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Investigating the factors influencing the implementation of green roofs by Housing Associations in Amsterdam

ORGANISATIONAL ANALYSIS WITH THE BEHAVIOUR CHANGE WHEEL AND THEORETICAL DOMAINS FRAMEWORK.

Image retrieved from Holstein & Langewen (2022)

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Investigating the factors influencing the implementation of green roofs by Housing Associations in Amsterdam

Organisational analysis with the behaviour change wheel and theoretical domains framework

By

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in partial fulfilment of the requirements for the degree of

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TU Delft

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Preface

With this master thesis, I complete my Master of Science in Complex System Engineering and Management at the Faculty of Technology, Policy and Management at Delft University of Technology. This research was conducted independently of any project or organisation and stems from curiosity within my field of work.

First and foremost, I would like to thank my supervisors, Juliette Cortes-Arevalo, Nihit Goyal, and Lisa Scholten, for the brainstorming sessions and valuable feedback on my submitted work. Additionally, I am grateful for the flexibility I needed to complete this master's alongside my job.

This research also advances my professional field and contributes to the further implementation of green roofs and potentially the full development of roof architecture as proposed by the National Roof Plan. All in all, besides the challenging moments, this project has provided me with a wealth of knowledge.

Daan Bloeme

Amsterdam, 14 August 2024

Executive Summary

Climate change poses significant challenges to urban areas, necessitating innovative solutions to enhance resilience and sustainability. This research explores the adoption of green roofs by housing associations in Amsterdam, a city highly vulnerable to climate change impacts such as flooding, extreme rainfall, droughts and extreme temperatures. Despite the recognized benefits of green roofs, their implementation remains limited. This study aims to identify the factors influencing housing associations' decisions to install green roofs and evaluate the effectiveness of current policy instruments in promoting this practice. While current policy instruments such as subsidies, Weerproof and coercion are in place, the adoption of green roofs has not been done by housing associations. The overarching research question is: “How do policy instruments for the promotion of green roofs influence the behaviour of housing associations in Amsterdam?”

The research focuses on the case study of housing associations in Amsterdam, combining desk research, interviews with policy officers and interviews with major housing associations. The Behaviour Change Wheel, incorporating the COM-B model and Theoretical Domains Framework, serves as the theoretical framework to analyse behavioural drivers and barriers. This comprehensive framework allows for a deeper understanding of the complexities surrounding the adoption of sustainable behaviours.

This research makes a contribution to the scientific literature through the use of the Behaviour Change Wheel (BCW) as a theoretical framework to analyse the adoption of green roofs by housing associations in Amsterdam. The BCW, typically applied within healthcare and behavioural sciences, is used in this study in a novel way within the context of urban sustainability and climate adaptation. By integrating the COM-B model and the Theoretical Domains Framework, this research provides in-depth insights into the behavioural drivers and barriers of housing associations. This methodological innovation broadens the applicability of the BCW and demonstrates its value for organizational behaviour change, specifically focused on sustainability and climate resilience.

Key findings indicate that while there is openness to the idea of green roofs among housing associations, significant barriers persist. These barriers include high installation costs, structural challenges, and a lack of knowledge about green roofs within housing associations. Current policies, such as subsidies and environmental guidelines, have not fully addressed these obstacles, particularly for existing buildings. For example, the subsidy availability has been inconsistent, which undermines the motivation for housing associations to commit to green roof projects. Additionally, while guidelines such as the “Nationale Dakenplan” have been established to promote green roofs, the lack of specific, targeted marketing and communication for housing associations limits their impact.

Reflective motivation is a primary barrier, with housing associations focusing on immediate and pressing needs like improving energy efficiency and addressing poor energy labels. This prioritization often leaves little room for green roofs, which are perceived as less critical. Financial constraints exacerbate this issue, as the high upfront costs of green roofs are often seen as prohibitive without sufficient subsidies or financial incentives. Moreover, housing associations often view the benefits of green roofs—such as increased biodiversity, urban heat island mitigation, and improved stormwater management—as less directly impactful on their primary goal of providing affordable housing.

The research highlights several intervention functions to overcome these barriers. These include enabling policies that integrate green roofs into energy label improvements, regional obligations for green roof implementation, targeted marketing campaigns, a stormwater runoff fee to create a business model for green roofs, and the promotion of comprehensive roof handbooks. Each of these interventions targets specific aspects of the COM-B model—capability, opportunity, and motivation—to encourage housing associations to incorporate green roofs more broadly.

By implementing these improvements, policy instruments can more effectively promote the adoption of green roofs, contributing to a more sustainable urban environment in Amsterdam. Further research should focus on validating these interventions in other cities to confirm their broader applicability. Additionally, evaluating the long-term impacts of these policies will provide insights into their effectiveness and inform future policy development.

Overall, the integration of comprehensive, targeted interventions can drive the widespread adoption of green roofs, enhancing urban resilience and sustainability in the face of climate change. This research provides a foundational understanding of the factors influencing green roof adoption and offers practical recommendations for policy enhancement to achieve a greener, more resilient urban landscape.

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1 Introduction

Limiting the effects of climate change requires collective action at multiple scales; local, national and worldwide. At the local level, cities have an important share in both the climate change and mitigating actions (Ostrom, E. 2010). Urban areas are challenged with rising temperatures, more extreme weather events and air pollution (IPCC, 2018). Being one of the lowest-lying and at the same time one of the most densely populated countries in the world, with most of its population living in urban areas, Dutch cities in the Netherlands are among the most vulnerable to climate change effects. Compared to Europe, the urbanization percentage is very high. According to the United Nations research, the percentage was 92%, compared to 80% in Western Europe and 74% across Europe, this is high (United Nations, Department of Economic and Social Affairs, Population Division 2018). Satisfying the needs of such densely populated areas is challenging and often amplifies the climate change effects. Urban areas suffer from extreme rainfall, long dry spells and increased temperatures (Li et al., 2020). Urbanization has further replaced natural (permeable) surfaces with roofs, roads and other sealed surfaces, which in turn increase the rainfall that need to be carried away by the sewage systems and increases temperatures due to a reduced natural coolant surface (Langemeyer, et al., 2018). Because a large part of the Dutch population lives in cities, it is important to keep these cities inhabitable.

A need for mitigating measures, such as water storage, increased sewage capacity and cooling mechanisms, is evident. However, with limited space it is difficult for cities to take mitigating measures. Due to this space scarcity in cities, roofs are seen as an opportunity. In the Netherlands an area of 1280km2 is covered by roofs, of which 622km2 is flat (Rijksinstituut voor Volksgezondheid en Milieu, 2022). Using this roof surface for mitigating measures is vital in keeping cities healthy and liveable. Green roofs go as far back as the gardens of Babylon, however modern green roof technology started in Germany in the 1980s with reliable technology that provided sophisticated irrigation and protection (Nancy, 2020). Green roofs could provide part of the solution in combating climate change. However, according to research from READAR – Real Estate Reader (2020), only 0.5% of the 1.5milion researched roofs has implemented this technology. Most of the green roofs can be found on schools or hospitals. For example, Tilburg counted only 101 green roofs in 2018, with a potential of 90.000 roofs left in Tilburg there is still a great opportunity to increase the number of green roofs (READER – Real Estate Reader, 2020).

Green roofs play a crucial role in mitigating the impacts of climate change, including heat stress, flood risks, and air pollution (Zhang & He, 2021; Cortinovis et al., 2021; Alim et al., 2022; Tian et al., 2012), thereby fostering a healthier living environment. Despite widespread recognition of their benefits, the adoption of green roofs remains limited due to various factors, such as installation costs and structural considerations. For instance, the cost of installing a green roof can vary significantly. A basic green roof typically ranges from €50 to €80 per square meter (Milieu Centraal, 2022), while those with thicker substrate layers, diverse plant species, and enhanced water retention capabilities may cost up to €130 per square meter (Solar Sedum, 2023). Considering an average roof size of 50 square meters (Delphine, 2023), installation expenses could range from €2500 to €6500.

The Dutch government, and their municipalities, are keen to increase the number of green roofs to keep urban areas liveable and to increase biodiversity (Ministerie van Algemene Zaken, 2022). In order to increase the implementation of green roofs, municipalities, waterboards and provinces have applied different incentive programs to increase the number of green roofs (Subsidie Voor Een Groen Dak, Interpolis). On a national level there is only one indirect incentive, which is not specifically introduced for green roofs, but can be used. This program is called the MIA (*MIA En Vamil Voor Ondernemers*, 2023). The MIA is only available for businesses and organisation, and within this lies a big potential. In Amsterdam, 40% of the dwellings are owned by housing associations, yet these associations have thus far taken little action to green their rooftops, despite significant potential. The first pilot projects with housing associations were carried out in 2016, unfortunately, these did not lead to further steps (Holstein & Langewen, 2022). This research focuses on the factors influencing housing associations and examines how these organisations can be better incentivized to install green roofs on their properties by using the Behaviour Change Wheel and Theoretical Domain Framework as theoretical framework.

1.1 Scientific Relevance

In this thesis, a methodical approach is employed to investigate the implementation of green roofs by organisations, utilizing behaviour change models as a central framework. By integrating behaviour change models the research aims to understand the underlying mechanisms influencing organisational decisions regarding green roof adoption. Moreover, a holistic perspective is adopted to explore the intricate interaction between various factors, including barriers, drivers, policy instruments, and behavioural change variables. This comprehensive view allows for a deeper understanding of the complexities surrounding the adoption of sustainable behaviours, particularly within organisational contexts. Through this analysis, different strategies for promoting the adoption of sustainable behaviours, such as incentive schemes, educational initiatives, and policy interventions, will be explored and evaluated for their effectiveness in facilitating organisational change towards greener practices.

1.2 Societal Relevance

This thesis holds significant societal relevance by addressing key aspects concerning housing associations and their engagement in green roof implementation. By focusing on increasing opportunities, capabilities, and motivations for housing associations to adopt green roofs, the research contributes to fostering sustainable urban environments.

Furthermore, the study highlights the importance of just climate benefit policies, recognizing that poorer households may lack the resources to invest in green roofs independently. By exploring policy alternatives that better represent barriers and drivers in society, the research aims to promote equity and inclusivity in sustainability initiatives. This includes advocating for policies that provide support and incentives specifically targeted towards disadvantaged communities, ensuring that the benefits of green roof adoption are accessible to all socioeconomic groups. Through these efforts, the thesis seeks to advance the discourse on sustainable urban development and promote social justice within environmental policy frameworks.

1.3 Relevance to the CoSEM master

Firstly, complex systems engineering and management involve navigating intricate interactions within socio-technical systems. Green roof promotion policies in Amsterdam

encapsulate a multifaceted system, including governmental regulations, environmental concerns, economic incentives, technological feasibility, and stakeholder behaviours. Analysing policy instruments' impact on housing associations deepens comprehension of complex socio-technical systems.

Furthermore, the research delves into interdisciplinary aspects pivotal to the program. Complex systems engineering mandates an interdisciplinary lens, merging insights from engineering, social sciences, economics, and policy studies. Examining the interplay of policy instruments, technological innovation, economic incentives, and stakeholder behaviour demands holistic perspectives and interdisciplinary collaboration, resonating with the program's ethos.

Additionally, Amsterdam serves as an intriguing case study for probing policy interventions and sustainable urban development. As a global city confronting environmental issues, Amsterdam's experiences with green roof promotion policies offer invaluable lessons applicable to urban settings worldwide. Studying Amsterdam's initiatives fosters insights into effective policy implementation and sustainable urban practices, enriching students' understanding of complex systems in diverse contexts.

1.4 Outline of the research

This research consists of an introductory section. Chapter 2 delves into the current state of science regarding green roofs, followed by the methodology of the research outlined in Chapter 3. After this exposition, Chapter 4 further highlights the case within this research. Chapter 5 explores the results concerning the current policy situation, and Chapter 6 presents the influencing factors for housing associations. Chapter 7 provides analysis of the results and implications for the policy instruments, and Chapter 8 is used to conclusively answer the research questions.

2 State of the Art

In this literature review, the focus is on the current knowledge regarding policy implementation and green roofs. The goal is to understand what various researchers in the field have already done and what the outcomes are. The research was conducted using Scopus, and only articles after 2010 were included in the study. The search query found in Table 1 was used for this purpose.

Topic	"green roof" or "living roof" or "vegetated roof"	Search query: (TITLE-ABS-KEY ("Green roof" OR "living roof" OR "vegetated roof") AND TITLE-ABS-KEY ("policy" OR "incentive" OR "regulation") AND TITLE-ABS-KEY ("adoption" OR "uptake" OR "placement"))
Aim	"Adoption" or "uptake" or "placement"	
Process	"Policy" or "incentive" or "regulation"	

Table 1: Search Query

As not all articles are relevant, several excluding criteria have been established. The excluding criteria are:

- Does not contain information about policies implemented.
- Green roofs are not specifically highlighted but are considered in a broader context.

Figure 1 illustrates the process of selecting publications.

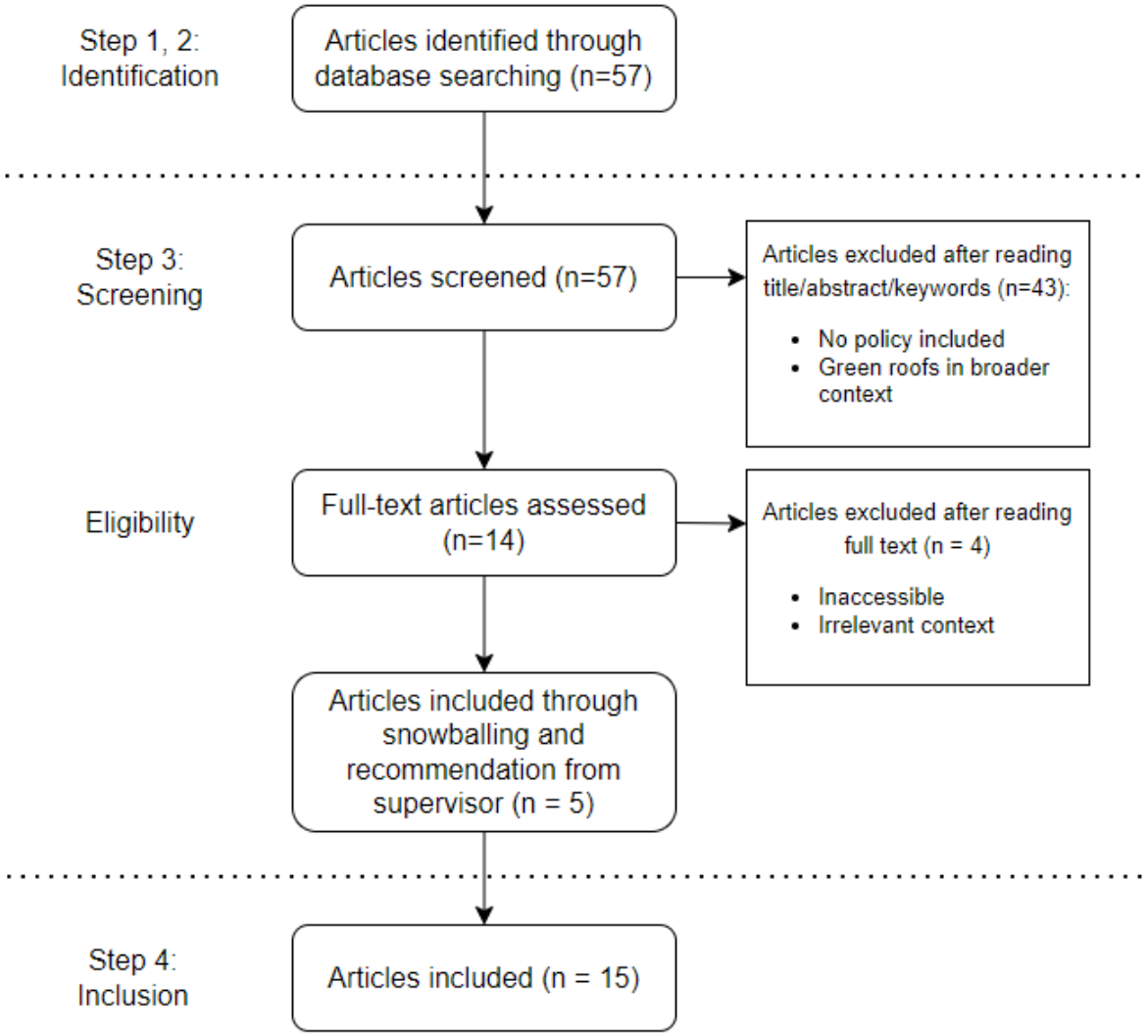

Figure 1: Publication Selection Method

2.1 Green roof measure

In literature, a distinction is made between different types of green roofs. This distinction, as emphasized by the majority of publications, is primarily categorized into extensive and intensive green roofs (Claus & Rousseau, 2012; Brudermann & Sangkakool, 2017; Sangkakool et al., 2018; Tsang et al., 2010; Mullen et al., 2013). The difference is characterized by the thickness of the substrate, the growing medium, and the vegetation used. An extensive green roof is characterized by a substrate layer up to 20cm with mainly grasses, herbs, and sedum. Intensive green roofs are characterized by substrate thicknesses of 20cm and above, accommodating shrubs and trees. Within the literature, research has predominantly focused on the effects of extensive green roofs, given their lower maintenance requirements and lower investment costs (Mullen et al., 2013; Brudermann & Sangkakool, 2017; Claus & Rousseau, 2012). Also, intensive green roofs do not provide significant extra benefits in comparison to extensive ones.

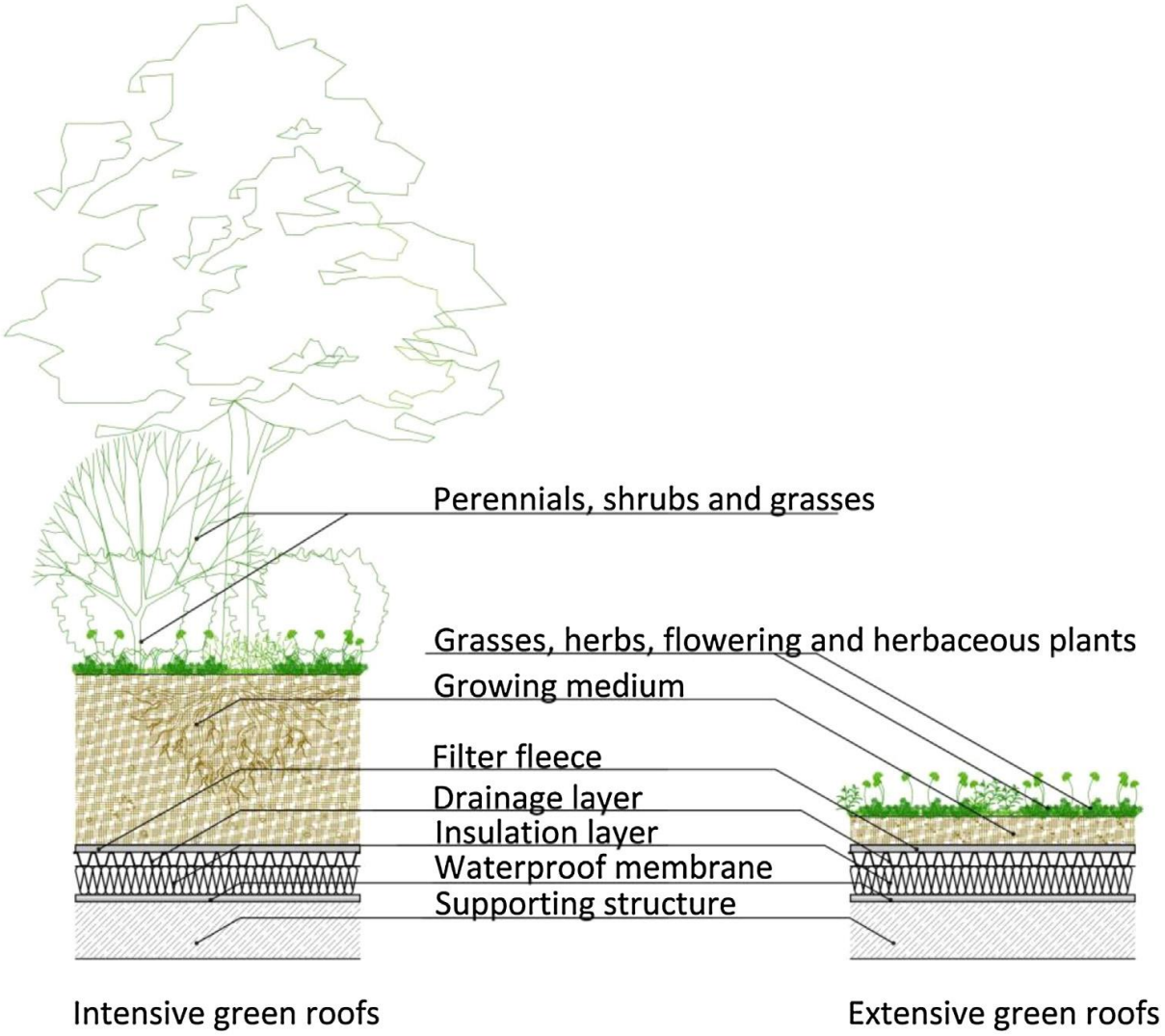

Figure 2: Differences Intensive and Extensive Green Roofs (Brudermann & Sangkakool, 2017)

Green roofs offer various benefits, which can be categorized into private and public benefits, as well as private and public costs. Claus and Rousseau (2012) mention social costs in the form of regulatory costs, but otherwise, costs such as installation and maintenance are borne by the building owners (private). Examples of private benefits include *increased lifespan of roofing, reduction of energy consumption (cooling and heating), fire-resistant properties, noise reduction, and improved aesthetics* (Claus & Rousseau, 2012; Mullen et al., 2013; Tsang & Jim, 2010; Irga et al., 2017).

Public benefits *encompass mitigating the Urban Heat Island Effect, enhancing the quality of stormwater runoff and its impact, improving air quality, reducing greenhouse gas emissions, promoting aesthetics, and increasing biodiversity.* Due to the uneven distribution of costs and benefits, it is suggested to provide incentives to private parties to stimulate the uptake of green roofs aesthetics (Claus & Rousseau, 2012; Mullen et al., 2013; Tsang & Jim, 2010; Irga et al., 2017).

2.2 Factors influencing green roof uptake

2.2.1 Barriers for the uptake

The adoption of green roof by homeowners is still difficult due to different negative factors. These barriers are different depending on the geographical location. However, certain barriers can be found in every part of the world (Zhang & He, 2021). According to Zhang and He (2021) the most important barriers are the lack of government policy and action, unsound economic benefit assessment, individual unwillingness, and unsound technology development. The lack of government policy and action is seen as the biggest barrier (Alim et al., 2022; Mahdiyar et al., 2020; Brudermann & Sangkakool, 2017; Zhang & He, 2021), however according to Wilkinson et al., (2022) the high initial installation costs are the main problem for the adoption.

Barrier	Description
Technical	▪ Structural loads ▪ Structural damages with improper placement ▪ Risk of leakage ▪ Weak under wind loads
Economical	▪ High capital cost ▪ High maintenance costs ▪ Unsound economic benefits assessments
Environmental	▪ Lack of rainfall ▪ Disposal of materials after product life
Lack of governmental policy	▪ Lack of promotion ▪ Lack of incentives ▪ Lack of policy pressure ▪ Regulation prohibiting green roofs
Lack of knowledge	▪ Lack of public awareness ▪ Scepticism ▪ Lack of local research ▪ Complexity of maintenance and installation

Table 2: Factors influencing the uptake of green roofs negatively

Before homeowners even consider the costs, the first thing is to receive and look for information about green roofs. Information about the possibilities, the maintenance, carrying capacity and weight of the product poses another hurdle (Alim et al., 2022; Brudermann & Sangkakool, 2017; Mahdiyar et al., 2020; Wilkinson et al., 2022; Zhang & He, 2021). The lack of knowledge and information occurs throughout the entire life cycle of green roofs. Studies show different costs and intervals for the maintenance of green roofs. It is indicated that green roofs often need irrigation and fertilization (Irga et al., 2017), however the type of green roof is not stated in this research. Alim et al., (2022) states that the high intervals and

costs only apply to intensive green roofs, and extensive green roofs require less maintenance and is therefore less costly. The lack of information and knowledge among potential adopters causes fear and uncertainty, but the absence of this knowledge also means that potential adopters do not see or know green roofs as a possible method of sustainability.

Lack of knowledge on the demand side is a barrier, however on the supply side there is also a lack of expertise. Unsound technical development, or a lack of experience and competence also forms an issue throughout countries wanting to adopt more green roofs (Alim et al., 2022; Mahdiyar et al., 2020; Wilkinson et al., 2022). The supply side which lacks competence creates an extra risk for homeowners and companies willing to adopt a green roof.

The body of knowledge shows a wide variety of barriers throughout the world. In the Netherlands the main barriers are the installation and maintenance costs, structural and static challenges, possible damage and legal and political constraints (van der Meulen, 2019). These barriers overlap, the only addition to the body of knowledge is legal constraints. Table 2 summarises the barriers which influence the uptake of green roofs.

2.2.2 Drivers for the uptake

The drivers for green roofs are mostly split into three segments: policy pressure, market pressure and innovation and technology advancement. Policy pressure is seen as the driver with the most potential, also for creating momentum to move green roofs from niche to regime at an acceptable speed (Alim et al., 2022; Zhang & He, 2021; Brudermann & Sangkakool, 2017). As is stated by Geels and Schot (2007), it is impossible to transition from niche to regime without pressure from regulation or incentives. Policy pressure can be in different ways such as mandatory or voluntary policies, regulations, guidance, standards or initiatives (Zhang & He, 2021).

Homeowners seeking a better quality of life and sustainability within an urban environment often turn to green roofs. Additionally, increasing the value of the house serves as a clear motivator for homeowners. This type of customer demand creates market pressure (Alim et

Driver	Description
Policy Pressure	▪ Regulation ▪ Incentives ▪ Information and Advocacy ▪ Demonstration and Provision
Market Pressure	▪ Homeowners seeking a better quality of life ▪ Sustainability in urban environments ▪ Increase value of houses ▪ Certification for installers and contractors
Innovation and Technological Advancement	▪ Decrease investment ▪ Retrofit possibilities ▪ Increase energy efficiency

Table 3: Drivers for the uptake of green roofs

al., 2022; Zhang & He, 2021). For contractors, sustainability standards and certifications for green buildings can add extra pressure to install more green roofs from the market perspective (Zhang & He, 2021).

Innovation and technology advancement can help drive the adoption of extensive green roofs. Sustainable solutions for retrofitting upgrades to existing buildings will become more interesting, extensive green roofs can be one of the solutions provided. Improving the current green roof systems can also help decrease investment and increase energy efficiency (Zhang & He, 2021).

2.3 Policies

2.3.1 Policy types

In addition to incentives, the literature distinguishes various forms of policies to stimulate the uptake of green roofs. Several publications (Pianella et al. 2016; Wilkinson et al., 2022) categorize these policies into four main types: Information & Advocacy, Incentives, Government Demonstration & Provision, and Regulation. Various possibilities within this classification are outlined in Table 4.

Policy category	Voluntary / Mandatory	Description
Information of Advocacy Mechanism	Voluntary	▪ Provision of information to the market ▪ Guidelines for green roofs ▪ Information sessions ▪ Encourage participation and engagement ▪ Develop toolkits ▪ Implement awards and recognition programs
Incentives	Voluntary	▪ Financial support ▪ Stormwater discounts ▪ Expedited permit application times ▪ Tax benefits ▪ Stormwater runoff fee
Government Demonstration and Provision	Voluntary	▪ Urban infrastructure planning ▪ Ensuring existing regulations do not pose barriers ▪ Leadership
Regulation	Mandatory	▪ Require new buildings to install green roofs ▪ Require a green roof with renovation ▪ Setting sustainability requirements

Table 4: Policy categories

Different cities employ different policy approaches to accelerate the uptake of green roofs. According to Liberalesso et al. (2020), 53% of implemented policies are subsidies, in other words incentives. Cities such as Rotterdam, Singapore, Stuttgart, and Toronto utilize this approach (Wilkinson et al., 2022; Irga et al., 2017). Regulation, on the other hand, is viewed as the most effective policy tool to accelerate the uptake of green roofs (Irga et al., 2017; Wilkinson et al., 2022; Liberalesso et al., 2020). For example, Basel requires every new or renovated roof to be green, resulting in the highest area of green roofs per capita globally (Irga et al., 2017). Wilkinson et al. (2022) recommends that combining a voluntary policy with mandatory regulation may yield the best results, however that our cities and societies are too

complex to say a specific voluntary or mandatory approach in unequivocally the best approach.

It is noteworthy that only Pianella et al. (2016) emphasizes the need to tailor the policy approach to local barriers. The article suggests that if there is sufficient funding or motivation, providing information alone may be adequate to increase the uptake of green roofs. It is also mentioned that simplifying or removing policy barriers can be beneficial. Irga et al. (2017) notes that barriers on the northern hemisphere are likely different from those in Australia, and copying policies may not be effective.

2.3.2 Proposed strategies to increase uptake

Brudermann & Sangkakool (2017) and Sangkakool et al. (2018) also suppose a strategy to determine the right policy interventions. In their study, the SWOT framework is utilized to identify various aspects of green roofs, which are then combined into strategies that can lead to increased implementation of green roofs in two different locations worldwide: Thailand and Europe. It is noteworthy that the SWOT analysis differs in different regions, demonstrating variations between different areas. For instance, the research highlights that Thailand focuses more on mitigating the Urban Heat Island effect, while Europe is more concerned with reducing floods. While Irga et al. (2017) and Pianella et al. (2016) briefly mention this, Brudermann and Sangkakool (2017) is the first study to consider geographical differences. Brudermann and Sangkakool (2017) and Sangkakool et al (2018) are the only two publications that take into account the various barriers specific to the target audience.

Among the different strategies, subsidies are the most frequently mentioned (Mullen et al., 2013; Irga et al., 2017; Brudermann & Sangkakool, 2017; Sangkakool, et al. 2018; Wilkinson et al., 2022; Durdyev et al., 2022). Mullen et al. (2013) explores the optimal level of subsidies and whether they should be general or targeted. The findings suggest that targeted subsidies can be more impactful but may also incur higher transaction costs. Additionally, disseminating information about the economic and ecological benefits is considered a strategy with significant potential.

2.3.3 Policy in the Netherlands

In the Netherlands, no subsidies are provided at the national level. Subsidies are granted at a local level, and the level at which this is done varies greatly geographically. For instance, the province of Zeeland offers a provincial subsidy, the city of Amsterdam has a subsidy from the water board, and the city of Rotterdam solely from the municipality (Subsidie Voor Een Groen Dak, Interpolis). Table 5 displays the largest cities along with their corresponding subsidies. The subsidies have been categorized by:

- Area. There is compensation based on the area of the green roof.
- Water Storage. There is compensation based on the amount of water which can be stored.
- Quality. The city differentiates for different green roofs (intensive / extensive, minimum water storage per m^2)
- Biodiversity. Extra subsidy for certain types of plants.

There are similarities, however most have a different angle of subsidizing. Within the various subsidies, there are minor differences such as compensation for the amount of water storage and the level of compensation. Occasionally, there is also an emphasis on enhancing

biodiversity, with compensation for the number of plants being encouraged. Only one city provides full compensation for low-income homeowners. However, no city provides incentives such as tax reduction or a stormwater runoff fee. This is also what was found in the study of Liberalesso (2020).

However, not all policy supporting the adoption of green roofs in the Netherlands is organised on a local level. Measures such as Building Research Establishment Environmental Assessment Method (BREEAM) certification (Breeam, n.d.) and the Bijna Energie Neutrale Gebouwen (BENG) regulation (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020) are organised on a national level in order to support sustainable buildings. A green roof has a positive effect on both measures (Sempergreen, 2023). Other national schemes include the VAMIL and the MIA (Milieu Investerings Aftrek), these schemes offer the possibility of tax benefits for entrepreneurs or companies (MIA en Vamil voor ondernemers, 2024). While these measures can have a positive effect for the adoption of green roofs, it is not implemented specifically for green roofs meaning that there is no obligation for businesses or individual to actually adopt green roofs. No other national measures are taken in order to increase the adoption rate of green roofs.

City	Inhabitants (x1000)(CBS,	Incentive	Source
Amsterdam	918,1	Area - Waterboard	AGV, 2023
Rotterdam	663,9	Water storage, Area, Biodiversity	Gemeente Rotterdam, 2023
's-Gravenhage	562,8	Water storage	Gemeente Den Haag, 2023
Utrecht	367,9	Area, Quality	Gemeente Utrecht, 2023)
Eindhoven	243,7	Area, Water Storage	Gemeente Eindhoven, 2023
Groningen	238,1	No available subsidy in 2023	Gemeente Groningen, 2023
Tilburg	227,7	Water storage, Quality	Gemeente Tilburg, 2023
Almere	222,8	Area, Quality. Provided by the province of Flevoland	Flevoland, 2023
Breda	186,4	Area, Quality, Biodiversity	Gemeente Breda, 2023
Nijmegen	182,5	Area, Quality	Gemeente Nijmegen, 2023

Table 5: Incentives in the 10 biggest cities of the Netherlands

2.4 Knowledge gap

Although much research has been conducted and various strategies have been proposed to accelerate the adoption of green roofs, there are no studies focussing on increasing the adoption of green roofs by housing associations and organisations. Mahdiyar et al. (2020) examined various barriers and determined their priorities which could also be applied for organisation. However, the next step, testing them and applying them towards policy alignment is missing. The alignment of policy with the needs of these organisations has to be done at the local level. This is evident in the research of Sangkakool et al. (2018) and Brudermann and Sangkakool (2017). Aligning policies with the social, technical, and economic obstacles experienced in society and creating a method for determining this is crucial to accelerate the adoption of green roofs in different parts of the world.

3 Methodology

3.1 Research Questions

In the area of sustainable urban development, the integration of green roofs has emerged as a promising strategy to address environmental challenges and enhance the overall resilience of urban liveability. This thesis undertakes an analysis of green roof policies across Amsterdam and how the existing policy interventions stimulate housing associations to adopt green roofs. This exploration aims to incorporate the barriers and drivers inherent in the city, with the goal of revealing a comprehensive understanding of the nuanced policy landscapes governing green roofs. The outcome links policy to drivers and barriers and determines why the policies work or don't. Based on this information a recommendation is given to improve existing policy. The research question accompanying the knowledge gap is:

"*How do policy instruments for the promotion of green roofs influence the behaviour of housing associations in Amsterdam?"*

Answering this question will give an overview of the effectivity of current policy and will provide useful information for policy makers to adapt policy to be more effective. The research question can be decomposed into four different sub questions:

SQ1: What are the current policy instruments influencing green roof uptake and what are their features?

SQ2: What influences housing associations in implementing green roofs?

SQ3: To what extent do current policy instruments address factors that influence this decision-making process?

SQ4: What implications does that have for policy instruments and how can current policy instruments be improved?

3.2 Research approach, design and methods

In this section the chosen research approach and design, essential for guiding our research, is explained and argued. This concise explanation outlines the rationale behind the methodological choices and establishes a focused framework for exploring, analysing, and interpreting the core research questions in this research. Creswell & Creswell (2018) define research design as the plan, structure, and strategy formulated to answer research questions. It encompasses the overall framework that guides the collection, analysis, and interpretation of data in a study. Research design involves decisions about the study's structure, the type of data to be gathered, and the methods for obtaining and analysing that data. It serves as a blueprint for the entire research process, providing a systematic and organized approach to address the research problem or question at hand (Creswell & Creswell, 2018).

In this research, the factors influencing the effectiveness of policies and the policies themselves are examined. The research is conducted within a complex system where various factors are intertwined. Crowe et al. (2011) argue that a case study is a suitable research approach when an in-depth, multi-faceted complex system needs to be studied. Case studies are used to explain, describe or explore events and/or phenomena that occur in

everyday context. Case studies can also provide insights into what gaps exits and why an implementation strategy is chosen over another (Crowe et al., 2011).

According to Priya (2020) an explanatory case study focuses on the “Why” and “How” questions. Answering these questions is at the centre of this research. Within this research the focus is one case, this method allows researchers to explore the complexities and nuances of a subject, providing rich, detailed insights that might not be achievable through other research methods. Case studies are particularly useful for investigating contemporary issues where the boundaries between the phenomenon and its context are not clearly defined. They often employ multiple sources of data, such as interviews, observations, and documents, to triangulate findings and enhance the validity and reliability of the research.

The limitations of this research approach are that it may not be generalizable to broader populations or contexts, the interpretation of data in exploratory multiple case studies can be subjective and multiple case-studies can be time-consuming and resource-intensive (Yin, R.K., 2014). In order to gather enough valuable data within the time limit of this project, four case studies will be done. Subjectivity will be mitigated as much as possible by including document analysis, multiple case studies and interviews with experts in the field.

3.3 Theoretical framework

As the literature review has revealed, there is a lack of structural analysis regarding the stimulation of housing associations in implementing green roofs. This research examines the various ways in which housing associations can be motivated to invest in green roofs on their buildings. To achieve this goal, the study incorporates the COM-B model, the Theoretical Domain Framework (TDF), and the Behaviour Change Wheel (BCW).

By utilizing the COM-B model, the study can delve deeper into the psychological and physical factors influencing behaviour change among housing associations regarding green roof adoption. The model's focus on capability, opportunity, and motivation offers a structured approach to understanding the complexities involved in incentivizing these organisations (Michie et al., 2011). To perform a thorough analysis of the responses from the various interviews, Atkins et al. (2017) elaborated the TDF within the COM-B model. The concepts used in that research serve as the basis for the analyses in this study.

The Behaviour Change Wheel, a well-established framework in behaviour change research, offers a systematic model for categorizing interventions based on capability, opportunity, and motivation (Michie et al., 2011). This framework provides a practical toolkit for designing, implementing, and evaluating interventions aimed at modifying behaviour, making it a valuable resource for guiding this research (Seppälä et al., 2017).

3.3.1 COM-B

The Behaviour Change Wheel serves as a comprehensive framework for understanding and implementing behaviour change interventions. At its core lies the COM-B model, the model suggests that for behaviour change to occur, there must be Capability, Opportunity, and Motivation (Allison, et al., 2021). Below are the various components elaborated:

1. *Capability*: This refers to the psychological and physical capacity to engage in a specific behaviour. Capability encompasses both the physical and psychological skills required to perform the behaviour, as well as the individual's knowledge and

understanding of the behaviour. For an organisation this refers to the resources and human resources within the organisation (Michie et al., 2011).

2. *Opportunity*: Opportunity denotes external elements impacting behaviour, comprising social norms, cultural influences, physical environment, and resource accessibility. These factors can either facilitate or impede behaviour change (Michie et al., 2011).
3. *Motivation*: Motivation denotes the psychological impetus or readiness to participate in a behaviour, encompassing conscious and subconscious factors such as attitudes, beliefs, emotions, and perceived benefits or costs (Michie et al., 2011).

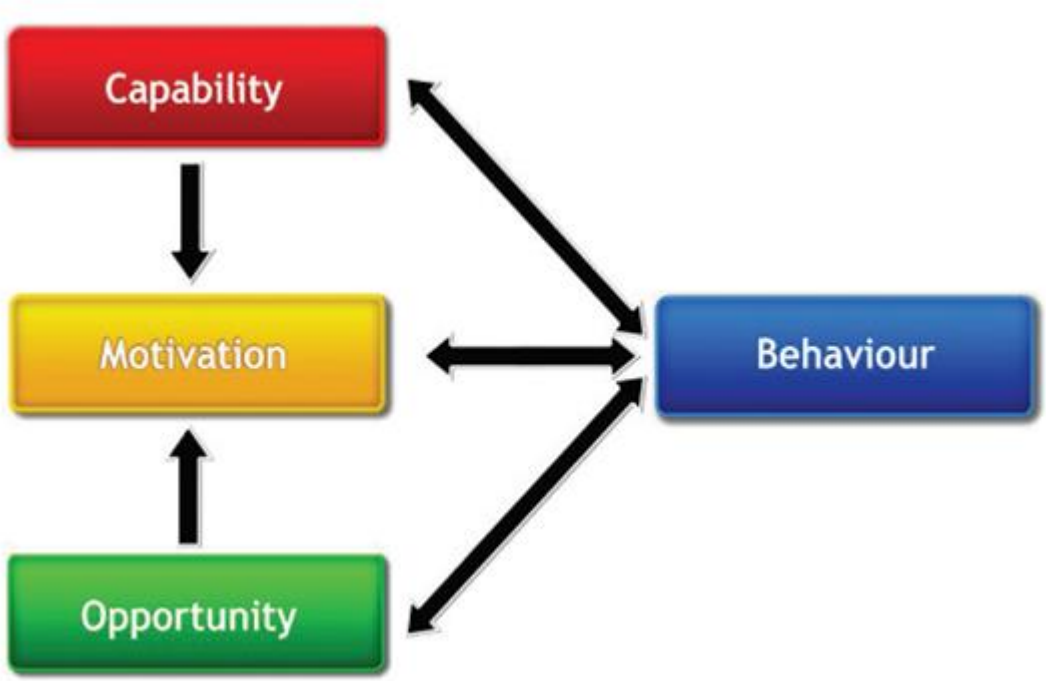

Figure 3: COM-B model (Michie, 2011)

3.3.2 Theoretical Domains Framework

The COM-B model can be further explained using the Theoretical Domains Framework (TDF) (Allison, et al., 2021). Figure 5 shows the relationships between the TDF domains and the various components of the COM-B model. These different components help to analyse and categorize interview questions and answers. As described later, the various components of the COM-B model interact with the Behaviour Change Wheel. Atkins et al. (2017) developed guidance for the proper use of the TDF, which has already helped various professionals achieve more reliable results.

To obtain reliable results, the guidance of Atkins et al. (2017) is used. The various domains established are further explained in Table 6. The combination of the two frameworks are used to collect data, and analyse it. The findings are used to inform the selection of intervention strategies by using the Behaviour Change Wheel.

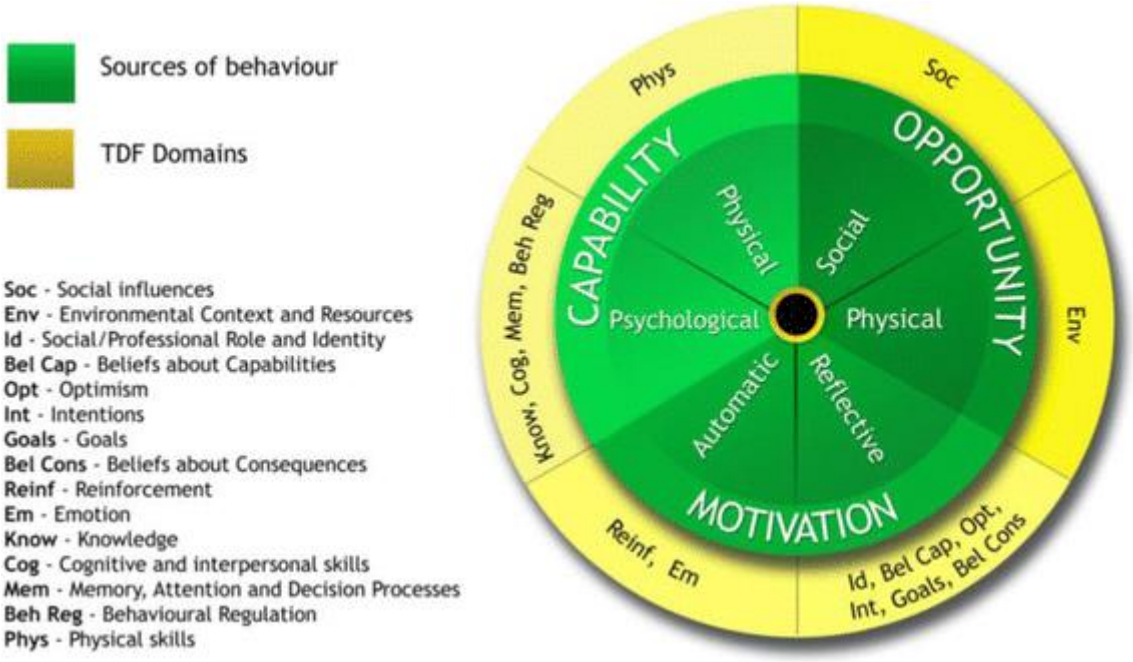

Figure 4: Theoretical Domains Framework (Allison, et al., 2021)

TDF Domain	Explanation
Knowledge	Knowledge about green roofs, procedures and possibilities
Skills	Skill to install green roofs, development and practice of skills
Memory, attention and decision processes	Ability to retain information, and to select the alternative most suited to the situation
Behavioural regulation	Anything aimed at managing or changing objectively observed or measured actions
Social influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours. Including social pressure and norms
Environmental context and resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour. Including the organisational resources
Social/Professional role and identity	The role the organisation has got, identifies with and focusses on. Including how they see their role in society
Beliefs about consequences	Beliefs about the risks, benefits, and practical implementation of green roofs
Reinforcement	The relationship between the implementation of green roofs and the stimulus given
Intentions	A conscious decision to act in a certain way
Goals	Representation of the outcomes which the organisation wants to achieve
Beliefs about capabilities	Acceptance, or beliefs, about the truth, reality of validity of talent, ability or facilities the organisation can put to use
Optimism	Confidence that things will happen for the best
Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event

Table 6: Theoretical Domains Framework, the 14 domains. Adapted from Atikins, et al (2017).

3.3.3 Behaviour Change Wheel

The Behaviour Change Wheel delineates nine intervention functions, activities aimed at changing behaviour. These functions are tailored to address specific determinants identified

through systematic analyses, ensuring interventions effectively target underlying factors precipitating behaviour change (Michie et al., 2011). Intervention functions are direct mechanisms used to change behavior in individuals or groups. They specifically focus on influencing people's motivations, capabilities, and opportunities to act.

1. *Education*: Providing information and knowledge to individuals to enhance their understanding of the behaviour and its consequences.
2. *Persuasion*: Using strategies such as communication and messaging to influence attitudes, beliefs, and intentions related to the behaviour.
3. *Incentivization*: Offering rewards or incentives to encourage and reinforce desired behaviours.
4. *Coercion*: Implementing measures to impose penalties or restrictions on engaging in undesired behaviours.
5. *Training*: Providing skills training and practical guidance to develop capabilities necessary for behaviour change.
6. *Restriction*: Limiting access or availability to resources or environments that enable undesired behaviours.
7. *Environmental restructuring*: Modifying the physical or social environment to make desired behaviours easier and more accessible.
8. *Modelling*: Demonstrating desired behaviours through social modelling or role modelling to encourage imitation.
9. *Enablement*: Providing support, resources, or assistance to overcome barriers and facilitate behaviour change.

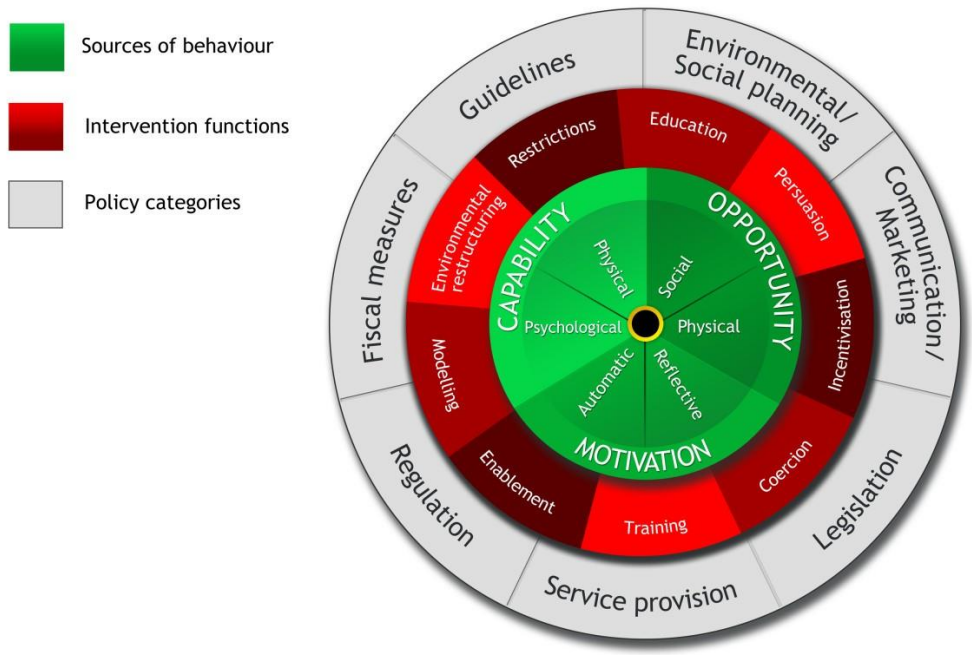

Figure 5: Behaviour Change Wheel (Michie et al., 2011)

The outer ring of the Behaviour Change Wheel is constructed from 7 different policy categories, actions on the part of responsible authorities that enable or support interventions. These policy categories encompass a wide range of approaches, from communication and marketing initiatives to legislative measures and environmental planning strategies. By delineating these categories, the Behaviour Change Wheel provides a structured guide for policymakers and practitioners to select and implement policies that align with the desired behaviour change objectives. In this list, the policy categories in the Behaviour Change Wheel are outlined, shedding light on the diverse strategies available for promoting behaviour change across different contexts and populations. Policy categories are broader measures that enable or support intervention functions by creating a favourable environment or framework. These are often implemented at the institutional, community, or governmental level.

1. *Communication/marketing*: Using print, electronic, telephonic, or broadcast media.
2. *Guidelines*: Creating documents that recommend or mandate practice. This includes all changes to service provision.
3. *Fiscal Measures*: Using the tax system to reduce or increase the financial cost.
4. *Regulation*: Establishing rules or principles of behaviour or practice
5. *Legislation*: Making or changing laws
6. *Environmental/social planning*: Designing and/or controlling the physical or social environment.
7. *Service provision*: Delivering a service.

The BCW goes beyond providing a full range of interventions, it forms the basis for a systematic analysis of selecting the right interventions and policies. An intervention can be implemented through different policy categories. In the model, there are various connections between intervention functions, the COM-B model and the policy categories. These connections illustrate how different policy categories are linked to interventions, and how they, in turn, influence the various components of the COM-B model in the centre of the model. The relations between the components can be found in Table 7 and Table 8.

	Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Communication/ Marketing	√	√	√	√				√	
Guidelines	√	√	√	√	√	√	√		√
Fiscal			√	√	√		√		√
Regulation	√	√	√	√	√	√	√		√
Legislation	√	√	√	√	√	√	√		√
Environmental/social planning							√		√
Service Provision	√	√	√	√	√			√	√

Table 7: Relations between policy categories and interventions

Model of behaviour: sources	Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
C-Ph					√				√
C-Ps	√				√				√
M-Re	√	√	√	√					
M-Au		√	√	√			√	√	√
O-Ph						√	√		√
O-So						√	√		√

Table 8: Relations between the COM-B model and the interventions

3.3.4 Strengths and Limitations

In behavioural change, there is a general recognition of the influence of the environment (Michie et al., 2011). In the BCW model, the environment is naturally included in the analysis. This is one of its strengths. The Opportunity component represents the context and serves as the starting point for intervention design. Additionally, the BCW allows for the integration of various components in the analysis of potential behaviour change. This integration stems from analysing many frameworks and combining them into one.

The limitations of the framework are that, in the process of combining multiple frameworks into one, important intervention functions or frameworks may have been overlooked. Furthermore, there will always be a human judgment factor in the research when categorizing behaviour patterns and conceptualizing intervention functions and policy categories (Michie et al., 2011).

3.4 Research methods

The aim of the research is to analyse the existing policy implementation in the municipality of Amsterdam for the adoption of green roofs by housing associations. The objective is to stimulate housing associations to adopt green roofs. In this section the methods and tools required will be discussed. The methods exist of desk research and semi-structured interviews.

3.4.1 Desk Research

In this research the desk research encompasses document analysis and policy design. It involves the systematic examination and interpretation of existing materials, such as reports, publications, policies, and other relevant documents, to gather information and insights pertinent to the research question or topic.

Document analysis, a key component of desk research, involves scrutinizing written or visual materials to extract meaningful information and identify patterns, trends, and themes. This research delves into academic papers, government reports, organisational documents, and media sources, to gain a comprehensive understanding of the policy instruments currently in place. Through document analysis, the different features such as historical contexts, policy frameworks, stakeholder perspectives, and empirical evidence are uncovered. For the document analysis Microsoft Word and Excel will be used to order and store data. The policies which have been identified will be structured according the Behaviour Change Wheel, the policy categories and intervention functions are the structured which has been chosen and can be found in Appendix A. Document analysis is often combined with other qualitative research methods in as a means of triangulation and is particularly applicable to qualitative case studies (Bowen, 2009).

The advantage of document analysis for this research lies in its non-obtrusiveness and lack of reactivity, as it remains unaffected by the research process (Bowen, 2009). This contrasts with semi-structured interviews, which have the disadvantage of lower validity and are more susceptible to the researcher's bias, influenced by the nature of the questions asked (George, 2023). Another contrast between document analysis and semi-structured interviews is that document analysis might provide insufficient detail, while semi-structured interviews provide depth and richness in data (Bowen, 2009; George, 2023).

3.4.2 Semi-Structured interviews

The interviews will consist of semi-structured interviews. This choice was made because it offers flexibility in gathering unknown information during the interview, and semi-structured interviews provide richness of data. The limitations of this type of interview include low validity and the potential for the researcher's bias to have a greater impact (George, 2023). While document analysis in included in the research results can be triangulation with results from a source which lacks obtrusiveness and reactivity (Bowen, 2009). In Appendix A.1, the questions included in the interview can be viewed.

In this research project, we conduct expert interviews involving human participants, a process requiring approval from the Human Research Ethics Committee (HREC) at TU Delft. Before participation, all respondents must sign a consent form, which is included in Appendix A.2 and provides details on data protection and processing. Participants are informed upfront about the voluntary nature of their involvement. Additionally, we seek permission for recording and guarantee anonymity to all participants.

The participants are from different governing bodies such as the municipality of Amsterdam and Waternet, and from four different housing associations with different positions. In table 9 there is an overview of the different positions and interviewees.

Type of Organisation	Number of Interviewee	Position
Housing association	#1	Energy transition
Municipality	#2	Team subsidy green
Housing association	#3	Senior policy advisor sustainability
Waternet	#4	Climate adaptation officer
Municipality	#5	Team roofs
Housing association	#6	Projectleader sustainability
Housing association	#7	Maintenance team

Table 9: Participants in this research

3.4.3 Data Analysis

Documents

Part of the research involves studying policy documents, news articles, legislative texts, and vision documents. This grey literature is found via the website of the municipality of Amsterdam or through Google. Additionally, interviews with the municipality are used to verify that all relevant documents and policy papers have been identified. Once the policy documents are collected, they are analysed based on content analysis. The content analysis looks at where and how green roofs can be influenced by policy. When a link to green roofs or climate adaptation is identified, the text is thoroughly examined to determine whether it

falls within the scope of the research. The result of this analysis is an overview of the various policy instruments and policy documents present in the municipality of Amsterdam, as well as at the national level.

Coding logic

According to the Behavior Change Wheel (BCW), statements can sometimes be categorized under different aspects of the COM-B model as well as other components of the BCW (Michie et al., 2011). This is a subjective part of the BCW and is minimized as much as possible by performing the coding twice. Two weeks after the initial coding, the coding is performed again without showing the previous codes. This helps reduce some of the subjectivity in coding, although it cannot be completely eliminated.

Additionally, various interventions, such as Weerproof, fall under different intervention functions. For example, Weerproof can be classified under Education with events and presentations, but also under service provision by helping individuals and housing corporations make the city climate-adaptive. In this research, the intervention function which is seen to be most dominant is chosen to reduce repetition. This also contains some subjectivity, which is partially mitigated by comparing policy documents and interviews. Through triangulation, a better estimation of the main intervention function can be made.

Terminology

When determining whether a certain factor is unclear, limiting or enabling, the broader context in which something is said is considered. It looks not only at what has a direct influence but also at factors that can have an indirect influence. An example of a limiting factor is: if person A has 10 euros in his pocket and spends 2 euros on a sandwich, this is a limiting factor for then buying a drink.

Since limiting, enabling, and unclear factors are subjective from the researcher's perspective, these factors are added to be evaluated independently again three weeks later. After all results have been recorded, a final check is performed with ChatGPT using contextual discourse analysis. Any differences between the results from ChatGPT and the researcher are re-evaluated to eliminate any errors and misconceptions.

Semi-structured interviews

All interviews are recorded, transcribed, and then analysed. After an interview has taken place, the transcript is read twice to become immersed in the data. This is according to the steps proposed by Burnard (1991). After reading the transcripts, the most important quotes are collected in an Excel sheet. The list of categories for the coding scheme is translated from the Behaviour Change Wheel. By using these categories, an inductive method is employed to identify key themes. Thematic analysis refers to the process of identifying themes in the data which capture meaning that is relevant to the research question, and perhaps also to making links between such themes. In this way Thematic Analysis helps the researcher identify patterns in the data …(Willig, 2014b, p. 147)

The various semi-structured interviews are analysed by reading the transcripts and collecting quotes that pertain to the COM-B model or elements of the Behaviour Change Wheel, such as the policy categories and intervention functions. The following steps are performed:

1. **Collect Quotes**: Gather relevant quotes from the transcripts and list them in an Excel spreadsheet.
2. **Assign Domains**: Use the coding scheme provided in Appendix A.3 to assign the corresponding domain from the Theoretical Domains Framework or link the relevant segment from the Behaviour Change Wheel to each quote.
3. **Determine Factors**: Identify whether each factor is enabling, limiting, or unclear.
4. **Check:** When all quotes are identified, assigned to a domain and determined the limiting or enabling factor a check is done. The check entails the same process again, three weeks after the first coding.

After completing these steps for all interviews and quotes, compile an overview of the various statements to analyse where the most significant limiting and enabling factors are within the COM-B model. Based on the identified COM-B factors, the connections found in Tables 8 and 9 are used to evaluate how the current intervention functions align with the enabling and limiting elements mentioned by the housing corporations and the municipality. By making these connections, it becomes clear which factors can be further stimulated, improved, or removed.

3.4.4 Analysis and Recommendations

As indicated in the theoretical framework, Table 7 and Table 8 are used to analyze whether the current policy instruments are sufficiently effective in promoting green roofs. This is done by comparing the results from the COM-B model of the interviews with housing associations to the existing policy instruments. Certain factors will be identified as either limiting or enabling, allowing for the conclusion that additional focus is needed or that there are gaps in the policy.

Subsequently, policy instruments from the literature will be proposed to help stimulate specific components of the COM-B model. The researcher will also make additional suggestions that could serve as potential enhancements. These recommendations for policy improvement are not developed according to a specific theoretical framework or model. Therefore, the proposed recommendations will require further investigation. Future research will be outlined, explaining how it could contribute and potentially be carried out.

4 The case: Housing Associations in Amsterdam

In this research, the case of housing associations in Amsterdam is being investigated. A multiple case study approach is employed, wherein various housing associations are compared to yield more generalizable results. The housing associations included in this research are Lieven de Key, Eigen Haard, Stadsgenoot, and Ymere, which constitute the largest housing associations in the city. Amsterdam is considered as the case study environment, delineating the context in which the different housing associations operate. Following the discussion of the various housing associations, a stakeholder analysis is presented, and finally, the green roof projects that have been undertaken are further elaborated and discussed.

4.1 Municipality of Amsterdam

Since its establishment in 1275, the city of Amsterdam has grappled with a perpetual battle with water. While water has brought economic prosperity, it has also led to floods and damage to the city itself (De Amsterdamse Bevolking Sinds 1900 | Website Onderzoek En Statistiek, 2022). Since the first expansions of the canal belt in 1613 (Grachtengordel Amsterdam – Van Wereldformaat, n.d.), urban planners have been striving to maintain the city's liveability and accommodate its growing population, although this primarily benefited the wealthier segments of society at the time (De Amsterdamse Bevolking Sinds 1900 | Website Onderzoek En Statistiek, 2022). Working-class neighbourhoods such as the Jordaan and De Pijp have historically lagged behind in terms of liveability, evident in their small dwellings and limited green spaces. The population growth since 2008 has been unprecedented, with the city even experiencing a decline in residents for some time. As of early January 2020, the city counted 872,380 inhabitants (De Amsterdamse Bevolking Sinds 1900 | Website Onderzoek En Statistiek, 2022). Now, as the city continues to grow, the challenge is to maintain its liveability amidst changing circumstances. While Amsterdam has experience in this regard, it has never faced extreme weather changes before.

In poorer neighbourhoods, housing associations have always been crucial for accommodating Amsterdam residents. In 1995, 58% of housing was managed by housing associations. Since then, this

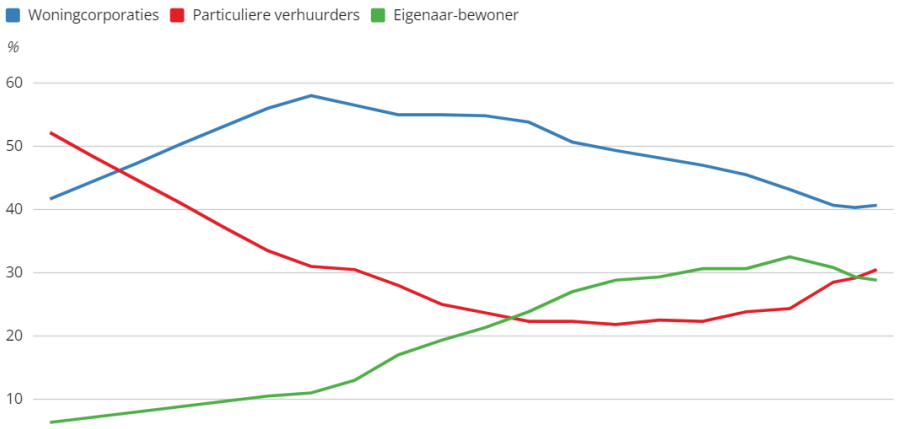

Figure 6: : Distribution of the housing stock (Dashboard: Woningvoorraad Amsterdam | NUL20, n.d.)

percentage has gradually declined every year, and currently, housing associations manage approximately 40% of the dwellings in Amsterdam. Figure 7 illustrates the share of housing by group, clearly showing the shift in ownership (Dashboard: Woningvoorraad Amsterdam | NUL20, n.d.).

To ensure the continued existence of Amsterdam, it is imperative to maintain a minimum level of groundwater, as the foundation of Amsterdam would otherwise deteriorate (SOURCE). However, too much water also poses a problem. With the occurrence of more extreme rainstorms in Amsterdam, sewage overflow is becoming more frequent. The excessive rainfall causes sewage to be discharged into the Amsterdam canals, resulting in deteriorating water quality (Dieleman, 2023). The sewerage system has been a vital asset for public health and the environment for over 100 years. Preserving a well-functioning sewer system is of significant and enduring value to the city of Amsterdam. With the current effects of climate change, the city of Amsterdam is experiencing more frequent heavy rainfall, heatwaves, droughts, and the risk of flooding. To manage urban wastewater and address the impact of these intense downpours, it is necessary to replace more sewers than before (Omgevingsprogramma Riolering 2022-2027, n.d.) Figure 8 illustrates the areas in the city where issues related to waterlogging are most urgent. It is evident that there are regions in the city that require action. The city of Amsterdam suggests the following options for managing rainwater: (1) Retaining and storing, (2) draining, (3) infiltrating, (4) using, or (5) building water-resilient structures (Gemeente Amsterdam Klaas-Bindert de Haan, n.d.).

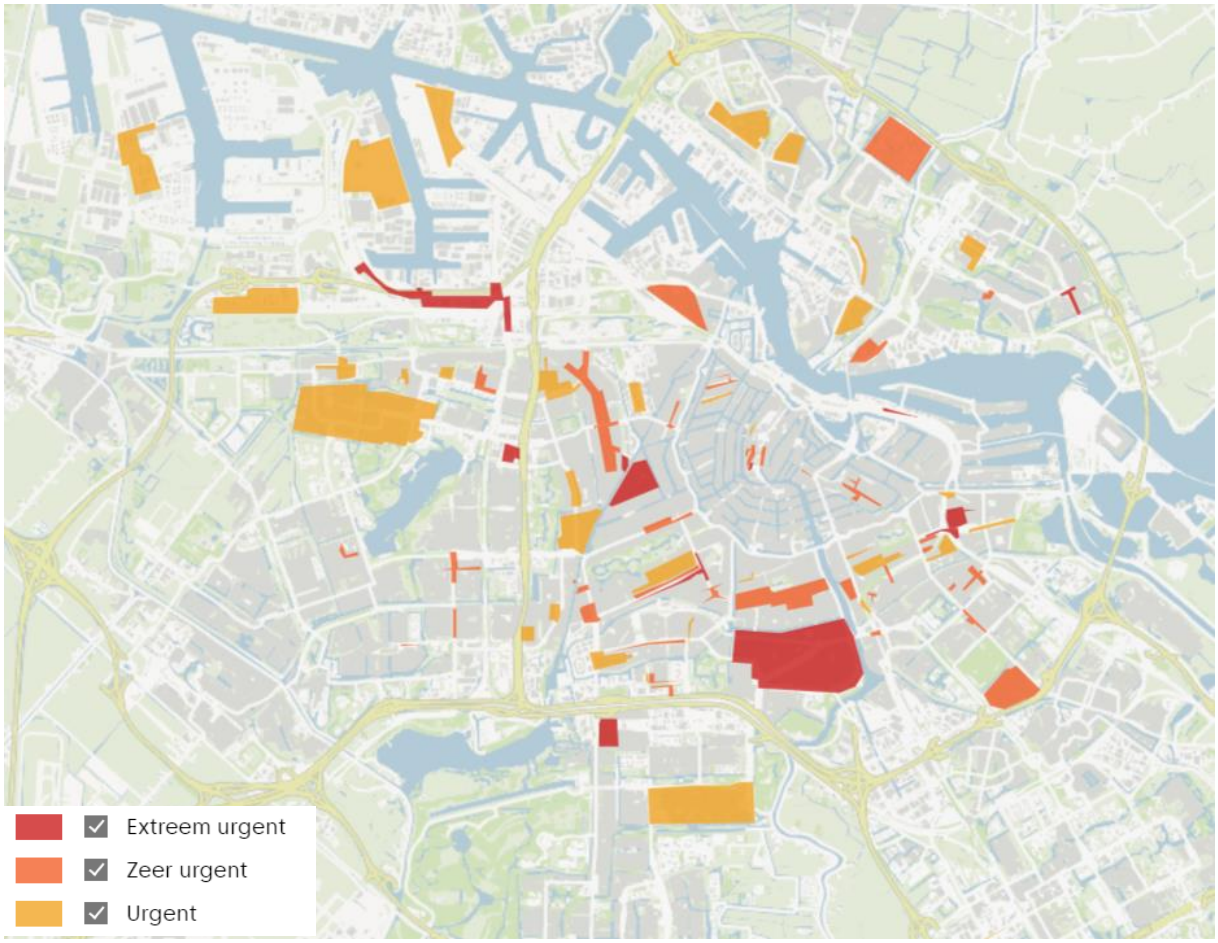

Figure 7: Map of the critical areas for waterlogging in Amsterdam (Gemeente Amsterdam Klaas-Bindert de Haan, n.d.)

The city of Amsterdam is structured into different divisions, with the main administrative branches of the organisation being: Area Development Works and Urban Management, Business Operations, Social Affairs, Digitalization Innovation and Information, and Space and Economy. Within the Space and Economy division, the Space and Sustainability department bears responsibility. Space and Sustainability in Amsterdam face the challenge of maintaining a liveable city while promoting sustainability. With a growing population and demand for green, sustainable living environments, they must make smart use of limited space and environmental conservation. The team of experts, including urban planners, urban designers, and ecologists, collaborates with citizens and businesses to develop solutions to these challenges (Gemeente Amsterdam, n.d.-b). Their focus is on creating spatial plans and facilities that make the city attractive for both current and future generations. The Amsterdam Omgevingsvisie 2050 serves as a guide for their work, shaping the city's future in consultation with the community. Additionally, they collaborate with other agencies at regional and national levels to achieve sustainable growth collectively. Figure 9 illustrates the organisational chart of Amsterdam.

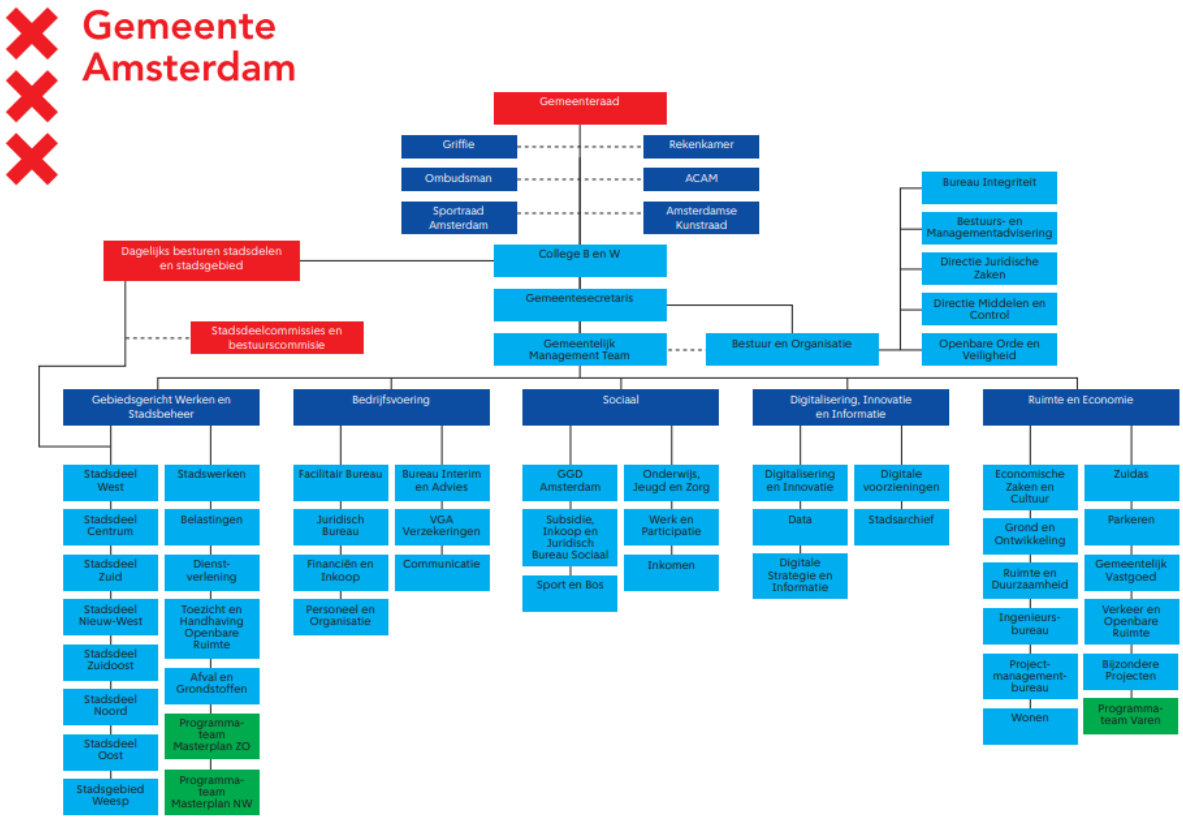

Figure 8: Organisational structure of the municipality of Amsterdam (Organisatie, n.d.)

4.2 Waternet / Waterboard Amstel, Gooi & Vecht

A water board (waterschap) is a public entity established based on the Waterschapswet and is responsible for managing water resources in a specific region in the Netherlands. Additionally, the term "water board" is also used to refer to the area over which the water board has authority. Water boards, like provinces and municipalities, are decentralized governmental bodies. The primary responsibility of the water board is to ensure dry feet in the Netherlands (Beleid, Wet- En Regelgeving, n.d.).

In part of Amsterdam, the Amstel, Gooi & Vecht Water Board (Waterschap AGV) is responsible for carrying out these tasks. As shown in figure 10, a small portion is under the jurisdiction of the Hollands Noorderkwartier Water Board, but for the scope of this research, we will focus solely on the Amstel, Gooi & Vecht Water Board (Waterschap AGV). The Waterschap AGV protects against floods, ensures sufficient clean drinking water for everyone, and keeps the surrounding water clean (Onze Taken, n.d.). Since the Waterschap cannot do all of this alone, it collaborates with various partners. In Amsterdam, this partner is Waternet.

Figure 9: Overview of the different waterboards in the Netherlands (Waterschappen Kaart, n.d.)

Within Amsterdam, the Waterschap AGV and the Municipality of Amsterdam have established an executing agency called Waternet. The Waternet foundation purifies wastewater, produces drinking water, and keeps surface water clean and at the right levels. Waternet is the only water company in the Netherlands that takes care of the entire water cycle (Ons Water, n.d.).

4.3 Weerproof

Weerproof is a collaboration between Waternet and the Municipality of Amsterdam and represents the network approach of the Klimaatadaptatie Amsterdam program (Over Weerproof – Weerproof, 2024). This organisation addresses four major themes: Heat, Drought, Water Overload, and Flooding. Weerproof connects residents, professionals, knowledge institutions, and governments to share experiences, collaborate, and seize opportunities together. Until February 9, 2024, the organisation was called Rainproof, which indicates that it was then focused on dealing with extreme rainfall (Rainproof Is Weerproof! - Weerproof, 2024).

Weerproof operates independently of the Municipality of Amsterdam or Waternet, but it does advocate for their interests (Weerproof.nl, n.d.). In collaboration with the municipality, housing associations, and companies, this organisation implements the policies of the Municipality of Amsterdam.

4.4 Housing associations

For investigating the influence of current public policy on the willingness of housing associations to implement green roofs, it was decided to study various housing associations in Amsterdam. Amsterdam was chosen because 40% of the dwellings are owned by housing associations, indicating significant potential for sustainability in this city. Additionally, in collaboration between the Amsterdam municipality, Rainproof Amsterdam (now Weerproof), Rooftop Revolutions, and various housing associations, several pilot projects have been conducted to explore the utilization of green roofs under the name the RESILIO project (Holstein & Langewen, 2022). In these pilot only extensive green roofs have been implemented. The RESILIO project has also already researched the potential of green roofs in Amsterdam.

Within Amsterdam, there are various housing associations, as depicted in Table 6. These associations vary in size and may have executed pilot projects. This study can include the housing associations with the following characteristics:

- Relatively large housing association
    - *Is crucial to increase the potential of the research, and the hypotheses is that there are more resources to accomplish green roofs.*
- Located in Amsterdam
    - *Consistency in policy climate is crucial; using housing associations from other cities may introduce too many variables.*

With the above criteria in mind, the housing associations in this study are Eigen Haard, Ymere, Stadsgenoot, Lieven de Key, de Alliantie and Rochdale. The selection of the cases can also pose some limitations in the data, while the focus is on larger associations the effects of the policy instruments might not be representative for the smaller housing associations. Another limitation is that housing associations in Amsterdam might be influenced differently than housing association in, for example, Rotterdam. However, using this research as a basis for policy makers can be valuable while it provides a way of thinking.

Name of housing association	Number of pilot projects	Size (in dwellings)	Location
Eigen Haard	1	56.959	Amsterdam
Ymere	1	+- 65.000	Amsterdam
Stadsgenoot	4	+- 30000	Amsterdam
Lieven de Key	1	+- 34000	Amsterdam
Rochdale	0	+- 40000	Amsterdam
De Alliantie	2	+- 56000	Amsterdam / Hilversum / Almere
Parteon	0	17.205	Zaanstreek
DUDOK Wonen	0	9.048	Het Gooi
PRE Wonen	0	-16	Zuid-Kennemerland
Samenwerking B.A.	0	912	Amsterdam

Table 10: List of housing associations in Amsterdam

To further green and climate-adapt Amsterdam, housing associations have a significant role to play. As previously mentioned, housing associations manage a large portion of Amsterdam's housing stock and are therefore responsible for a significant portion of the roofs. The collective of Amsterdam housing associations is united under the Amsterdam Federatie of Woning Corporaties (AFWC). Housing associations are nonprofit entities, which allows them to keep rents low (Het Werk Van Woningcorporaties En De AFWC – AFWC, n.d.).

Housing associations play an essential role in the Dutch housing market. When the associations were established, society and later the government were willing to invest in exchange for an affordable housing supply. Because the housing association is self-owned, they can act according to their own interests (Wie Is De Baas Van De Corporatie?, 2020). Housing associations operate within the municipal climate, where their income comes from tenants, and the government guarantees the financing of the associations. Therefore, the housing association stands at the intersection of these three parties.

The Housing Act (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024a) outlines the main tasks and regulations for housing associations. These range from the responsibilities of the housing associations, such as providing affordable rental housing, separating commercial and social activities, and the supervision of housing associations.

4.5 Interaction between Municipality, Tenants, and Housing Associations

Municipalities and tenants' organisations have more influence on the policy of housing associations. For example, these three parties annually agree on the number of houses to be built (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024b). The agreements for 2024 to 2027 are detailed in the document “Working Together on Housing.” These agreements state that Amsterdam residents experience the housing crisis daily, but this is not the only problem. The climate crisis is also addressed in these agreements. Although many aspects are being worked on, it is also stated that not all goals and wishes can be fulfilled due to limited resources (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024b).

The severity of the climate crisis and the liveability in the city are immediately apparent. The first chapter of this document focuses on making existing homes more sustainable and improving housing quality. This includes looking at insulation, housing quality, making homes gas-free, solar energy, and climate adaptation, nature-inclusive, and circular renovation. One of the agreements under this last point is formulated as follows: “Municipality and associations work together to effectively anticipate the effects of climate change. We strengthen the existing cooperation and create an agenda together that outlines what we will work on during the period 2024-2027” (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024b).

4.6 Stakeholders

In the case of enhancing policy instruments within the municipality of Amsterdam, it is imperative to consider various stakeholders. To accomplish this systematically, the Power-Interest Grid is employed, as illustrated in Figure 11. This grid enables differentiation in the significance of stakeholders based on their power and interest levels within the context. The PI grid comprises four quadrants: players, context setters, subjects, and the crowd (Ackermann & Eden, 2011):

- Players, characterized by high power and high interest, are pivotal stakeholders whose active participation is crucial and require close management.
- Context setters, possessing power but low interest, necessitate occasional attention to maintain satisfaction, primarily during critical junctures.
- Subjects, exhibiting high interest but low power, should be regularly informed to mitigate potential disturbances.
- The crowd, lacking significant power and interest, are considered potential rather than active stakeholders, requiring minimal monitoring.

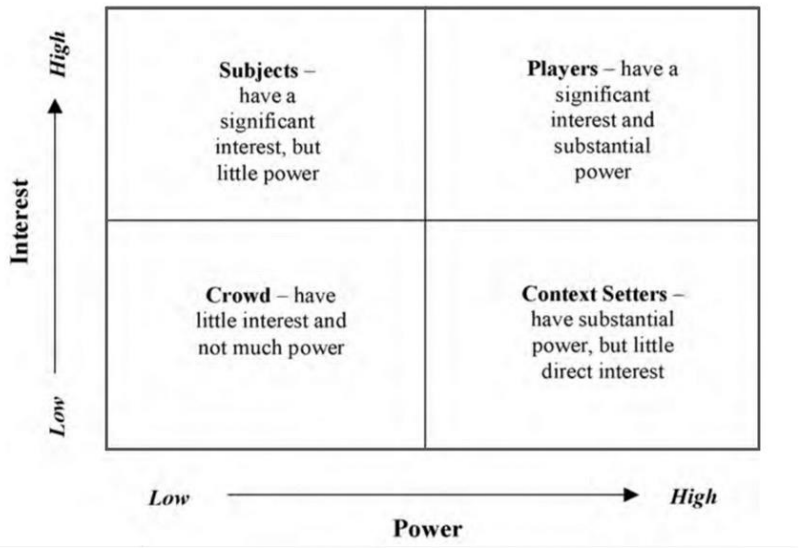

Figure 10: PI grid for stakeholders (Ackermann & Eden, 2011)

4.6.1 Players

In implementing green roofs, the primary stakeholder is the housing association itself. Without the housing association, it is not possible to implement a green roof on the building; they will always be part of the complex system and decision-making process. Housing associations are engaged in making buildings more sustainable to reduce energy consumption and improve energy labels.

In addition to housing associations, the Municipality of Amsterdam is crucial. Various policies need to be implemented by the municipality to stimulate adoption. Furthermore, the municipality aims to increase the city's greenery, make it climate-adaptive, and ensure the city's liveability. In 2022 and 2023, there was no subsidy for green roofs, which may have affected implementation. Apart from encouraging green roofs, the Municipality of Amsterdam can also enact legislation, perform a supervisory role, and set the right example.

Everything which has to do with water is done by the Water boards. The Amstel, Gooi, and Vecht Water Board (AGV) can also introduce incentive schemes. The water board is responsible for water levels, drainage, and water quality and thus has a direct interest in implementing green roofs. This direct interest stems from the water retention capacity of green roofs; if water can be retained on roofs rather than immediately drained into the sewage system, it can alleviate pressure on drainage systems. In Amsterdam, a split was made within the AGV water board in 1997 (Quené, 2023), resulting in the establishment of the Waternet foundation. Waternet is the joint executive agency of the Municipality of Amsterdam and the water board. The secretary of AGV does not hold the highest authority at Waternet. Amsterdam has delegated its tasks to the general director of Waternet. This individual is the highest authority and therefore controls the tasks of the water board and their priorities. Thus, Waternet not only has an executive role but has also acquired a political or policy-forming function.

4.6.2 Context Setters

The policy regarding green roofs is mainly determined at the local level. Therefore, the Dutch government does not have a direct stake in co-governance and decision-making. However, the government does have the power to intervene, introduce new subsidies, establish regulations, and influence local authorities. This research does not consider the national government.

4.6.3 Subjects

Within the context of green roofs, several organisations are dedicated to creating a climate-adaptive city, including the installation of green roofs. One such organisation is Weerproof Amsterdam. Weerproof Amsterdam is an initiative of the Municipality of Amsterdam and Waternet aimed at preparing the city for climate change. Weerproof Amsterdam operates as a network approach within the Climate Adaptation Amsterdam program but does not have direct authority to implement policies. However, Weerproof influences residents and professionals, builds networks, and organizes events. While Amsterdam Weerproof has some influence in the city, it lacks direct decision-making power.

Additionally, Rooftop Revolutions is an organisation present throughout the country, including Amsterdam. Rooftop Revolutions provides advice to property owners on greening roofs, supports governments in achieving their climate adaptation goals, and assists residents in improving their views. While the organisation cannot change policies, it can encourage initiative and share knowledge among stakeholders.

For the installation of green roofs, there are various options, but for larger roofs, it is often done by installation companies. These companies have a direct economic interest in installing green roofs. Associated with these installation companies are the suppliers of materials. This combination of parties is referred to as the supply side. On the supply side, it

is important to be able to install green roofs, to lobby for and promote subsidies, but also to provide information to stimulate the implementation of green roofs.

4.6.4 Crowd

The only ones who could be categorized here are the residents of the housing association's buildings. These residents benefit from the improvement of the living environment, quality of

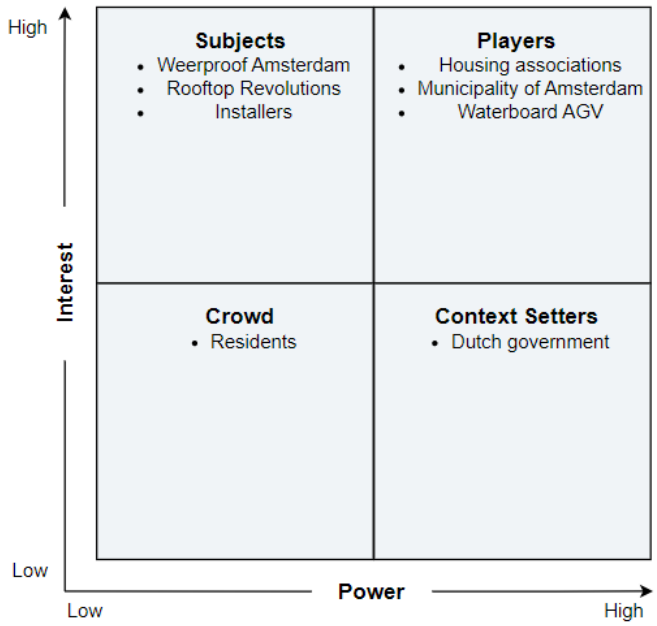

Figure 11: PI grid for the case of housing associations in Amsterdam

living, and cooling in the summer. However, the residents do not have direct influence and their primary interest will not lie in the installation of green roofs.

4.7 RESILIO Project and Green Roof Initiatives:

The RESILIO project, a collaborative effort between the Amsterdam municipality, Rainproof Amsterdam (now Weerproof), Rooftop Revolution, and housing associations, is explored in this section. We examine the objectives, outcomes, and implications of the RESILIO project.

RESILIO stands for 'Resilience nEtwork of Smart Innovative cLImate-adapative rOoftops'. The RESILIO project ran from 2018 to 2022 and was a collaboration between the municipality of Amsterdam, Waternet, MetroPolder Company, Rooftop Revolution, HvA, VU, Stadgenoot, de Alliantie, and De Key. The project was co-financed by the ERDF fund of the European Union through the Urban Innovative Actions program.

The RESILIO project focuses on testing blue-green roofs (BG roofs) as a solution for making the city climate-adaptive. Here, "blue" refers to a water retention roof. The project centred on various research themes, including:

- The cooling effect.
- Water conservation and evaporation
- Solar panel efficiency
- Interaction between solar panels and plants

Additionally, the project explored how to create a business case for blue-green roofs. This involves transfer mechanisms for the identified costs and benefits. Appendix C describes the various transfer mechanisms identified by RESILIO. RESILIO identified three categories under which these transfer mechanisms fall:

1. Co-investment
2. Enhancing BG roof benefits
3. Reducing costs

Although this project realized 3000m² of BG roof on private property, there are still not many owners in the market implementing this innovation. By installing more BG roofs, people can see the results and will likely be motivated to install more. Additionally, applying for the subsidy was complicated due to the required technical details. This can be addressed by opening a ‘roof counter,’ a central place where owners can seek assistance.

5 Policy Situation

The existing policy situation was collected in two different ways: first, through desk research, where various policy documents, vision documents, and environmental policies were qualitatively studied, and then through interviews with policy officers from the municipality of Amsterdam and Waternet. By applying these two methods, a good overview was obtained regarding the different policies already in use. In this chapter the current policy situation is further elaborated based on the policy categories of the Behaviour Change Wheel. In table 11 an overview of the different policies which are currently in place is given. Policy categories are broader measures that enable or support intervention functions by creating a favorable environment or framework. These are often implemented at the institutional, community, or governmental level.

Policy Category	Policies
Fiscal Measures	Verhuurdersheffing (Landlord Levy)
Guidelines	Green Deal Groene Daken Nationaal Dakenplan Weerproof
Environmental / Social planning	Omgevingsvisie Groenvisie 2050 Welstandsnota Isolation Push
Communication / Marketing	N/A
Legislation	Wet Betaalbare Huur (Affordable Rent Act) Regional Obligation
Service Provision	Daken Kansenkaart (Roof Opportunities Map)
Regulation	BENG BREAAM

Table 11: Existing policy categories

5.1 Policy Categories

5.1.1 Fiscal Measures

The “Verhuurderheffing” (Landlord Levy) introduced in 2014 entailed a levy targeting landlords of rental homes in the regulated sector, specifically homes with rents below the rent allowance threshold (for 2021: €753.33). The levy was calculated based on the value of the rental properties (Verhuurderheffing, n.d.). Since housing associations largely own such properties, and the levy significantly increased due to rising housing prices, it became difficult for these associations to invest in anything beyond essential needs, such as green roofs (Municipality #2). However, the “Verhuurderheffing” was abolished in 2023 (Kamerstukken I, 2022, 36129, nr. 529, p. 1). As Minister De Jonge for Housing and Spatial Planning stated: “We face great challenges that we can only tackle together. By abolishing the Verhuurderheffing, housing associations will have more investment capacity to fulfil their mission: building more new affordable homes, accelerating the sustainability of the housing stock, and ensuring lower housing costs” (Ministerie van Binnenlandse Zaken en

Koninkrijksrelaties, 2022). As Municipality #2 also indicates, the abolition of the “Verhuurderheffing” will allow housing associations to focus on more than just green roofs. The financial space that becomes available must be invested in sustainability, addressing overdue maintenance, and constructing new homes.

5.1.2 Guidelines

From the *Green Deal Groene Daken* (2014 to 2019), the *Nationale Dakenplan* was developed through a subsidy from the national government (Municipality #2). The *Nationale Dakenplan* has established various standards, procedures, and methods for installing multifunctional and green roofs. This initiative was developed by the private sector in collaboration with various water boards and municipalities (Kennisbank Nationaal Dakenplan, n.d.).

Several spin-offs have emerged from the *Nationale Dakenplan*, such as WeerProof in Amsterdam (Municipality #2). Although WeerProof plays a significant role in Amsterdam as a discussion partner for climate adaptation strategies (Housing Association #2), it is still unclear, according to Municipality #3, how the customer (housing association, company, or individual) can make a well-informed decision. WeerProof, along with the municipality of Amsterdam and Waternet, could play a better role in indicating the right timing for implementing transition tasks, integrating them with activities such as maintenance, major renovations, demolition, or new construction (Municipality #2).

5.1.3 Environmental / Social planning

Within the municipality of Amsterdam, various policy documents address the spatial planning of the city. The most important and almost always leading document is the Omgevingsvisie 2050 (Environmental Vision 2050) (Gemeente Amsterdam, n.d.-b). This document provides a broader perspective on Amsterdam's environment. It encompasses several components, including the Omgevingsplan (Environmental Plan), the Hoofdgroenstructuur (Main Green Structure), and the Welstand (aesthetic guidelines). This policy framework focuses on green structures with a function that extends beyond individual neighbourhoods. Relatively small green structures, such as green roofs, are not included in this policy framework. For green roofs or smaller green structures, the Groenvisie 2050 (Green Vision 2050) is utilized (Huisman & Wijten, 2020).

Omgevingsplan

Part of the Omgevingsvisie 2050 is the Omgevingswet (Environmental Law), which came into effect on January 1, 2024. This law establishes the Omgevingsplan (Environmental Plan) for the entire territory (Gemeente Amsterdam, n.d.). The Omgevingsplan determines the spatial planning of the general rules for organizing the territory of the municipality of Amsterdam. An example is the stormwater ordinance. The *Hemelwaterverordening* (stormwater ordinance) stipulates that new buildings and existing buildings undergoing major changes after May 11, 2021, must have stormwater storage of 70 litres per square meter of built area (Omgevingsplan Amsterdam, 2022, p. 74). Due to this regulation, green roofs are often installed, although it is not strictly necessary (Municipality #1).

The *Hemelwaterverordening* also specifies exceptions. For buildings designated for "Business and Administrative Services," a green roof with a water storage capacity of 30 litres per square meter is sufficient (Omgevingsplan Amsterdam, 2022, p. 75).

Groenvisie 2050

The Groenvisie (Green Vision) 2050 document serves as a roadmap towards a resilient city by 2050. Amsterdam emphasizes the importance of green spaces in protecting the city against drought, heatwaves, and extreme rainfall. The introduction highlights opportunities on facades, rooftops, and in gardens, which should be better utilized to enhance biodiversity. The Groenvisie aims to achieve a balance between greenery and infrastructure, nature and recreation, as well as between people and animals. It envisions Amsterdam as a green city and outlines steps to further green the city from now until 2050, including:

- Green routes: Ensuring that within 10 minutes of walking from any doorstep, one can reach a park, and within 15 minutes of cycling, a natural area (Huisman & Wijten, 2020).
- Green by default: Prioritizing green over tiles, bricks, and asphalt wherever possible, creating natural environments conducive to social interaction (Huisman & Wijten, 2020).
- Public and accessible green spaces: Making allotment gardens, sports parks, and school gardens more accessible to a broader population (Huisman & Wijten, 2020).
- Landscape parks: Developing rugged natural areas, food forests, and increased opportunities for physical activity around the city (Huisman & Wijten, 2020).
- New forests and parks: Establishing a new urban forest and additional city parks (Huisman & Wijten, 2020).

Furthermore, a crucial aspect of the vision is promoting greenery within neighbourhoods and enhancing their green spaces, including (Huisman & Wijten, 2020):

- Diverse green spaces for all residents.
- Green solutions that address various challenges.
- Designing and managing the city to include nature.
- Collaborative efforts towards green initiatives.

The document identifies four key levels of focus: Green buildings and plots, Neighbourhood green spaces, park areas, an city landscape integration. The Groenvisie 2050 aims to translate its ambitions and principles into policy frameworks and practical implementations. Steps include translating these goals into district practices, updating green standards, integrating the Hoofdgroenstructuur (HGS) into the 2040 structural vision and environmental strategy, incorporating natural elements into new construction, and outlining guidelines for allotment gardens (Huisman & Wijten, 2020).

While the document primarily outlines Amsterdam's ambitions for greening the city and preparing for climate resilience, it does not directly detail how these will translate into further policy documents. However, green roofs are recognized as integral to creating a biodiverse, nature-inclusive, and liveable city.

Welstandsnota

Within the municipality of Amsterdam, the quality of the built environment is highly valued; it is in the public interest to handle this environment with care. The Welstandsnota De Schoonheid van Amsterdam (Aesthetic Guidelines of Amsterdam) is intended to assess and implement building plans according to reasonable requirements (Commissie Ruimtelijke Kwaliteit - Welstandsnota, n.d.). The Welstandsnota sets criteria based on the type of roof where the green roof is to be installed (Gemeente Amsterdam, 2016, p.92):

1. Flat or slightly sloping roofs:
    a. Maximum slope of 25 degrees
    b. Any parapet for a thicker roof package must be placed at least 1 meter plus the thickness of the package from the roof edge.
2. Sloping roofs:
    a. Not on tiled roofs, slate roofs, or roofs with similar finishes
    b. Not prominently visible from public spaces
3. Monuments:
    a. Only allowed if the architectural or monumental values are not affected.

Whether the Welstandsnota has a significant impact on the installation of green roofs is debatable. Housing Association #2 indicates that green roofs are generally not visible from the street, so the impact is likely minimal. On the other hand, Municipality #3 suggests that issues could arise with fencing or roofs transitioning to more usable rooftop spaces, emphasizing that aesthetic considerations should still be met.

Isolation push

With the abolition of the “Verhuurderheffing” (Landlord Levy), agreements have been made to insulate various rental properties owned by housing associations. The goal of action line 2 in the National Insulation Program is to have landlords make 1 million rental homes more sustainable. This also involves phasing out poor energy labels. Housing associations are required to improve the poor energy labels of approximately 675,000 homes across the Netherlands by 2028 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024). The abolition of the “Verhuurderheffing” (Landlord Levy) frees up 1.7 billion euros annually to invest in various challenges, including insulation and improving the liveability of neighbourhoods (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024a).

5.1.4 Communication / Marketing

According to Municipality #1, the renewal of the subsidy is announced through official channels, but residents do not typically read these. To raise awareness about the subsidy, the news channel AT5 has been engaged to further promote its visibility (Municipality #1). This indicates that some efforts are being made to publicize the new subsidies.

5.1.5 Legislation

According to Municipality #3, the Affordable Rent Act (Wet Betaalbare Huur) will play a significant role for housing associations. This law regulates the mid-rent segment. Currently, the law is being considered in the Senate, and there is a possibility that it will be implemented (Wet Betaalbare Huur (36.496), n.d.). The rent price in this segment will be based on a points system. Points are awarded for outdoor space (Municipality #3), but the Policy Book on Valuation System for Independent Housing does not mention green roofs or how they can contribute to the points (Huurcommissie, 2024).

Within the municipality of Amsterdam, legislation is also conducted on a neighbourhood basis. The areas of De Pijp and Willemspark/Vondelpark require a green roof to be installed when new extensions or constructions are carried out (Gemeenteblad 2023, 538788 | Overheid.nl > Officiële Bekendmakingen, 2023). In Oost, it is stated that cooperation will be given if a green roof conflicts with the zoning plan (Gemeenteblad 2018, 198876 | Overheid.nl > Officiële Bekendmakingen, 2018).

5.1.6 Service Provision

In addition to urban planning, there is also the Daken Kansenkaart (Roof Opportunities Map). This is an existing tool developed by Rooftop Revolution in collaboration with the government. This tool is seen as a way to visualize the possibilities for roofs, including green roofs (Municipality #2).

The Daken Kansenkaart allows users to see what can be done with roofs to further promote sustainability. It not only considers green roofs but also water retention roofs, solar panels, or combinations of these options. Although the Daken Kansenkaart is still in its beta version, it can serve as a method for helping in planning the use of rooftops (Rooftop Revolution, 2021).

5.1.7 Regulation

BENG

For all new buildings, since January 1, 2021, all permit applications must comply with the Nearly Zero-Energy Buildings (BENG) standards. The European Energy Performance of Buildings Directive (EPBD) forms the basis of these requirements (Energieprestatie - BENG, 2017). BENG sets the maximum energy demand in kWh per m², including heating and cooling. For green roofs, the indoor temperature of a building is most relevant.

Well-insulated buildings are designed to retain heat as efficiently as possible, which can lead to high indoor temperatures, posing health risks and causing discomfort (Energieprestatie Indicatoren - BENG, 2017). To mitigate this risk, the TOjuli indicator is used. This indicator measures the risk of overheating and assesses whether it remains acceptable. One of the potential measures suggested in the Factsheets Koudetechnieken is the installation of extensive green roofs (Factsheets Koudetechnieken, 2020).

BREEAM

BREEAM, a sustainability assessment method for buildings, integrates green roofs as a key aspect of environmentally friendly design strategies. Green roofs help achieve higher BREEAM scores by meeting criteria related to energy efficiency, water management, and ecological value. They fit within BREEAM categories such as Land Use and Ecology, and Water, and support broader sustainability goals. By incorporating green roofs, developers and architects can meet stricter environmental requirements and contribute to a more sustainable urban environment, resulting in a more holistic approach to sustainable building according to BREEAM standards (BREEAM, n.d.).

5.2 Intervention Functions

Currently, several interventions are in place, though not every intervention function is present. Below, the various existing interventions are categorized and further explained. Intervention functions are designed to bring about behaviour change (Michie, S., 2011). Intervention functions are direct mechanisms used to change behavior in individuals or groups. They specifically focus on influencing people's motivations, capabilities, and opportunities to act.

Intervention Function	Intervention
Environmental restructuring	N/A
Restrictions	N/A
Education	Events of Weerproof RESILIO
Persuasion	N/A
Incentivisation	Subsidy
Coercion	N/A
Training	N/A
Enablement	N/A
Modelling	Map green roofs

Table 12: Current intervention functions

5.2.1 Education

As mentioned in Chapter 4, Weerproof was established by the municipality of Amsterdam to make the city climate adaptive. Weerproof is used by housing associations as a discussion partner (Housing Association #2) and organizes events to introduce housing associations to climate-adaptive measures, including green roofs. The effectiveness of this approach is evident, with housing associations such as Rochdale, Ymere, De Alliantie, and Eigen Haard being partners (Nieuwsoverzicht - Weerproof, 2024). For housing associations interested in installing green roofs, Weerproof also provides knowledge to implement green roofs (Housing Association #2). Weerproof assists in discussing initial options, but for more detailed projects, housing associations are referred to providers such as Dakdokter, Groene Loket, Rooftop Revolution, or SolarSedum (Aan De Slag Met Groene Daken - Weerproof, 2024). Weerproof also meets with housing associations four times a year to discuss potential measures, encourage the installation of green roofs, and promote the new subsidy (Municipality #1, #4, #5).

Different government bodies Invest in housing associations by fostering collective knowledge development and providing actionable perspectives without pushing too hard, in order to include the older generations within the housing associations (Municipality #2). It has been observed that younger employees of housing associations often possess this knowledge, while the older generations tend to be more conservative. This broadening of knowledge is also achieved by setting up communities of practice and involving employees in thinking about climate-adaptive actions (Municipality #2).

The RESILIO project is a pioneer in the field of blue-green roofs, initiated to research and learn from the installation of such roofs throughout the city. Although RESILIO focuses on blue-green roofs, the project has also initiated a learning trajectory for various housing associations regarding green roofs (Housing Association #3, Housing Association #4). Additionally, a report has been created detailing the lessons learned from the research and highlighting key considerations for starting such a project.

5.2.2 Incentivization

Since April 2024, the Municipality of Amsterdam has introduced a new subsidy for green roofs. This subsidy targets all roofs 30m2 and larger, requiring a minimum water retention

capacity of 30L per m2 and biodiverse planting. This means that individuals, homeowners associations (VvE), housing associations, and businesses can apply for the subsidy. Therefore, the subsidy is not specifically aimed at housing associations (Municipality #1). Currently, there are few criteria attached to the success rate of the existing subsidy scheme. The primary goal is for the subsidy to be utilized before its term expires, preferably just before a new allocation (Municipality #1). If the subsidy fund depletes quickly, it suggests that stricter criteria could have been applied. Conversely, if the fund remains unused, it may indicate overly stringent criteria or insufficient publicity (Municipality #1). It is noted that the subsidy does not target a specific demographic; thus, benefiting one group may disadvantage another (Municipality #1).

5.2.3 Modelling

Amsterdam has been a leader in promoting green roofs in the Netherlands (Municipality #2), with subsidies available since 2016 (Housing Association #1), and existing green roofs in the city. Many of these roofs are still unknown, prompting current efforts to create a map that catalogues all green roofs in Amsterdam (Municipality #3). This initiative aims to showcase the city's efforts and motivate others to take similar steps. Municipality #3 emphasizes Amsterdam's role as a pioneer in promoting green roofs, noting a recent allocation of €150 million to invest in municipally owned real estate (Municipality #3).

6 Influencing Factors

This chapter outlines the different components of the Theoretical Domain Framework. These are categorized under the COM-B model as described in the theoretical framework. The results are derived from various interviews and coded according to the coding document.

During the interviews, it becomes clear that two domains predominantly play a role in determining behaviour. It is noticeable that the environmental context and resources exert the greatest negative influence, followed by goal setting, on the implementation of green roofs. The most mentioned factor that positively influences is reinforcement, which includes subsidies, possible rewards, and potential sanctions. Knowledge can contribute positively to or negatively affect implementation, depending on its presence within the housing associations.

6.1 Capabilities

Encompasses the skills and knowledge needed to exhibit certain behaviours. Components such as knowledge, skill, and memory play a significant role. Only skill is related to the physical component of capabilities; the other three components affect the psychological aspect. Below, the different components are further elaborated (Michie et al., 2011). Table 13 presents an overview of the times certain factors have been quoted by different stakeholders, a summary of the quotes is also given.

		COM-B section		Housing Association			Municipality		
				+	-	0	+	-	0
1.1.1	Skills	C-Physical	+Present in two out of four housing associations, by collaborating with partners - N/A 0 N/A	3	0	0	0	0	0
1.1.2	Knowledge	C-Psychological	+ Knowledge is present at two out of four housing association, one without knowledge actively tries to increase knowledge - Two out of four housing associations do not know how to implement 0 Grouping green roofs and green facades under the same header	6	5	2	1	0	0
1.1.3	Memory, attention and decision processes	C-Psychological	associations - Two out of four do not have policies surrounding green roofs for existing buildings, and the other two say it is last on their list of priorities 0 Subsidies which stopped resulted in green roofs being less top of	1	2	5	0	0	0
1.1.4	Behavioural regulation	C-Psychological	+ One housing association tries to raise awareness - Renovation of exisiting buildings is traditional attwo out of four housing associations and according to the municipality 0 N/A	1	2	0	0	1	0

Table 13: Results of capabilities from interviews

6.1.1 Skills

Limiting factors

No components have emerged that could be a limiting factors from this domain.

Enabling factors

As mentioned earlier, the organisation mentioned by Housing Association #3 is ahead in installing green roofs. Here, the skill to implement and execute green roofs is present. This organisation, and the organisation of Housing Association #4, collaborates with roofing partners who advise on whether or not to install a green roof. This skill to judge, as well as to implement, has helped the organisation for a long time in installing high-quality green roofs.

6.1.2 Knowledge

Limiting factors

Overall, it becomes clear from the interviews that housing associations lack knowledge about green roofs. For instance, Housing Association #2 indicates that there is no knowledge whatsoever within the organisation regarding green roofs, and green walls and green roofs are grouped together as a knowledge segment (Housing Association #1). Additionally, it is mentioned that there is some unfamiliarity within the organisation regarding green roofs (Housing Association #1). The absence of knowledge is also reiterated by Housing Association #2, who states that awareness and knowledge are lacking.

Enabling factors

On the other hand, it appears that in some places, knowledge is indeed present. For example, Municipality #2 from a governing body states that the right expertise can indeed be found within housing associations; this person works and interacts with these employees. This is also reflected in Housing Association #2, where despite indicating a lack of knowledge, efforts are being made in collaboration with Wageningen University to improve knowledge within the organisation. The organisation mentioned by Housing Association #3 seems to be ahead; green roofs have been implemented here for a long time, and in the interview, it is stated that they and their partners certainly possess the knowledge to install green roofs. How the knowledge is spread throughout the organisation is also confirmed by Housing Association #4. Partners know how to install it and make recommendations, which are then reviewed by the housing association.

6.1.3 Memory, attention and decision processes

Limiting factors

Most housing associations do not have policies for green roofs (Housing Association #2), which means that no attention is given to implementing them. Climate adaptation, including green roofs, is not a theme within the organisation (Housing Association #1), and it is not top-of-mind for building managers. Housing Association #3 states that while there used to be a policy for installing green roofs, the current status of the policy and implementation is unknown since the subsidy was changed. Attention seems to have diminished since the subsidy was discontinued (Housing Association #3). Housing Association #4 also stated that installing a green roof is last on the list of priorities.

Enabling factors

However, green roofs are installed; even where there is no policy, as noted by Housing Association #2. This is done in new construction projects. In new construction projects, there is a focus on applying green roofs, albeit as a last resort. This is used as a closing post. This may be related to the influences of regulations (Municipality of Amsterdam 2016). Housing Association #3 states that the policy to install green roofs on visible roofs has led to more green roofs being installed. It also happens that a green roof is installed when there is heat stress, but this is only done if the roof also needs renovation (Housing Association #4).

6.1.4 Behavioural regulation

Limiting factors

The renovation of buildings by housing associations is kept quite traditional, and perhaps even somewhat conservative (Housing Association #1, Housing Association #4, Municipality #2). Therefore, it does not go beyond replacing the existing roofing and painting the window

frames. Out-of-the-box thinking is also not applied in the renovation part (Housing Association #1).

Enabling factors

Efforts are being made to change this; for instance, Housing Association #2 states that they are working on raising awareness about green roofs, how to implement them in current processes, and how to look at renovating the existing housing stock differently.

6.2 Opportunity

Several components in the external environment influence the behaviour of housing associations. These external environments, social influences, and possible resources are part of the opportunity that can influence behaviour negatively or positively (Michie et al., 2011). Table 14 presents an overview of the times certain factors have been quoted by different stakeholders, a summary of the quotes is also given.

		COM-B section		Housing Association			Municipality		
				+	-	0	+	-	0
1.2.1	Social influences	O-Social	+ Residents who ask for green roofs is motivating three out of four housing assoications - Builders see green roofs as a delaying factor in new construction 0 N/A	3	2	1	0	0	0
1.2.2	Environmental context and resources	O-Physical	+ New construction has enough funds for green roofs, allocation of resources is an enabling factor - Investment costs is the biggest limiting factor, in existing construction also the carrying capacity. 0 N/A	2	8	5	1	2	1

Table 14: Results of opportunities from interviews

6.2.1 Social influences

Limiting factors

In new construction, but also in renovation, the role of the builder plays a significant role. It is stated that builders consider green roofs, and greenery in general, a delaying factor in the construction process and therefore do not view implementation positively. Additionally, it is stated that it is an obligation (Housing Association #2). In addition, for renovation projects, it is necessary to ensure that a majority of residents are positive about the plans; this participation process delays the renovation process and thus the implementation of green roofs (Housing Association #1).

Enabling factors

However, Housing Association #1 sees a positive rhythm within the organisation, and everyone is positive about sustainability, which in this study also includes green roofs. This positive attitude towards green roofs can also be found among residents, except that participation can be slowing down. Residents can also request green roofs themselves, which is why implementation occurs more frequently (Housing Association #3, Housing Association #4). In addition, the interest of residents can lead to community building if there is access to green roofs. This access can lead to a group feeling that contributes to a better living environment and tenants who stay longer (Housing Association #2).

6.2.2 Environmental context and resources

Limiting factors

The installation of a green roof involves a considerable investment, as mentioned earlier, the cheapest green roof still costs €50 to €80 per square meter (Milieu Centraal, 2022). Sufficient funds must be available to make this investment, which is a common problem (Housing

Association #1, Housing Association #2, Municipality #2, Municipality #3, Housing Association #4). In many cases, available resources must also be invested in another challenge, namely improving the energy label. Due to the various goals and the allocation of these resources, money is often the underlying challenge (Housing Association #2, Municipality #2, Housing Association #4).

These different goals and different issues are also expected by the municipality of Amsterdam according to Housing Association #2. For example, there are different departments with different conflicting interests. This can be difficult for housing associations, as they must choose which goal they pursue. This is especially evident in the case of monumental buildings; due to the complexity of regulations, aesthetics, and heritage, it is difficult to make these buildings sustainable or install a green roof (Housing Association #1).

Furthermore, the construction of the building poses problems. For example, Municipality #2 indicates that in many existing buildings, especially those from the 1950s, there are often no correct construction calculations or drawings available. This makes people reluctant to take alternative measures. Moreover, sometimes the weight of the green roof is too great to safely lie on the roof structure of buildings (Housing Association #2, Housing Association #3, Housing Association #4).

Additionally, the fate of existing residential complexes is discussed in consultation with the municipality. If it is decided that a complex will be sold, the housing association will not invest in it. Conversely, if it is determined that the complex will remain in the portfolio, investments will be made. Unfortunately, the municipality is currently slow in making policy decisions, which prevents the housing association from making informed choices (Housing Association #4).

Enabling factors

In project development and new construction, the situation is different; there is enough money available here to realize green roofs or other nature-inclusive construction projects (Municipality #2). This is partly due to the need to comply with regulations but also to the separation between new construction and maintenance within housing associations (Municipality #2).

In addition, housing associations also have various parties with whom they speak to develop policies, seek advice, and present issues. For example, Housing Association #1 indicates that they speak with Wageningen University to monitor and improve policies and that in Amsterdam, the organisation "Weerproof" was set up to serve as a discussion partner for housing associations and other parties (Municipality #2, Housing Association #2).

6.3 Motivation

Under motivation, we categorize reflective processes and automatic processes. These processes are subdivided into different segments described below. Table 15 presents an overview of the times certain factors have been quoted by different stakeholders, a summary of the quotes is also given.

		COM-B section		Housing Association			Municipality		
				+	-	0	+	-	0
1.3.1	Social/Professional role and identity	M-Reflective	+ Housing association should provide liveable housing - The primary goal of a housing association is affordable housing 0 N/A	1	4	0	1	0	0
1.3.2	Beliefs about consequences	M-Reflective	+ Green roofs add value to property - Additional costs when there are lekkages 0 Smart system is expensive	6	5	2	1	3	0
1.3.3	Optimism	M-Reflective	+ Green roofs are seen as complicated for exisiting buildings - N/A 0 N/A	0	2	0	0	0	0
1.3.4	Intentions	M-Reflective	+ For new construction the architect decides, which are more inclined to add green roofs - One housing association say green roofs are not adopted in policies 0 N/A	2	1	0	0	0	0
1.3.5	Goals	M-Reflective	+ Long term goal is climate adaption - All housing associations, and municipalities say the primary goal is the energy transition. Most resources are used for this purpose 0 N/A	4	13	0	0	1	0
1.3.6	Beliefs about capabilities	M-Reflective	+ N/A - Perceive the implementation difficult for rents and current goals 0 Initiative is from project developer	0	4	1	0	0	0
1.3.7	Reinforcement	M-Automatic	+ Increase liveability, easies to pass heat stress test and legislation for new constructions - Green roofs do not provide additional RC-value and most benefits are not quantified 0 N/A	8	4	1	0	0	0
1.3.8	Emotion	M-Automatic	+ Subsidy feels as doing something together with society - Fear for leakages 0 N/A	1	1	0	0	3	0

Table 15: Results of motivations from interviews

6.3.1 Social/Professional role and identity

Limiting factors

Various housing associations all indicate that the primary function of housing associations is to offer affordable housing. Adding a green roof, although it improves the living environment, results in higher costs that they cannot pass on to tenants (Housing Association #1, Housing Association #2, Municipality #2, Housing Association #3). Additionally, housing associations mainly see the benefits of green roofs going to the municipality or Waternet, not necessarily to the housing association itself (Housing Association #3). The lack of responsibility also results in a poorer implementation of green roofs.

Enabling factors

However, a green roof does improve the living environment, which contributes somewhat (Municipality #2). Additionally, green roofs are often implemented from a social perspective (Housing Association #4).

6.3.2 Beliefs about consequences

Limiting factors

Housing associations have different beliefs about what happens after a green roof is installed. For Housing Association #3 and Housing Association #4, an important factor is that it is difficult if a leak occurs; according to the interviewee, the entire construction must be removed to find the leak. Additionally, there are many unknowns that are classified as risks (Municipality #2), housing associations find it expensive (Municipality #2, Municipality #3) while receiving less in return (Housing Association #3). This leads to increased costs, and the return seems lower. Housing Association #3 indicates that they are perceived as

underperforming while spending more, so you get less in return. Additionally, Housing Association #4 considers the increase in property value due to a green roof irrelevant in Amsterdam, as the housing market does not account for this due to its oversaturation.

Enabling factors

Housing Association #1 has a different view on the return; here, it is stated that green roofs add more value to a property and that green roofs help with cooling when a heat wave occurs (Housing Association #3). Additionally, Housing Association #4 sees the value in protecting the roofing material, as its lifespan is extended by shielding it from the sun.

6.3.3 Optimism

Limiting factors

Due to the weight and complexity of blue-green roofs, it is too difficult to implement them on existing buildings. This also applies to smaller green roofs (Housing Association #3). When renovating roofs, the roofers complain about green roofs and rather not have them installed on flat roofs while it creates a problem in case of leakages (Housing Association #4)

6.3.4 Intentions

Limiting factors

Housing Association #2 indicates that new policy is currently being developed for climate adaptation, but green roofs are not included in this. This differs from Housing Association #3, where green roofs are part of the policy but more as an addition rather than a requirement. This planning process is also evident with Housing Association #4, where long-term maintenance plans consider whether a green roof will be installed or if only renovations will be carried out, financially it has to make sense.

Enabling factors

Although the housing association does not have specific policies regarding green roofs, it is up to the architect to install a green roof. This happens in new construction, but it's more of a trend in architecture rather than driven by housing associations (Housing Association #1).

6.3.5 Goals

Limiting factors

Housing associations are currently burdened with improving poor energy labels (Housing Association #1, Housing Association #2, Municipality #2, Housing Association #3, Housing Association #4). Poor energy labels here refer to E-F-G. Green roofs do not contribute to improving energy labels, creating a conflict of interest (Housing Association #3). The goal to improve poor labels leads to priorities on insulation (Housing Association #3), a primary focus on energy transition (Housing Association #1, Housing Association #4), and a preference for solar panels over green roofs (Housing Association #2, Housing Association #4). For this reason, Housing Association #2 also states that climate adaptation, including green roofs, has been postponed and is not a priority. First, stop the leak before mopping up the water (Housing Association #2).

There are also no agreements on climate adaptation in the performance agreements with the municipality; there's just a mention in one sentence, and in the next three (Municipality #2). This reflects that the goal is not to work on climate adaptation measures, resulting in green roofs lagging behind.

Enabling factors

Although short-term goals do not focus on climate adaptation, it is noted that something needs to be done in the coming years (Housing Association #2). This is because something has not been done well in recent years. Additionally, the long-term goal to be CO2 neutral by 2050 is a driving force behind climate adaptation (Housing Association #1).

6.3.6 Beliefs about capabilities

Limiting factors

When a property's value increases, for example by installing a green roof, rental prices would normally be raised. This is not possible at housing associations (Housing Association #1). Additionally, it's firmly stated that nothing more can be rented out if energy labels are not increased, so with low energy labels, this would encourage housing associations to increase the labels (Housing Association #3). Another issue identified is that the municipality wants conflicting things. This is not feasible (Housing Association #3). Additionally, the Amsterdam Metropolitan Region discussed an intent statement for climate adaptation, but Housing Association #2 indicates that this housing association did not sign it due to its ambitious and unrealistic goals.

Enabling factors

Especially in new construction, there is an increasing number of green roofs, which lies with the project developer or architect. The perception that this is happening and going well contributes to further implementation (Housing Association #2, Housing Association #1).

6.3.7 Reinforcement

Limiting factors

According to Housing Association #1, the biggest issue is that green roofs do not provide an additional thermal resistance (RC value). This is what housing associations are currently focused on, and other housing associations also suggest this as a good solution to stimulate green roofs. Quantifying favourable side effects has not been done yet, so there is no extra incentive to install green roofs (Housing Association #1, Housing Association #3). Additionally, without subsidies, it's not financially feasible for many housing associations (Housing Association #2, Housing Association #3).

Enabling factors

If green roofs have a positive impact on residents, this can be beneficial, such as contributing to a better view from visible roofs (Housing Association #3, Housing Association #1). Additionally, existing legislation in new construction, such as rainwater ordinances, heat stress tests, and other adaptation legislation, also positively influence the installation of green roofs (Housing Association #2, Housing Association #3).

6.3.8 Emotion

Limiting factors

The novelty of water buffering is new and exciting for many people. This is because the roof is seen as a roof and not as storage space (Housing Association #2). Additionally, getting and keeping it waterproof is a tense matter for residents in buildings; if it leaks, everyone is affected (Municipality #2, Housing Association #2, Housing Association #4).

Enabling factors

The existing subsidy was seen positively, not necessarily because it covered costs but because it resulted in a shared sense of responsibility (Housing Association #3).

6.4 Key findings

Participants from housing associations involved in the study reported that the implementation of green roofs is rare in existing buildings. A mix of physical opportunities, reflective motivation, and psychological capability plays a role in this. Housing associations are generally open to the idea of implementing green roofs. However, although they are somewhat engaged with green roofs, they do not prioritize them, face resource shortages, and sometimes encounter policy barriers.

Implementing green roofs in existing buildings is particularly challenging. In contrast, the process seems to proceed smoothly with new constructions. This section focuses on key findings related to existing buildings unless explicitly stated otherwise.

6.4.1 Current obstacles and drivers

Reflective Motivation

The primary influence stems from the focus of current policies. Housing associations have agreements with both municipal and national governments to work towards energy transition. This transition mainly emphasizes insulation and reducing energy consumption. As Housing Association #2 put it, "first fix the leak before mopping the floor." The agreement is to phase out poor energy labels (E, F, G) by 2028. These poor labels are always associated with existing buildings. If this is not achieved, housing associations have to reduce rents of properties with poor labels (Municipality #3, Housing Association #4). Due to this pressure and the scale of the task, housing associations focus on insulating buildings, installing solar panels, and adjusting heating systems. Every available euro is invested in improving the energy labels. This focus and the set goals hinder the implementation of green roofs in existing buildings. This is also reflected in the policies of housing associations; most lack policies on climate adaptation, let alone green roofs (Housing Association #2).

Additionally, the role of housing associations in society has significantly changed. Previously, housing associations were responsible for the entire residential area, not just individual homes (Municipality #2). Nowadays, their role has been reduced to their core task: providing affordable housing. Although green roofs help reduce maintenance costs (Alim et al., 2022), the initial investment is lower without a green roof. While the main goal is to supply affordable housing, the investment of green roofs cannot be incorporated in higher rents which provides an obstacle. The high investment costs are something which has also been discussed by Claus and Rousseau (2012), where most costs are made by the owner of the building. Moreover, green roofs do not have a direct impact on the buildings in which investments are made. Benefits such as relieving the sewer system, increasing biodiversity, and reducing the Urban Heat Island effect do not motivate housing associations as they do not contribute to providing affordable housing. The uneven distribution of benefits was also in the literature (Claus & Rousseau, 2012; Mullen et al., 2013; Tsang & Jim, 2010; Irga et al., 2017).

The belief that green roofs do not have direct positive effects on housing association buildings is widespread among housing associations. Although this belief is according to literature incorrect (Claus & Rousseau, 2012; Mullen et al., 2013), it limits their actions. Besides the perception that green roofs offer little benefit, there are also concerns about

potential negative consequences. There is an expectation that it will be more challenging to identify and fix leaks and that maintenance costs will be higher.

If a housing association does seek assistance with implementing a green roof or wants to explore the possibilities, they can approach Weerproof. Weerproof is already a discussion partner for several housing associations, helping them develop climate adaptation policies. Weerproof supports and encourages housing associations to install green roofs, which serves as a motivator for implementation. However, the maintenance departments of housing associations are sometimes unaware of this organisation's existence and its potential assistance (Housing Association #4).

The availability of subsidies is noted as a driving factor in the implementation of green roofs. These subsidies foster a sense of shared responsibility with the municipality, help secure project financing, and justify the greening efforts to managers (Housing Association #3). Although the subsidy was temporarily unavailable, it has recently been reinstated. However, the fluctuating availability of the subsidy is detrimental to the consistent implementation of green roofs (Municipality #1). As been mentioned by Mullen (2013) and Irga (2017) the subsidies are necessary to stimulate the uptake of green roofs by distribution of the costs, much the same as the distribution of the benefits.

For new construction, the primary factor for implementing green roofs is the stormwater regulation. This regulation mandates a minimum water storage capacity on the roof, often supplemented with a green roof. Additionally, new constructions require green additions (Housing Association #2). Typically, the focus is on the inner courtyard first, followed by a potential green roof.

Physical Opportunity

Implementing green roofs in new construction projects is common, but it is challenging in existing buildings. This difficulty arises from the absence of construction drawings, low load-bearing capacity, and, perhaps most importantly, financial constraints. When construction drawings are missing, it is challenging to determine the roof's load-bearing capacity. Without this information, installing a green roof poses a risk that housing associations are unwilling to take. Even if construction drawings are available, the load-bearing capacity is often insufficient. Strengthening the structure to support a green roof is usually too expensive, making it unfeasible. This barrier has also been found in the literature and is hard to overcome (Alim et al., 2022; Mahdiyar et al., 2020; Brudermann & Sangkakool, 2017).

Even when construction drawings are present and the load-bearing capacity is adequate, implementing green roofs remains difficult. Housing associations often lack sufficient funds for both the energy transition and green roof installation. Since financial resources are primarily allocated to energy transition measures, freeing up funds for green roofs is challenging.

Housing associations also encounter conflicting interests within the municipality. Some municipal departments prioritize solar panels, while others advocate for green roofs. These competing interests vie for rooftop space. Consequently, housing associations must make trade-offs, investing in measures that offer the most significant return per euro spent.

Psychological Capability

Knowledge is, in the literature, seen as one of the biggest barriers to increase the number of green roofs (Brudermann & Sangkakool, 2017; Mahdiyar et al., 2020; Wilkinson et al., 2022; Zhang & He, 2021). However, housing associations seem to have enough knowledge to implement green roofs (Housing Association #3, Housing Association #4). The problem is that the teams which are responsible for the maintenance of buildings have a conventional mindset, using mostly standard sustainability and maintenance measures. This conventional mindset could stem from a lack of knowledge in teams which do the maintenance (Housing Association #2).

Sometimes the knowledge is not available. To address this, Weerproof organizes events discussing climate adaptation and roof greening. This knowledge-sharing through communities of practice helps housing associations acquire and apply the necessary information. However, it is unclear how much this currently aids in the actual implementation of green roofs.

Conclusion

The implementation of green roofs appears to be well-supported in new construction projects, with sufficient incentives for housing associations to include green roofs in building plans or through architectural design. This success is influenced by existing policy categories. Evaluation methods like BREEAM and BENG play significant roles, and the stormwater regulation makes green roofs almost necessary. Additionally, new construction projects do not face financial constraints as they are often more commercially oriented.

Currently, policies encourage green roofs in existing buildings but do not prioritize them. The focus remains on energy transition. Climate adaptation, where green roofs play a role, is also not the main focus and, therefore, not always a top priority. This indicates that the primary obstacles lie in the area of reflective motivation. In summary, the current policy structure promotes green roofs, but not sufficiently to make a significant impact. To accelerate the implementation of green roofs by housing associations, especially in existing buildings, interventions are needed that align with current policies and further enhance greening, cooling, and liveability in neighbourhoods and homes.

6.4.2 Intervention functions

Various interventions have been implemented to promote green roofs. Some of these interventions are also broadly aimed at climate adaptation rather than solely on green roofs but contribute to the implementation of green roofs.

Subsidy (Incentivization)

For some time, the city of Amsterdam has provided subsidies for green roofs. Subsidies have been available since 2010 to stimulate the implementation of green roofs (Municipality #1; Amsterdam, 2018). In 2022, a subsidy was also available, but the allocated funds were quickly exhausted, making it impossible to apply for the subsidy (Municipality #1; *Na Twee Jaar Weer Geld Beschikbaar Voor Groene Daken, Tuinen En Monumentale Bomen*, 2024). The unavailability of the subsidy reduced the drive for implementing green roofs at least for one housing association. As Municipality #1 stated, a subsidy must be consistently available to avoid creating uncertainty. The new subsidy, introduced in April 2024, is expected to once again provide an incentive for housing associations to implement green roofs. The introduction of subsidies has been practiced for a long time and will not face much resistance

from stakeholders. The current subsidy is aimed at existing buildings since new constructions are not eligible for the subsidy (*Subsidie Groen in Amsterdam*, 2024).

Due to the lack of financial resources (Housing Association #1, #3, #6, #7), the subsidy helps housing associations to balance their budgets. Additionally, offering the subsidy helps create a sense of community and share costs, as the benefits of green roofs also extend to the entire city. The introduction of subsidies is also one of the suggested measures by Brudermann & Sangkakool (2017) and Wilkinson et al. (2022) to encourage green roofs, though it is mentioned that targeted subsidies might be beneficial. However, this could result in higher transaction costs, as confirmed by Municipality #1.

One downside of the subsidy is that it is intended for all residents of Amsterdam, which means there is a chance that the subsidy may not be equitably distributed across the city. Municipality #1 pointed out that one must have the money upfront to install a green roof and thereby qualify for the subsidy. This may result in more affluent households taking advantage of the subsidy sooner than housing associations or poorer households. This is also noted by Mullen et al. (2013), who describe it as a transfer of public funds to (building) owners.

Events Weerproof (Education)

Weerproof focuses on improving and stimulating knowledge about green roofs by establishing a community of practice. Knowledge is shared, and a partner network is built to facilitate knowledge sharing (About Weerproof - Weerproof, 2024). The organisation's website offers a wealth of information, but housing associations do not seem to come into contact with Weerproof (Housing Association #4). Sharing knowledge in this way will be an asset for many stakeholders, and the acceptability within the city of Amsterdam is expected to be high. Additionally, establishing this organisation helps ensure flexibility in the municipal environment, as it is a collaboration between Waternet and Amsterdam and can manoeuvre within the complex governance structure (Municipality #1, Municipality #3). Since the organisation is essentially part of the policy bodies, it is expected to be affordable to maintain.

However, it is questionable whether Weerproof is effective in stimulating green roofs. Weerproof helps to increase knowledge, build a network, and deepen knowledge with other professionals. But whether this sufficiently encourages housing associations to install green roofs on existing buildings is unknown; this intervention function is thus an indirect intervention with difficult-to-measure results.

RESILIO (Education)

The project, conducted in collaboration with housing associations, the city of Amsterdam, Waternet, Weerproof, and other market parties, was funded by European subsidies (Municipality #2) and functioned as pilot projects to increase knowledge in the city. Despite the subsidies, it took a long time for housing associations to participate; it was challenging to get the housing associations on board (Municipality #2). The scope of the project made it difficult to execute (Municipality #2).

However, the project resulted in significant knowledge gains for housing associations (Housing Association #3, Housing Association #4). For other housing associations the knowledge was lost due to a lack of clear reporting (Housing Association #2), or the project was not known to the employees (Housing Association #1). This knowledge has led some housing associations to consider how to handle roofing, its quality, and how to seal it as

effectively as possible during renovations. However, it also created some reluctance due to the risk of leaks, as Housing Association #3 mentioned that an entire roof had to be redone.

Ultimately, the project was quite expensive but was funded by European Union subsidies. It is challenging to repeat such a project in the short term due to the difficult implementation process, high investment costs, and lack of additional value in a pilot project.

An improvement would be to launch targeted marketing campaigns to raise awareness about these initiatives. Use multiple communication channels, including social media, newsletters, and workshops, to reach a broader audience. Collaborate with industry associations to ensure the information reaches all relevant stakeholders.

Maps (Modelling)

The municipality has created climate adaptation maps that show how Amsterdam scores on four different themes. Various stress tests have been conducted to determine where problems may arise or currently exist. Based on the outcomes of these maps, a climate adaptation strategy is being developed (Gemeente Amsterdam Klaas-Bindert de Haan, n.d.-b). Additionally, a monitoring map is being developed to display all green roofs in Amsterdam. This measure is important for many parties to create policies, which is why it is considered an acceptable measure. It is also practical, easily implementable, and inexpensive. The question remains how effective this is in encouraging housing associations to install green roofs, as they are not aware that these maps exist.

6.4.3 Policy categories

Stormwater Ordinance (Legislation)

The stormwater ordinance primarily affects new construction; it can also apply to existing buildings but only in the case of major maintenance (Amsterdam Environmental Plan, 2022, p. 74). For new construction, the stormwater ordinance is highly effective in implementing green roofs; ultimately, the step from a retention/blue roof to a green roof is small (Housing Association #2) and is thus installed more quickly.

Introducing such a regulation is inexpensive, easy to implement due to national sewerage requirements, has few side effects, and applies to all construction. In short, a policy category that works well for new construction but lacks influence for existing buildings.

BREEAM and BENG (Regulation)

Introducing building certification has a significant impact on promoting sustainable new buildings. This regulation encourages architects and developers to consider the various components that can be incorporated into and onto a building, including green roofs. As a result, green roofs are promoted in new buildings but not in existing ones.

Omgevingsvisie / Groenvisie 2050 (Environmental / Social Planning)

The Omgevingsvisie and Groenvisie 2050 demonstrate an ambition to green the city, enhance biodiversity, and implement various measures against heat and water-related issues. The plans mention increasing greenery in neighborhoods, replacing backyard tiles with plants, and expanding access to green areas. However, it's notable that the possibility of installing green roofs is not addressed. The document outlines different levels of focus, including “Green Buildings and Plots”, yet it does not emphasize green roofs as a key element, nor does it elaborate on what this would entail.

Additionally, it is unclear how this document impacts current intervention functions for green roofs and, consequently, housing associations. It is particularly striking that neither the municipality nor the housing associations mention this documentation, despite it being a guiding document for urban developments.

7 Discussion

7.1 Interpretation of results

This research explores the limiting and enabling factors within the COM-B model and how these are influenced by intervention functions from the Behavior Change Wheel model to promote the adoption of green roofs among housing associations in Amsterdam. The study involved analysing policy documents, interviewing employees of the Municipality of Amsterdam, and conducting interviews with several housing associations to identify obstacles. A clear difference emerged between the implementation of green roofs in new construction and existing buildings.

Several successful measures are already in place to encourage the installation of green roofs in new constructions, such as the Stormwater Ordinance and sustainable building certifications like BENG and BREEAM. However, measures for existing buildings are often lagging. Although many housing associations recognize the importance of green roofs, they are rarely implemented during renovations of existing structures.

The remainder of this text delves deeper into current policies regarding green roofs for existing buildings. Table 16 provides an overview of the components within the COM-B model, highlighting which elements are currently being promoted and where further opportunities for intervention exist.

	Education	Persuasion	Incentivitsation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
C-Physical					x				x
C-Psychological	x				x				x
M-Reflective	x	x	x	x					
M-Automatic		x	x	x			x	x	x
O-Physical						x	x		x
O-Social						x	x		x

	=Current intervention function
x	=Intersection between COM-B and Intervention function
	=Current obstacles in COM-B not adressed

Table 16: Overview of possible additional stimulans from intervention functions

As shown in Table 16, various intervention functions could further stimulate the COM-B model. Currently, the focus is on three intervention functions, though not all have proven to be equally effective. For instance, education and incentivization target reflective motivation, yet this remains one of the biggest challenges. This could be due to the temporary absence of subsidies between 2022 and 2024 or the ineffective targeting of the appropriate audience with educational efforts. Interviews revealed that education often fails to reach renovation teams, who tend to adhere to traditional methods when renovating buildings. This is influenced both by the partners of housing associations and their own staff. Although education is provided through Weerproof, it currently seems insufficient to effectively enhance reflective motivation and remove these obstacles.

Additionally, the third intervention function focuses on Modeling, but it primarily stimulates automatic motivation, which is not a major limiting factor. The decision to develop a map to promote green roofs is, according to this research, insufficient or ineffective in encouraging housing associations to adopt green roofs.

The municipality has introduced several interventions to promote green roofs across the city. However, most of these interventions are not specifically targeted at housing associations but at all city stakeholders. The recently introduced subsidy has had little impact so far, making it difficult to assess its effectiveness. Despite the efforts, they appear insufficient to significantly encourage housing associations to implement green roofs on existing buildings. For new buildings, the implementation rate is higher, and therefore, additional stimulation is less necessary.

There is still room for expanding policies regarding green roofs for existing buildings; many intervention functions have yet to be utilized to effectively promote green roofs among housing associations. The findings suggest that improving existing intervention functions, such as education, could already help increase the adoption rate. The findings also suggest that it is possible to update current policy categories such as the guidelines in the Omgevingsvisie and focus more on the implementation of green roofs on existing buildings.

While much of the drive for further green roof implementation can come from the Municipality of Amsterdam, housing associations can also take proactive steps. The results indicate a traditional approach to renovating existing homes, often without specific policies on green roofs. By raising awareness within housing associations and motivating renovation teams, these organizations could make a significant impact, potentially in collaboration with the municipality.

7.2 Recommendations

In this section we are discussing the possible improvements on the current interventions present in the case of housing associations in Amsterdam. The aim is to improve the adoption of green roofs by housing associations based on the research, and key findings, which have been done over the past months.

One of the advantages of the Behaviour Change Wheel is that the different components that influence behaviour can be linked to Intervention Functions and then to corresponding Policy Categories. Using the Behaviour Change Wheel model and the relationships shown in table 7 and table 8 in Chapter 3.4.3, the necessary intervention functions can be determined.

This study reveals that there are obstacles in three main components of the COM-B model that need to be minimized to ensure the desired behaviour—implementing green roofs—emerges. As seen in Table 8, there are several options to stimulate these components of the COM-B model.

7.2.1 Intervention Functions

The key intervention functions are Enablement (psychological capability, physical opportunity), Education (psychological capability, reflective motivation), Persuasion, and Incentivization (reflective motivation). Since most resistance or obstacles to implementing green roofs lie within reflective motivation, measures targeting this component can more effectively encourage housing associations to adopt green roofs.

Stormwater Runoff Fee (Incentivization)

Brudermann & Sangkakool (2017) proposed introducing a stormwater runoff fee. This would allow housing associations to create a business model for installing green roofs, similar to what is done with solar panels (Housing Association #4). One significant benefit for the city, especially for water boards, is that a green roof can retain water and release it later. If less water flows directly into the sewer system, less investment is needed in the sewer system, and the water is of better quality and easier to purify (Claus & Rousseau, 2012; Mullen et al., 2013). The stormwater runoff fee could be structured so that the owner of the green roof receives compensation for all the litres of water retained by the roof.

This intervention creates a business model that allows housing associations to earn money and potentially lower rents. This is already the case with electricity from solar panels (Housing Association #4), so the step to implementing the same business model for stormwater is smaller.

Implementing it on a small scale is not feasible. If this measure also applies to private roofs under, for example, 200m², the administration would be so cumbersome that it is not feasibility. If it applies only to large roofs, such as those over 1000m², the administration is limited, but the benefits remain. This measure is likely effective in encouraging housing associations to install green roofs. Creating a revenue model that lowers residents' costs or frees up capital for housing associations to invest will make the financial incentive effective.

The challenge with this measure is its cost. A stormwater runoff fee can become quite expensive with more rain, and over time it will incur additional costs. Whether this creates a positive business model for water boards is uncertain. To determine feasibility, research must assess the savings in sewer renovation and expected revenue.

Promotion of Roof Handbook (Education)

The National Roof Plan has produced handbooks for various roofs in recent years, detailing how to install a red roof (utility roof), a green roof, a blue roof (retention roof), or a yellow roof (solar panels). This handbook can help housing associations make decisions for roof renovations. There is already competition for roof space (Housing Associations #3, #4). This handbook can assist maintenance teams in making choices. It is unclear if these handbooks are currently used within housing associations.

As mentioned in the discussion the renovation teams do have a traditional mindset towards the renovation of existing buildings, or might lack the knowledge in doing so. These handbooks can help create awareness and spread knowledge about the usage of roofs, and taking a different approach in renovating current buildings.

7.2.2 Policy Categories

There are various policy categories that can help provide housing associations with the space to install green roofs. Under the current policy, such as the insulation push, housing associations may find it challenging to free up capital for additional investment in green roofs. Moreover, existing policies are primarily focused on new construction, while the majority—81%—of buildings were constructed before the year 2000 (KadastraleKaart.com - De Gratis Online Kadasterkaart, 2024). This suggests that focusing on existing buildings could significantly increase the number of green roofs in Amsterdam. In this section

Energy Labels (Regulation)

The biggest obstacle faced by housing associations is the current focus on making existing buildings more sustainable (Housing Association #1, #3, #4, Muncipality #2), with insulation being one of the primary measures taken (Municipality #3; Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2024a). Because national and municipal policy focuses on the energy transition, there is no money, and possibly no manpower, left to invest in green roofs. Housing Association #4 notes that 80% to 90% of the money goes to this transition. In insulation, it is essential to meet specific RC-values; without these RC-values, it is not possible to improve the poor energy labels of buildings.

Research on the effects of green roofs on building energy consumption shows that green roofs help reduce energy consumption (Alim et al., 2022; Zhang & He, 2021; Irga et al., 2017; Claus & Rousseau, 2012). The contribution of a green roof depends on the type of green roof and the climate where it is installed. The RESILIO project indicates that a blue-green roof also contributes to the RC-value of the roof (Holstein & Langewen, 2022), while blue roofs alone contribute less than green roofs alone. According to RESILIO research, the RC-value of a blue-green roof could be 4.8 compared to 2.3 for the same roof without a blue-green roof (Amsterdam University of Applied Sciences (HvA), 2022).

For housing associations, as well as individuals and companies, adding a green roof to possible insulation measures for increasing the energy label can help promote green roofs. Since RESILIO has not conducted extensive research on the exact effects, further studies should be carried out, possibly on existing projects. The effectiveness of the measure depends on the added RC-value of the roof. The better a green roof insulates, the more effective the measure is. As Housing Association #3 points out, housing associations aim to achieve an RC-value of 6 on existing roofs. If a green roof adds only 0.5 to the RC-value, the effect will be less significant than if it adds 6.

Adding green roofs to insulation measures may lead to financing opportunities from the Heat Fund or the Energy Saving Loan. This would free up more money for individuals and homeowners' associations to invest in green roofs, thus extending the intervention's impact beyond just housing associations.

Implementing this policy category can impact a variety of intervention strategies that are developed. It creates opportunities to persuade housing associations to install green roofs, provides an incentive to meet energy labels, and offers maintenance teams of housing associations an additional method for sustainability.

Regional Obligation (Legislation)

Currently, the Municipality of Amsterdam requires green roofs to be installed when an extension is added to a building in certain areas, such as De Pijp and Oost. These areas face significant pressure on the sewer system and potential flooding (Gemeente Amsterdam, Klaas-Bindert de Haan, 2022). This regulation has led to the addition of small green roofs. The willingness of several housing associations to collaborate on neighborhood improvements has already been expressed and could be further strengthened through targeted measures like those currently in place.

A targeted, area-specific approach for existing buildings, especially during renovations, could be effective in implementing green roofs in the most critical zones. Although the effectiveness of such measures in problem areas is promising, it is important to note that

housing associations generally do not appreciate coercion. This sentiment is reflected in the Climate Adaptation Intentions Declaration, where housing associations have shown a preference for managing these issues independently rather than adhering to mandated measures. Nonetheless, geographic targeting is justified as it is crucial for addressing urgent climate-related challenges.

Implementing this policy appears relatively straightforward. The necessary research has been conducted, and the components required to introduce such an obligation are in place. The main challenge is ensuring that the structural capacity of the roofs can support the installation of green roofs.

7.3 Concluding

The implementation of green roofs in existing buildings by housing associations is significantly hindered by a combination of factors related to reflective motivation, physical opportunity, and psychological capability. Key obstacles include the strong policy focus on energy transition, financial constraints, and the perception that green roofs offer limited direct benefits to housing associations. Additionally, structural challenges and conflicting municipal interests further complicate the integration of green roofs in existing structures. While new constructions benefit from policies and regulations that facilitate green roof adoption, existing buildings do not receive the same level of support or priority.

To overcome these barriers and promote the adoption of green roofs, several intervention functions have been identified. These include enablement through energy labels, coercion via regional obligations, persuasion targeted at residents, incentivization with a stormwater runoff fee, and education through the promotion of a roof handbook. Each intervention aims to address specific aspects of the COM-B model—capability, opportunity, and motivation—to encourage housing associations to incorporate green roofs more broadly.

In summary, while there is openness to the idea of green roofs among housing associations, the current policy framework and resource allocation primarily towards energy transition measures limit their implementation in existing buildings. To accelerate the adoption of green roofs, it is crucial to align interventions with existing policies and enhance efforts in greening, cooling, and improving the liveability of neighbourhoods and homes. By addressing the identified obstacles and leveraging targeted intervention functions, it is possible to create a more conducive environment for the widespread implementation of green roofs in existing buildings.

8 Conclusion

8.1 Research questions

The aim of this research was to determine which policy instruments influenced the promotion of green roofs and to explore how these policy instruments or interventions could be improved to further stimulate the implementation of green roofs. This main research question was formulated as follows:

"*How do policy instruments for the promotion of green roofs influence the behaviour of housing associations in Amsterdam?*"

Current policy instruments influence housing associations to a certain extent. There are examples where housing associations are stimulated to implement green roofs, but also instances where this does not happen or is insufficient to bring about significant change. For new buildings, there seems to be no problem in promoting green roofs; however, for existing buildings, there is a greater challenge due to more barriers and obstacles to installing green roofs. According to the Behaviour Change Wheel, the current policy instruments do not seem to address the challenges mentioned by housing associations. The policy instruments are therefore insufficient and not effective enough in encouraging housing associations to significantly increase the number of green roofs on existing buildings.

Furthermore, national policies such as the insulation push, improving energy labels, and the Landlord Levy have a substantial impact on the capabilities of housing associations. While the municipality of Amsterdam cannot directly change these national policies, it is possible to align local policies with these national directives.

Concrete examples of successful interventions include the increased investments in sustainability initiatives following the abolition of the "Verhuurderheffing". Additionally, the stormwater ordinance has effectively stimulated the installation of green roofs in new constructions by creating a legal obligation.

To enhance the effectiveness of current policy instruments, it is essential to address both financial and knowledge barriers. Consistent and targeted marketing, such as campaigns using social media and community workshops, can increase awareness and knowledge dissemination. Expanding existing policies to include green roofs in energy label improvements can align with national sustainability goals. Area-specific approaches can tailor interventions to local needs, and additional incentives like a stormwater runoff fee should be considered, despite potential long-term costs.

Furthermore, fostering collaboration between stakeholders—housing associations, the municipality, and residents—can enhance the collective effort towards implementing green roofs. Engaging these groups in regular discussions and workshops can build a shared vision and facilitate knowledge sharing.

In conclusion, policy instruments for the promotion of green roofs influence the behaviour of housing associations in Amsterdam by addressing financial, regulatory, knowledge, and motivational factors. By implementing the suggested improvements, policy instruments can more effectively promote the adoption of green roofs, contributing to a more sustainable urban environment in Amsterdam. Future research should focus on evaluating the long-term

impact of these interventions and exploring new strategies to further incentivize green roof adoption.

Sub-question 1

What are the current policy instruments influencing green roof uptake and what are their features?

The uptake of green roofs in Amsterdam is shaped by a range of policy instruments, reflecting various strategies and objectives within the Behaviour Change Wheel framework. These instruments include fiscal measures, guidelines, environmental and social planning, communication and marketing efforts, legislation, and service provision.

A significant fiscal measure impacting green roof implementation was the "Verhuurderheffing" (Landlord Levy), which constrained housing associations' investment capacity. Its abolition in 2023 has since increased financial flexibility, enabling more investments in sustainability initiatives, however this does not include green roofs.

Guidelines such as the Nationale Dakenplan have established standards and procedures for installing green roofs, promoting collaboration between the private sector, water boards, and municipalities. These guidelines are complemented by local initiatives like WeerProof, which supports climate adaptation strategies and helps stakeholders make informed decisions about green roof implementation.

Environmental and social planning documents like the Omgevingsvisie 2050 (Environmental Vision 2050) and Groenvisie 2050 (Green Vision 2050) provide a comprehensive framework for Amsterdam's green infrastructure. These plans emphasize the importance of integrating green spaces into urban development to enhance climate resilience and biodiversity.

Communication and marketing efforts aim to raise awareness about green roof subsidies and related benefits. By engaging local media and using official channels, these efforts seek to inform and motivate residents and businesses to adopt green roofs.

Legislation such as the Affordable Rent Act and specific neighbourhood regulations mandate the installation of green roofs under certain conditions, further supporting their adoption. Additionally, tools like the Daken Kansenkaart (Roof Opportunities Map) visualize potential uses for rooftops, including green roofs, to assist in planning and decision-making.

Sub-question 2

What influences housing associations in implementing green roofs?

Housing associations face a complex decision-making process when it comes to implementing green roofs. This process is influenced by several key factors: financial considerations, regulatory requirements, knowledge and expertise, and motivational aspects. Understanding these factors is crucial for developing effective policies that promote the adoption of green roofs.

Firstly, financial constraints are a primary factor influencing the decision to implement green roofs. The high initial costs of installation and maintenance can be prohibitive for many housing associations. Although the abolition of the "Verhuurderheffing" (Landlord Levy) has increased financial flexibility, associations still need to balance investments in green roofs with other urgent needs such as improving energy labels and addressing overdue

maintenance. Almost always is the need to improve energy labels prioritized over green roofs.

Secondly, regulatory frameworks play a significant role in driving the adoption of green roofs. Policies such as the Omgevingsvisie 2050 and specific neighbourhoods regulations mandate the installation of green roofs in new constructions or during major renovations. These regulations create a legal obligation for housing associations, ensuring a baseline level of implementation. Additionally, standards like BENG (Nearly Zero-Energy Buildings) and BREEAM (Building Research Establishment Environmental Assessment Method) encourage nature-inclusive building practices, including the integration of green roofs into the design phase of new projects.

Thirdly, the availability and dissemination of knowledge are crucial for the successful implementation of green roofs. Mostly in departments which are responsible for the maintenance of buildings do not have the necessary knowledge which results in green roofs not being top-of-mind. These departments also have a traditional mindset towards the maintenance of existing buildings, this might also be due to the lack of knowledge.

Fourthly, motivational factors, including the perceived benefits and potential risks of green roofs, heavily influence decision-making. Housing associations may be hesitant to invest in green roofs due to concerns about maintenance challenges, such as the potential for leaks and the complexity of repairs. Conversely, the positive impacts of green roofs on urban biodiversity, climate resilience, and aesthetic value can serve as strong motivators.

Sub-question 3

To what extent do current policy instruments address factors that influence this decision-making process?

The various intervention functions present address the key factors in the COM-B model effectively. For instance, the subsidy significantly influences the financial decision to install green roofs. With the subsidy, it becomes easier for housing associations to justify and execute green roof projects. However, it is crucial that the subsidy remains consistently available to provide certainty for investment from housing associations and to ensure that policies regarding green roofs do not become neglected.

Interventions such as the RESILIO project and Weerproof events also effectively target reflective motivation, though their effectiveness is limited by the lack of awareness and knowledge dissemination. While this knowledge has been shared for some time, some teams remain unaware of it. A marketing campaign about these two measures could potentially help to convey this knowledge more effectively to various housing associations.

Moreover, modelling by the municipality seems to have little to no impact on housing associations. Nonetheless, it is not necessary to abolish this intervention, as it helps address the challenges faced by the city.

For new constructions, the stormwater ordinance plays a crucial role in promoting the installation of green roofs. This intervention effectively stimulates reflective motivation and is highly effective. Additionally, housing association teams observe that more needs to be done for nature-inclusive building, although it sometimes has a negative impact on the construction of a complex.

Sub-question 4

What implications does that have for policy instruments and how can current policy instruments be improved?

The existing policy instruments somewhat help housing associations implement green roofs, particularly in new constructions. For new buildings, there is no need to further stimulate housing associations to install green roofs; the real need is to encourage their implementation in existing buildings. Current policy instruments are not as effective as they could be, primarily due to a lack of marketing. The existing measures need to be better known among the appropriate personnel within housing associations.

Moreover, current policies can be expanded. The biggest obstacle for housing associations is that a large portion of resources is allocated to improving energy labels, and green roofs do not currently contribute to this. Research suggests that green roofs may improve a building's insulation and could potentially serve as a measure to enhance energy labels. This possibility should be explored to motivate housing associations to use the same resource allocations for green roofs as they do for other sustainability measures.

Additionally, a targeted approach can be adopted, either through area-specific initiatives or by better promoting existing knowledge through more focused dissemination. Knowledge promotion can be broadened by marketing campaigns aimed at the entire population of Amsterdam.

Lastly, providing an extra incentive in the form of a stormwater runoff fee is a possibility. Although literature suggests this could be effective, it may become very expensive in the long term, making it less attractive to implement.

In conclusion, to enhance the effectiveness of current policy instruments, it is essential to address both the financial and knowledge barriers faced by housing associations. Consistent and targeted marketing, expansion of existing policies to include green roofs in energy label improvements, area-specific approaches, and additional incentives like a stormwater runoff fee should be considered. By implementing these improvements, policy instruments can more effectively promote the adoption of green roofs, contributing to a more sustainable urban environment in Amsterdam.

8.2 Implications for policy makers

The current intervention functions should address the various factors of the COM-B model where the most significant obstacles are present. Events organized by WeerProof or studies like RESILIO should focus on improving Reflective Motivation. Since these interventions seem to be less effective—evidenced by the insufficient knowledge among renovation teams or their traditional approaches—an initial step should be to investigate why these interventions are not adequately promoting green roofs. According to the Behaviour Change Wheel, these intervention functions are well-suited to enhance green roof adoption. Given the challenges for the scientific community to investigate this thoroughly, it would be valuable for policymakers to explore how these interventions can be utilized more effectively or targeted more precisely.

8.3 Implications for further research

This study has identified the measures that stimulate housing associations to install green roofs and how these associations can be influenced. Additionally, it has examined the

obstacles that housing associations face and how these obstacles could potentially be reduced. Since the research was conducted on a relatively small scale, the results may not be generalizable to other municipalities, cities, or countries. To determine the broader applicability of the findings, follow-up research in other cities is necessary. If similar studies in cities such as Arnhem and Rotterdam produce the same results, it can be concluded with some confidence that the findings are transferable to other regions.

Although the results may not be generalizable to other municipalities, regions, cities, or countries, several policy instruments introduced in the discussion could be studied for their effectiveness, feasibility, and cost. This can be done by testing different policy approaches in a serious gaming environment or in various working groups. As indicated in the limitations, the different intervention functions and policy categories are not currently ready for practical application. One example is the *Stormwater Runoff Fee*. Such a scheme creates a business model for installing green roofs on larger buildings. By managing or slowing down rainwater runoff, certain sewer renovations could potentially be avoided. The savings from these avoided costs could partially or entirely be used to incentivize housing associations or other property owners to install green roofs. Future research could focus on exploring the revenue generated per unit of water managed or retained and assessing the feasibility of such a business model.

Furthermore, a major challenge is that all current resources are focused on improving the energy performance certification of buildings. As proposed, green roofs could potentially be included among the measures to increase the RC value (thermal resistance). While existing literature suggests that green roofs can contribute to energy savings for both heating and cooling, the findings are not consistent. Variations exist between geographical locations and among different types of green roofs. Given these substantial differences, it is essential to investigate how green roofs specifically influence energy efficiency in the Netherlands. By identifying the energy savings associated with each type of green roof—based on factors such as substrate, thickness, vegetation, and underlying layers—this information could be more readily integrated into the energy performance calculations.

8.4 Limitations

The research focused on the Amsterdam area. Although Amsterdam plays a pioneering role in green roofs (Municipality #2), the limited geographic scope affects the generalizability of the results. While the findings may potentially be applicable on a larger scale, given that much policy originates from the national government, further research should be conducted in other locations to confirm this applicability.

The main limitation of this research is that the recommendations have not been further analysed. Analysing these potential intervention functions and associated policy categories would significantly strengthen the study and make it more applicable for practical implementation. Currently, the research primarily reflects the researcher's perspective on the different policy forms that could be implemented. While this perspective is informed by existing literature and semi-structured interviews, it is not based on a policy-oriented framework.

Additionally, the limited number of participants poses a constraint. The small sample size may introduce participant bias that might be less pronounced in a larger study. It is also

possible that participants who were selected were not fully aware of current developments within their own organisation or in the city of Amsterdam.

Finally, the Behaviour Change Wheel provides a good indication of measures that might work, but human behaviour is complex. This complexity can lead to some relationships between interventions, COM-B factors, and policy categories being less effective than anticipated. To ensure the proposed changes are effective, further research is needed to validate whether these interventions would work as expected.

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Appendix A: Method Interviews

Appendix A.1 Interview questions

Appendix A.1.1 Housing Associations

Thank you for participating in the research. I am conducting my master's thesis at TU Delft for the degree in Complex System Engineering and Management. The topic of my research revolves around encouraging housing associations to implement green roofs.

I anticipate that the interviews will take approximately 45 minutes to an hour. As mentioned in the consent form, all collected data will be securely stored. The focus of my study is on designing policy instruments to incentivize organisations, particularly housing associations, to adopt green roofs. This is significant as 40% of the dwellings in Amsterdam and 28% in the Netherlands are managed by housing associations.

1. Role, involvement and experience:
    - 1.1 Can you please provide a brief overview of your role and responsibilities within the housing association? / Kunt u een beknopt overzicht geven van uw rol en verantwoordelijkheden binnen de wooncorporatie?
    - 2.1 How long have you been involved in green roof initiatives or sustainable building practices within the housing association? /Hoelang bent u al betrokken bij groendakinitiatieven of duurzame bouwpraktijken binnen de wooncorporatie?
    - 3.1 What concrete steps has your organisation taken to implement green roofs? / Welke concrete stappen heeft jouw organisatie gezet om groene daken te implementeren?
    - 4.1 What are the results so far? / Wat zijn de resultaten?
2. COM-B
    1. **[1.1 Capability: 1.1.1 Knowledge, 1.1.2 Skills, and 1.1.3 Memory]** Can you describe how your housing association's available **knowledge**, **expertise**, and **experience** have influenced the green roof implementation so far? / Hoe beoordeelt u het kennisniveau, de expertise of het bewustzijn van de voordelen van groene daken binnen de organisatie?
    2. **[1.1 Capability: 1.1.6 Other capabilities]** How have considerations such as **cost-effectiveness** and **resource availability** so far enabled or limited the green roof implementation? / Hoe beïnvloeden overwegingen zoals kosteneffectiviteit, beschikbaarheid van middelen of wettelijke vereisten beslissingen met betrekking tot de implementatie van groendaken?
    3. **[1.1 Capability: 1.1.4 Behavioural regulation]** In your experience, how do rules and policies within the housing association shape decisions regarding sustainable building practices such as green roofs? / Naar uw ervaring, hoe vormen regels en beleid binnen de woningcorporatie beslissingen met betrekking tot duurzame bouwpraktijken zoals groendaken?
    4. **[1.3 Motivations – 1.3.2. Belief about consequences, 1.3.6. Emotions?]** How do employees within the housing association **view** implementing green roofs? / Hoe kijken de medewerkers binnen de wooncorporatie aan tegen het implementeren van groene daken?
    5. **[1.3 Motivation – 1.3.5 Goals and 1.3.6 Intentions]** Is there any **internal (i.e. within the organisation) goals, intentions** or **motivations** to implement

green roofs? Why or why not?/ Is er binnen de organisatie interne motivatie om groendaken te implementeren? Waarom wel of niet?

6. **[1.3 Motivation – 1.3.1 Social/professional role and identity]** What **social or cultural factors** influenced the implementation of green roofs within the organisation and among tenants? / Welke sociale of culturele factoren beïnvloeden de acceptatie van groene daken binnen de organisatie en onder huurders?
7. **[1.3 Motivation – 1.3.3 reinforcement]** In what ways have the **costs and benefits of green roof**s enabled or limited the organisation's decision-making about the green roof implementation? / Op welke manieren worden de kosten en baten van groene daken gewogen in de besluitvorming van de organisatie?
8. **[1.3. Motivation – 1.3.2. Belief about consequences, 1.3.6. Emotions?]** Have you observed any **changes in priorities or attitudes within the housing association** regarding green roofs over time? If so, to what factors do you attribute these changes? / Heeft u in de loop van de tijd veranderingen waargenomen in prioriteiten of opstelling binnen de woningcorporatie met betrekking tot groendaken? Zo ja, aan welke factoren schrijft u deze veranderingen toe?
9. **[1.2. Opportunities – 1.2.1 Social influence]** Can you identify specific **beliefs, attitudes or perceptions among stakeholders** that may enhance or limit the adoption of green roofs? / Kunt u specifieke overtuigingen, attitudes of percepties onder belanghebbenden identificeren die de adoptie van groendaken kunnen beïnvloeden?
10. **[1.2 Opportunity – 1.2.2 Context]** Do you think the housing association has the capacity to comply with regulation while implementing green roofs? How does this affect the organisation, taking into account factors such as the **Building Regulations or access to funding**? / Denkt u dat de woningcorporatie de capaciteit heeft om groendaken te implementeren? Hoe beïnvloedt dit de organisatie, rekening houdend met factoren zoals het Bouwbesluit of de toegang tot financiering?
11. **[1.2 Opportunity – 1.2.2 Context]** In your opinion, what **strategies or interventions can be effective to overcome obstacles and promote the adoption** of green roofs within housing associations? / Naar uw mening, welke strategieën of interventies kunnen effectief zijn om obstakels te overwinnen en de adoptie van groendaken binnen woningcorporaties te bevorderen?
12. **[1.2 Opportunity – 1.2.2 Social influences]** In your opinion, do you have sufficient **collaborations with external parties to gather information and accelerate construction**? / Hebben jullie, naar jou mening, voldoende samenwerkingen met externe partijen om informatie in te winnen en de aanleg te versnellen?
13. In your opinion, are there any other factors or specific challenges influencing the housing associations when considering and implementing green roofs? / Naar uw mening, wat zijn de belangrijkste factoren die woningcorporaties beïnvloeden bij het overwegen en implementeren van groendaken?

3. Behaviour Change Wheel

1. **[2.2 Policy Categories]** Do you see certain external policies or regulations as encouraging or limiting your organisation to build green roofs? And certain measures that actually hold it back? / Ziet u bepaalde beleidsmaatregelen of regelgeving als stimulans voor uw organisatie om groene daken aan te leggen? En bepaalde maatregelen die het juist tegenhouden?
2. Do you know the RESILIO pilot project? And if so, how does it play a role? Have you taken lessons from it that are still being applied? / Hoe speelt het pilot project van RESILIO een rol bij jullie? Hebben jullie daar lessen van meegenomen die nog worden toegepast?
3. **[2.1. Intervention functions]** In what ways do you think your organisation could be supported in implementing green roofs? For example, through **education, training, rewards, restrictions, modelling, changing or restructuring anything** ?/ Op welke manieren denkt u dat uw organisatie zou kunnen worden ondersteund bij het implementeren van groene daken? Bijvoorbeeld door educatie, trainingen of beloning?

Appendix A.1.2 Policy makers municipality of Amsterdam

Thank you for participating in the research. I am conducting my master's thesis at TU Delft for the degree in Complex System Engineering and Management. The topic of my research revolves around encouraging housing associations to implement green roofs.

I anticipate that the interviews will take approximately 45 minutes to an hour. As mentioned in the consent form, all collected data will be securely stored. The focus of my study is on designing policy instruments to incentivize organisations, particularly housing associations, to adopt green roofs. This is significant as 40% of the dwellings in Amsterdam and 28% in the Netherlands are managed by housing associations.

1. Background
    a. How long have you been involved in policy making with regard to green roofs?
    b. What is your role with regard to policy implementation for green roofs in the City of Amsterdam? Which challenges have you encountered (inside the municipality)?
2. COM-B
    a. **[1.1 Capability: 1.1.4 Behavioural regulation]** In your experience, how do rules and policies shape the decisions of housing association regarding sustainable building practices such as green roofs?
    b. **[1.3 Motivation – 1.3.3 reinforcement]** How do you think the **costs and benefits of green roof**s influence the housing associations in the green roof implementation?
    c. **[1.2 Opportunity – 1.2.2 Context]** In your opinion, what **strategies or interventions can be effective to overcome obstacles and promote the adoption** of green roofs within housing associations?
    d. Which actors are involved in the decision making process (or have influence)?
        i. F.e. Installers, housing associations, citizens etc
    e. Is there a clear division in responsibility or roles?
    f. What are, in your opinion, the most important decisions in deciding for a policy, or stimulating housing associations?

g. How do you communicate with the external environment (citizens, housing associations etc) that certain policies or actions are in place?
h. How did you come to the current policy instruments? (Such as Weerproof initiative and the current policy employed end of April)
    i. What would you add or remove in an ideal world?
i. Subsidies for green roofs have been there before, is this what is planned to stimulate housing associations? Or are there other plans which have not been implemented? How about the two years that there was no subsidy?
j. What benefits do green roofs have for the city?
k. When does the city consider the current policy instruments a success?

3. Behaviour Change Wheel
    a. **[Intervention functions]** In what ways do you think the municipality could support housing associations in implementing green roofs? For example, through **education, training, rewards, restrictions, modelling, changing or restructuring anything** ?
    b. **[2.2 Policy Categories]** Do you see certain policies or regulations as encouraging or limiting housing associations to build green roofs?
    c. Do you know the RESILIO pilot project? And if so, how does it play a role? Have you taken lessons from it that are still being applied? / Hoe speelt het pilot project van RESILIO een rol bij jullie? Hebben jullie daar lessen van meegenomen die nog worden toegepast?

Appendix A.2 Consent Form

The consent form is written in Dutch while it is most likely that most participants speak Dutch rather than English as their mother language.

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd "*Investigating the Effects of Policy Instruments on Decision-Making of Housing Associations in Amsterdam for implementing green roofs*". Dit onderzoek wordt uitgevoerd door Daan Bloeme van de TU Delft.

Het doel van dit onderzoek is om te bepalen hoe de huidige beleidsinstrumenten aansluiten op de daadwerkelijke situatie en hoe de beleidsinstrumenten verbeterd kunnen worden om woningcorporaties te stimuleren om groene daken te plaatsen in Amsterdam en zal ongeveer 45 minuten in beslag nemen. De data zal gebruikt worden voor de scriptie benodigd voor het afronden van de master Complex System Engineering and Management. U wordt gevraagd om antwoorden te verstrekken op de vragen die worden gesteld.

In het geval van persoonlijke interviews worden de interviews opgenomen via audio of video, in het geval van een online interview. Zoals bij elke online activiteit, is er altijd een risico op een inbreuk mogelijk. Naar ons beste vermogen zullen uw antwoorden in deze studie vertrouwelijk blijven. We minimaliseren de risico's door data anoniem te houden, geen namen te noemen en de data op een veilige server van de TU Delft op te slaan. Daarnaast wordt 2 jaar na het uitvoeren van het onderzoek de data verwijderd worden om risico's te minimaliseren.

Uw deelname aan dit onderzoek is volledig vrijwillig, en u kunt zich elk moment terugtrekken zonder reden op te geven. U bent vrij om vragen niet te beantwoorden. Er wordt geen financiele compensatie verstrekt voor het meedoen. Het einde van de scriptie is geschat op juli 2024.

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. Ik heb de informatie over het onderzoek gedateerd [*DD/MM/YYYY*] gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
10. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam, woonplaats, email adres en positie, niet gedeeld worden buiten het studieteam.	☐	☐
11. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt 2 jaar na het uitvoeren van het onderzoek	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor de onderzoeksresultaten	☐	☐

Handtekeningen

_____ _____ _____

Naam deelnemer Handtekening Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

_____ _____ _____

Naam onderzoeker Handtekening Datum

Contactgegevens van de onderzoeker voor verdere informatie: Daan Bloeme, 06-27878153, djbloeme@gmail.com

Appendix A.3 Coding Scheme

Model part	Definition	Category type	Definition Category	
COM-B (1)	The COM-B model is utilized for coding the interviews. This is because the COM-B model is based on the internal decision-making mechanisms of the organization. The facets in the BCW model then correspond to these mechanisms.	1.1. Capability	Capability is defined as the individual's psychological and physical capacity to engage in the activity concerned. It includes having the necessary knowledge and skills.	Physical Psychological
		1.2. Opportunity	Opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it.	Social Physical
		1.3. Motivation	Motivation is defined as all those brain processes that energize and direct behaviour, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making.	Reflective Automatic
BCW (2)	The Behaviour Change Wheel is used to categorize the different policies in place and connect the obstacles to possible alterations or additions in the current policy mix.	2.1Policy Categories	In the Behaviour Change Wheel, policy categories are broad intervention areas aimed at influencing behavior. Each category represents a different approach to shaping and supporting behavior change.	
		2.2. Intervention functions	In the Behaviour Change Wheel, intervention functions are strategies designed to change behavior. Each function targets specific aspects of behavior to achieve effective change.	

	Domains	Quote examples
Physical	1.1.1. Skills	"We hebben verschillende partners voor onze daken, hovenieren en onderhoud."
Psychological	1.1.2. Knowledge	"Het is bewustwording en kennis ontbreekt inderdaad"
	1.1.3. Memory, attention and decision proces	"Een groen dak is eigenlijk nog niet echt top of mind "
	1.1.4. Behavioural regulation	"Out of the box denken bij renovatie wordt nog niet gedaan"
Social	1.2.1. Social influences	"Bewoners vroegen erom, ook een reden om groen te plaatsen"
Physical	1.2.2. Environmental context and resources	"Je hebt niet onbeperkt geld beschikbaar, moet verdeeld worden. Alles is financieel gedreven."
Reflective	1.3.1. Social/professional role and identity	"Ons hoofddoel is gewoon om een woningen te hebben voor huurders betaalbare woningen. "
	1.3.2. Beliefs about consequences	"Ik vind dat je het terugziet in de waarde van je portefeuille. "
	1.3.3. Optimism	"Dat is het grote nadeel en dat hoor je ook wel van de monteurs van de dakdekkers. Die willen geen groene daken. Ze hebben er
	1.3.4. Intentions	"Ik denk dat daar groene daken sowieso niet meegenomen gaan worden in het beleid. Het wordt projectmatig"
	1.3.5. Goals	"Prioriteit is het uitfaseren van slechte energielabels"
	1.3.6. Beliefs about capabilities	"Als er wat gebeurt, dan is dat eigenlijk op initiatief van de projectontwikkelaar. "
Automatic	1.3.7. Reinforcement	"Dat is wel een van de redenen (warmtestress bij oudere) waarom we hier ook actief in waren"
	1.3.8. Emotion	"Corporaties hebben toch een soort dak aversie, want een van de vragen die we ook bij RESILIO ontdekten"
	2.1.1. Fiscal Measures	
	2.1.2. Guidelines	
	2.1.3. Environmental / social planning	
	2.1.4. Communication / Marketing	
	2.1.5. Legislation	
	2.1.6. Service Provision	
	2.1.7. Regulation	
	2.2.1. Environmental restructuring	
	2.2.2. Restrictions	
	2.2.3. Education	
	2.2.4. Persuasion	
	2.2.5. Incentivisation	
	2.2.6. Coercion	
	2.2.7. Training	
	2.2.8. Enablement	
	2.2.9. Modelling	

Appendix B: Selected articles for literature review

#	Year	Title	Authors
1	2022	Green roof as an effective tool for sustainable urban development: An Australian perspective in relation to stormwater and building energy management.	Alim, M. A., Rahman, A., Tao, Z., Garner, B., Griffith, R., & Liebman, M.
2	2017	Green roofs in temperate climate cities in Europe – An analysis of key decision factors.	Brudermann, T., & Sangkakool, T.
3	2012	Public versus private incentives to invest in green roofs: A cost benefit analysis for Flanders.	Claus, K., & Rousseau, S.
4	2022	Strategies for implementation of green roofs in developing countries.	Durdyev, S., Koç, K., Karaca, F., & Gürgün, A. P.
5	2017	The distribution of green walls and green roofs throughout Australia: Do policy instruments influence the frequency of projects?	Irga, P. J., Braun, J., Douglas, A. N., Pettit, T., Fujiwara, S., Burchett, M., & Torpy, F. R.
6	2018	Stewardship of urban ecosystem services: understanding the value(s) of urban gardens in Barcelona.	Langemeyer, J., Camps-Calvet, M., Calvet-Mir, L., Barthel, S., & Gómez-Baggethun, E.
7	2020	Green Infrastructure and Public Policies: An International review of Green Roofs and Green Walls Incentives.	Liberalesso, T., Cruz, C. O., Silva, C. M., & Manso, M.
8	2020	Barriers to green roof installation: An integrated fuzzy-based MCDM approach.	Mahdiyar, A., Mohandes, S. R., Durdyev, S., Tabatabaee, S., & Ismail, S.
9	2019	Costs and benefits of green roof types for cities and building owners.	Van Der Meulen, S. H.
10	2013	Green roof adoption in Atlanta, Georgia: The effects of building characteristics and subsidies on net private, public, and social benefits.	Mullen, J. D., Lamsal, M., & Colson, G.
11	2016	Green roofs in Australia: review of thermal performance and associated policy development.	Pianella, A., Bush, J., Zheng-Dong, C., Williams, N. S., & Aye, L.
12	2012	Challenges and Strategies for Greening the Compact City of Hong Kong.	Tian, Y., Jim, C. Y., & Tao, Y.
13	2011	Game-Theory approach for resident coalitions to allocate Green-Roof benefits.	Tsang, S., & Jim, C. Y.
14	2022	Mandatory or voluntary approaches to green roof implementation: a comparative study among some global cities.	Wilkinson, S., Ghosh, S., & Pelleri, N.
15	2021	Towards green roof implementation: Drivers, motivations, barriers and recommendations.	Zhang, G., & He, B.

Appendix C: Transfer mechanisms RESILIO project

Transfer-Mechanism	Category	Description	Principal conditions
Co-Investment	1	Co-investment in the construction costs of BG roofs by stakeholders benefiting from BG roofs, but having no (or very limited) responsibility for the TCO of the roof owner as the main investor.	Willingness to pay and taking responsibility for TCO/construction costs based on monetized benefits and positive sustainable societal and urban development.
Direct payment	1	Direct payment of maintenance costs for BG roofs by stakeholders benefiting from BG roofs, but having no (or very limited) responsibility for the TCO of the roof owner as the main investor.	Willingness to pay and taking responsibility for TCO/construction costs based on monetized benefits and positive sustainable societal and urban development.
Subsidies	1	Subsidies for the construction and/or maintenance costs of the roof owner as the main investor (or collective of owners), to promote the implementation of BG roofs as a sustainable solution for urban climate adaptation.	Follow-up on the 80% EU-UIA subsidy, which formed the financial basis under the RESILIO project, to ensure a sustainable impact on urban development and citizen well-being.
Tax differentiation	1	Tax differentiation: Fiscal incentives based on tax exemptions/differentiation for the roof owner as the main investor (or a collective of owners), to offset a portion of the TCO based on the impact of the investment in the BG roof.	Changes and/or exemptions in tax policy for specific tax benefits (e.g., water tax, sewerage charges, or other aspects where the benefits of BG roofs apply).
Volume compensation	1	Volume compensation: Investments in BG roofs create water storage capacity for urban water management. The roof owner as the main investor (or a collective of owners) could receive a volume compensation to offset a portion of the TCO based on the impact of the investment in the BG roof.	All BG roofs must be connected to an interconnected system of BG roofs to be part of urban water management, and the storage capacity must be large enough to play a meaningful role in the overall water management system.
Renting accessible rooftop space	2	Renting accessible rooftop space: For accessible roofs, the roof design could consider (commercial) exploitation by the roof owner or contracted third parties who pay rent to compensate for a portion of the TCO.	Accessible rooftop space that is regularly/unrestrictedly accessible for activities such as urban farming or as outdoor space for cafes/restaurants or as meeting/recreational space (with catering).
Payment model for benefits or use of accessible rooftop space.	2	Building users could pay for access to an (attractive) rooftop space, or for specific benefits such as lower heating demand on the floor directly below the BG roof (due to the cooling effect of the BG roof).	Rooftop space accessible to building residents for recreational purposes (not applicable to RESILIO). Legally permitted rent increase and/or negotiating a higher rent for specific residents based on benefits (difficult to apply to RESILIO's social housing).
Integration of value-adding rooftop solutions	2	BG roofs are part of a broader portfolio of sustainable solutions for urban buildings. Any combinations can add value to the rooftop environment.	Combining with (transparent) solar panels for sustainable energy production at the building level. This is not applicable to RESILIO due to technical limitations regarding the building's load-bearing capacity.
Reduction of construction and/or maintenance costs	3	Reduction of various types of costs within the TCO over the lifespan of the roof for the main investor, including one-time construction costs and periodic maintenance expenses.	Realistic options for cost reductions can be considered to achieve a neutral or positive NPV for the investment in BG roofs. If the technology has reached an advanced stage of development and is more widely available, costs may be lower.