PIISA

Piloting Innovative Insurance Solutions for Adaptation

D3.4 Results of survey on applicability in Nordic region

Authors: Georges Farina, Peter Robinson, Simone Kroes, Lisette Klok, Wouter Botzen

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Abbreviations and acronyms

Acronym	Description
NBS	Nature-Based Solutions

1 Introduction

Nature-based solutions (NBS) such as green roofs offer promising potential for climate adaptation in urban areas (Cohen-Schacham et al., 2016; Kabisch et al., 2022). However, their uptake varies significantly across Europe (Davies et al., 2021). In the Netherlands, green roofs are undergoing development – about 0.5% of Dutch flat roofs have a green roof (Brugman, 2023), through municipal incentive programs. Major Dutch cities like Amsterdam, Rotterdam, Utrecht or The Hague have offered subsidies[1] since the late 2000s - covering up to 50 % of installation costs - as part of broader climate resilience strategies. Rotterdam's subsidy scheme alone had led to nearly 360 000 m² of green roofs by 2018[2] .

By contrast, green roofs in cities of the European Nordic region remain sparse (Nordic Council of Ministers, 2023). In Helsinki, a geospatial analysis from HSY's Decumanus dataset (2016)[3] identified only a few hectares of actively vegetated flat roofs, out of over 1.5 million m² of potentially suitable flat rooftop area.

Green roofs may indeed offer climate-risk mitigating benefits at an individual building-level (*e.g.* protect the roof layers of buildings against weather damages, reduce indoor climate variations); as well as at a collective level once upscaled (*e.g.* against pluvial flooding) (Shafique et al., 2018). However, their effectiveness as a risk mitigation tool is still under investigation, and the potential for insurance mechanisms - such as premium differentiation - depends on a clear understanding of both local performance conditions and the institutional barriers and enablers that shape green roof adoption.

At the same time, European insurers are facing a sharp rise in claims linked to extreme weather events and climate change (Bueno Rubial et al., 2024; Collier et al., 2021) prompting growing interest in their potential role in supporting climate adaptation. While the involvement of insurers in adaptation remains low, they are potentially well-positioned to influence risk awareness, promote preventive measures, and ultimately incentivize adaptation practices like green roofs (Jarzabkowski et al., 2019; Mills, 2009).

This report presents the results of Loop 2 (Loops are development cycles used in the project) of the PIISA project's green roofs pilot, focused on assessing the applicability of green roofs and green roof insurance products in the Nordic[4] region. While Loop 1 centered on the Netherlands,

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[1]https://www.rotterdam.nl/groene-daken https://www.amsterdam.nl/subsidies/subsidieregelingen/subsidie-groen-amsterdam/
https://www.groendak.nl/ook-utrecht-geeft-subsidie-op-groene-daken/#:~:text=Ook%20Utrecht%20geeft%20subsidie%20op%20groene%20daken.%20U,worden%20tot%20een%20maximum%20van%20%E2%82%AC%20250%20vergoed.
Subsidie klimaatadaptatie aanvragen (voor opvang regenwater) - Den Haag
[2] https://interlace-hub.com/green-roof-subsidy-rotterdam
[3]https://www.hsy.fi/en/environmental-information/open-data/avoin-data---sivut/green-roofs-in-the-helsinki-metropolitan-area
[4] The word "Nordic" has been used officially in the PIISA grant agreement and documentation in order to refer to the Nordic climate regions of Europe. However, for easier referencing, the term "Nordic" is used from now on to refer to the European Nordic countries (Denmark, Norway, Sweden, Finland).

it included not only the analysis of the green roof strategy of the Dutch insurer Interpolis[5] but also broader research activities: a cost-benefit analysis of green roofs, an evaluation of the effectiveness of various upscaling incentives (such as subsidies and premium discounts), and household surveys to assess public acceptance of green roofs and their behavioural drivers. Loop 2 builds on these insights to explore how similar approaches could be adapted for Nordic cities. The aim is to assess whether green roofs can be an effective climate adaptation measure in Nordic contexts, and whether insurers could play a role in (and benefit from) increasing green roof uptake. The pilot therefore aims to inform business models for nature-based climate adaptation solutions that align private incentives with public benefits.

To address these questions and shed light into green roof business models adapted for this region, Loop 2 combines two complementary approaches. First, a stakeholder consultation process, including a webinar and semi-structured interviews with researchers, urban planners, and insurance professionals, captures context-specific insights into the barriers and enablers across the Nordic region. Second, a literature review focuses on existing studies of green roof performance, costs, and benefits under Nordic climate conditions, providing a broader evidence base for understanding their adaptation potential.

This report begins with a concise overview of the methods (Section 2) for the survey and literature review used in Loop 2. It then presents the key findings from the interviews (Section 3), followed by a discussion that places these insights in context with existing literature (Section 4). The report concludes with a synthesis of implications and recommendations for scaling up green roofs and green roof insurances in the Nordic region (Conclusion).

[5] Interpolis has experimented a climate adaptation strategy that includes various programs to incentivize homeowners to adopt prevention measures - including NBSs and green roofs. Interpolis offers green roofs to address damage claims from homeowners experiencing roof leakages caused by extreme rainfall. Additionally, Interpolis provides complementary free services (information, inspection of roofs). Previously, a 10% discount was also offered on the insurance premium to encourage homeowners to install green roofs. This Interpolis initiative is a starting point and a case study for the PIISA green roof pilot (see deliverable D3.3).

2 Methods

This report relies on two complementary methods: stakeholder interviews, and a targeted literature review. Together, these approaches allow for both context-specific insights and broader validation against existing evidence on green roofs in cold climate settings.

2.1 Stakeholder interviews

A total of 13 semi-structured interviews were conducted with key stakeholders in the Nordic region. On the one hand, these included representatives from insurance companies operating in the Nordic region (n=4). On the other hand, interviewees included other urban planning stakeholders (n=8): three researchers, two urban policymakers (from Helsinki and Tampere), two representatives from engineering and consulting firms, and one from a national homeowners' association.

The interviews aimed to explore the perceived benefits, barriers, enabling factors, and constraints affecting the uptake of green roofs (primarily) and NBS (additionally) in Nordic cities. A specific focus was placed on the potential role of insurance mechanisms in supporting or scaling such solutions.

Participants were selected through opportunistic sampling, based on relevance, prior engagement with PIISA partners, scientific publications that concern green roofs in the Nordic region, and availability. The PIISA green roof webinar (30/01/2025) was also used as an opportunity to recruit potential interviewees, and to start briefly assessing barriers and enablers on green roofs in the Nordic region (see Appendix C). All interviews followed semi-structured guidelines tailored to the stakeholder group (see Appendices A and B), thus covering consistent themes and topics, while allowing space for respondent-driven insights. Interview transcripts were analysed qualitatively to extract key insights, with attention to recurring themes, stakeholder-specific perspectives, and notable differences across sectors.

Finally, eight interviews with Dutch insurers conducted earlier in the project (during Loop 1) were used as background and comparative basis (see Kroes & Klok (2024)). While not part of this data collection phase, they provide a comparative basis for reflecting on how barriers and enablers differ between the Dutch and "Nordic" insurance markets.

2.2 Literature Review

The literature review synthesizes existing research on green roof performance, costs, benefits, and incentives in Nordic urban climates. Sources were identified through targeted searches on Google Scholar and Semantic Scholar, using combinations of search terms such as "green roofs", "cold climate", "Nordic", "Nordic cities", "biodiversity", "stormwater", "damages", "co-benefits", "Finland", "Sweden", "Denmark", "Norway".

A total of 23 peer-reviewed articles and technical reports were selected. These span multiple disciplines - hydrology, ecology, engineering, urban planning, and environmental economics - and provide insights into both the physical functioning and broader societal impacts of green roofs in cold climates. The literature reviews help contextualizing the interview results and highlight areas of alignment or divergence with existing evidence.

3 Stakeholder interviews

3.1 Interviews with insurance companies

Interviews with insurance companies were conducted to identify the enablers and barriers to incorporating NBS and green roofs specifically into insurance products – and to understand how these factors vary across the Netherlands and the Boreal region. This chapter outlines how four insurers in the Nordic region reflect on those questions, and how it compares to the findings obtained in the Netherlands.

3.1.1 Current examples

The outcomes of the interviews show that insurers in both the Netherlands and the Nordic region take initiatives for climate adaptation. The most common initiative that insurers in both regions apply is providing prevention advice on how to reduce climate-related risks to policyholders. In some cases, Dutch insurers have moved beyond general advice to concrete measures, such as offering green roofs as an insurance product. In contrast to offering NBS insurance products, Nordic insurers still emphasise climate-damage prevention tips, ranging from online guidance to on-site assessments by building experts. For instance, as part of these on-site assessments, building experts perform a free property health check every four years, offering specific advice and suggestions to reduce risks of climate damage.

3.1.2 Barriers

While green roof uptake is increasing in the Netherlands, their uptake is limited in the Nordic region. Correspondingly, Nordic insurers are not actively promoting green roofs or other types of NBS – a trend also observed among Dutch insurers. A key underlying factor is the uncertainty around risk reduction: insurers in both regions emphasise that unless green roofs demonstrably reduce risk, there is little incentive to engage with NBS-related products. Compared to Dutch insurers, insurers in the Nordic region see three additional barriers (see Table 1):

1. Adjusting building structure is costly

In the Nordic region, insurers noted that the added weight - especially when accounting for retained rain and snow - can compromise the integrity of buildings not originally designed to support such loads. This perceived risk is heightened by the region's climate, which may lead to more snow accumulation in the future. Moreover, the installation of green roofs can increase property values, potentially leading to higher insurance premiums. The high cost of construction further acts as a deterrent.

2. Regulation and permissions

Insurers in the Nordic region highlighted complex regulatory environments as an obstacle. In Sweden, rebuilding after damage requires municipal approval, which must align with detailed legislative frameworks and general planning considerations. In Finland, strict building codes include requirements related for building resilience, e.g. snow load and ice formation during winter, making compliance particularly challenging for green roofs. Concerns include water insulation, ventilation, structural weight, fire safety, and roof slope. Unlike in the Netherlands, there are no known subsidies for green roofs in these countries, further reducing incentives.

3. Risk distribution and insurability

Issues related to risk allocation and insurability were more explicitly raised by insurers in the Nordic region than by Dutch insurers. Insurance typically covers only sudden and unforeseen events, leaving ambiguity about who – municipality, insurers, or property owner – bears responsibility for climate-related building damages. For example, if a property owner fails to take climate adaptive measures and weather-related damages occur, the financial burden may fall on the insurer or municipality. However, if preventive measures—such as green roofs—are implemented and later sustain damage due to climate change, it is unclear who is responsible for the costs. This responsibility may differ depending on the property type: for owner-occupied homes, it typically lies with the owner or, in the case of apartment blocks, with the owners' association; for rental properties, responsibility often falls to the property company or municipality. While insurance policies could potentially be adapted to cover such risks, questions about installer error or maintenance responsibility complicate claims and accountability. This uncertainty can make property owners hesitant to invest in such solutions, as they may be left shouldering the risk—similar to the hesitations seen with energy-saving or residential renewable energy measures, where perceived obstacles often outweigh incentives. The lack of a clear accountability framework therefore hinders efforts to promote risk prevention measures.

3.1.3 Enablers

Despite existing barriers, insurers also identified enablers for including NBS into insurance policies. Some of these enablers align with findings from the Netherlands, although some differences emerged. Two main enablers are highlighted (see Table 1).

1. Differentiating insurance premiums

Insurers stressed that for green roofs to gain traction, they must demonstrably reduce risk and lead to tangible economic benefits. A primary incentive would be offering lower premiums - not only for the property with the green roof but potentially across the policyholder's entire insurance portfolio. This approach goes beyond the Dutch takeaways, where insurers only mentioned premium differentiation for the insured property itself, without considering discounts across the broader insurance portfolio. Once green roofs are well established as climate risk reduction assets on household level - insurers are more likely to promote this offering premium reductions.

2. Public-private collaboration

Insurers underlined the importance of collaborating with local governments and the construction sector to support green roofs uptake. This includes co-funding through subsidies and helping customers identify trustworthy contractors for damage repair - even for materials and/or services the insurer does not cover - thereby building trust. A new insight, not mentioned by Dutch insurers, is the potential role of insurers in covering financial risks linked to NBS. For example, insurers could step in if a green roof underperforms, such as failing to prevent water damage and thereby not delivering the expected roof structure protection benefits. This can help reduce uncertainty and encourage uptake among property owners and developers.

3.1.4 The way forward: Incentives

The incentives identified in the Netherlands are familiar to insurers in the Nordic region and no new incentives were mentioned (see Table 1). However, three critical points were stressed again.

- First, as Dutch insurers also highlighted, access to household-level data on climate risks and on the risk-reducing effects of NBS is key, and still to be established.

- Second, while enhanced collaboration and data sharing on climate risks and adaptation measures would be beneficial, insurers noted that competition laws prevent information exchange between insurance companies, thus hindering the sharing of knowledge and data.
- The development of climate adaptation labels for rebuilt or renovated houses is perceived as a promising option, though still in its infancy. Building on this, insurers proposed the development of renovation standards specifically aimed at reducing future climate-related damages.

3.1.5 Key takeaways

Many of the barriers, enablers, and incentives identified are similar between insurers in the Netherlands and the Nordic region, suggesting some potential for replicating strategies across climate regions. As their involvement in climate adaptation and risk prevention increases, a more deliberate focus on creating public-private collaboration and enhancing knowledge and data exchange could help overcome barriers to NBS insurance solutions. The specific types of public-private partnerships were however not mentioned during interviews with insurers from the Nordic region. Practical examples may include the Interpolis case, whereby 1) insurance companies shared data on climate risks with the municipality on green roof constructions; and 2) simultaneously offer premium discounts for green roofs owners in addition a subsidy from a municipality.

However, differences between insurers in the Netherlands and the Nordic region exist:

- Location-specific factors play a significant role. In the Nordic region, building features must account for climatic conditions and regulatory hurdles are more pronounced due to zoning plans and a lack of subsidies, which is different from the Netherlands.
- Prevalence of green roofs also differs. Green roofs are more commonly integrated into the urban landscape in the Netherlands, and early efforts to support them – through funding, partnerships, and regulations – are somewhat more developed.

		Netherlands (n=8)	Nordic region (n=4)
Barriers	1. Absence of a robust business case		
	2. Limited awareness and knowledge of climate risks		
	3. Siloed, sectoral approach to climate adaptation		
	4. Unclear role of insurers in climate adaptation		
	5. Adjusting the building structure is costly		
	6. Regulatory hurdles related to permissions		
	7. Risk distribution and insurability		

Enablers	1. Differentiating insurance premiums		
	2. Information infrastructure on prevention		
	3. Build Back Better approach		
	4. Adjusting insurance policy coverage		
	5. Public-private collaboration		
Incentives	1. Exchanging best practices		
	2. Developing climate adaptation labels		
	3. Data on nature-based solutions and risk reduction		
	4. Creating internal and external awareness		
	5. Establishing a long-term vision		
	6. Collaborating with key stakeholders		

Table 1: Barriers, enablers and incentives of nature-based solution insurance products for insurers in the Netherlands and the Nordic region gained in interviews.

3.2 Interviews with urban planners and researchers

This section presents findings from a series semi-structured interviews conducted with key stakeholders following the guidelines outlined in Appendix B. The interviews included researchers (3), urban policymakers from Helsinki and Tampere (2), engineering and land-use planning consulting companies (2), a homeowners association (1).

3.2.1 Current initiatives and development trends

Overall, green roof implementation in the Nordic region is at a relatively early stage, with development concentrated in new construction projects and specific municipal initiatives. Several interviewees emphasized that green roofs are not yet the norm and often require persistent advocacy throughout planning and construction phases. A few specific municipal initiatives were outlined:

- In Tampere, green roofs have been introduced through collaboration between city departments[6]. The city developed a guideline tool to help planners and developers select appropriate Nature-Based Solutions and green roof types based on project and building characteristics, *e.g.* roof slope, structure weight, and plot density. This tool primarily applies to new construction, where municipalities have more influence. Deck courtyards and outbuildings (e.g. carports) are more commonly targeted for green roofs, as they align with existing policies and green space accounting mechanisms.

[6] https://ilmastovahti.tampere.fi/en/actions/1.4.8

- In Vantaa[7], the city has introduced new norms for vegetated roofs in the airport area, with all relevant departments (e.g. schools, health, planning) endorsing a common set of guidelines. This cross-departmental alignment signals strong municipal support for vegetated roofs and is seen as a model for upscaling efforts.
- In Helsinki, *Forum Virium* is piloting greening projects[8] in innovation districts, particularly in dense suburban areas undergoing redevelopment. These pilots aim to add multifunctional green elements like green roofs and measure benefits such as temperature regulation and biodiversity using environmental DNA. However, green roofs still require substantial promotion and justification at each planning stage.
- In Oslo, early green roof research pilots[9] were established over a decade ago, and are still ongoing. While green roofs are part of the broader blue-green infrastructure strategy in Oslo (Strategi for grønne tak og fasader, 2030), actual implementation in built-up areas remains limited. A revealing example was given by an interviewee: in a recent municipality-led experiment where green roofs, raingardens, or permeable pavements were offered to homeowners of a neighbourhood; only two green roofs were implemented, suggesting continued preference for ground-level solutions.

More generally, across interviews, public buildings such as kindergartens and schools were frequently mentioned as promising sites for green roof implementation, both as demonstration projects and as a means of fostering early public familiarity with the concept. While interest is growing, particularly from private developers in multi-unit housing projects, green roofs in detached homes and smaller private buildings remain rare. One interviewee from the Finnish Home Owners' Association noted they had seen virtually no demand or inquiries related to green roofs during their three years in the role.

3.2.2 Key benefits of green roofs

During the interviews, stakeholders were asked what are the most important benefits of green roofs in the case of Nordic cities – in order to identify how they might differ from the benefits highlighted in the Netherlands. Responses highlighted that the emphasis on those specific benefits were motivated by practical experiences, local climate constraints, and specific policy or planning contexts. Rather than a generic list of benefits, interviewees highlighted a smaller and often cautious list of benefits.

Stormwater management was frequently mentioned as a motivating factor, particularly in urban planning contexts like Tampere and Helsinki. Here, green roofs are valued for their potential to reduce sewer load during heavy rainfall and improve water quality by filtering runoff. However, some researchers cautioned that in Nordic climates, green roofs contribute only minimal quantitative stormwater retention, though they may help during winter melt events by delaying runoff and reducing flood peaks.

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7 https://kaupunkitilaohje.vantaa.fi/fi/viheralueet-ja-kasvillisuus/vihertehokkuus-ja-kasvikatot
8 https://forumvirium.fi/en/projects/pilotgreen-brings-new-ways-to-increase-vegetation-in-cities/
9 https://www.oslo.kommune.no/miljo-og-klima/slik-jobber-vi-med-miljo-og-klima/klimatiltak/gronne-tak-og-fasader/piloter-pa-gronne-tak-og-fasader/

In Finland, many benefits were discussed with a degree of nuance or uncertainty. While thermal insulation was noted, it was rarely highlighted as the primary driver. One planner observed that green roofs on summer cottages provided better indoor climate stability, while others acknowledged potential energy savings, but without concrete data.

Biodiversity emerged as a more consistently emphasized benefit, particularly in newer policy discussions. In Finland and Norway, there is concern about the ecological value of typical sedum roofs, which were often described as limited in their habitat support. Several interviewees advocated for meadow roofs or native plant mixes, which can better support pollinators and dynamic rooftop ecosystems. Researchers also noted the potential of using roofs to observe ecological succession over time, as species composition naturally evolves.

Interviewees in Oslo stressed the growing importance of access to green areas in the perceptions of citizens, and mentioned the "3-30-300" urban greening guideline[10] proposed by Konijnendijk (2023). Biodiversity, and specifically pollinator presence, was highlighted also as a central concern and motivation of urban dwellers. In Helsinki, environmental DNA is being explored as a tool to monitor rooftop biodiversity as part of pilot projects.

In dense urban areas, aesthetic and social benefits - such as enhancing visual quality, providing greenery where ground-level space is scarce, and supporting recreational or food production uses - were acknowledged, though these were often downplayed in more technical planning discussions. Forum Virium noted that although these benefits are real, they are "underemphasized" in policy arguments, which tend to prioritize quantifiable environmental outcomes.

A key takeaway from the interviews is that the perceived benefits of green roofs vary by stakeholder type. Biodiversity and water quality are gaining attention as justifications in policy-making, as suggested by the report issued by the Nordic Council of Ministers (2023). On the other hand, thermal and stormwater management benefits are acknowledged but often seen as context-dependent or needing further evidence.

3.2.3 Barriers to Implementation

The most frequently mentioned barriers to green roof implementation across the interviews relate to structural limitations, regulatory barriers, and limited knowledge.

Structural and climatic challenges are central in the Nordic region. Interviewees highlighted widespread concerns about snow loads, moisture damage, and roof collapse, particularly in older buildings not originally designed for such additions. Partly, those concerns were dubbed to be unfounded by interviewees, and based on prior bad construction practices. These concerns persist even where technical solutions exist. For example, the Finnish Home Owners' Association emphasized that fears about moisture and structural stress are major reasons why green roofs

[10] The 3-30-300 is an urban planning guideline that emphasizes equity in access to trees and green spaces and their benefits. Its sets a threshold for all neighbourhoods: a minimum of "3 well-established trees in view from every home, school, and place of work, no less than a 30% tree canopy in every neighbourhood; and no more than 300 m to the nearest public green space from every residence" (Konijnendijk, 2023, p1).

are rare in detached homes, especially in Northern Finland where winters are longer and harsher. Similar concerns were raised by planners and researchers in Oslo and Tampere.

Economic and regulatory barriers further complicate implementation. Green roofs are often perceived as expensive relative to their benefits, especially when compared with more familiar technologies like solar panels. Detached homes - already facing a slowdown in new construction - have little incentive to pursue green roofs without clear financial benefits. Municipal officials and researchers also described a lack of subsidies or supportive incentives for green roofs, unlike in some other EU countries. This is compounded by strict building codes in places like Finland, which require green roofs to meet demanding structural and safety standards (e.g. fire resistance, drainage, and slope limitations).

Institutional silos were repeatedly flagged as a challenge in cities like Helsinki and Tampere. Urban nature and green roofs often fall between administrative categories, requiring collaboration across zoning, water management, and building departments. This fragmented responsibility makes it difficult to deliver integrated solutions or consistent guidance.

Knowledge gaps were also cited repeatedly. A recurring challenge raised by stakeholders is the lack of long-term monitored case studies. Many existing green roofs have not been systematically evaluated for structural durability, thermal performance, CO_2 footprint, or even vegetation health. This gap weakens the evidence base needed to justify investments, particularly for private developers or public agencies. Several experts pointed out also to the consequences of this gap in construction and maintenance practices: landscape architects and structural designers often lack training in plant selection, substrate behaviour, and long-term maintenance needs. In Finland, for example, it was noted that many professionals designing green roofs are unfamiliar with horticultural practices or local ecological conditions. Maintenance teams also frequently lack the expertise required to sustain plant communities over time and fall back to practices (*e.g.* fertilisation, use of invasive species) that lead to green roofs not delivering all the ecosystem services that they could be.

Lastly, public perception is a central barrier. Interviewees consistently cited low awareness and/or skepticism as major obstacles - particularly outside of experts and urban planners. Even among motivated property owners, uncertainty about construction methods, costs, and long-term reliability limits adoption. The Finnish Home Owners' Association suggests that adoption is being implemented rather on smaller auxiliary structures (e.g. garages, saunas, sheds) to build confidence, without putting main buildings at risk.

3.2.4 Enablers and opportunities for upscaling

Several enablers and opportunities for scaling up green roofs were identified in the interviews. Two main way forwards were outlined:

3.2.4.1 Establishing harmonized data and standards on green roofs

Several interviewees recommended the creation of a centralized knowledge platform or data hub, to systematically gather evidence on green roof costs and benefits. This could help build design guidelines at the national – or even transnational level – for the construction and maintenance of green roofs. Such a resource could include region-specific information on load-bearing requirements, plant palettes, moisture management, and successful case examples. It could help reduce uncertainty and support standardization, especially in smaller-scale or detached housing projects.

Interviewees also emphasized that such standardization approaches could help in achieving stricter protocols in green roof projects and constructions. Based on experience, early collaboration between planners, architects, and contractors is one main success factor in the green roof projects. On the contrary, green roofs that are introduced late in the design process are often excluded due to budget or technical conflicts.

Standardizing green roof approaches could also help in factoring them in adaptation policies. For instance, harmonized cost-benefit data adapted to Nordic climates could strengthen the case for integrating specific types of green roofs into urban stormwater planning - particularly in dense areas with limited open space (for other types of surface-level NBS) or with aging infrastructure. Green roof underperformance or failure can also be avoided through such an approach. Interviewees identified the need for better and consistent training programs - both for maintenance personnel and for landscape professionals - to ensure quality and consistency in green roof upkeep.

Consultants working with the construction sector pointed to existing voluntary certification and labelling systems - such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) - as important potential enablers. These systems award points for green roofs, incentivizing their inclusion without requiring legal mandates. Although not binding, they influence market preferences and design decisions. Such a system could also help in achieving such a level of standardization. This recommendation echoes options of climate adaptation labels identified by insurers.

3.2.4.2 Public-private collaborations

Public-private collaboration was identified multiple times as a key opportunity for scaling up green roofs. In some cities, such collaborations are already taking shape - for instance, through the work of Forum Virium and similar actors who support companies by providing access to creative and deliberative tools and data that help the process of planning the development of green infrastructures, including green roofs. Stakeholders emphasized the importance of user-friendly, digital resources to help non-experts make informed decisions. Collaborative planning between city authorities, developers, and property owners - already seen in Helsinki and Oslo - was cited as especially valuable in managing shared urban spaces and coordinating installations on buildings with multiple stakeholders. While public buildings such as schools, kindergartens, and care facilities have been common demonstration sites due to their centralized management and visibility, interviewees suggested extending this logic to privately owned buildings, including large commercial properties. These sites could play a similar role in normalizing green roofs.

Additionally, although interviewees stated that the role of insurers in green roof adoption remains limited. It could, however, be further developed. This is partly due to a lack of clear data on risk profiles - such as how green roofs affect water damage, snow loads, or structural integrity over time. However, several stakeholders saw potential for insurers to act as neutral intermediaries by collecting and analysing claims data related to roof performance – echoing thus the point made above on building evidence for green roof performances. This evidence could help clarify when and where green roofs reduce risks, potentially improving market confidence and encouraging wider adoption.

4 Consistency of findings with literature

This literature review assesses the performance, costs, benefits, and existing incentives of green roofs in the (European) Nordic region. Since the lack of evidence on green roof benefits was mentioned by stakeholders, this review aims at assessing where research gaps lie precisely. Additionally, because the goal of this pilot is to inform the development of scalable European business models for green roofs - not only from the perspective of insurers, but also in terms of broader public value - we examine not only risk reduction, but also societal benefits such as aesthetic and recreational value, biodiversity enhancement, and urban well-being. The main insights are summarised in Table 2.

4.1.1 Climate risk protection in Nordic climates

4.1.1.1 Individual benefits and risk protection

The protection of buildings against damages and the increased lifespan of roof structures and membranes in comparison with traditional roofs is one of the main benefits of green roofs (Bianchini & Hewage, 2012; Nurmi et al., 2013; Shafique et al., 2018). This makes green roofs a relatively low risk investment compared to traditional roofs according to some studies (Bianchini & Hewage, 2012). Yet lifespan is scarcely studied in the Nordic context (Andenæs et al., 2018; B. G. Johannessen et al., 2017).

Green roofs are often promoted for their potential to moderate building energy use and enhance structural resilience. However, studies show that the thermal insulation benefits in the Nordic region is limited. Due to high baseline insulation standards in buildings, energy savings from green roofs - especially in heating - are generally negligible (Andenæs et al., 2018; Collins et al., 2017). Instead, their primary individual-level benefit lies in reducing surface temperature fluctuations on the roof membrane, which can extend the roof's lifespan, leading to savings in repair and maintenance costs (Nurmi et al., 2013).

Cold climate conditions also introduce specific design and performance challenges. Frost and freeze-thaw cycles can reduce the insulation capacity of green roof substrates. To maintain functional performance under these conditions, substrates must have high drainage capacities (typically 15–20%) to prevent moisture buildup and frost damage (Andenæs et al., 2020).

4.1.1.2 Stormwater management and flood risk protection

Evidence shows that green roofs can play a role in reducing pluvial flood risks in cities through stormwater retention and peak flow reduction (Ercolani et al., 2018; Versini et al., 2015). Empirical studies specific to Nordic climates report that green roofs can attenuate peak runoff by 65–90% during rain events, with even thin-layer systems achieving annual runoff reductions of up to 20% (Akther et al., 2018; Bengtsson et al., 2005; Villarreal & Bengtsson, 2005). This hydrological performance is largely driven by vegetation and evapotranspiration, which in these climates can turn out even more significant than the substrate's storage capacity (Czemiel Berndtsson, 2010; Krebs et al., 2016).

Seasonality significantly influences performance. In winter, green roofs accumulate more snow than conventional roofs due to vegetation trapping, which can increase snow load and lead to water saturation during thawing. Efficient drainage design is therefore essential to handle meltwater safely and prevent overload (Braskerud & Paus, 2022; Johannessen et al., 2018).

Roof slope also impacts significantly water retention performance. While retention generally decreases with steeper slopes and higher rainfall intensities, sedum-based green roofs have been shown to retain significant runoff on moderately sloped surfaces during low-intensity events (<0.4 mm/min) (Morgan et al., 2013; Locatelli et al., 2014).

In addition to managing water quantity, green roofs can influence runoff quality. Several studies report reductions in pH and the filtering of certain pollutants (Versini et al., 2015). However, fertilized substrates may introduce nutrients into runoff, posing potential environmental risks (Czemiel Berndtsson, 2010).

4.1.2 Societal co-benefits of green roofs in Nordic climates

Green roofs can offer other important intangible benefits to residents. While difficult to value in monetary terms, they can be a large part of the overall total economic value provided by NBS (Raymond et al., 2017). For instance, aesthetic benefits have been shown to have a fairly large proportion in the social value provided by green roofs in a case study in Finland (Nurmi et al., 2016).

Overall, evidence also suggests that residents have positive perception for green roofs and have a high demand for them, even in the absence of direct use of green roofs, *i.e.* just as urban assets that residents do not get to walk on or interact with (Mesimäki et al., 2017, 2019). The actual type of landscape of green roofs varies according to public perception: some value orderly, curated greenery, while others prefer spontaneous, wilder aesthetics. Notably, even small green roofs contribute to social well-being and urban liveability (Mesimäki et al., 2017, 2019).

Additionally, green roofs can serve as important ecological substitutes in otherwise fragmented urban environments and habitats, and thus support biodiversity. Research specific to Nordic ecosystems shows they support diverse plant and insect communities, including threatened species (Gabrych et al., 2016; Jauni et al., 2020). Meadow plants typical of the region thrive on substrates around 20 cm deep, and roof height (up to 11 m) does not hinder biodiversity (Kuoppamäki et al., 2021).

Vegetation dynamics shift over time, with unintended species often overtaking planted ones—an effect influenced by local climate (Lönnqvist et al., 2021). However, this ecological succession tends to increase biodiversity and reduce nutrient leaching (Oberndorfer et al., 2007), reinforcing the long-term ecological value of green roofs.

4.1.3 Enablers and barriers to adoption

The adoption of green roofs in all contexts is constrained by a mismatch between private costs and public benefits, a challenge otherwise known as the *split incentives problem* (Joshi & Teller, 2021; Teotónio et al., 2021). This problem is also highlighted in Nordic climates. For instance, energy savings and property value gains – private benefits - often fall short of covering installation and maintenance expenses (Nurmi et al., 2016). Broader societal gains - such as stormwater mitigation, biodiversity, and visual amenity - remain undervalued in most cost-benefit analysis, if not entirely disregarded (Vijayaraghavan, 2016).

Nordic countries largely depend on regulatory approaches – zoning laws for instance - or integration into urban development guidelines, with limited use of financial or market-based instruments (Burszta-Adamiak & Fiałkiewicz, 2019). The absence of financial incentives, *e.g.*

subsidies or stormwater fee incentives, represents a missed opportunity for upscaling (Nordic Council of Ministers, 2023). In contrast, other Europeans countries - such as Germany - presents more comprehensive incentive frameworks at municipality level, combining regulations with stormwater fee rebates and co-financing programs (Burszta-Adamiak & Fiałkiewicz, 2019).

4.1.4 Main takeaways and research gaps

The review indicates that there is already a substantial body of evidence on the hydrological, ecological, and co-benefits of green roofs, and how they vary in Nordic urban contexts. However, several important knowledge gaps remain - particularly in areas relevant for assessing green roofs as risk-reducing infrastructure.

Indeed, the literature tends to have a disciplinary focus, that frames green roofs mainly as urban infrastructures designed for either urban greening and biodiversity enhancement, or urban rainwater management. What was found in literature reflects the current trends in Nordic countries. As outlined by the stakeholder interviews, green roofs are mostly driven by a rationale of municipal urban greening and/or rainwater storage. Thus, green roofs are not necessarily assessed and evaluated as individual risk mitigation assets. This leads to a significant gap in existing literature, which in turn limits the development of insurance-linked mechanisms and the broader institutional uptake of green roofs in Nordic cities:

- There is very limited evidence on building damage prevention: there is little empirical research directly evaluating how green roofs mitigate risks such as water infiltration, membrane failure, or structural degradation - key concerns for insurers.
- Long-term performance in the Nordic climate: only a few studies monitor durability or maintenance over time in cold climates, where snow loads and freeze-thaw cycles may impact structural integrity.

Therefore, in order to build stronger evidence to position green roofs as viable climate-adaptation tools within insurance, future academic research should also orient towards assessing green roofs as risk mitigation measures.

Field	Main insights	References
Urban hydrology	• Green roofs can reduce significantly runoff in terms of peak discharge and volume. Median peak attenuation can reach 65-90%. • Green roofs can improve quality of rain runoff (*e.g.* decrease pH) but also have adverse effects (*e.g*. if fertilization of GR soils) • Roof vegetation in Nordic and wet climates play a bigger role than in other climates to reduce runoff • Evapotranspiration plays a large role in regeneration of retention capacity – more than material storage capacities • Roof slope does not necessarily affect negatively runoff on sedum roofs for small events (0.4mm/min), than retention dismisses alongside slope. • Even thin green roofs (of a few mm) can reduce annual runoff by up to 20% • Snow accumulation is higher on green roofs than traditional roofs. Need for good drainage systems in addition to green roof in Nordic climates.	(Akther et al., 2018; Bengtsson et al., 2005; Braskerud & Paus, 2022; Czemiel Berndtsson, 2010; B. Johannessen et al., 2018; Krebs et al., 2016; Locatelli et al., 2014; Morgan et al., 2013; Versini et al., 2015; Villarreal & Bengtsson, 2005)
Ecological biology	• Green roofs can successfully provide habitat for threatened plants and animal species from Nordic region. • Meadow plants perform better on ~ 20 cm roof substrate. Height (up to 11m) does not affect negatively plant survival. • Vegetation on roofs are not static: roof age and substrate depth significantly affect diversity. • Ecosystem services increase with age of roofs (biodiversity increases, leaching of nutrients is reduced with age). • Unintended vegetation often outcompete intended species, influenced by temperature and precipitation patterns.	(Gabrych et al., 2016; Jauni et al., 2020; Kuoppamäki et al., 2021; Lönnqvist et al., 2021; Oberndorfer et al., 2007)
Building engineering	• The exact thermal insulation effect remains difficult to estimate. • Energy savings are negligeable; but reduced temperature fluctuations due to thermal insulation increases roof lifespan. • Frost can reduce thermal insulation, hence substrates require high drainage (15-20%) to optimize insulation • There is a significant quality risk in (blue-)green roof construction, mainly due to multiple building actors • Documentation on risk mitigation in construction process of (blue-)green roofs is still too small; there is no standardized approach • Performance of green roofs in the long run is a research gap	(Andenæs et al., 2018, 2020; Collins et al., 2017)
Economics	• Private benefits alone do not cover the costs of green roofs; accounting for societal benefits (*e.g.* scenic benefits) make them socially profitable • Green roof incentive schemes are diverse: regulation, tax allowance, reduced stormwater fees, biofactor, cofinancing, etc. Germany has the most diverse set of incentives, while countries from the Nordic region mostly rely on regulation: more emphasis is given on integrating green roofs into local planning and building regulations.	(Burszta-Adamiak & Fiałkiewicz, 2019; Nordic Council of Ministers, 2023; Nurmi et al., 2016)
Anthropology / mixed methods	• Small roofs also provide significant benefits to residents • Green roof non-use values for urban dwellers are not only visual and aesthetic but include a variety of benefits: intangible nature values, experience of social cohesion, multisensory experiences, restorative experiences. • Representations of green roofs are diverse (from very managed to wild, from direct active use to just visual)	(Mesimäki et al., 2017, 2019)

Table 2: Summary of literature review on green roof costs, benefits, and uptake in the Nordic region

5 General conclusions

This report assessed the applicability of green roofs and green roof insurance readiness level in the Nordic region, building on earlier insights from the Netherlands. Drawing on stakeholder interviews and a targeted literature review, the analysis identified the key conditions for the uptake of green roofs and the potential role of insurers in supporting upscaling.

First, findings reveal that green roof implementation in the Nordic region remains limited and uneven, particularly when compared to the Netherlands. Despite some promising municipal pilot programs, especially in Helsinki, Tampere, and Oslo, green roofs are not yet mainstream and are typically confined to new developments or auxiliary structures. This is due to a combination of climatic, structural, regulatory, and economic factors specific to Nordic urban environments.

Second, benefits perceived by stakeholders - such as stormwater regulation, biodiversity, and aesthetics - are often acknowledged but not always considered sufficient to justify investment. Moreover, some performance expectations remain uncertain or poorly monitored, particularly around long-term performances, thermal insulation efficiency and pluvial flood risk reduction.

Third, both insurance and non-insurance stakeholders emphasized significant barriers: structural constraints, fragmented institutional responsibilities, lack of long-term performance data, and persistent public scepticism. Insurers flagged the difficulty of quantifying the risk reduction potential of green roofs at the household level – and not at the catchment scale for instance - which limits the development of incentive-based products such as premium differentiation or information packages.

However, the report also identifies multiple opportunities for enabling green roof uptake. The main ones are the production of information materials for different stakeholder groups, the standardization of design and construction practices, the systematic monitoring of existing roofs, the integration of green roofs into certification and labelling systems, and the development of visible demonstration sites in large public and commercial buildings.

Interviewees also noted that while insurers are unlikely to act as data aggregators themselves, they may begin to collect more granular data to inform decisions around premiums or discounts for risk mitigation measures. However, in much of the Nordic region (with the exception of Norway), data sharing between insurers and municipalities remains limited. To effectively support the uptake of green roofs and similar measures, a neutral, regional observatory could play a key role in aggregating and analyzing data across stakeholders. In the long run, insurers could benefit from these data platforms to devise claims and premiums. In turn, they could end up offering coverage products for new green roof structures and collecting the claims data over time to refine further knowledge on their risk.

Finally, the literature review reinforces these findings, but also hints at a disciplinary focus on stormwater management and biodiversity; with relatively limited research on risk prevention and structural durability. Addressing these gaps will be critical for positioning green roofs as credible, insurable adaptation measures in Nordic cities.

Ultimately, the findings point that green roofs are not yet "risk-ready" for widespread insurance integration in the Nordic region, but they could become so. Overall, stronger evidence for green roofs adaptation benefits will help advancing the learning curve and dispelling their barriers; which in turn could lead to stronger policy support.

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Appendix A: Insurers interview questions

1) Current Policies / Solutions

What insurance products and solutions - related to green roofs or nature-based solutions (NBS), or green roofs specifically - are you currently offering?

Are there any specific initiatives or campaigns your company is running implementing to address climate change?

What types of clients are they targeting (private individuals, SMEs, public entities, etc.)?

2) Benefits of Green Roofs

What benefits do you see in promoting green roofs or other nature-based solutions in cities, particularly in the Nordic region?

How could your company benefit from more green roofs and closely related solutions being adopted by homeowners?

3) Barriers to Green Roof Insurance

What are the main barriers or challenges your company faces when trying to offer green roof or NBS insurance products? E.g. regulatory, financial, or logistical limitations

How do you think these barriers could be addressed?

4) Opportunities and enablers

What opportunities do you see for green roofs or NBS insurance products in the homeowners' insurance market?

5) Knowledge Gaps and Research Needs

What knowledge gaps do you think exist within your company regarding green roofs, NBS, or climate adaptation?

What kind of research, climate services, or expertise or even data that would be most useful to help your company and the market move forward with these solutions?

Additional Questions :

Are there any local or national regulations that are incentivizing your company to offer nature-based solutions in your products? How do these influence your strategy and operations?

How do you think insurance companies could better collaborate with external entities (e.g., climate service providers, researchers, or government agencies) to implement green roofs or NBS insurance products?

Appendix B: Researchers and policymakers' interview questions

1) What are current green roof – and closely related solutions - initiatives / successes? What is the state of the development of green roofs in your country / city?

2) Benefits of Green Roofs

What are the most important benefits of green roofs and NBS in Nordic cities ?

E.g. Thermal / aesthetic amenities / pluvial flood / biodiversity / protect against damages

3) Barriers to Green roof implementation

Are there existing initiatives (e.g., subsidies, insurance discounts) that support the adoption of green roofs? What is missing to support the upscaling of green roofs?

Could you rank the main challenges / limiting factors to adopting green roofs and other NBS in your region? (e.g., regulatory, logistical, political)?

What role does public perception and awareness play in the adoption of green roofs?

4) Opportunities for advancement

What are – in the current situation - the main drivers or enablers for expanding green roof adoption ?

What type of collaborations between societal stakeholders (e.g. policy makers, urban planners, insurers and homeowners) could help scale up NBS/green roof? Especially insurers ?

How can existing policies be improved or expanded to better support the wider adoption of green roofs ?

Do you see promotion of NBS (incl. green roofs) as a significant element of adaptation promoting insurance strategies in the Nordic countries? Please motivate your answer.

5) Knowledge gaps and research needs

What are the main gaps in research, knowledge or data about green roofs and NBS ?

Appendix C: Stakeholder input during green roofs webinar 30/01/2025

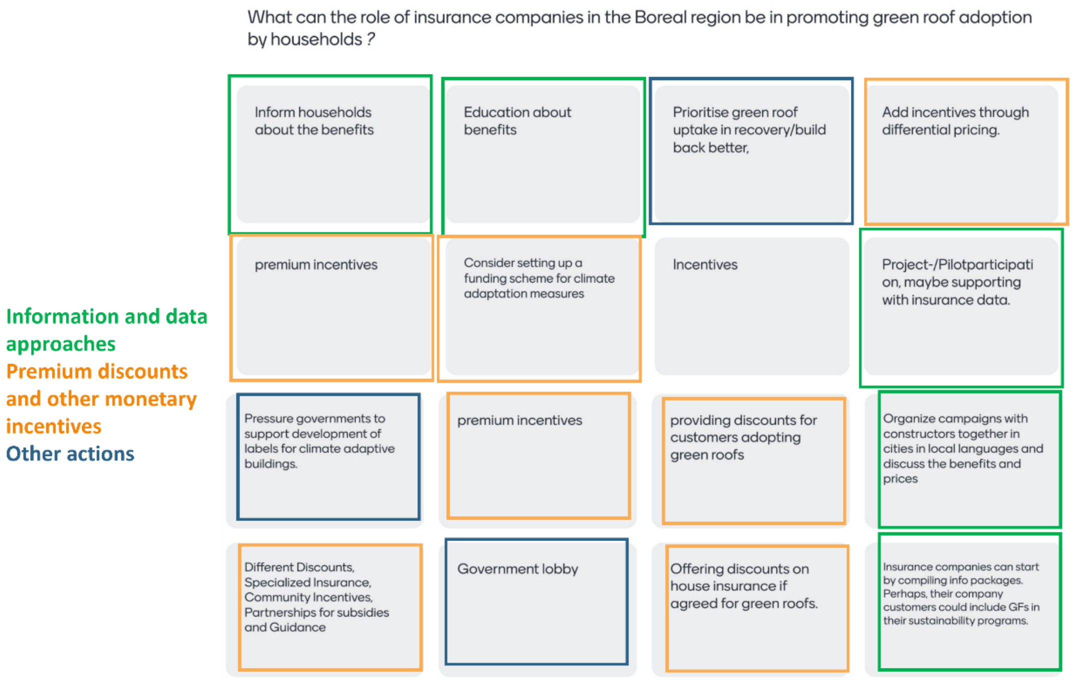

Figure 1: results from Mentimeter question on green roof insurance incentives asked during the 30/01/2025 webinar. (n=23)

The purpose of these questions was to collect input from participants about the potential mechanisms insurers could leverage to increase the uptake of green roofs in the Nordic region.

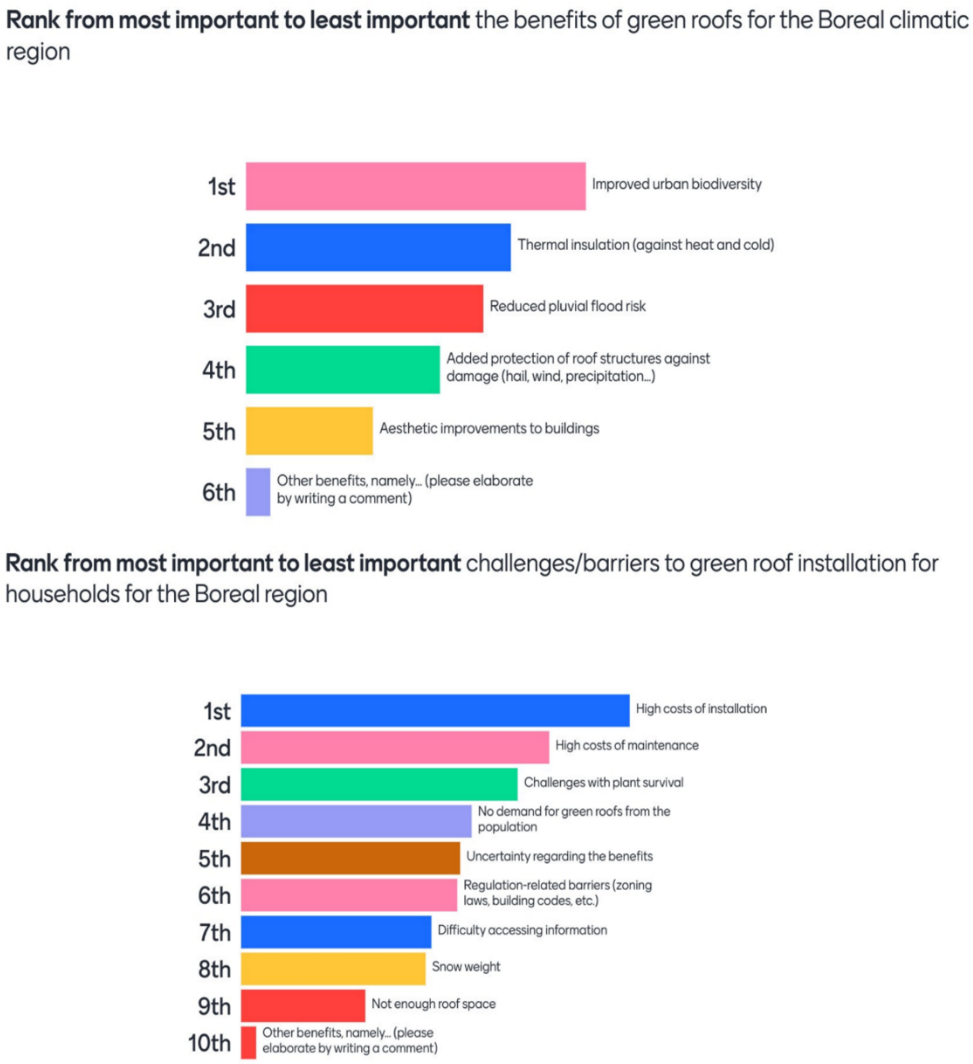

Figure 2: results from Mentimeter question on green roof benefits asked during the 30/01/2025 webinar.