Stimulating the application of green roofs

A case study in Leeuwarden

Master thesis

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Abstract

An increasing number of people will experience climate impacts in cities. Green roofs can be regarded as a nature-based solution in cities to contribute to climate change adaptation and mitigation. Green roofs contribute to overall sustainability as they offer public ecosystem services such as mitigating heat effects, enhancing biodiversity, and contributing to a better air quality. Other benefits are rainwater storage, better isolation, aesthetics, noise reduction, and roof life prolongment. Although subsidies on green roofs are available in the Netherlands, implementation is not going very rapidly. In the city of Leeuwarden green roof application could also be improved in the light of climate change adaptation and mitigation. Therefore, this thesis aims to help understand the current situation of green roof application in the city of Leeuwarden, and to provide recommendations to stimulate this application. Literature is studied to get insight into enabling or hindering factors regarding green roof application. Data by the municipality on green roof subsidy applications are used to make an analysis on neighborhood level. Also, based on a spatial analysis in QGIS, potential areas are pointed out in which green roofs have potentially the most effect in the city. Furthermore, eight semi-structured interviews were conducted to identify the different views of actors regarding green roof implementation. These actors consist of the municipality, an expert, a gardener, entrepreneurs, and inhabitants. Ten recommendations are provided to stimulate green roof application in Leeuwarden. These recommendations consist among others of: the municipality should apply green roofs or other greenery to the public spaces wherever it is possible, subsidies need to be tailored to the inhabitants of the city, greenery needs to be mandatory in new building projects, publicity regarding green roofs should increase, negative environmental impacts should be minimized, and the municipality should collaborate with experts, housing associations, local greenery studies, and gardening companies to develop policy and to increase the share of green roofs.

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1 Introduction

In this chapter the background of the research is given on which the research problem is based. Then, the research objective and forthcoming research questions are formulated.

1.1 Background

In the following decades, climate change impacts are expected to become more prevalent. These impacts consist of, for example, longer periods of drought and excessive precipitation (IPCC, 2021). Especially in cities, some of the effects are experienced more severely in comparison to rural areas because of urban characteristics such as the materials used, dense building blocks, and obstacles for cooling by wind (Battista et al., 2016, Salata et al., 2015). Furthermore, since this century and for the first time in history, more people live in cities than in non-urban areas (Cook et al., 2013). In developed countries in Europe, between 80 and 90% of the population is expected to live in urban areas by 2030 (Antrop, 2004). Consequently, an increasing number of people will experience climate impacts in cities, making climate change and urbanization current topics of interest (Shafique et al., 2018).

Urban green and blue spaces counteract these pressures to an extent by providing habitats for species and environmental, social, and cultural benefits while contributing to both climate change adaptation and mitigation (Goddard et al., 2010, Kabisch et al., 2016). Green roofs can be regarded as such a nature-based solution in cities (Frantzeskaki, 2019, Kabisch et al., 2017), as they can be part of new urban development strategies to mitigate these adverse effects of urbanization and to improve the environment (Dunnett and Kingsbury, 2008, McDonough, 2005, McPhearson et al., 2018). Green roofs contribute to overall sustainability as they offer public ecosystem services such as mitigating heat effects, enhancing biodiversity, and contributing to a better air quality (Mees et al., 2013). Green roofs are able to store rainwater and reduce run-off and therefore sewage overflows in periods of high precipitation rates (Oberndorfer et al., 2007). Other benefits for property owners are for example energy savings (Sailor, 2008), aesthetics (White and Gatersleben, 2011), noise reduction (Connelly and Hodgson, 2013), and thermal comfort (Sailor, 2008, Wong et al., 2003). Compared to the lifetime of regular roofs, green roofs prolong the roof life (Wong et al., 2003). Generally, a conventional flat roof has an expected lifetime of 25 years, while a green roof can last for 40-50 years (Kantor, 2015).

Green roofs are becoming increasingly popular, especially in Western cities (Sims et al., 2016). For example, five frontrunner cities studied by (Mees et al., 2013) are Basel, Chicago, London, Rotterdam, and Stuttgart. Although green roofs are applied relatively successful in these cities compared to other cities, the policies that are in place regarding green roofs in these cities differ (Mees et al., 2013). Therefore, governance arrangements and policy sectors might be different between cities in order to develop successful green roof policies. Though, based on different empirical studies it can be said that climate adaptation governance seems to get best of the ground with a government-led approach (Johnson and Priest, 2008, Juhola and Westerhoff, 2011, Mees et al., 2013, Storbjörk, 2007). Despite this, alternative types of governance might still be best for adaptation. Mees et al. (2013) for example categorized these as hierarchical governance, interactive governance, and market governance.

1.2 Problem description

1.2.1 Academic relevance

According to Mees et al. (2013) future research on the forms of adaptation governance could help discern the scope of governance arrangements required for adaptation themes. Besides water safety, heat stress and fresh water supply, green roofs can also be considered as such a theme. This future research could for example help verify or falsify the need for a dominant public arrangement for climate adaptation. Furthermore, according to Sarabi et al. (2019), and van der Jagt et al. (2020) research about the structural conditions regarding barriers to implement nature-based solutions is

largely absent. An example of such a barrier is a lack of governance cooperation between different fields on which more effort is needed according to Dauda and Alibaba (2020). Furthermore, generic overviews of systematic barriers might overlook sensitivity to geographical and policy context, hampering solutions which could be more tailored to a specific local scale (Dorst et al., 2022).

1.2.2 Societal relevance

Following from the traditional notion that mitigation is global and adaptation is local, it is now widely accepted that place-based adaptation needs to be assisted and guided by policies at lower levels of government (Burton, 2011). As such, adaptation to climate change impacts has become a new public policy field in Europe (Biesbroek et al., 2010). In the Netherlands, these guiding governmental layers would imply provinces and municipalities. In practice, local governments tend to implement no-regret measures that serve multiple societal goals and are worth implementing no matter which event actually happens (Mees et al., 2013). In literature, green roofs are considered as such a no-regret measure (Clar and Steurer, 2021, Mees et al., 2013).

Currently, several municipalities in the Netherlands are providing subsidies for homeowners to apply green roofs (Groenedakenshop.nl, 2022). Although these subsidies are available in the Netherlands, implementation is not going very rapidly; only 0.5% of the potential roofs in the country were green roofs in 2020 (Readar, 2020). In only one city in the Netherlands the share of green roofs is above 2%. In other cities - completing the list of ten cities with the highest share of green roofs – between 1.4% and 2% of the roofs are green roofs.

The city of Leeuwarden is not within this list of the ten cities in which green roofs were applied the most (Readar, 2020). Yet, the municipality of Leeuwarden provides subsidies for homeowners investing in green roofs. In line with the benefits of green roofs mentioned in the literature, the municipality substantiates the subsidy regarding green roofs because of the contributions in terms of biodiversity, air quality, cooling, pleasant living environment, and water retention and runoff (Gemeente Leeuwarden, 2022c).

1.3 Research objective

Knowing that place-based adaptation measures – such as green roofs – should be assisted and guided by policies at lower levels of government such as municipalities (according to Burton, 2011), application in the city of Leeuwarden seems hard to get off the ground according to the data by Readar (2020). Although subsidies are provided for green roofs, application could be improved for this important (no-regret) measure in light of climate change adaptation. Therefore, this thesis aims to help understand the current situation of green roof application in the city of Leeuwarden, and to provide recommendations to stimulate this application.

1.4 Research questions

Based on the research objective the following main research question is developed:

How can the application of green roofs be stimulated in the city of Leeuwarden?

The main research question will be answered based on the following secondary research questions:

1. What policies and incentives can be provided, and what are hindering and enabling factors for green roof application?
2. How many green roofs are there currently in Leeuwarden, and which areas have the most potential for green roofs to be applied?
3. How can green roof application be stimulated in Leeuwarden according to different actors?

1.5 Thesis outline

In chapter 2, key theories on green roofs are introduced. The research strategy and applied methods are described in chapter 3. The results can be found in chapter 4. These consist of maps explaining the current state of green roofs in Leeuwarden, and also include interview results. In chapter 5, the results are elaborated upon based on this thesis's theoretical framework. In chapter 6, the conclusions are drawn and the research questions are answered. Lastly, recommendations are provided to simulate the application of green roofs in Leeuwarden.

2 Theory

2.1 Green roofs

Basically, green roofs are roofs that are planted with a distinct form of vegetation/plants on a growth medium of soil (Dauda and Alibaba, 2020, Shafique et al., 2018). In order to make it operate properly, several components of the green roof – which are of equal importance – are included (figure 1) (Dauda and Alibaba, 2020). Green roofs are also referred to as vegetated roofs, eco roofs, roof gardens, or living roofs (Fassman-Beck et al., 2013, Francis and Lorimer, 2011, McDonough, 2005, Piro et al., 2018). Multiple types of green roofs are determined in the relevant literature. The most usual distinction is the one between intensive and extensive green roofs (Dunnett and Kingsbury, 2008, Hendriks et al., 2016). However, semi-intensive green roofs are sometimes also considered as a category (Yang et al., 2008), while another distinction can be made between single-course extensive and multi-course extensive (UGSA, 2011). To stick to the most common distinction between extensive and intensive green roofs, the different characteristics are outlined in table 2.1 (based on Berardi et al., 2014, and Hendriks et al., 2016). Based on the literature studied, green roofs are mostly installed on (semi-) flat roofs as the surface is often larger compared to sloped roofs, for instance with industrial buildings. Furthermore, most energy efficiency and drainage benefits can be achieved by (semi-) flat roofs (Cutlip, 2006). Nevertheless, they can also be applied to sloped roofs since the additional load is relatively small, especially with an extensive green roof design (Theodosiou, 2009).

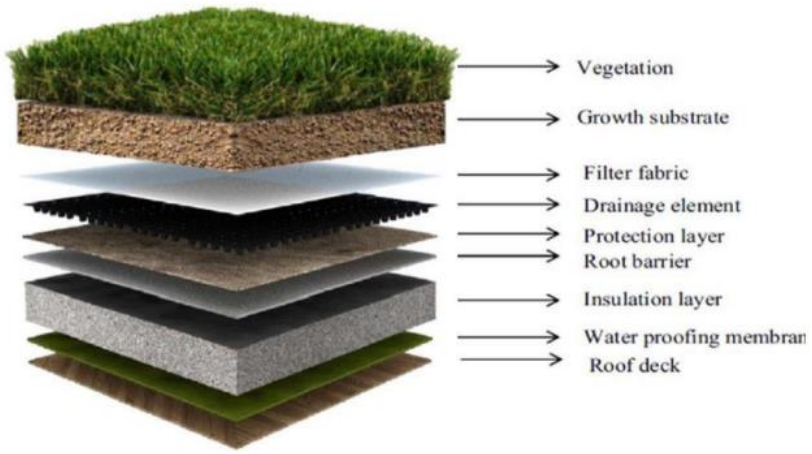

Figure 2.1 Typical components of a green roof (Dauda and Alibaba, 2020)

Table 2.1 Extensive and intensive green roofs (based on Berardi et al., 2014, and Hendriks et al., 2016)

Characteristics	**Extensive**	**Intensive**
Thickness of growing media/soil layer	Max. 20 cm	Min. 20 cm
Diversity of plants	Low (moss, sedum, grass, and herbs)	High (grass, shrub, and tree)
Vegetation height	Max. 50 cm	Min. 50 cm
Accessibility	Inaccessible	Accessible
Weight	60-150 kg/m2	Above 300 kg/m2
Construction	Easy	Technically complex
Maintenance	Simple	Moderate
Costs	Low	High
Irrigation	Not necessary	Drainage and irrigation necessary

In developed urban areas, all natural aspects have been changed into hard surfaces such as roads and buildings. As such, roof areas account for around 40-50 percent of the total impermeable surfaces in urban areas (Stovin et al., 2012). These increasing levels of impermeable surfaces and decreasing levels of greenery are causing cities to be more prone to urban heat islands and surface water flooding. Moreover, the impacts are expected to be exacerbated by increased precipitation rates due to climate change (Mees and Driessen, 2011). Especially in cities, some effects of climate change are therefore experienced more severely in comparison to rural areas, as mentioned in the introduction (Battista et al., 2016, Salata et al., 2015). Due to the accumulation of social, cultural and financial capital in overburdened environments, urban areas are regarded as vulnerable to the impacts of climate change (Carter, 2011, Corfee-Morlot et al., 2011). Furthermore, the share of people living in cities increases in comparison to non-urban areas (Cook et al., 2013), and a growing number of people will therefore experience climate impacts in cities (Shafique et al., 2018). Consequently, cities are increasingly required to take action in order to mitigate and adapt to climate change (Frantzeskaki et al., 2019).

A measure which generally contributes to tackling big societal urban challenges such as climate adaptation, biodiversity and heat mitigation, is to plant greenery in cities (Knuijt, 2020). Creating more green spaces in cities brings nature to the urban sphere and enhances biodiversity. Planting greenery can therefore be seen as the next step to ensure that cities become a resilient place in which people can work and live in the future. As was mentioned in the introduction, the application of green roofs is such a greenery measure contributing to urban resilience.

Applying green roofs is feasible for both new developments and for the retrofitting of existing roofs (Castleton et al., 2010, Gagliano et al., 2016). According to Castleton et al. (2010), retrofitting old buildings is more cost effective, especially in terms of low energy efficiency due to poor isolation, compared to applying it to new buildings.

2.2 Disadvantages, challenges and difficulties

Although green roofs bring multiple benefits (see chapter 1.1), there are some factors hindering the application of green roofs. These are for example the high initial costs and maintenance costs (Dauda and Alibaba, 2020). A lack of resources on the governmental side can be caused by institutional competition for resources. This might be the case for municipalities which have their origins in institutional policy silos (Droste et al., 2017). Also, the private sector might be skeptical about the profitability of such business models, and may therefore be less willing to invest (Dorst et al., 2022). Besides the governmental and private actors, citizen engagement might be challenging as well. Engaging citizens is, according to Dorst et al. (2022), often perceived as difficult, contested, or insufficiently prioritized. On the other hand, citizens might lack the interest to engage with or participate in green initiatives (Egusquiza et al., 2019, Wamsler et al., 2020). Furthermore, there is not one ideal design that can be applied to all areas and in all circumstances. There are different types of roofs, which is why the roof type first needs to be studied before selecting the best type of green roof to achieve multiple benefits (Shafique et al., 2018). Materials used for roofing can also degrade, and leakage problems could occur. A life cycle analysis of green roofs is thus hard to perform because of the difficulty of estimating costs for air quality, ecological improvement, temperature, and noise reduction. These uncertainties regarding the effectiveness of said measures can be seen as a barrier (Sarabi et al., 2019). Also, the construction of the green roofs might be seen as a challenge (Deely et al., 2020). On the governance side, a lack of cooperation between different policy fields could hinder green roof application (Dauda and Alibaba, 2020, Dorst et al., 2022). Also, a lack of overarching frameworks to support adaptation initiatives at lower levels can be a barrier (Hulme et al., 2007, RCEP, 2010). Furthermore, limited resources and capacity at the local level could be hindering factors, as adaptation is dependent on local governmental choices. Accordingly, an overall lack of political will

and low priority for adaptation measures can reinforce barriers to green roof application (Carter, 2011). This can also be applied to awareness, relevance, and knowledge exchange regarding green roofs to make sure the target groups are informed well (Dorst et al., 2022).

Berardi et al. (2014) identified economic benefits and barriers based on multiple journal articles. These are categorized in table 3 (Berardi et al., 2014).

Table 2.2 Economic benefits and barriers of green roofs (Berardi et al., 2014)

Economic benefits	**Economic barriers**
Reduce energy consumption	High construction costs
Increase thermal isolation in retrofitting	High maintenance costs, especially with intensive green roofs
Reduce maintenance costs of roof due to lengthening life	Complexity of construction
Reduce costs of water rain off and urban infrastructure	Risks of failure
Improve market and price of the buildings	Expensive integration in existing buildings if structure needs to be adjusted
Increase usable surface of the building	

2.3 Policies: governance arrangements for climate adaptation

For a long time, it has been assumed that environmental governance should be exercised in a top-down manner based on technical, instrumental, and procedural expertise, stemming from nineteenth-century ideals and post-war functionalism (De Roo, 2016b, Friedmann, 1987). Today, with a society of growing democratic and equitable values, this direction of absolute control seems to be difficult to achieve (De Roo, 2016b). It became increasingly clear that planning is a communicative process, including different actors and interests (Spit and Zoete, 2003). Accordingly, in the 1990s a fundamental shift was recognized in theory, and communicative approaches arose in planning theory (e.g. Allmendinger, 2017, De Roo, 2016a, Healey, 1996, Innes, 1995). At the same time, the concept of governance emerged, acknowledging that the public sector was not the sole controlling actor anymore in solving societal problems (Driessen et al., 2012). Instead, attention shifted to the interaction between the state, market, and civil society. According to Mees et al. (2013), there is a general consensus about the involvement of non-state actors in environmental governance. The state, market, and civil society should share responsibilities for public matters when the boundaries between the public and private sectors are blurred (Stoker, 1998). However, the exact type of governance arrangement could differ in terms of feasibility to effectively deal with the environmental issue.

Climate change adaptation can, for example, be seen as such an environmental issue with characteristics of complexity, uncertainty, and ambiguity (Mees et al., 2013). Consequently, governance arrangements could range from top-down on the one end to bottom-up self-governance on the other, with several possible configurations in between. According to Mees et al. (2013) these different types of configurations indicate that more discretionary power can be allocated to non-state actors. Having more actors involved could be a potential source of shifting modes of governance.

Overall, governance arrangements can be classified in line with three aspects (Mees et al., 2013): responsibilities among different actors, the steering strategy, and policy instruments. Governance arrangements regarding the public-private divide, in turn, can best be analyzed based on juridical, economic, and political considerations (Mees et al., 2013, Nelissen, 2002). Governance arrangements regarding green roof policies currently exist in multiple countries. In table 2.3, these green roof policies are shown (Berardi et al., 2014, Shafique et al., 2018). They consist mainly of mandatory policies,

financial incentives, and water or property fee reductions. In line with these policies, the application of green roofs is encouraged, and consequently multiple environmental benefits could be achieved. Besides these direct policies, there are also more indirect policies such as sustainability labels for buildings. BREEAM is such a certifying method by which buildings get rated on sustainability. It is the most used certificate within Europe, and the method is also being applied in the Netherlands (DGBC, 2022, Dutch Green Building Council, 2022). When having such a certificate, there are multiple subsidies that can be applied for. Such an indirect funding policy is fundamental for the diffusion of green roofs (Berardi, 2012).

Table 2.3 Green roof policies (Berardi et al., 2014, Shafique et al., 2018)

Country	**Policy**
Germany	Green roofs mandatory to be applied to all flat roofs with a surface area larger than 100m2 (Munich) 50 percent of the costs will be compensated (Esslingen) 5000 euros refund for users applying green roofs (Darmstadt) Reduction of stormwater fees after applying green roofs (Bonn, Cologne, and Mannheim)
Denmark	Green roofs are usually to be applied in all new roofs with roof pitch under 30 degrees (Copenhagen)
Canada	Green roofs mandatory at new buildings over 200 m2, with green roof covering 20-60 percent of the total roof m2 (Toronto) Green roofs mandatory at all new buildings over 5000 m2. Otherwise the owner has to pay the fees (Vancouver, BC)
Switzerland	Users are repaid 20 percent of the green roof costs (Basel)
Singapore	Gross Floor Incentive Scheme for users
Japan	Green roofs mandatory at new primary building over 1000m2 and new public building over 250 m2. Otherwise the owner has to pay a fine annually (Tokyo)
USA	50 percent of the costs or $100.000 for development of green roofs covering at least 50 percent of a rooftop space (Chicago, IL) Floor Area Ratio bonus per square foot of green roof (Portland, OR and Seattle, WA) Green roof rebate program of $5 per square foot (Washington, DC) One year tax credit of up to $100.000 (or $4.5 per square foot) for users applying green roofs of 50 percent or more (New York City, NY) Credit against the Business Privilege Tax of 25 percent of all costs incurred to construct a green roof up to $100.000 (Philadelphia, PA) Stormwater Management Tax Credit of 10 percent of the costs for new stormwater management techniques up to $10.000 (Baltimore, MA) 50 percent credit in the stormwater fees for applying green roof (Minneapolis, MN)

	$10 reduction in a property's sewer fees for every square foot of green roof (Nashville, TN) Green Roof Density Bonus up to 8 square foot for 1 square foot of green roof (Austin, TX) $5 incentive per square foot of green roof (Milwaukee, WI)

3 Methodology

3.1 Research strategy

In order to answer the main research question, a qualitative approach is used as it focuses on quality, depth, richness, and understanding (Clifford et al., 2010). Based on Sayer (1992), Clifford, et al. (2010) discern two types of research designs: intensive and extensive. In an intensive research design, the emphasis is on describing a single case, or a small number of cases. Also, qualitative methods are usually deployed in intensive research to answer 'how, what, and why' questions. In this thesis, an intensive research design is therefore used, with qualitative methods being deployed to answer these research questions.

3.2 Single case study

In this research, the focus is on empirics as the case study concentrates on the city of Leeuwarden. According to Tight (2017), a case study involves studying a particular case or a number of cases. Furthermore, he argues that the case has to be complex and bounded, studied in its context, and that the analysis undertaken seeks to be holistic (Tight, 2017). In the literature, it is furthermore argued that one cannot generalize from a case study, but according to Flyvbjerg (2006) this statement is not true; case studies can serve as an example, and can be valuable for scientific development. A case may be so important or interesting that it deserves to be studied in its own right (Punch, 2014). The intention is thus not to generalize based on a case study, but rather to understand the case in its complexity, entirety, and context.

3.3 Data collection methods

In order to gain deeper insight into enabling or hindering factors regarding green roof application, the relevant academic literature is consulted. Search engines like Scopus and Google Scholar are used to examine relevant journal articles. Also, snowballing is used as sources within articles proved to be relevant for the research. The results of this literature study are documented in chapter 2: Theory.

Data by the municipality on green roof subsidy applications are used to make an analysis on neighborhood level. This analysis consists of a number of applications per neighborhood, with additional data from the Dutch National Statistics Bureau (CBS). By using QGIS, a spatial analysis could be made. Also, stress tests maps have been used to determine areas in which severe climate impacts can be expected. These are compared with a map of roof types in Leeuwarden. Then, potential areas are pointed out in which green roofs have potentially the most effect.

Semi-structured interviews are conducted to identify the different views of actors regarding green roof implementation. In semi-structured interviews an interview guide is employed with questions that focus on the content of the (qualitative) research. Although the questions are ordered, the interviewer must be flexible in this type of interview (Dunn, 2005). Semi-structured questions are planned in advance, and they tend to be open-ended questions such as why, what, who, where, or could be even less structured (Olsen, 2012). Eight interviews have taken place with the following actors:

1. Project leader of the municipality of Leeuwarden;
2. Servant active on subsidies of the municipality of Leeuwarden;
3. An inhabitant with an intensive green roof;
4. An inhabitant with an extensive green roof;
5. An employee working in an industrial building;
6. A freelancer working and owning an industrial building;
7. A gardener who applies and sells green roofs; and

8. A sustainability expert working at a consultancy bureau, who also lives in Leeuwarden and has an extensive green roof.

The entrepreneurs, the gardener, and the expert were selected based on the author's own network. The interviewees from the municipality were selected by approaching a general contact of the municipality. The inhabitants were approached based on contact details provided by the interviewees of the municipality. By interviewing these participants, a varied set of actors was selected to allow for the topic to be approached from different viewpoints. The interviews took place during April and May 2022 in the language preferred by the interviewee; either Dutch or Frisian. The interviewees were held in person if possible, but some interviews had to be held online due to the Covid-19 issues. The interviews had a duration between 30 and 45 minutes and they were audio recorded with the interviewees' consent.

The interview guides are created based on codes, stemming from the research's theory. Opposed to inductive – generating understandings from the data themselves – this pre-set of codes is developed deductively, where codes are drafted from the theory (Clifford et al., 2010). However, also inductive coding is used as additional codes were derived from the interviews that were initially not drawn from theory. This does not mean that the inductive codes are not present in theory, but that they were initially not deducted from theory. Combining both deductive and inductive coding might be more fruitful, as it results in a more complete set of codes (Campbell et al., 2013, Tashakkori et al., 1998). The interview guide can be found in Appendix 1 and the codes in Appendix 2.

3.4 Ethics

According to Longhurst (2016), two ethical issues are important: confidentiality and anonymity. These two aspects are taken into account during the interviews and the interviewees were informed about their rights (Longhurst, 2016). The interviewees' identities are not mentioned in the report, although the reader can always get an impression of the interviewees' backgrounds. The interviews were recorded, and quotes are used within the report. Also, the interviewees received a copy of the transcription to make sure all content was properly noted. All data is stored on a password protected computer. Furthermore, since the thesis is part of a university course, the purpose is learning rather than the work being published. In case the work will be published, outside of the university database, it will be communicated to all interviewees who were involved.

Regarding the interviews itself, interviewees had the right to:

- decline to answer any particular question;
- ask for the audio-recorder to be turned off at any time;
- end the interview at any time;
- withdraw from the study up until three weeks after participating in the research;
- ask any questions about the study at any time during participation; and
- ask for the erasure of any materials that are not wished to be used in any reports of this study.

3.5 Data analysis

The in-depth, semi-structured interviews were recorded and transcribed before they were analyzed by using ATLAS.ti. By using this software, transcripts were analyzed by labeling pieces of text according to the codes outlined in Appendix 2. Then, the different code groups were used to structure the results from this primary data analysis. Data from all of the interviews was relevant for answering the research questions posed in this thesis.

Besides interviews there was also data provided by the municipality of Leeuwarden regarding green roof application in the municipality. This data consisted of a list of green roof subsidy applications,

including street addresses. By doing an internet search on the addresses, the neighborhoods could be added to the list. Thereafter, the number of green roof applications per neighborhood were imported into QGIS and added to a layer made by the Dutch National Statistics Bureau (CBS) and the Cadaster, including an array of data on neighborhood level stemming from 2020. Then, maps and tables were created to show the dispersion of green roofs within the city of Leeuwarden, and to compare the number of green roof applications with the socioeconomic background of neighborhoods. These results are presented in section 3.6.2.

3.6 Study area description

The city of Leeuwarden will be used as a case study in this research. The municipality wants to be climate adaptive by 2035, a date by which public space should be prepared for heat effects and excessive water (Gemeente Leeuwarden, 2020). Based on a stress test, the municipality identified multiple actions which need to be undertaken to become climate adaptive. These actions consist of communicating risks to stakeholders, writing an agenda with measures, taking climate adaptation into account with tenders, planting trees, and providing subsidies for greenery and water retention. Forthcoming from this last measure, the municipality of Leeuwarden provides subsidies for homeowners to invest in green roofs (Gemeente Leeuwarden, 2022b). These subsidies are provided in the way of a financial incentive so that investors are eligible for receiving money per square meter, depending on the water storage ability and total roof surface. The exact subsidies are shown in table 3.1. The total amount of subsidy per plot is € 10.000,-.

Table 3.1 Subsidy on green roofs in Leeuwarden (Gemeente Leeuwarden, 2022b)

Extensive green roof (water retention capacity of 25-50 liters per m²)	
Roof surface	**Subsidy**
6-100 m²	€ 30,-
100-250 m²	€ 20,-
>250 m²	€ 10,-
Intensive green roof (water retention capacity of >50 liters per m²)	
Roof surface	**Subsidy**
6-100 m²	€ 35,-
100-250 m²	€ 25,-
>250 m²	€ 15,-

4 Results

In this chapter, the results of the data analysis are documented based on data from the municipality and the interviews . In section 4.1, the current state of urban green roof application is documented. In section 4.2 the different roof types and potential areas in the city are analyzed, and in section 4.3 some practical insights on extensive green roofs are given based on an interview visit at a gardening company. Finally, the interview results are documented in line with the code groups described in section 4.4-4.7.

4.1 Current state of green roof application in Leeuwarden

Currently, around 116 green roofs have been applied in the municipality of Leeuwarden. In table 4.1, a list of the number of subsidy payments provided by the municipality is shown. The total number of payments in this table is slightly lower than the actual number of green roof applications due to the time needed for the administrative aspects of providing subsidies.

Table 4.1 Green roof applications per year (data provided by the municipality of Leeuwarden)

Year	Number of green roof subsidy payments
2019	29
2020	35
2021	36
2022	12 (until May 2022)

93 of the 116 green roofs have been applied in the city of Leeuwarden and in the adjacent villages of Goutum and Hempens. The other 23 green roofs were applied in villages further away from the city of Leeuwarden within the municipality. In figure 4.1 the 93 green roofs are included and subdivided per neighborhood in the city. From the map it becomes clear that the number of green roofs in the city center is relatively low compared to neighborhoods located further away from the city center.

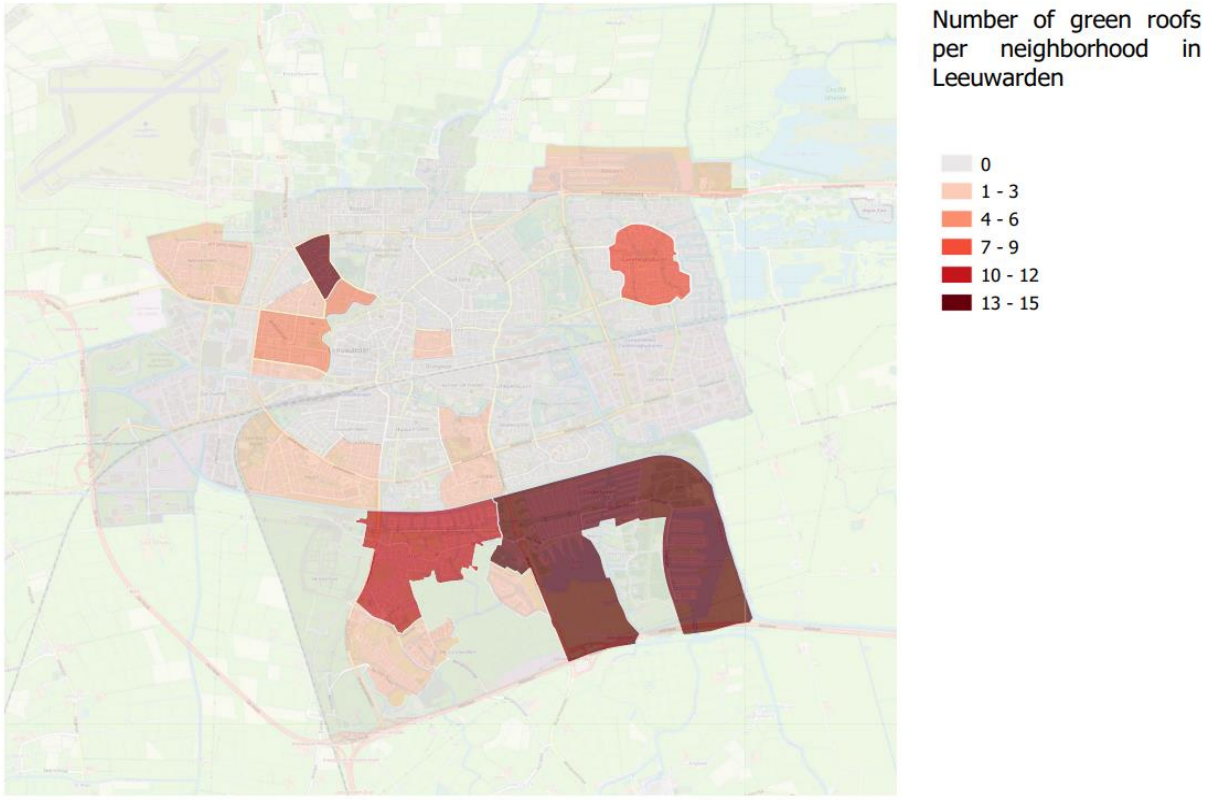

Figure 4.1 Number of green roofs per neighborhood in Leeuwarden

The data from figure 4.1 is shown in table 4.2. The neighborhoods that are colored in the darkest shade of red in the figure are listed at the top in table 4.2. The third column of the table shows the average income in the respective neighborhoods, based on data from the Dutch National Statistics Bureau (CBS). The average income of all neighborhoods in table 4.2 is €25.600. The average income of all other neighborhoods within the city of Leeuwarden without green roofs is €21.700.

Table 4.2 Number of green roofs per neighborhood and the average income

Neighborhood	**Green roofs**	**Average income (x €1.000)**
Zuiderburen	15	30
Bonifatius	14	32
Goutum	11	29
Camminghaburen-Midden	7	24
Vossepark	5	26
Transvaalwijk	4	27
Huizum-Dorp	3	26
Blitsaerd	3	35
Techum	3	25
Molenpad	2	21
Vogelwijk	2	28
Westeinde	2	23
Harlingervaart Noord	2	-
Julianapark	2	25
Nijlân	2	21
Aldlân-West	2	23
Wiarda	2	29
De Klamp	2	-
Oldehove	1	27
Huizum-Badweg	1	24
Cambuursterpad	1	19
Zamenhofpark	1	22
Zeeheldenbuurt	1	22
Sonnenborgh	1	24
Gerard Dou	1	23
Bilgaard	1	17
Havankpark	1	32
Hempens/Teerns	1	31

4.2 Stress tests

In the Province of Fryslân, there are different stress tests in which areas are prioritized that are under stress due to precipitation, drought, heat, and floods. Stress tests regarding these four themes are created within the 'Friese Klimaatatlas'. The Province of Fryslân, the waterboard Wetterskip Fryslân, and all Frisian municipalities created this atlas together in order to identify areas that are likely to be under stress (Gemeente Leeuwarden, 2022a). In figure 4.2, places that are experiencing flooding in case of extreme precipitation are indicated. In figure 4.3, two maps are provided, which show places of heat stress for the years 2014 and 2050. When comparing the map of green roofs in the city (figure 4.1) with the maps of flooding and heat stress (figure 4.2 and 4.3), it becomes clear that the areas in which the most green roofs are applied are definitely not the areas in which climatic effects are expected to have the most impact. For example, in the neighborhood of Zuiderburen, the most green roofs have been installed, but this area is one of the least impacted areas in the city in terms of flooding and heat stress. The neighborhood is located in the southeast of Leeuwarden, and is relatively far from

the city center. There is also a lot of water in the area, as can be seen in the bottom right corner of figure 4.2.

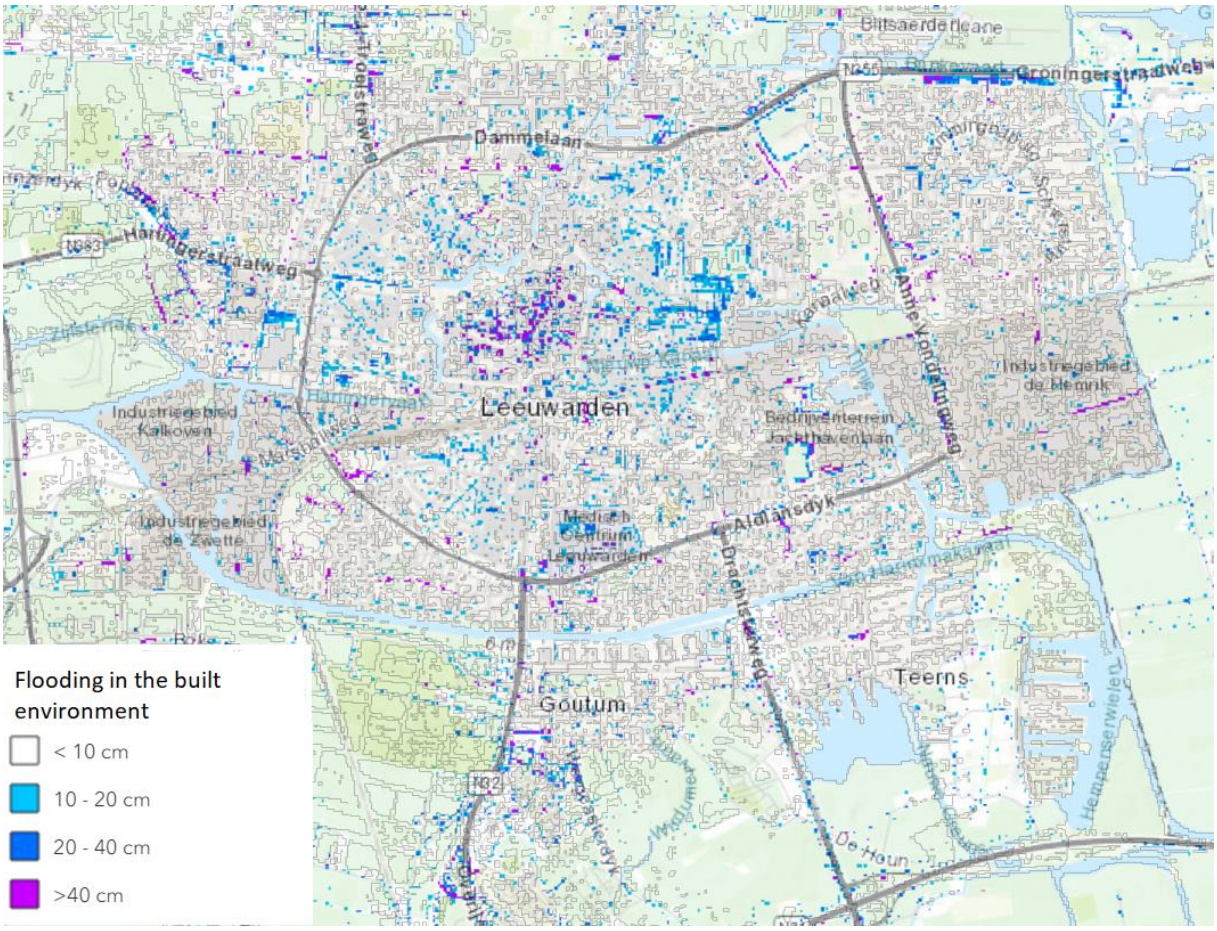

Figure 4.2 Flooding in the built environment

Figure 4.3 Heat stress maps of 2014 (left) and 2050 (right)

4.3 Potential areas for green roof application

There are multiple potential areas in the city where more green roofs could be applied. In figure 4.4, a city map containing the different roof types is shown. The map is a sewerage map in which a distinction is made between separated and mixed sewerage pipes of wastewater and rainwater. The pink color represents the flat roofs that are connected to the mixed system, and the light-yellow color represents the flat roofs that are connected to the separate sewerage system. Consequently, in these areas there is the most potential for green roofs to be applied as most benefits can be achieved with (semi-) flat roofs (Cutlip, 2006). Three red rectangles have been put into figure 4.4, which will be elaborated upon more in-depth in the remainder of this section.

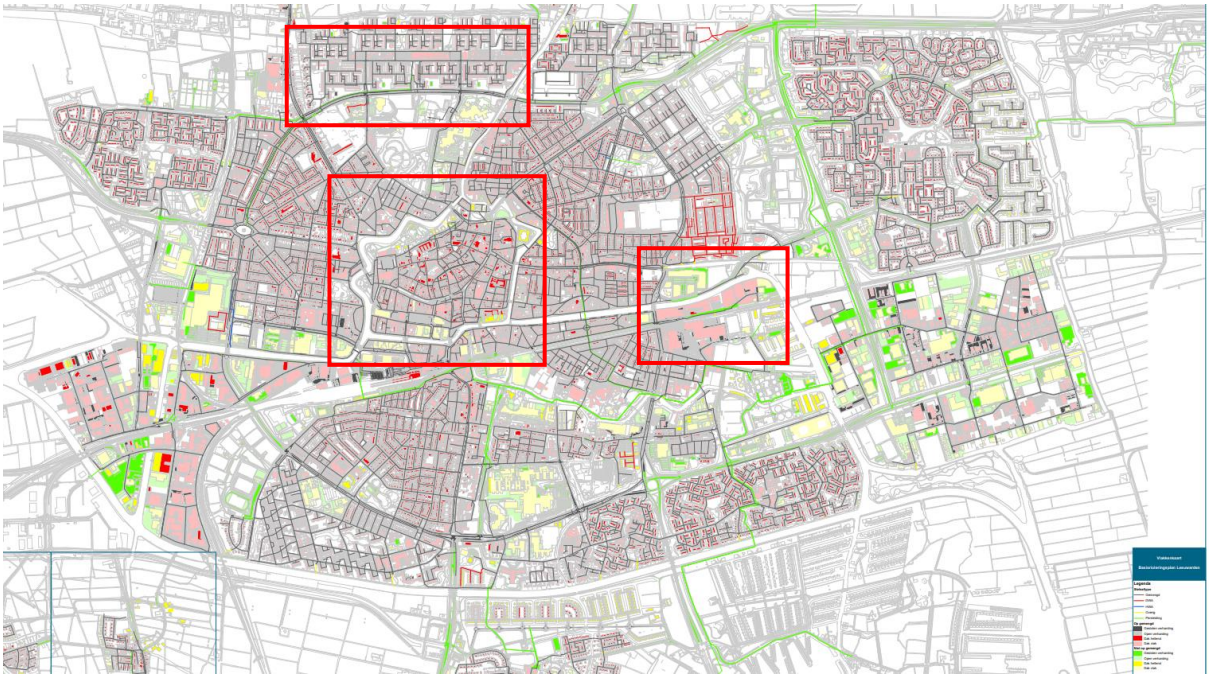

Figure 4.4 Roof types and sewerage system in Leeuwarden (provided by the municipality of Leeuwarden)

The rectangle in the upper part of figure 4.4 represents a part of the neighborhood of Bilgaard (see figure 4.5). In this neighborhood almost all houses and flats have flat roofs. In the center of the area is a shopping mall with a flat roof. Although this area is not expected to be impacted heavily by climate change impacts (see figure 4.2 and 4.3), there is a lot of potential for green roofs to be applied.

Figure 4.5 Bilgaard

Figure 4.6 Bilgaard visualized in Google Earth

The rectangle in the middle of figure 4.4, representing the city center, is visualized in figure 4.7. In this area, climate change impacts are expected. The pink and light-yellow colors in this map indicate there is some potential for green roofs to be applied. For example, in figure 4.8 the Fries Museum is shown. This building was recently built and is equipped with a large black roof in the middle of the city center. On this building, and in adjacent buildings in the city center, there is therefore a lot of potential for green roofs to be applied.

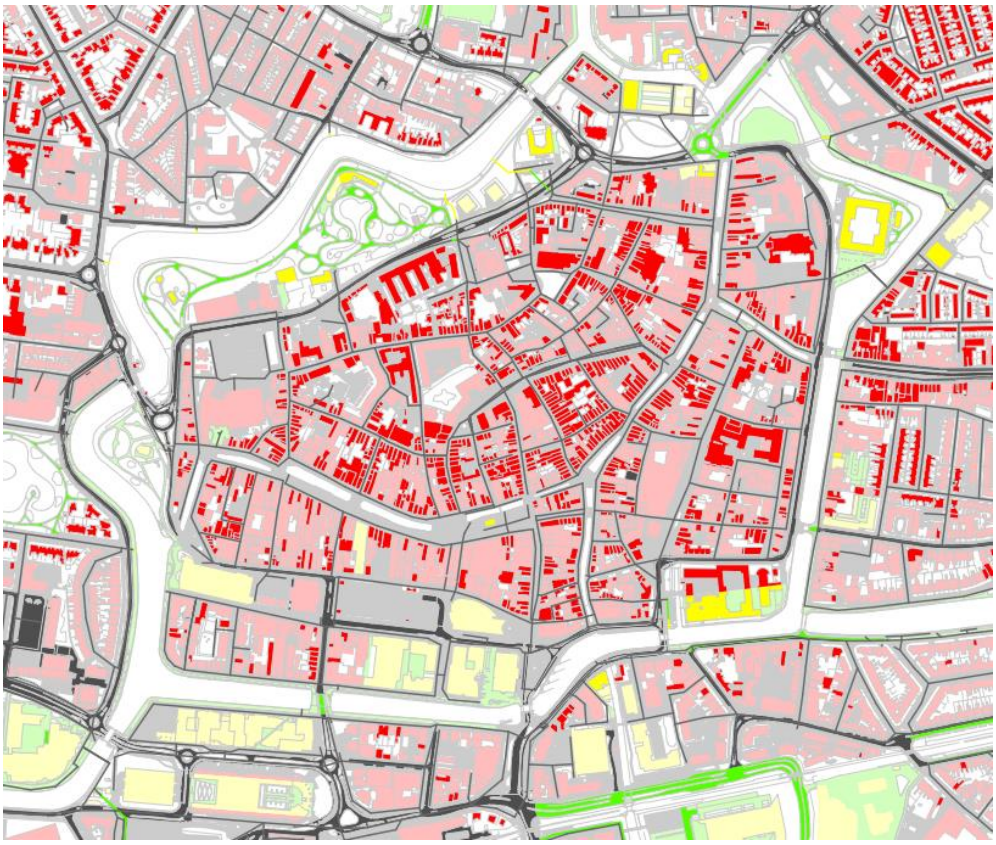

Figure 4.7 City center

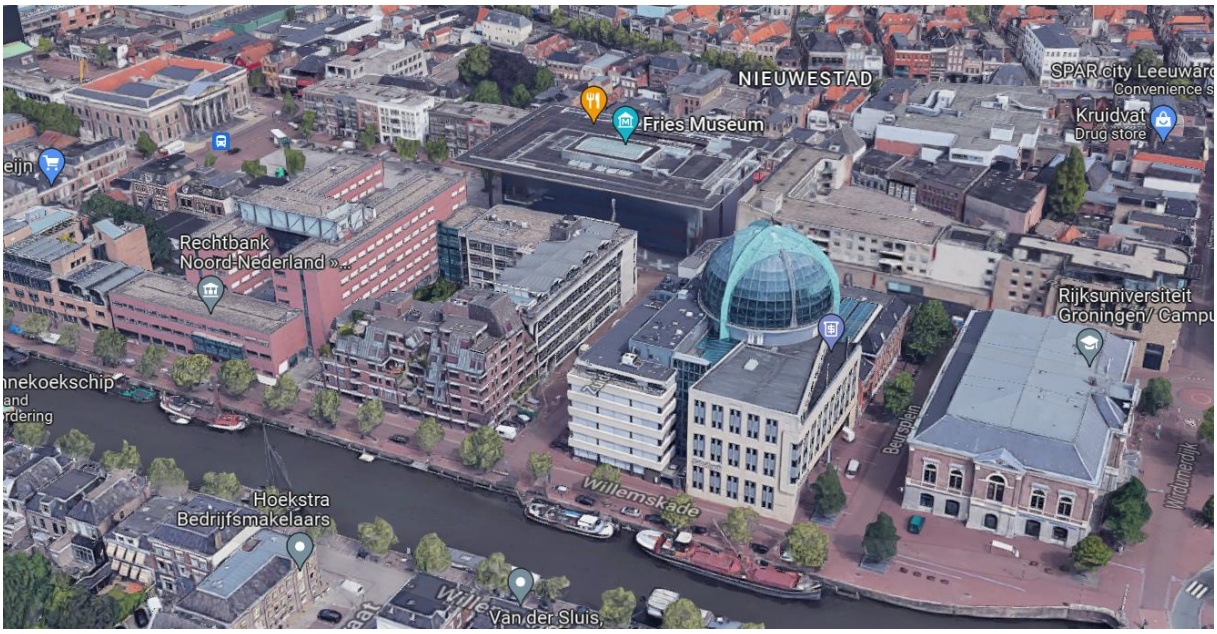

Figure 4.8 City center visualized in Google Earth

The third rectangle in figure 4.4 contains the shopping mall ‘De Centrale’ and factories (see figure 4.9). The buildings in this area contain large surfaces of flat roofs, as indicated with the light-yellow and pink colors. In figure 4.10, these large black roofs can be seen. Heat impacts are expected to be present in this area as is shown in figure 4.3. Therefore, green roofs could help mitigate the heat impacts in this area.

Figure 4.9 Shopping mall 'De Centrale' and factories

Figure 4.10 Shopping mall 'De Centrale' and factories visualized in Google Earth

4.4 Extensive green roofs

Based on the interviews with the municipality of Leeuwarden, it became clear that there is only one intensive green roof application in Leeuwarden. Extensive green roofs are more convenient to apply and during the two-hour visit of the gardening company, different extensive green roofs were shown. The company is a dealer of two types of extensive green roofs; layers that are rolled up in a roll (figure 4.11), and green roofs that are placed in cassettes (figure 4.12). The rolls can be rolled out on roofs and the cassettes can be put next to each other to fill the roof surface.

Figure 4.12 Sedumroll (Sempergreen, 2022)

Figure 4.11 Sedumcassette (Mobilane, 2022)

These types are similar to the components depicted in figure 1.1, but between the substrate layer and the filter fabric there is an additional layer in which water can be retained. This layer consists of either rockwool or lava grains. With rockwool, the most water can be retained which can be taken up by the plants in dryer times. In figure 4.13, these materials are shown; on the right hand side the lava grains can be seen, and in the next compartment lies a roll of rockwool.

Figure 4.13 Lava grains and rockwool (picture provided by gardener)

4.5 Green roof characteristics

4.5.1 Green roofs and maintenance

The interviewee having the only intensive green roof in the city indicated to be satisfied with the roof, since it is both used as garden and as green roof, with the advantages of heat mitigation and increased biodiversity (see figure 4.14). This roof's substrate layer has the function of keeping out weeds, and because of its structure the weeds can be kept out pretty easily. The other two interviewees with a green roof in Leeuwarden installed an extensive green roof with sedum plants.

Figure 4.14 Intensive green roof in Leeuwarden (own photographs)

The gardener mentioned that maintenance is important for both intensive and extensive green roofs. Weeds and other plants that are not meant to be on the green roof, need to be taken out once or twice per year, although maintenance is not necessarily required according to the expert, as long as the water drainage functions properly. The other interviewee with an extensive green roof mentioned that it only takes around 15 minutes per year to take out the weeds with taproots. The extensive green roof is shown in figure 4.15.

Figure 4.15 Extensive green roof in Leeuwarden (own photograph)

4.5.2 Roof construction and slope

The interviewees acknowledged that the roof construction is important for the type of green roof that is used. The interviewee with an intensive green roof mentioned that the roof construction had to be strengthened to apply the green roof. This can be done in a relatively simple manner, by adding an iron joist. The gardener also mentioned that with extensive green roofs, the roof construction is oftentimes not a problem due to the low roof load. Therefore, the two entrepreneurs thought an extensive green roof would be possible to be applied on their roofs, due to the proper iron roof construction present on their buildings. Also, the roof slope would not be a problem with their buildings. In case it might be a problem, the gardener mentioned that L-shaped strips could be applied to make sure the roof stays in its position. With cassettes such extra measures should be taken when the slope exceeds the 20-25 percent degrees. The fact that there are a lot of houses in the city of Leeuwarden with gabled roofs is thus seen as a barrier by the expert and the interviewees from the municipality.

4.6 Advantages

4.6.1 Rainwater storage

Most of the interviewees mentioned rainwater storage as an advantage of green roofs. According to the gardener, this is also the main reason why subsidies are applied, since green roofs can relieve pressure from the sewerage system in times of heavy precipitation. The municipal project leader further mentioned that, in public spaces, the water nuisance cannot always be handled, and that green roofs could therefore be a solution on private plots. Even if the sewerage capacity would be increased, there would still be problems with heavy precipitation, and therefore the project leader added that there is some responsibility for inhabitants to take measures on their plots. The interviewee having an intensive green roof also mentioned that their neighborhood is colored red on the map with water nuisance, and that it was part of their decision to apply the green roof.

4.6.2 Biodiversity improvements

Another advantage mentioned by all interviewees is improved biodiversity. The gardener mentioned that more insects and birds are expected to be present on green roofs and that this could be valuable for biodiversity, especially in cities. This was confirmed by the interviewees having a green roof. The interviewee having an intensive green roof mentioned that their roof also was some sort of experiment for them to see whether the number of insects and birds could increase in their area. This seemed to work according to the interviewee: *“there are already a lot of insects and we figured out that there are a lot of species that need plants to stay here. Last week a house sparrow was seen here for the first time in three or four years.”* Besides biodiversity, some interviewees also mentioned the air quality to be improved as a result of green roofs.

4.6.3 Mitigate heat effects

The ability of green roofs to mitigate heat effects was also mentioned by some interviewees. The gardener for example mentioned that this effect would really make an impact if all flat roofs in the city would be covered by green roofs. The municipal servant also mentioned that this would really help, especially in the inner city and on industrial properties. The interviewee having an extensive green roof mentioned that their solar panels also functioned better as the green roof mitigated the heat underneath the panels. The fact that green roofs mitigate heat was also the main reason for the interviewee having an intensive green roof to apply the roof, since it was impossible to be on the roof in the inner city in the summer. Furthermore, some interviewees mentioned the roof time prolongation due to green roofs. Black roofing can become very hot in the summer and therefore the green roof makes sure that it is protected.

4.6.4 Isolation

Thermal comfort inside buildings was mentioned as another advantage by the interviewees. The expert having an extensive green roof mentioned that the shed's temperature is more stable now with the green roof. The other interviewee having an extensive green roof also mentioned that in spring the thermal comfort benefits could be felt. The interviewee also mentioned that the room temperature never exceeds 21 degrees, in comparison to the situation before green roof application, when temperatures were reaching 25-26 degrees. Both entrepreneurs also mentioned that a green roof could benefit the inside working temperature, and that it could be a proper solution to mitigate the heat: *"Every summer we work in the building and then it is really warm. So an air-conditioning or an isolation measure should be applied to increase thermal comfort"*. Also, during wintertime isolation effects can be experienced as the interviewee having an extensive green roof mentioned energy savings to be a benefit. According to the gardener, this is an excellent argument in favor of green roofs, especially due to the current gas dependency on Russia.

4.6.5 Aesthetics, noise reduction, and application

Besides qualitative advantages, there is also the visual aspect of green roofs that some interviewees mentioned to be a reason for people to implement this solution. The gardener mentioned that it is sometimes the main reason for green roof application, and the employee working in an industrial building pointed out that this visual aspect would be especially nice on gray industrial locations. In addition, noise reduction benefits might be experienced according to the interviewee having an extensive green roof. Especially if there are multiple green roofs in a neighborhood, they might enhance the quality of life.

Regarding green roof application, multiple interviewees mentioned green roofs are easy to apply. Although it is some effort, people can do it by themselves according to all interviewees having a green roof. This was also done by the interviewee with the intensive green roof. Though, according to the interviewee with the extensive green roof the installation needs to be done very properly, as otherwise disadvantages could come up later.

4.7 Disadvantages

4.7.1 Degrading materials

Leakages or degrading materials could be results of the improper installation of a green roof, according to some interviewees. In case some materials should be repaired, then it is also more difficult to access these roof materials compared to a traditional roof, according to the interviewee with an intensive green roof. According to the municipal servant, another potential barrier for people to invest in green roofs is that in times of change in owners, the new owners might not like the green roof, and that therefore people might be hindered to invest in green roofs.

4.7.2 Costs

The most frequently mentioned disadvantage of green roof is costs. The interviewees mentioned that, although there is subsidy, it is relatively expensive for most inhabitants. Especially, because the advantages might also not always be clear for inhabitants according to the project leader. Other necessities in life might be more important to spend money on, such as food, drink, and health. Also, with the increasing prices of gas and other fixed charges, it is difficult for people to invest in green roofs according to the interviewee having an extensive green roof: *"It is then worth doing something about isolation, but the investment still needs to be made"*. The entrepreneurs also mentioned that the costs are the main barrier to investing in a green roof. Only in case the costs are somewhat being earned back due to lower energy costs in the long run, then it would be considered. The employee also

mentioned that thermal comfort is valuable, and that some money can be spent to increase this comfort.

A clear overview of costs and benefits therefore needs to be made to consider a green roof according to the employee. Thus, according to the interviewees the priorities are likely to be on other subjects than green roofs. One interviewee mentioned that it would be nice if companies would take more responsibilities in the field of climate change, but that a governmental top-down approach would be more effective. Also, housing associations were mentioned during the interviews to be important actors in increasing the share of green roofs, although the project leader mentioned that these associations already have a lot of other priorities with higher salience in terms of improving buildings. Moreover, the expert mentioned that with a relatively low surface to be covered, the investment is not that high, and that a lot of benefits can be gained. The gardener also mentioned that it does not have to be very expensive if the green roof is taken into account from the beginning of a project. Especially when building multiple houses with green roofs, the costs can be limited according to the gardener.

4.7.3 Lack of awareness, relevance, and knowledge

Another barrier to green roof application is the lack of information. Generally, the interviewees mentioned that the public is not aware of green roofs and their benefits. The interviewee with an extensive green roof also tried to increase awareness and relevance in the neighborhood by informing the neighborhood association: *"... but I did not get a response. Sometimes you first need more awareness, so for that matter there is a huge backlog for green roofs"*. Also the interviewee with the intensive green roof mentioned that people often react in a negative way to their green roof: *"not by people that know us well in the meantime and know our experiences, but by neighbors who do get more positive and curious about the green roof. A lot of people don't know anything about the possibilities and benefits of green roofs"*. The entrepreneurs were not very aware of the benefits of green roofs, as almost no information on green roofs had ever reached them. Though, they mentioned that if people would be informed better and would be more aware of green roof benefits, that people would be more likely to apply green roofs. Also, the gardener stated that this exchange of knowledge is the first step to make the public aware of green roofs. The expert mentioned that there is relatively a lot of information if you search for it, but then the information is overwhelming and not very convenient for the public. Furthermore, constructors are lacking knowledge on green roofs according to the expert. The freelancer also mentioned that when the roof was renovated, the constructor never considered a green roof or another option than a conventional roof. Also, the interviewee having an extensive green roof mentioned an example in which a constructor was just not willing to apply a green roof. Furthermore, the interviewee mentioned that the knowledge infrastructure should already start at universities to increase awareness and provide the right information. A lack of knowledge was also experienced by the interviewee having an intensive green roof when they proposed a green roof to be installed at a school in their neighborhood: *"Then they said that it was not possible because of solar panels. But that combination works especially well, and an architect also said that it would not work"*. Especially when air-conditioning or heat pumps are applied, the interviewee mentioned that green roofs also could have been considered as a more sustainable solution.

Some non-municipal interviewees mentioned that there is also a lack of knowledge within the municipality. Therefore, it was mentioned that the municipality should cooperate more with people or experts that possess knowledge on topics such as green roofs, trees, and water retention in order to execute policies well. The gardener mentioned: *"They do not need to include these people in their teams, but just like the way you are interviewing us. That would already be very helpful for the municipality"*. Another interviewee mentioned that the amount of knowledge on greenery should be

improved first, before spreading municipal information on green initiatives: "*You cannot stimulate green roofs if you don't know how it works, how it looks, and what it does.*"

4.7.4 Municipal priorities

Although the municipality mentioned that additional measures should be taken on privately owned plots, a full covering of the costs of greenery on these plots is not feasible according to the project leader. Though, multiple interviewees mentioned the lack of greenery in public spaces in the city. The expert for example mentioned the lack of will to implement greenery at the recently renovated station area and the plans regarding the area of the new football stadium. The interviewee having an extensive green roof mentioned that the municipality and utility companies could apply green roofs on public facilities, such as bicycle parking and power stations. Another interviewee also mentioned that there is a lack of greenery in the city at all public squares in the city. Also, regarding maintenance and structural policy, the municipality could make improvements, according to the interviewee: "*Municipal services are mowing all wildflowers each spring because it needs to look properly. And you can see vehicles with boiling water to kill every growing bit in the street. Then I think, what are you doing for God's sake, while you pretend you stimulate greenery in the meantime.*"

4.7.5 Lack of cooperation and environmental impact

Another disadvantage or barrier mentioned by the interviewees with a green roof is the lack of cooperation with gardening companies. One interviewee mentioned that the companies involved were too much focused on the financial aspects, and another interviewee mentioned that companies were not interested in applying the green roof due to the limited surface to be covered. Therefore the impression of the interviewee was that the policy was focused on subsidizing gardening companies instead of applying green roofs.

Although green roofs bring lots of environmental benefits according to the interviewees, the gardener also mentioned the environmental impact as often neglected in the green roof story. The gardener mentioned for example the huge amount of packing materials and transport movements that are coupled with green roof application. When multiple green roof applications are initiated together, then this impact can be reduced as much as possible, according to the gardener. The interviewee with the intensive roof also mentioned the sedum cultivation to perhaps be not very environmentally friendly, although these impacts are difficult to avoid. Though, it was also mentioned that it will in every case be more environmentally friendly compared with air conditioners.

4.8 Policies

4.8.1 Incentives

The subsidy incentive that the municipality currently provides, is seen by the interviewees as a measure that helps to stimulate green roof application. The interviewees from the municipality mentioned that the subsidies are increasingly more known to people, also because gardening companies are making clients aware of the subsidies. Furthermore, the subsidies are mentioned on the website, which makes them more accessible to people who look for them. Though, the expert mentioned that they found the subsidy because they knew it was available. Only the people that know of the subsidies are able to find them, according to the interviewee. The information exchange on subsidies could be improved according to the expert: "*If I do not know exactly what the subsidies are as a sustainability advisor, then my neighbors will not know for sure either.*" The entrepreneurs, for example, did not know that there was a subsidy for green roofs. The current subsidy scheme is created by the municipality and according to the gardener the policies would be improved if parties with practical experience would be involved in developing these policies.

One interviewee experienced the subsidy scheme and the corresponding contact with the municipality as very bad. The roof had to be installed by a certified gardening company to be eligible for the subsidy, but the companies were not willing to apply the roof and mentioned it could be done by the homeowners themselves, especially because it is easy to apply and the certificate is important for the product, and not for the company installing the green roof. This was communicated with the municipality, and the interviewee received a message that the subsidy was expected to be not a problem. However, it became a problem later as the interviewee was told that the subsidy could not be provided and that the roof needed to be installed by the certified company. Though, the interviewee mentioned that there does not have to be a problem with the subsidy, because the roof needs to be shown on photographs after it is installed, and the quality can be checked even if homeowners install the roof themselves.

Nevertheless, costs are still seen as high and subsidies are not accessible for everyone, since an investment still has to be made. The gardener mentioned for example that if the costs are not fully compensated in a neighborhood with a low socioeconomic background, then green roofs are unlikely to be applied. The expert also emphasized that the subsidy could be made more dependent on income to counter the problem. Then, the required investment of people with a lower income would be less. The interviewee with an extensive green roof also mentioned that sustainable financing is needed in order to make sure green roofs are accessible for more people. Banks could finance the amount of money that people would normally spend on the gas bill. This can be seen as capitalized interest, which then can be used to invest in isolation measures or green roofs. The interest redemption costs will be paid back gradually in this case, which are not higher than the costs one would normally pay for gas. This makes it budget neutral and more accessible for lower incomes, according to the interviewee. The entrepreneurs also mentioned that some sort of loan or fund needs to be in place in order to allow lower income classes to participate in green roof application.

4.8.2 Publicity and examples

Publicity and attention on green roofs could be improved according to the non-municipal interviewees. The gardener explained that the public needs to be informed that it is very convenient and easy to apply. Furthermore, the interviewee mentioned that green roof initiatives need to take place in a collective way so that calculations, materials, and transport costs or efforts can be reduced. There is an important role for the municipality in sharing knowledge with their inhabitants. Campaigns could be launched in order to increase attention for green initiatives, according to the gardener. The municipal servant indicated that attention could be increased at housing associations, environmental associations, and homeowner associations. Furthermore, the servant mentioned that publicity could be increased by sharing the idea in public locations, such as festivals and petting zoos. Currently, there is an example green roof shown at the local gardening company. According to the expert, the example of green roofs could be shown in more stores.

Some interviewees also pointed to the fact that the municipality could set the right example by putting green roofs on governmental buildings and public facilities. Further information could also be provided at the municipal desk. Another interviewee agreed on the exemplary function of governments: *"Give the right example and apply green roofs on (semi-)governmental buildings, and show the advantages, make a green park on top of the municipal city hall. It is not that difficult and it will cost money, but everything costs money"*. The interviewee with the extensive green roof mentioned to have a vanguard role in the neighborhood, as other people came to see and ask about the green roof. This was also the case with solar panels and the loading dock for the electric vehicle. In this way, an example was given for other neighbors to invest in these measures.

Collaboration with local education could stimulate green roof application as well, as it can be included in school programs. Collaboration with housing associations was also mentioned as an opportunity to increase the application of green roofs, since these associations own lots of buildings with flat roofs. Also, the expert mentioned that the message should be tailored to the target audience in order to be effective. Marketing bureaus could help to do this. Though, one of the most important tasks is to increase awareness within the municipal organization, before publicity can be increased, according to some interviewees.

The interviewee with an extensive green roof wanted to increase publicity and therefore started a project with which an additional discount of 10 percent could be received. This action was also used in other parts of the country, and the interviewee was positive regarding collaboration with the gardening company and the municipality. More media attention could help to further increase the application of green roofs. The interviewee with an intensive green roof also proposed to give media attention to the green roof so that publicity could be further increased. However, according to the interviewee the municipality was not very eager to do this. The entrepreneurs mentioned also that campaigns are important to increase the application. This could for example be done by tv, leaflets, emails, or social media.

4.8.3 Mandatory policies

Some interviewees also mentioned the possibility to make green roofs mandatory in some cases. The gardener for example mentioned that the inclusion of greenery could be a mandatory option for new housing projects, for instance by developing a CO2 compensation rule. Change of policy would be more fruitful than increasing the subsidy, according to the gardener. Also according to the municipal servant it would be helpful to have mandatory policies. The project leader mentioned the plan to make an obligation for new housing projects to make sure measures are taken to slow down the water flow to public spaces. The expert further said that in new plans, the municipality is able to start designs and projects with more greenery in it. The interviewee with the intensive green roof mentioned that mandatory policies need to be present in the future to increase greenery, and also for the use of air conditioners or other energy-intensive systems consuming energy which should be generated in a sustainable way.

Other measures that could be taken according to the gardener are the planting of trees, painting roofs white, or putting water boilers on roofs. Other subsidies are currently already in place in the municipality of Leeuwarden, as there are multiple subsidies available for measures contributing to an improved living environment. These measures are mostly focused on greenery and water, the so-called green and blue subjects. Also, there are other actions such as removing tiles and adding trees to public spaces. Currently, there is the project BOSK, for example, in which trees are moved through the city and are going to be planted afterwards (see figure 4.16). All interviewees agreed that multiple measures are needed in order to mitigate and adapt to climate change.

Figure 4.16 Project BOSK (own photographs)

5 Discussion

In this chapter, the study results are elaborated upon based on the theory outlined in chapter 2. The same structure is used in the theory and results chapters.

5.1 Green roof characteristics

The general description of green roofs – planted with a distinct form of vegetation on a growth medium of soil – (Dauda and Alibaba, 2020, Shafique et al., 2018) – was recognized in the interviews. Also, the additional load of an extensive roof is relatively small according to Theodosiou (2009), which was confirmed by the gardener. The costs of an extensive green roof are classified as low in the literature studied, and the costs for an intensive green roof as high (see table 2.1). Although these costs can be seen as relative pertaining to context, costs were generally regarded as high by the interviewees.

In chapter 2, it was mentioned that the huge amount of impermeable surfaces in urban areas and decreasing levels of greenery make cities more prone to urban heat island effects and surface water flooding (Stovin et al., 2012), while the impacts are expected to be exacerbated by climate change (Mees and Driessen, 2011). This was also confirmed by the interviewees, as it was noticed that there is a lack of greenery and that large surfaces in the city of Leeuwarden are impermeable surfaces.

5.2 Advantages

The advantages of green roofs that were mentioned in the studied literature (see section 1.1) also were mentioned in the interviews. The advantages of biodiversity improvements, rainwater storage capacity, and thermal comfort were the most mentioned advantages (see table 5.1). All advantages from the studied literature were also mentioned in the interviewees. Though, multiple interviewees mentioned the benefit of green roofs to be easy to apply. This was not explicitly mentioned in the studied literature.

Table 5.1 Advantages of green roofs mentioned by interviewees

Code	Grounded
Biodiversity improvements	13
Rainwater storage	9
Thermal comfort (isolation)	9
Heat mitigation	6
Roof life prolongation	6
Easy to apply	5
Aesthetics	3
Better air quality	3
Energy savings (isolation)	2
Noise reduction	1

5.3 Disadvantages

The disadvantages mentioned by the interviewees are listed in table 5.2. Initial costs are identified as the main barrier for the application of green roofs, both in literature and by the interviewees. High maintenance costs were included as a disadvantage in the article by Berardi et al. (2014), but this was only mentioned once by an interviewee who did not have a green roof. The lack of information (awareness, knowledge exchange, and relevance) was expounded in the literature by Dorst et al. (2022), and was confirmed by the interviewees. Roof construction is mentioned as a barrier by Deely et al. (2020). Some interviewees also pointed to this as being an important factor, but not necessarily a disadvantage. Therefore, 'roof construction' is included in the code group of 'green roof

characteristics' (see Appendix 2). The negative environmental impacts of green roofs were not mentioned in the literature studied, but were mentioned by some interviewees instead. This was also the case for 'lack of priority'.

Table 5.2 Disadvantages of green roofs mentioned by interviewees

Code	Grounded
Initial costs (costs)	32
Awareness (lack of information)	20
Knowledge exchange (lack of information)	20
Lack of priority	16
Relevance (lack of information)	8
Knowledge/capacity (lack of governmental resources)	7
Lack of governmental will	7
Environmental impact	6
Lack of cooperation (governance)	4
Degrading materials	2
Financial resources (lack of governmental resources)	2
Disapproval by new owners	1
Maintenance costs (costs)	1

5.4 Policies

In chapter 2, a wide array of governance arrangements was mentioned which could be applied to the field of climate change adaptation. These could range from top-down to bottom-up and self-governance arrangements (Mees et al., 2013). These arrangements can be classified by responsibilities, steering strategy, and policy instruments. In the interviews, these governance arrangements and policy propositions also were discussed. One interviewee for example mentioned that in the light of climate change, a top-down approach would be best so that quick action can be taken. However, it was also mentioned that an approach of self-governance would be appreciated, especially if companies take action themselves.

The green roof policy arrangements mentioned in literature consist mainly of mandatory policies, financial incentives, and water or property fee reductions (see table 2.3 based on Berardi et al., 2014 & Shafique et al., 2018). In Leeuwarden there is currently only a financial incentive, although the municipality mentioned to be working on a mandatory policy to make sure water retention measures are taken in new building projects. Also, other interviewees mentioned that a mandatory policy would help stimulate the application of green roofs. According to the gardener, this obligation could be applied to new building projects with a CO2 compensation rule or a mandatory percentage of greenery. The financial incentives and the proposed mandatory policies are similar to the international examples outlined in Table 2.3. Though, water or property fee reductions were not mentioned during the interviews. An indirect policy with sustainability labels is regarded as fundamental for the diffusion of green roofs by Berardi (2012). This was also not mentioned during the interviews.

Another policy steering strategy which was not directly mentioned in the studied literature, is publicity. Almost all interviewees agreed that more publicity would help stimulate the application of green roofs. Also, some interviewees undertook action themselves in order to increase publicity by offering to contact a newspaper, and launching a campaign by which reduction on costs can be gained by participating in the initiative's action. Also, interviewees mentioned examples of a loan or banks offering a sustainable financing option. These were not mentioned in the literature studied.

6 Conclusion and recommendations

6.1 Conclusion

In chapter 1 the aim of this thesis was determined to help understand the current situation of green roof application in the city of Leeuwarden, and to provide recommendations to stimulate this application. Therefore, the following main research question was developed:

How can the application of green roofs be stimulated in the city of Leeuwarden?

The following secondary research questions are answered before the main research question is answered:

1. What policies and incentives can be provided, and what are hindering and enabling factors for green roof application?

This first secondary question is mainly answered in chapter 2. Based on literature research, relevant articles were found to get insight into policies and factors influencing green roof application. Three types of policies are determined based on the journal articles studied: mandatory policies, financial incentives, and water or property fee reductions. Also, during the interviews ideas on policies and incentives were provided as enabling factors for green roof application. These are part of the third secondary question.

The main hindering factor of green roof application is costs. Both in theory and the interviews this factor was considered as the main barrier. A lack of information was also considered as a hindering factor. Homeowners and companies often lack the awareness and knowledge of green roof benefits and existence, but this is also lacking at governmental organizations and construction companies according to the interviewees. The roof construction might also be not sufficient for green roof application, governments and homeowners might lack the priority or resources to invest in green roofs, and there might be a lack of cooperation to apply green roofs. Also, negative environmental impacts can be seen as a hindering factor. Yet, there is consensus on the environmental benefits outweighing the negative impacts of green roofs.

2. How many green roofs are there currently in Leeuwarden, and which areas have the most potential for green roofs to be applied?

Currently, around 116 green roofs have been applied in the municipality of Leeuwarden. 93 of the 116 green roofs have been applied in the city of Leeuwarden and in the adjacent villages of Goutum and Hempens. The other 23 green roofs were applied in villages further away from the city of Leeuwarden within the municipality. In the neighborhoods of Zuiderburen, Bonifatius, and the village of Goutum, the most green roofs have been applied.

Although there are multiple flat roofs in the city at which green roofs could be applied, there are three specific areas with lots of potential. These areas are the neighborhood of Bilgaard, the city center, and shopping mall ‘De Centrale’ and adjacent factories. In these areas there are relatively a lot of buildings with flat roofs, and climatic impacts are expected to be especially present in the city center and the shopping mall and factories.

3. How can green roof application be stimulated in Leeuwarden according to different actors?

The interviewees’ ideas were mainly focused on financial incentives, with subsidies to stimulate green roof application. These subsidies could be higher according to the interviewees. To make sure this incentive is to a certain extent accessible for everyone, the subsidy could be made dependent on income. The subsidy would then be proportionally lower for higher incomes and higher for lower

incomes. Loans could also be initiated with banks offering a sustainable financing option. With this loan, the financial incentive is more accessible for lower-income households. Mandatory policies were also mentioned by the interviewees, in which new housing projects could include the obligation to include green roofs or other greenery measures.

Another stimulating measure according to the interviewees is publicity. Current publicity was seen as insufficient by all non-municipal interviewees. Publicity could be increased by including green roofs in university and school programs. Then also collaborations could be initiated with local greenery studies and gardening companies to launch projects in Leeuwarden to apply green roofs or other greenery measures. Furthermore, the knowledge on green roofs at gardening and construction companies will eventually increase if more attention is given to the subject in school programs. Housing associations also own a significant amount of buildings with flat roofs, so collaboration with these associations is an opportunity to increase the share of green roofs. Also, leaflets and additional municipal information would increase the awareness of green roofs among inhabitants and other actors in the city. The climate square in the gardening shop is a nice example to show green roofs, but this can be done in more similar shops. Furthermore, information can be provided at the municipal desk.

Having all information from the secondary research questions, now the main research question can be answered: **"How can the application of green roofs be stimulated in the city of Leeuwarden?"**

6.2 Recommendations

First of all, recommendations will be mentioned on how the research can be improved. This thesis focused on the municipality of Leeuwarden, but including more municipalities might increase insights on how green roof policy can be improved. Also, more actors could be interviewed. By including more adopters of green roofs, more experiences can be gained. Other actors such as housing associations and homeowner associations could also be interviewed to have a more diverse and complete image on how policy could be improved. Finally, a study on green roof awareness in the municipality of Leeuwarden might help to get a better view of the level of awareness in the city, and this might increase publicity among participants at the same time.

Based on this study, the following recommendations are proposed to increase green roof application in Leeuwarden:

First, the municipality needs to make sure that the idea of green roofs is widely shared and supported within the municipal organization and structure. In this way, inconsistency among different departments can be minimized and the collective idea of increasing the amount of greenery in the city can be strengthened.

Second, the municipality needs to give the right example by applying green roofs or other greenery to the public spaces wherever it is possible. This can for example be done at bicycle parking, car parking, public transport facilities, and other properties belonging to the municipality. To illustrate, as was mentioned in an interview, the roof of the municipal city hall can be covered with a green roof or green park.

Third, subsidies need to be tailored to the inhabitants of the city. As became clear in section 4.3, the higher the average income per neighborhood, the more green roofs are applied. Especially in lower income neighborhoods the climatic effects are expected to have the most impact, so it is important that financial incentives are also accessible for lower-income neighborhoods. This can be done by making subsidies more income dependent and by initiating loans. As was mentioned during an interview, banks could play a role in financing the amount of money that people would normally spend on the gas bill. This amount can be seen as capitalized interest, which then can be used to invest in

isolation measures or green roofs. Then, the interest redemption costs will be paid back gradually, which are not higher than the costs one would normally pay for gas. This makes it budget neutral and more accessible for lower incomes.

Fourth, the current rule, that a certified constructor has to install the green roof in order to receive subsidy, should be changed. As checks with photos are also obligatory, homeowners or owners of buildings can also install the roofs themselves. In case this is not done properly, the subsidy can be postponed until the roof has reached the requirements asked by the municipality. This makes it more convenient for people to install green roofs, and it is less expensive as became clear from the interviewees' experiences. As became clear from the interviews with the municipality, this change of rules is currently in progress.

Fifth, green roofs or other greenery needs to be mandatory in new building projects. Currently, rules regarding water retention measures are planned to be operational soon, but specific mandatory rules regarding greenery should also be initiated. Project inquiries should start with the requirement of including a percentage or amount of greenery. If this is taken into account from the start of projects, then the costs can also be incorporated and minimized. Also, application of green roofs can be made mandatory for existing buildings with flat roofs. If this is not possible due to legislative issues, it can at least be more stimulated.

Sixth, the municipality should collaborate with local greenery studies and gardening companies to launch projects in Leeuwarden to apply green roofs or other greenery measures. Also, collaboration with housing associations is needed in order to increase the number of green roofs on buildings owned by these associations.

Seventh, publicity regarding green roofs should increase. This can be done by providing examples, as was mentioned in the second recommendation, but also by spreading leaflets and additional municipal information to increase the awareness of green roofs among inhabitants and other actors in the city. Also, information and publicity in gardening and construction shops can be increased, and (social) media attention can be given to green roof initiatives. To make the publicity more tailor-made to the desired target group, marketing bureaus could be consulted.

Eighth, gardening companies and external experts should be invited in policy development and policy evaluations. These actors have lots of practical experience which could be valuable for municipal policy. Also, other actors and target groups need to be invited in policy development. These actors include inhabitants, housing associations, homeowner associations, businesses and other governmental organizations.

Ninth, to make sure the negative environmental impacts are minimized as much as possible, local green roof initiatives need to be coordinated in a way that materials and resources can be used efficiently and that transport movements are minimized. Neighborhood or street initiatives can for example be launched in which local plans can be made to increase an area's greenery, but also in combination with other measures such as solar panels.

Tenth, connections could be made with other governmental subsidies. By connecting green roof subsidies with national or Provincial subsidies, the effect can be amplified and more budgets becomes available. On the national level, the subsidies regarding isolation of buildings could for example be combined with green roof subsidies.

References

ALLMENDINGER, P. 2017. *Planning theory*, Macmillan International Higher Education.

ANTROP, M. 2004. Landscape change and the urbanization process in Europe. *Landscape and urban planning,* 67**,** 9-26.

BATTISTA, G., PASTORE, E. M., MAURI, L. & BASILICATA, C. 2016. Green roof effects in a case study of Rome (Italy). *Energy Procedia,* 101**,** 1058-1063.

BERARDI, U. 2012. Sustainability assessment in the construction sector: rating systems and rated buildings. *Sustainable development,* 20**,** 411-424.

BERARDI, U., GHAFFARIANHOSEINI, A. & GHAFFARIANHOSEINI, A. 2014. State-of-the-art analysis of the environmental benefits of green roofs. *Applied energy,* 115**,** 411-428.

BIESBROEK, G. R., SWART, R. J., CARTER, T. R., COWAN, C., HENRICHS, T., MELA, H., MORECROFT, M. D. & REY, D. 2010. Europe adapts to climate change: comparing national adaptation strategies. *Global environmental change,* 20**,** 440-450.

BURTON, I. 2011. Adaptation to climate change: context, status, and prospects. *Climate change adaptation in developed nations.* Springer.

CAMPBELL, J. L., QUINCY, C., OSSERMAN, J. & PEDERSEN, O. K. 2013. Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement. *Sociological methods & research,* 42**,** 294-320.

CARTER, J. G. 2011. Climate change adaptation in European cities. *Current opinion in environmental sustainability,* 3**,** 193-198.

CASTLETON, H. F., STOVIN, V., BECK, S. B. & DAVISON, J. B. 2010. Green roofs; building energy savings and the potential for retrofit. *Energy and buildings,* 42**,** 1582-1591.

CLAR, C. & STEURER, R. 2021. Climate change adaptation with green roofs: Instrument choice and facilitating factors in urban areas. *Journal of Urban Affairs***,** 1-18.

CLIFFORD, N., COPE, M., GILLESPIE, T. & FRENCH, S. 2010. *Key methods in geography,* London, Sage.

CONNELLY, M. & HODGSON, M. 2013. Experimental investigation of the sound transmission of vegetated roofs. *Applied Acoustics,* 74**,** 1136-1143.

COOK, E. M., HALE, R. L., KINZIG, A. & GROVE, J. M. 2013. Urban-suburban biodiversity. *Encyclopedia of Biodiversity: Second Edition***,** 304-313.

CORFEE-MORLOT, J., COCHRAN, I., HALLEGATTE, S. & TEASDALE, P.-J. 2011. Multilevel risk governance and urban adaptation policy. *Climatic change,* 104**,** 169-197.

CUTLIP, J. 2006. Green roofs: a sustainable technology. *Sustainability and the Built Environment***,** 1-6.

DAUDA, I. & ALIBABA, H. Z. 2020. Green roof benefits, opportunities and challenges. *Int. J. Civ. Struct. Eng. Res,* 7**,** 106-112.

DE ROO, G. 2016a. Being or becoming? That is the question! Confronting complexity with contemporary planning theory. *A planner's encounter with complexity.* Routledge.

DE ROO, G. 2016b. Shifts in planning practice and theory: From a functional towards a communicative rationale. *Fuzzy planning.* Routledge.

DEELY, J., HYNES, S., BARQUÍN, J., BURGESS, D., FINNEY, G., SILIÓ, A., ÁLVAREZ-MARTÍNEZ, J. M., BAILLY, D. & BALLÉ-BÉGANTON, J. 2020. Barrier identification framework for the implementation of blue and green infrastructures. *Land Use Policy,* 99**,** 105108.

DGBC. 2022. *Over DGBC* [Online]. Available: https://www.dgbc.nl/over-dgbc-43 [Accessed 17 March 2022].

DORST, H., VAN DER JAGT, A., TOXOPEUS, H., TOZER, L., RAVEN, R. & RUNHAAR, H. 2022. What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions. *Landscape and Urban Planning,* 220**,** 104335.

DRIESSEN, P. P., DIEPERINK, C., VAN LAERHOVEN, F., RUNHAAR, H. A. & VERMEULEN, W. J. 2012. Towards a conceptual framework for the study of shifts in modes of environmental governance–experiences from the Netherlands. *Environmental policy and governance,* 22**,** 143-160.

DROSTE, N., SCHRÖTER-SCHLAACK, C., HANSJÜRGENS, B. & ZIMMERMANN, H. 2017. Implementing nature-based solutions in urban areas: financing and governance aspects. *Nature-based solutions to climate change adaptation in urban areas.* Springer, Cham.
DUNN, K. 2005. Doing qualitative research in human geography: Interviewing. *Qualitative Research Methods in Human Geography'.(Ed. I. Hay.) pp*, 50-82.
DUNNETT, N. & KINGSBURY, N. 2008. *Planting green roofs and living walls*, Timber press Portland, OR.
DUTCH GREEN BUILDING COUNCIL. 2022. *BREEAM-NL* [Online]. Available: https://www.breeam.nl/wat-is-breeam-nl-1 [Accessed 17 March 2022].
EGUSQUIZA, A., CORTESE, M. & PERFIDO, D. Mapping of innovative governance models to overcome barriers for nature based urban regeneration. IOP Conference Series: Earth and Environmental Science, 2019. IOP Publishing, 012081.
FASSMAN-BECK, E., VOYDE, E., SIMCOCK, R. & HONG, Y. S. 2013. 4 Living roofs in 3 locations: Does configuration affect runoff mitigation? *Journal of Hydrology,* 490**,** 11-20.
FLYVBJERG, B. 2006. Five misunderstandings about case-study research. *Qualitative inquiry,* 12**,** 219-245.
FRANCIS, R. A. & LORIMER, J. 2011. Urban reconciliation ecology: the potential of living roofs and walls. *Journal of environmental management,* 92**,** 1429-1437.
FRANTZESKAKI, N. 2019. Seven lessons for planning nature-based solutions in cities. *Environmental science & policy,* 93**,** 101-111.
FRANTZESKAKI, N., MCPHEARSON, T., COLLIER, M. J., KENDAL, D., BULKELEY, H., DUMITRU, A., WALSH, C., NOBLE, K., VAN WYK, E. & ORDÓÑEZ, C. 2019. Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making. *BioScience,* 69**,** 455-466.
FRIEDMANN, J. 1987. *Planning in the public domain: From knowledge to action*, Princeton University Press.
GAGLIANO, A., DETOMMASO, M., NOCERA, F. & BERARDI, U. 2016. The adoption of green roofs for the retrofitting of existing buildings in the Mediterranean climate. *International Journal of Sustainable Building Technology and Urban Development,* 7**,** 116-129.
GEMEENTE LEEUWARDEN 2020. UITVOERINGSAGENDA 2021 - 2035 Klimaatadaptatie.
GEMEENTE LEEUWARDEN. 2022a. *Friese klimaatatlas* [Online]. Available: https://www.leeuwarden.nl/nl/friese-klimaatatlas [Accessed 11 May 2022].
GEMEENTE LEEUWARDEN. 2022b. *Slim omgaan met water* [Online]. Available: https://www.leeuwarden.nl/nl/slim-omgaan-met-water [Accessed 20 March 2022].
GEMEENTE LEEUWARDEN. 2022c. *Subsidie vergroening tuinen of wanden* [Online]. Available: https://www.leeuwarden.nl/nl/subsidie-vergroening-tuinen-wanden [Accessed 24 February 2022].
GODDARD, M. A., DOUGILL, A. J. & BENTON, T. G. 2010. Scaling up from gardens: biodiversity conservation in urban environments. *Trends in ecology & evolution,* 25**,** 90-98.
GROENEDAKENSHOP.NL. 2022. *Subsidie voor groene daken Nederland en Belgie* [Online]. Available: https://www.groenedakenshop.nl/subsidie-groendak/ [Accessed 24 February 2022].
HEALEY, P. 1996. The communicative turn in planning theory and its implications for spatial strategy formation. *Environment and Planning B: Planning and design,* 23**,** 217-234.
HENDRIKS, C., SNEP, R., DE VRIES, E. & BROLSMA, R. 2016. Groene daken in Tilburg: operationele handvatten voor ontwikkeling van gemeentelijk beleid. Alterra, Wageningen-UR.
HULME, M., ADGER, N., DESSAI, S., LORENZONI, I., NAESS, L. & WREFORD, A. 2007. Limits and barriers to adaptation: four propositions.
INNES, J. E. 1995. Planning theory's emerging paradigm: Communicative action and interactive practice. *Journal of planning education and research,* 14**,** 183-189.
IPCC 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press.

JOHNSON, C. L. & PRIEST, S. J. 2008. Flood risk management in England: a changing landscape of risk responsibility? *International Journal of Water Resources Development,* 24**,** 513-525.
JUHOLA, S. & WESTERHOFF, L. 2011. Challenges of adaptation to climate change across multiple scales: a case study of network governance in two European countries. *Environmental science & policy,* 14**,** 239-247.
KABISCH, N., FRANTZESKAKI, N., PAULEIT, S., NAUMANN, S., DAVIS, M., ARTMANN, M., HAASE, D., KNAPP, S., KORN, H. & STADLER, J. 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society,* 21.
KABISCH, N., KORN, H., STADLER, J. & BONN, A. 2017. *Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice*, Springer Nature.
KANTOR, D. 2015. *Life Cycle Cost Comparative Analysis of Extensive Green Roofs in Switzerland and Holland.*
KNUIJT, M. 2020. Liveable Green Cities: Integrating Climate Adaptive Solutions and Circular Economy into the Built Environment. *Designing Sustainable Cities.* Springer.
LONGHURST, R. 2016. Semi-structured interviews and focus groups. *In:* CLIFFORD, N. C., M.; GILLESPIE, T.; FRENCH, S. (ed.) *Key methods in geography.* 3 ed. London: Sage.
MCDONOUGH, W. 2005. *Green roofs: ecological design and construction*, Schiffer Pub Limited.
MCPHEARSON, T., KARKI, M., HERZOG, C., SANTIAGO FINK, H., ABBADIE, L., KREMER, P., CLARK, C., PALMER, M., PERINI, K. & DUBBELING, M. 2018. Urban ecosystems and biodiversity. *Urban Climate Change Research Network second assessment report on climate change in cities (ARC3-2). Cambridge University Press, Cambridge*.
MEES, H.-L. P. & DRIESSEN, P. P. 2011. Adaptation to climate change in urban areas: Climate-greening London, Rotterdam, and Toronto. *Climate law,* 2**,** 251-280.
MEES, H. L., DRIESSEN, P. P., RUNHAAR, H. A. & STAMATELOS, J. 2013. Who governs climate adaptation? Getting green roofs for stormwater retention off the ground. *Journal of Environmental Planning and Management,* 56**,** 802-825.
MOBILANE. 2022. *Kant-en-klare duurzame sedumcassette voor een groen dak* [Online]. Available: https://mobilane.com/nl/producten/mobiroof/ [Accessed 12 May 2022].
NELISSEN, N. 2002. The administrative capacity of new types of governance. *Public Organization Review,* 2**,** 5-22.
OBERNDORFER, E., LUNDHOLM, J., BASS, B., COFFMAN, R. R., DOSHI, H., DUNNETT, N., GAFFIN, S., KÖHLER, M., LIU, K. K. & ROWE, B. 2007. Green roofs as urban ecosystems: ecological structures, functions, and services. *BioScience,* 57**,** 823-833.
OLSEN, W. 2012. *Data collection: Key debates and methods in social research,* London, Sage.
PIRO, P., CARBONE, M., DE SIMONE, M., MAIOLO, M., BEVILACQUA, P. & ARCURI, N. 2018. Energy and hydraulic performance of a vegetated roof in sub-Mediterranean climate. *Sustainability,* 10**,** 3473.
PUNCH, K. F. 2014. *Introduction to social research: Quantitative and qualitative approaches,* London, Sage.
RCEP 2010. Adapting Institutions to Climate Change. The Royal Commission on Environmental Pollution London.
READAR. 2020. *Infographic: Groene daken in Nederland* [Online]. Available: https://readar.com/infographic-groene-daken-in-nederland/ [Accessed 24 February 2022].
SAILOR, D. J. 2008. A green roof model for building energy simulation programs. *Energy and buildings,* 40**,** 1466-1478.
SALATA, F., GOLASI, I., VOLLARO, E. D. L., BISEGNA, F., NARDECCHIA, F., COPPI, M., GUGLIERMETTI, F. & VOLLARO, A. D. L. 2015. Evaluation of different urban microclimate mitigation strategies through a PMV analysis. *Sustainability,* 7**,** 9012-9030.
SARABI, S., HAN, Q., ROMME, A., DE VRIES, B. & WENDLING, L. 2019. Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban settings: A review. Resources 8: 121.

SAYER, R. A. 1992. *Method in social science: A realist approach*, Psychology Press.
SEMPERGREEN. 2022. *Sedummixmat* [Online]. Available: https://www.sempergreen.com/uploads/downloads/Factsheets_SG_NL/FS-Sedummixmat1.pdf [Accessed 12 May 2022].
SHAFIQUE, M., KIM, R. & RAFIQ, M. 2018. Green roof benefits, opportunities and challenges–A review. *Renewable and Sustainable Energy Reviews,* 90**,** 757-773.
SIMS, A. W., ROBINSON, C. E., SMART, C. C., VOOGT, J. A., HAY, G. J., LUNDHOLM, J. T., POWERS, B. & O'CARROLL, D. M. 2016. Retention performance of green roofs in three different climate regions. *Journal of Hydrology,* 542**,** 115-124.
SPIT, T. J. M. & ZOETE, P. R. 2003. *Gepland Nederland: een inleiding in ruimtelijke ordening en planologie,* Den Haag, Sdu Uitgevers.
STOKER, G. 1998. Governance as theory: five propositions. *International social science journal,* 50**,** 17-28.
STORBJÖRK, S. 2007. Governing climate adaptation in the local arena: challenges of risk management and planning in Sweden. *Local environment,* 12**,** 457-469.
STOVIN, V., VESUVIANO, G. & KASMIN, H. 2012. The hydrological performance of a green roof test bed under UK climatic conditions. *Journal of hydrology,* 414**,** 148-161.
TASHAKKORI, A., TEDDLIE, C. & TEDDLIE, C. B. 1998. *Mixed methodology: Combining qualitative and quantitative approaches,* Thousand Oaks, Sage.
THEODOSIOU, T. 2009. Green roofs in buildings: Thermal and environmental behaviour. *Advances in building energy research,* 3**,** 271-288.
TIGHT, M. 2017. *Understanding case study research: Small-scale research with meaning,* London, Sage.
UGSA 2011. The benefits and challenges of green roofs on public and commercial buildings. *A Report of the United States General Service Administration.*
VAN DER JAGT, A. P., RAVEN, R., DORST, H. & RUNHAAR, H. 2020. Nature-based innovation systems. *Environmental Innovation and Societal Transitions,* 35**,** 202-216.
WAMSLER, C., WICKENBERG, B., HANSON, H., OLSSON, J. A., STÅLHAMMAR, S., BJÖRN, H., FALCK, H., GERELL, D., OSKARSSON, T. & SIMONSSON, E. 2020. Environmental and climate policy integration: Targeted strategies for overcoming barriers to nature-based solutions and climate change adaptation. *Journal of Cleaner Production,* 247**,** 119154.
WHITE, E. V. & GATERSLEBEN, B. 2011. Greenery on residential buildings: Does it affect preferences and perceptions of beauty? *Journal of environmental psychology,* 31**,** 89-98.
WONG, N. H., CHEN, Y., ONG, C. L. & SIA, A. 2003. Investigation of thermal benefits of rooftop garden in the tropical environment. *Building and environment,* 38**,** 261-270.
YANG, J., YU, Q. & GONG, P. 2008. Quantifying air pollution removal by green roofs in Chicago. *Atmospheric environment,* 42**,** 7266-7273.

Appendix 1 – Interview guide

Intro	Interviewee will be thanked for participating in the interview.
Own introduction	Student Cultural Geography - CAG
Topic and goal of the research	The aim of this research is to help understand the current situation of green roof application in the city of Leeuwarden, and to provide recommendations to stimulate this application.
Anonymity	The interviewee will be informed that the content of the interview will only be used for this thesis and cannot be traced back. Also, the identity of the interviewee will not be mentioned.
Stopping + not answering	The interviewee will be informed that the interview can be stopped at any time and that questions can be skipped if the interviewee prefers to.
Length of the interview	The interview will take approximately 30-45 minutes.
Recording	The interview will be recorded, as it gives the opportunity to listen back instead of having to write down everything during the interview. Also, some notes will be made during the interview for extra clarification of the content. The interviewee will before the interview be asked for permission for recording.
Introducing questions	
1	What is your function, and how what is your connection to green roofs?
2	If so, on what projects regarding green roofs have you worked?
Main questions	
3	What are according to you the benefits of green roofs?
4	What are according to you the disadvantages of green roofs?
5	What do you think of the current application of green roofs? **For municipality/expert** - What types of green roofs are applied in Leeuwarden? - How is policy made for green roofs? How is the subsidy scheme created? - Is there collaboration with experts during the creation or execution of green roof policy? - Is there also subsidy on similar measures such as the planting of trees? **For seller of green roofs** - What types do you sell most? - How would you describe your clients?

	For residents/companies *With a green roof* - Why did you choose to apply green roofs? - What do you think of policy on green roofs? What policy was applicable to you? - What are benefits for you? - What are disadvantages for you? - Would you recommend green roof application to others? If yes, why. If no, why? *Without a green roof* - What do you know about green roofs? - Why do you not have a green roof? - Did you ever consider applying a green roof? - Has your roof ever been replaced? - Would a green roof be an option for you? If yes, why? If no, why? - How would you like to be informed about green roofs? - What would be a great stimulating measure for you from a government to apply a green roof?
6	How do you see the lifespan of a green roof compared to a conventional roof? - And maintenance? - Which buildings and areas are most promising for green roofs according to you?
7	How can green roof application be stimulated according to you? - What is the role of governments hereby? - And companies? - And inhabitants? - And how can housing corporations be stimulated to apply green roofs?
8	What barriers are there to the application of green roofs? - How can these barriers be overcome?
9	(If applicable) What do you think of the current state of green roof application in Leeuwarden? - What do you think of the current policy in Leeuwarden regarding green roofs? - What should according to you be changed to this policy? - Which neighborhoods are most likely to apply green roofs? - What are experiences with green roofs in Leeuwarden?

10	Which type of residents/people are most likely to apply green roofs? - What influence does the socioeconomic background have on green roof application?
11	How should green roofs be seen in an urban area in terms of reducing climate related effects? - Is it an end-solution or should it be applied in combination with other measures? - What role do you expect green roofs have in the future?
Closing questions	
	Is there anything I did not ask, but you would like to say?
	Do you have remarks for the interviews to come?
End remarks	
Next proceedings	The recording will be typed out and will be in the appendix of the thesis. All interview recordings will be analyzed, resulting in a results chapter.
Thanking	The interviewee will be thanked for participating in the interview.
Contact information	The interviewee will receive contact information, in case he/she wants to contact. Also, the interviewee can give contact information in case he/she wants to see the thesis when it is finished.

Appendix 2 – Codes

Code group	Code	Subcode	Deductive/inductive
Green roof characteristics	Vegetation/plants		Deductive
	Growth medium (soil)		Deductive
	Intensive green roof		Deductive
	Extensive green roof		Deductive
	Roof slope		Deductive
	Maintenance		Deductive
	Roof construction		Inductive
Advantages	Rainwater storage		Deductive
	Biodiversity improvements		Deductive
	Heat mitigation		Deductive
	Aesthetics		Deductive
	Better air quality		Deductive
	Roof life prolongation		Deductive
	Noise reduction		Deductive
	Isolation	Energy savings	Deductive
		Thermal comfort	Deductive
	Easy to apply		Inductive
Disadvantages	Costs	Initial costs	Deductive
		Maintenance costs	Deductive
	Lack of governmental resources	Financial resources	Deductive
		Knowledge/capacity	Deductive
	Lack of governmental will		Deductive
	Lack of information	Awareness	Deductive
		Relevance	Deductive
		Knowledge exchange	Deductive
	Degrading materials		Deductive
	Lack of cooperation (governance)		Deductive
	Environmental impact		Inductive
	Disapproval by new owners		Inductive
	Lack of priority		Inductive
Policies	Mandatory policies		Deductive
	Incentives		Deductive
	Water or property fee reduction		Deductive
	Sustainability label		Deductive
	Publicity		Inductive
	Examples		Inductive
	Multiple measures		Inductive
	Loan		Inductive