensive advantages typically associated with green roofs.

With the help of a better understanding and knowledge of how green roofs work and what benefits they have, it can lead clients, companies, and people at a grassroots level in Järfälla municipality to make decisions that lead to informed choices about green roofs and the opportunities they bring to the residents of the houses (Green Roof Institute, 2021 Accessed 17 Nov. 2023).

With this knowledge and understanding, the question of what the difference is between Urban Greens Sedum Roofs, “regular” Sedum roofs, or another version of Sedum roofs (Urban Green.

C, n.d. Accessed 27 Nov. 2023). Instead of falling into the trap of seeing it as a new green trend and only building Sedum roofs that only lead to a vicious circle of green washing, meaning that the part of the assignment where the researchers spoke highly of Sedum roofs might be revisited and reevaluated in future assignments and research.

There is also a need for an evolution or, at least, a reevaluation of the green area factor since its usage and scoring factors are not as useful as they could be in today's evolving world of green infrastructure and planning. One way of achieving this could be through the increased knowledge of the benefits that green roofs provide, not just to the municipalities but also to the future generation of children (Sundberg, 2023 21 November). As clichéd it may sound, they are our future after all. But of course there also needs to be more research done in the future and more in-depth projects at a larger scale. That will require more resources, both in terms of time and also funding and data. Additionally, more collaboration between different disciplines is necessary to ensure the success of the research. Research needs to be conducted more holistically and sustainably to ensure the best outcomes to make sure that the concept of GI and rooftop gardens becomes a trend that is hoped to solve all the sustainable issues of a municipality like Järfälla.

### **Overlapping Sustainable Development Goals to consider for GI Planning in Järfälla Municipality**

After collecting and analyzing the data, the researchers have come to the conclusion that many of UN's Sustainable Development Goals and their targets can be applied to GI and rooftop gardens in the development of new areas and neighbourhoods in not just Järfälla Municipality, but also across the globe. However, the researchers recommend that Järfälla keep the following Sustainable Development Goals in mind with the development of the municipality. Sustainable Development Goals (SDGs) 11 and 13 collectively aim to foster resilient, inclusive, and sustainable cities while addressing the urgent challenges posed by climate change (United Nations, 2015 Accessed 15 Dec. 2023). Under SDG 11, the targets emphasize the need to enhance participatory and integrated urban planning, ensuring that human settlements are safe, resilient, and inclusive.

This involves reducing the impact of disasters on vulnerable populations, providing universal access to green and public spaces, and promoting resource efficiency and climate adaptation in city policies (United Nations, 2015 Accessed 15 Dec. 2023). Concurrently, SDG 13 focuses on urgent action to combat climate change by strengthening global resilience and adaptive capacity to climate-related hazards. It calls for the integration of climate change measures into national policies and emphasizes the importance of education and awareness to build human and institutional capacity for climate mitigation, adaptation, impact reduction, and early warning systems (United Nations, 2015 Accessed 15 Dec. 2023).

Sustainable Development Goal 10 that states that the goal is to reduce inequality both within the country, and then among countries across the globe. This is because of the opportunities of equality, rooftop gardens can provide to the residents of the area and neighborhood.

Together, these goals and targets outline a comprehensive framework for creating cities that thrive in the face of climate challenges while prioritizing the well-being and inclusivity of their residents (United Nations, 2015 Accessed 15 Dec. 2023).

## **Participatory Planning in Green Infrastructure**

Finally, in consideration of SDG 10 when planning for GI, it is of utmost importance to strategize and increase efforts for the municipality to consistently and continuously learn citizens wants and needs on a regular basis. Further research by the municipality on best practices in terms of policy-making, planning, follow up, and feedback from case studies may be done to ensure decisions are carefully made. Furthermore, regardless of results from the use of artificial intelligence in Project IOTak, it is crucial to ensure that citizens' voices are heard, considered, and prioritized in decision-making. A plan for increasing synergy and addressing tradeoffs and tensions between scientific data gathered from the use of artificial intelligence and qualitative social data from citizen perspectives is recommended for municipality decision-making. Finally, it is recommended to utilize non-traditional means such as digital tools only as a supplement to traditional means for furthering education on ecosystem services and benefits of green roofs, and not as a replacement. This may involve, for example, the use of digital visualization tools to supplement actual site visits and open access of green roofs to the public and stakeholders.

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~Tañada and Willebrand

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- Lindberg,O(2023) Interview on IoTak from a municipal perspective interview by Willebrand [Teams] 5 December

## **7. Appendix**

### **7.1 Interview Questions**

#### **Interview with Green Roof Institute**

1. Who are you?
2. What do you do at the Green Roof Institute?
3. What is a green roof for you?
4. How do you go about selecting plants for the roof?
  - 4.1 What are some considerations and differences (due to conditions) between planning for green roofs in the south of Sweden versus the Stockholm area (or Jarfalla, hypothetically)?
5. How do you adapt them to the ecosystem services to be provided on the roof?
6. What additional ecosystem services would you like to highlight apart from the four you mention on your website?
7. Is it possible for those who will live/work in the buildings to influence the choice of ecosystem services?
  - 7.1 How do the ecosystem benefits of green roofs outweigh the costs of installation and maintenance? How could a client/individual/resident gain this perspective?
8. A major issue regarding green roofs is the question of who will take care of them, you have a cooperation with MKB, how does it work there?
9. What could be done better with the implementation of green roofs?
  - 9.1 Barriers and possible solutions for greater participation of multiple scales (from households to industries)?
  - 9.2 What's a situation that would be unadvisable to implement a green roof project?
10. What tips would you give to those interested in building green roofs?

#### **Interview with Barkarby Science**

1. Who are you?
2. What do you do at Barkarby Science?
3. What is a green (Smart) roof for you?
4. Is it possible for those who will live/work in the buildings to influence the choice of ecosystem services?
5. How do you decide whether a roof is suitable for several different services? Do you try to adapt the nearby roof?
6. What do you hope the results of this project will be?
  - 6.1 What follow-up is planned? Next steps? Would it be ideal to extend the campaign to green roofs for households, or industries/businesses first?
  - 6.2 What are the main challenges for the future of green roofs in Järfälla?
7. A major issue with green roofs is the question of who will take care of them, how do you plan for that?
  - 7.1 How is communication with citizens planned?
8. What could be done better?
  - 8.1 How can further use of digitalization and AI contribute to potential improvements in the future?
9. Who is the contact at KTH?
10. What tips would you give to those interested in building green roofs?

10.1 What do you think could be incentives for people to participate and become interested in green roofs?

### **Interview with Järfälla Kommun**

1. Who are you?
2. What do you do at Järfälla Municipality?
3. What is a green roof for you?
4. What is your plan for the smart roof project?
5. Has Järfälla Municipality implemented any previous projects with green roofs? If so, what was the result?
6. A big question about green roofs is the question of who will take care of them, how do you plan it?
7. How do you reach out to the residents of the municipality when implementing projects? How do they have the opportunity to influence decisions?
8. How have you reached out to the residents with this project?
9. What could be done better?
10. What advice would you give to those interested in building green roofs?

### **Street Interviews with citizens**

1. Are you aware of the municipality's pro-environment plans or projects?
2. Would you say that the municipality has good communication or collaboration with Järfälla citizens?
3. What advice would you give to the municipality if terms of planning and communication if they would be able to hear you today?

## **7.2 Surveys**

### **Survey 1 Questions**

1. How old are you?
2. Where do you live?
3. How long have you lived in Jakobsberg?
4. What is your current residential status?
5. How often do you visit green areas such as parks, forests, or gardens near you?
6. Why do you visit these green areas? (/Select all that apply) On a scale of 1-5 (where 1 is the lowest and 5 is the highest), how would you rate the quality of the green areas near you?
7. On a scale 1-5 (Where 1 is the lowest and the 5 the highest), how would you rate the quality of the urban green spaces close to you?
8. If nature based solutions would be implemented near you, what would prefer (choose all that apply):
9. If you chose "other," which nature based solutions would you want?

10. Would you like there to be more implementation of nature based solutions close to you? For example, rooftop gardens, allotment gardens, or more trees?
11. Please motivate your answer. You can answer anything- for instance, perhaps you would feel more unsafe if there were more trees planted, or maybe you really want a chance to grow your own food!
12. What is important to you regarding green spaces?
13. If you picked "other" please tell us why.
14. Are you aware of the existence of rooftop gardens or green roofs in your area?
15. If you are aware of rooftop gardens or green roofs, have you ever visited or utilized one?
16. What benefits do you associate with rooftop gardens and green roofs? Select all that apply)

### **Survey 2 Questions**

\*citizens were asked to rate the statements 1-5 with 1-strongly disagree and 5-strongly agree

1. "Humans have the right to modify the environment to suit their needs"
2. "When humans interfere with nature, it often produces disastrous consequences"
3. "Climate change is a real and important global issue"
4. "Despite our special abilities, humans are still subject to the laws of nature"
5. "Plants and animals have as much right as humans to exist"
6. "Human ingenuity will ensure that we do not make the Earth unlivable"
7. "If things continue in their present course, we will soon experience a major catastrophe"
8. "Access to public parks, wildlife, green spaces are important to my health"
9. "I think I am aware of green roof projects in my area"
10. "The municipality has effectively and sufficiently communicated to me about climate change and climate preparedness"
11. "The municipality's communication on climate change and climate preparedness is very important"
12. "I am well aware of Järfälla's "Climate City Contract 2030"

13. "It is important to have my own private green space"
14. "Heat stress is a real important issue in Järfälla"
15. "Climate change is an important issue for Järfälla"
16. "There is little one can do to solve heat stress"
17. "Heat stress has personally affected me in my residence"
18. "I am aware of how the municipality involves the community in the planning process"
19. "The municipality listens to the community in terms of what we need and want"
20. "I am satisfied with the municipality projects and initiatives so far"
21. "I try to actively involve myself by giving suggestions and participating in municipality initiatives and projects"
22. "My actions have too small of an effect to actually contribute to climate change"
23. "I would like to have a rooftop garden in my home"
24. "Cost is the main barrier from implementing green roofs in my home"
25. "I think my house is physically incapable of implementation of a rooftop garden"
26. "A rooftop garden is important for improving my house's air quality"
27. "A rooftop garden is important for improving my self-sufficiency in food and harvest"
28. "A rooftop garden is important for improving the aesthetics of my house"
29. "A rooftop garden is important for improving the economic value of my house"
30. "A rooftop garden is important for improving the recreational value (having a place to do hobbies) of my house"
31. "A rooftop garden is important for improving the recreational value (having a place to do hobbies) of my house"
32. "A rooftop garden is important for improving the biodiversity of plants and animals surrounding my house"
33. "A rooftop garden is important for improving the rainwater management of my house"
34. "I would rather have a rooftop garden that can have multiple benefits rather than just one benefit"

35. "I do not like to have animals or insects within or near my house"
36. "Rooftop gardens are difficult to maintain"
37. "I would be willing to pay for adding a rooftop garden to my house"
38. "I regularly visit public parks and green spaces"
39. "I like maintaining my own garden"
40. "I engage in community gardening, share gardening hobbies with neighbors"
41. "I would like to learn more about gardening technology and rooftop gardens"