RESILIO FINAL REPORT

A roof journey

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RESILIO, 'Resilience nEtwork of Smart Innovative cLImate-adapative rOoftops', is a collaboration between the City of Amsterdam, Waternet, MetroPolder Company, Rooftop Revolution, Amsterdam University of Applied Sciences (AUAS), Vrije Universiteit Amsterdam (VU), Stadgenoot, de Alliantie and De Key.

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BG RESILIO roof at Javastraat/Makasserstraat © Wieke Braat

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SUMMARY

In today's city environments, extreme weather conditions are a fact of life. Amsterdam, Mumbai, Nairobi or Sydney… climate change issues need to be tackled all around the world.

In the last couple of decades, Amsterdam has dealt with larger amounts of rainwater, severe heat stress and a decreased biodiversity. In order to strengthen urban resilience to climate change, **blue-green (BG) roofs** are increasingly being introduced. BG roofs place an additional water layer underneath the green layer. The idea is that these roofs reduce runoff after rainfall by retaining precipitation and mitigate heat stress, caused by increased evapotranspiration (the sum of evaporation from the land surface and transpiration from plants) and a higher albedo effect (the ability of surfaces to reflect sunlight).

Living laboratory

With RESILIO, a project which lasted from November 2018 to April 2022, Amsterdam created a living laboratory: 10,000 m^2 of BG roofs on existing social housing and privately owned real estate. The latter took place through a municipal grant scheme. The roofs have a 'Smart Flow Control' which anticipates heavy rain or drought, releasing or retaining water accordingly. The roofs are connected in a network, enabling remote regulation of rooftop water levels, based on weather forecasts and watermanagement settings.

Ambitious 'ecosystem'

RESILIO was developed in an Amsterdam 'ecosystem' which has experimented with BG roof solutions since 2013. Many of the partners involved in the project knew each other and their ambitions beforehand. Pilots and experiments, such as the first Polder roof and Project Smart Roof 2.0 (see chapter 2), had already brought the concept of micro watermanagement to life before the start of RESILIO.

Considerable progress

The RESILIO partnership, consisting of a quadruple collaboration between public authorities, knowledge institutes, the private sector and the voluntary sector, booked considerable progress in the adoption of governance strategies, cost-benefit analyses (CBA) and business case approaches, community involvement and engagement, public procurement, data collection and usage, as well as new Internet of Things (IoT) technology in a Decision Support System (DSS).

This report will guide you through the project and inform you about the lessons learned.

Chapter 1 is about the challenges cities face because of climate change and urbanisation. It describes how the RESILIO consortium took Amsterdam's initiatives for standalone BG roofs to the next level, towards an interconnected, intelligently steered network of BG roofs, owned by housing corporations. By extending BG infrastructure towards a neighbourhood network of flat rooftops, RESILIO created an opportunity to do research into the potential benefits of this nature-based solution, on a larger scale than before. An infographic explains how the RESILIO BG roof system works.

Chapter 2 gives a short history of the Amsterdam ecosystem of organisations, which actively tried to promote the introduction of a new BG environment on the Amsterdam 'roofscape'. The RESILIO consortium is introduced and the criteria of RESILIO's rooftop selections are explained. The chapter concludes with a summary of all the RESILIO BG roofs which were realised in Amsterdam, including two RESILIO Innovation Labs. The latter were used to do additional research into the RESILIO BG roof system, linked to student's programmes of the Vrije Universiteit Amsterdam (VU) and the Amsterdam University of Applied Sciences (AUAS). They were also used for educational purposes, visits and excursions.

Chapter 3 explains how RESILIO's project structure supported both scientific research into climate change impacts (pluvial flooding, heat, drought, biodiversity) and strategies to obtain knowledge about practical conditions – crucial to be able to actually benefit from the implementation of BG roofs. This includes technical innovation and product development, the design and installation of a water platform with intelligent data management, governance strategies to secure a viable and bankable business case, and – last but not least – proper participation and community involvement.

Chapter 4 explores the technique of a smart grid of interconnected RESILIO rooftops, creating a water platform which can respond to weather forecasts. A DSS and a dashboard are key elements of this platform. The chapter explains how a DSS integrates relevant information for decisions to either retain or discharge the water. A dashboard displays the history and actual information of the system, thereby supporting a user interface.

Chapter 5 is dedicated to the research performed in RESILIO on climate change impacts. The chapter explains the research objectives, the adopted research methods, and all the results which were achieved, including important lessons learned.

Chapter 6 focusses on governance research: the assessment of costs and benefits in a societal cost-benefit analysis (SCBA). An SCBA is used to explore ways to arrive at a sound business case for the development and upscaling of BG roofs. The notion of a transfer mechanism is introduced: a practical method to create a better distribution of costs and benefits between investing partners and beneficiaries of these investments.

Chapter 7 delves, at a more practical level, into the actual delivery of BG roofs. It sketches and analyses two practical delivery mechanisms which have been adopted in the RESILIO project: the procurement of BG roofs by the commissioning housing corporations and the grant scheme which supported private initiatives for installing BG roofs on property.

Chapter 8 explains how the RESILIO partners worked hard to inform residents of the RESILIO buildings and the surrounding neighbourhoods adequately, with the aim of promoting greater community involvement with climate change issues. The chapter contains a neighbourhood story, a personal account from a resident in one of the pilot areas.

Chapter 9

RESILIO strived for efficient communication within the project and with outside stakeholders. Chapter 9 provides an overview of the communication about, and dissemination of RESILIO findings during the project, locally, nationally and internationally. The chapter also touches upon international attention and recognition, as RESILIO has (already) won a number of awards.

Chapter 10

Based upon RESILIO's research and practical insights, the consortium can conclude that a smart grid of BG roofs can be a meaningful component of a city-wide climate adaptation strategy. The concluding chapter of this report sums up the messages to take home and provides ten recommendations.

1. INTRODUCTION

Innovation Lab Benno Premselahuis © Wieke Braat

1. INTRODUCTION

1.1. THE CHALLENGE: CLIMATE CHANGE AND URBANISATION

Worldwide, climate change has led to an increased frequency of irregular weather events. Increases in atmospheric water vapour concentrations have caused hydroclimatic changes such as extreme rainfall and increased droughts. [1] At the same time, average global temperatures have increased with warmer days becoming more frequent and growing in intensity. [2] The latest IPCC report shows that emissions of greenhouse gases from human activities are responsible for approximately 1.1 °C of warming since 1850-1900. And it states that, averaged over the next twenty years, global temperature is expected to reach or exceed 1.5 °C of warming. [3]

In Europe, climate change challenges are predominantly located in exceptionally urbanized settings, with over 70% of the continent's population living in towns or cities. [4] Due to social, political and technological changes, cities are developing fast and urban areas are rapidly expanding, converting surrounding nature into densely populated city structures. In the continually expanding cities, biodiversity has suffered: the enormous growth of the number of buildings has driven out many animals and organisms.

Urban environments foster higher surface and air temperatures than their rural counterparts, a phenomenon known as 'Urban Heat Island' (UHI). Caused by a lack of green spaces, higher absorption of solar radiation and non-circulation of air, these higher temperatures have led to increased levels of pollution and growing energy demands for cooling, as well as a higher mortality rate. [5] A significant number of buildings is not equipped for the increased temperatures during longer and more frequent periods. Heat stress in cities causes health problems for inhabitants and the overall wellbeing is under pressure.

Another consequence of climate change and expanding, impervious urban areas is the growing risk of pluvial floods, because (sometimes outdated) urban sewerage systems are confronted with intensified peak flows and growing volumes of precipitation runoff. Sewerage systems are unable to discharge the incoming streams, and then they clog up and overflow. [6] Wet feet in the streets and floating furniture in the basements could become a more and more frequent reality.

Coping with this rapidly changing environment is one of the world's most pressing issues. It has been recognised that, even with highly stringent measures to mitigate greenhouse gas emissions, further climate change consequences will continue to be felt. A mixture of both climate change mitigation and adaptation practices will therefore be necessary to combat this growing concern.

Figure 2: Growing risk of pluvial floods on a summer day

1.2 NATURE-BASED SOLUTIONS

Climate adaptation is greatly reliant on the support and diffusion of technological innovation and nature-based solutions (NbS). NbS are actions for societal challenges that are inspired by processes and functioning of nature. [7] Examples of NbS include ecosystem restoration, protection, and both maintenance and implementation of blue or green infrastructure. [8] Green roofs are an example of this. Due to a lack of urban space for the implementation of green infrastructure, they are increasingly seen as an effective solution to increase a city's resilience. They place a green plant layer on rooftops. The benefit of this in an urban context is the reduction of the UHI effect, as green infrastructure is less heat-absorbent than its alternative grey counterparts. [9]

To increase urban resilience to climate change, **blue-green (BG) roofs** are increasingly put forward. BG roofs place an additional water layer underneath the green layer. This particular solution has been tested in Amsterdam. The idea is that these roofs reduce runoff after rainfall by retaining precipitation and mitigate heat stress, caused by increased evapotranspiration (the sum of evaporation from the land surface and transpiration from plants) and a higher albedo effect (the ability of surfaces to reflect sunlight). In case of drought, the blue layer protects and aids the survival of the top plant layer.

1.3 RESILIO

The BG roof solution in Amsterdam was tested in the RESILIO project. Its objective: further development and upscaling of the blue-green infrastructure solution. RESILIO is an acronym for 'Resilience nEtwork of Smart Innovative cLImate-adapative rOoftops' and was a collaboration between the City of Amsterdam, Waternet, MetroPolder Company, Rooftop Revolution, Amsterdam University of Applied Sciences (AUAS), Vrije Universiteit Amsterdam (VU), Stadgenoot, de Alliantie and Lieven de Key. The project was co-financed by the European Regional Development Fund through the Urban Innovative Actions Initiative.

RESILIO applied an interdisciplinary approach with public and private stakeholders, in order to repurpose 10,000 m^2 of (social housing) rooftops in different neighbourhoods in Amsterdam. A network of smart BG roofs on social housing complexes and real estate in the city was created. The roofs contain smart valves which can gradually discharge excess rainwater based on real-time weather forecasts and watermanagement settings. By facilitating the deployment of such an innovative network of BG roofs, RESILIO aimed to optimise the watermanagement of the city and in doing so reduce climate risks such as flooding, decreasing biodiversity and heat stress.

Figure 3: RESILIO Partners

1.4 HOW DOES A BG ROOF WORK?

Planting: Different types of vegetation can grow on the roof, such as mosses, sedums, herbs, grasses, ferns, shrubs or a combination. There is a difference between extensive (sedum) and intensive (planting) green roofs.

Substrate: The planting is rooted in the substrate layer, similar to soil. This layer provides support and nutrition to the plants.

Filter layer: The filter layer prevents particles from the substrate from ending up in the water storage layer and clogging it up. It also ensures an even distribution of the water, which can be absorbed by the plants.

Water retention: The water retention is an extra drainage layer. This layer consists of a lightweight crate system in which rainwater is stored. Here, an integrated fibre technology has been incorporated, which makes water transportation from the storage to the plants possible.

Water- and root-proof layer: This layer protects the underlying roof construction from invading plant roots and prevents leaks.

Root-resistant bitumen: Root-resistant means that seeds from bird droppings, which could grow into roots, cannot have that effect.

Waterproof bitumen: This ensures that the water remains on the roof.

Cement: This layer consists of small cement blocks with granules, which act as an insulating layer.

Existing bitumen: The bitumen layer which is already on the roof.

Smart Flow Control (SFC): By means of this ‘smart valve’ the stored rainwater can be discharged or retained in the drainage layer. The valve responds to changes in the weather and opens and closes automatically at the right times.

Existing roof edge and drain: The roof system, also called roof construction, bears the weight of the roof and provides thermal insulation.

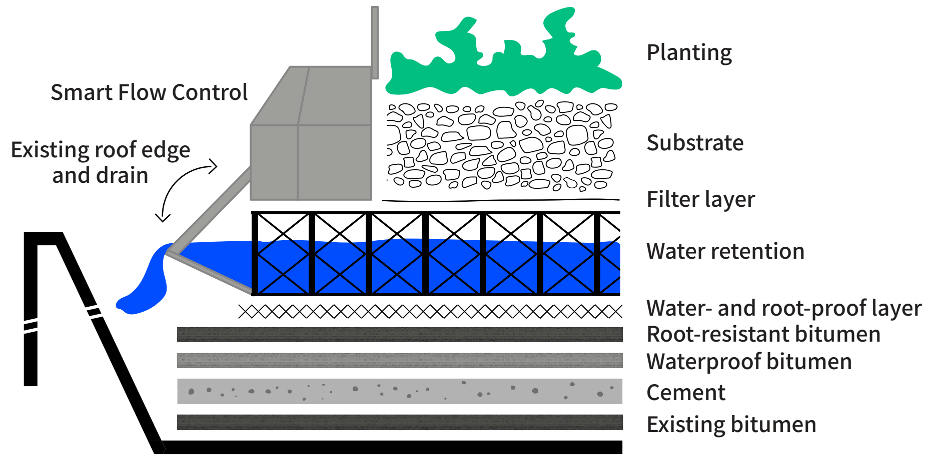


Figure 4: BG roof section

2. FACING THE CHALLENGE: CONCEPT, PARTNERSHIP AND ROOF SELECTION

BG roof on private real estate at Kop Weespertrekvaart © Wieke Braat

2. FACING THE CHALLENGE: CONCEPT, PARTNERSHIP AND ROOF SELECTION

2.1 FROM SPONGE CITY TO MICRO WATERMANAGEMENT

In The Netherlands, people have always lived with water and are used to getting rid of it as soon as it falls down. However, due to climate change Amsterdam is increasingly facing lengthy periods of heat and drought, causing wood rot and structural building damage as well as heat stress. Therefore the city needs to save water. But at the same time, more extreme rain showers result in pluvial flooding and the overflow of the sewerage systems. In other words, additional space for water is needed, so that it can be stored and reused – in a city that can be 'squeezed' when necessary, like a sponge. The blue-green (BG) roof solution is based on this Sponge City concept.

> How does a Sponge City respond to climate change?
> Prolonged drought? Recycle rainwater!
> Rainfall events? Anticipate & Capture!
> Extreme heat? Cooling by Evapotranspiration
> This is nature-based urban climate adaptation.

The Sponge City concept is a static model of a more water-robust city. As private properties in an urban environment are the de facto transfer point for raindrops, for the transfer into the urban drainage, this system is expanded using Internet of Things (IoT) and smart technology (more on this in chapter 4). This way, the roof landscape becomes part of the urban drainage system and a squeezable sponge city is created.

In a traditional urban area, roughly a 50/50 division between public and private space can be assumed. With the smart valves and a Decision Support System (DSS) (see chapter 4), the urban drainage system is enlarged by 100% and incorporates private space, as part of the full urban landscape in the drainage system. Smart valves create direct control of watermanagement.

2.2 BUILDING PARTNERSHIPS

2.2.1 BUILD UP

The City of Amsterdam has a major responsibility in enhancing urban climate resilience. Since 2013, both the City and Waternet (a public watermanagement organisation) have stimulated water-retaining roof systems, in different collaborations with a broad variety of partners. Examples of this are community building through the Amsterdam Rainproof network, pilot projects with a hands-on and academic approach, and dialogue with urban development and the Green Business Club Zuidas (Amsterdam's financial district). In fact, RESILIO is the follow-up to five years of research and development of smart BG roof technology by multiple partners in Amsterdam. The project is therefore a crucial building block to the already developing ecosystem of water-retaining and climate adaptive roof systems on private property.

Timeline:
2010: Start Network Green Roofs Amsterdam
2013: First Polder roof
2014: Start Amsterdam Rainproof
2015: Water neutral building envelope
2017: Project Smart Roof 2.0
2017: Zoning plan and Building code Centrumeiland
2018: RESILIO
2021: Municipal rainwater ordinance, making the retaining and re-using of rainwater mandatory in Amsterdam on new buildings and buildings that are radically renovated [10]

Project Smart Roof 2.0 is an important predecessor to RESILIO. This research roof was installed at the Marineterrein in Amsterdam. It was set up to demonstrate and scientifically validate function and value of the combination of blue (rainwater catchment, storage and reuse) and green (biodiverse) roofs for resilient and climate adaptive cities. [11] Watermanagement (blue) and plants (green) were carefully monitored using sensors. This provided a wealth of information, for example by using crates with fibre cylinders – which use the capillary effect (plants' natural ability to bring up water to their stems and leaves) to provide plants with water during dry spells. This creates natural irrigation without using pumps, hoses, or energy: just as it happens in the natural world. [12]

To scale up from single proof-of-concept rooftops to a smart grid of roofs, further development, testing and integration of the various innovations was required. RESILIO jumped into these research needs and brought together a mix of partners, keen to start scaling up.

2.2.2 THE CONSORTIUM

- The City of Amsterdam was responsible for the project management. Being connected to all partners and their roles, it retained overview and steered the project in the right direction. The City of Amsterdam was also responsible for the grant scheme (see 7.3) and the biodiversity research (see 5.3).

- Waternet, a public water organisation in Amsterdam which ensures the availability of safe, clean and sufficient water, was the initiator of 'dynamic micro waterbuffers'. On behalf of the City of Amsterdam and the regional Water authority Waternet is responsible for the entire water cycle in Amsterdam. In RESILIO, Waternet was responsible for the development of the Decision Support System (DSS) (using weather and water data) to which all roofs are connected for optimum water storage and cooling (see 4.2).

- MetroPolder Company is the brain behind the technology of smart BG roofs and was mainly involved in the construction and further development of the roofs. It also installed two RESILIO Innovation Labs (see frame B).

Figure 6: Smart Roof 2.0

- Rooftop Revolution is a foundation with a clear mission: all roofs should be utilised. It is responsible for clear communication and organised a number of citizen participation activities.

- Amsterdam has 12 km² of flat roof surface which can be transformed and become part of the waterbuffer smart grid across the city. Realistically, scaling up begins with transforming clusters of roofs (e.g. social housing, university buildings, business parks) in areas with extra high vulnerability. For this, three social housing corporations joined the consortium. With their extensive housing stock, they have the capacity to build a considerable number of BG rooftops (potentially also after the official end of the RESILIO project). It is their duty to contribute to a healthy environment for their tenants. The three housing corporations involved in the project were Stadgenoot, de Alliantie and Lieven de Key.

- To complete the partnership, knowledge partners Amsterdam University of Applied Sciences (AUAS) and the Vrije Universiteit (VU) conducted research and monitoring. More information about their research focus and results in chapters 5 and 6.

A 10th project partner in RESILIO was Consolidated. This company takes care of management, maintenance and renovation of flat and pitched roofs on behalf of professional building owners. Its maintenance processes are supported and optimised by an online portal for roof management (Dakota) which was used to select the roofs at the start of RESILIO. When the project was at the half-way mark, Consolidated was invited for the limited tender for the roofs of housing corporation Stadgenoot. As a result of the tender, Consolidated was selected as most favourable. However, this would have led to invoicing between project partners, which is not allowed in projects which are co-financed by European funds. Consolidated continued supporting the project as a subcontractor.

It can be said that collaboration and trust are most important in finding the right partners. In RESILIO a microcosm of partners was created, representing a quadruple collaboration of university, industry, government and civil society. However, one should be aware of how organisations differ, for example in terms of internal work cultures. Processes sometimes take longer than anticipated. And the same partners are not necessarily needed in every phase of the project. A partner such as Consolidated was extremely important in the beginning by selecting the right BG roofs, but by leaving the consortium it was able to take on a different role. For future consortiums process-based partnerships could be considered from the start, as for different stages of innovation different stakeholders are needed.

2.3 BG ROOF SELECTIONS

2.3.1 SELECTION BASED ON BOTTLENECK AREAS

RESILIO's basic idea was to set up a project which would predominantly focus on existing property in Amsterdam, as Amsterdam's climate stress tests identify this as most vulnerable to climate change. For example, the volumes of rainfall in the city of Amsterdam are rising. With a current discharge capacity of 20 mm/h, the city's drainage system simply cannot process new extreme volumes. The city's ambition for 2050 is to process 60 mm/h without any damage occurring. Of this volume, 20 mm is to be processed through the underground grey infrastructure, and 40 mm to be temporarily retained in public and private green spaces, such as roofs and gardens [12]. Whilst this 60mm processing capacity must be realised in the longer term, the current climate conditions regularly confront the city of Amsterdam with sewerage systems which are not capable of processing runoff volumes. This urged Amsterdam Rainproof to identify infrastructural bottlenecks by simulating 120mm of precipitation within two hours. The classification of bottlenecks range from 'urgent' (risk of damage to real estate) to 'extremely urgent' (risk of severe damage to real estate, vital infrastructure and hospitals, and disrupted accessibility).

Most of these bottleneck areas are in the inner city, mainly because public space here is scarce, so there is limited space for incorporating climate adaptive measures on the ground. Collaborating with private owners is therefore important. The paragraph above already identified the housing corporations as important stakeholders as they own a decent amount of property in the inner city.

By bringing in the data from Dakota, it was possible to select the building complexes with roofs suitable for the application of BG roofs. Together with Waternet, Consolidated initially selected five neighbourhoods which matched the existing property stock of the housing corporations involved and were also categorised as ‘vulnerable to pluvial floods in case of intensive precipitation’, as identified on the bottleneck map: Oosterparkbuurt, Geuzenveld, Rivierenbuurt, Indische Buurt and Kattenburg.

2.3.2 FROM SELECTION TO IMPLEMENTATION

However, in practice the housing corporations were not able to select all properties in the identified bottleneck areas, as there were also other interests involved – most importantly the timing of the project in relation to the planning of regular rooftop maintenance. In some bottleneck areas the roofs of existing property were not yet ready for replacement. Replacing them would make the total cost extremely high. Therefore priority was given to roofs which needed replacement anyway, in the upcoming five years. For this reason, Geuzenveld was replaced by Slotermeer.

In addition, some pre-selected roofs turned out not to have the right construction to sustain the heavy load of the blue and green layer. An example from this is that the roof selected by de Alliantie in the Rivierenbuurt had to be cancelled halfway through, because a recalculation of the load showed that the construction could not sustain it. An alternative roof was found, but not in the same neighbourhood. Rivierenbuurt as an implementation neighbourhood was subsequently cancelled.

Lastly, high costs also led to the cancellation of one particular roof. The tender for the second roof in Kattenburg showed a huge price increase (of more than 50%) compared to the first roof, which was realised by housing corporation Lieven de Key. The price hike exceeded the reserved budget and for that reason the partner decided not to continue with the realisation. More information about the procurement process in chapter 7.

2.3.3 PRIVATE PROPERTY OWNERS

As mentioned above, collaborating with private home owners is important for creating a climate resilient city. Therefore, in addition to collaborating with the housing corporations, the City of Amsterdam also developed a grant scheme to facilitate the realisation of BG roofs in private real estate. This scheme was set up for the entire city area and not specifically targeted at one pilot location. Both existing property owners, who wanted to transform their roofs, and owners of newly built property were able to apply. In the end, five private home owners were awarded financial support through the grant scheme (more information in 7.3).

A general lesson is that final implementation decisions on BG rooftops will always be multi-faceted and will depend, among other things, on rooftop maintenance planning, real estate portfolio strategies, local support and willingness to invest in sustainability.

FRAME A. AN OVERVIEW OF THE BLUE-GREEN RESILIO ROOFS

HOUSING CORPORATION ROOFS

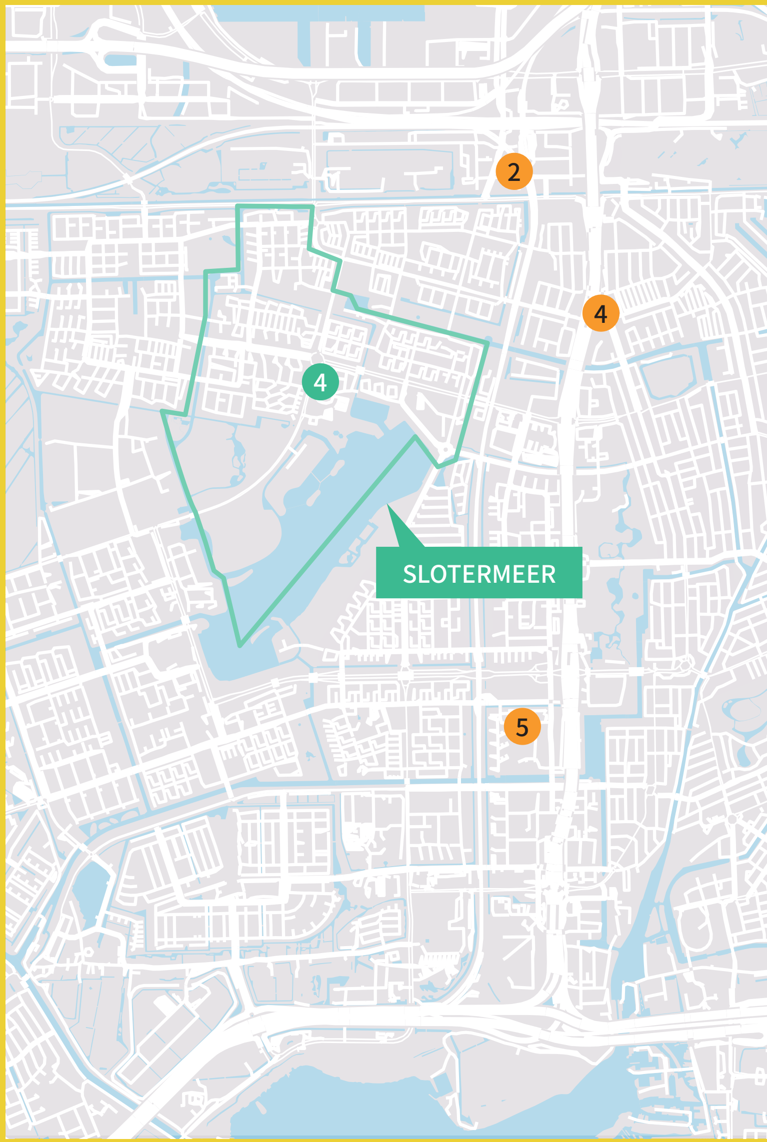

ROOF 1 AND 2

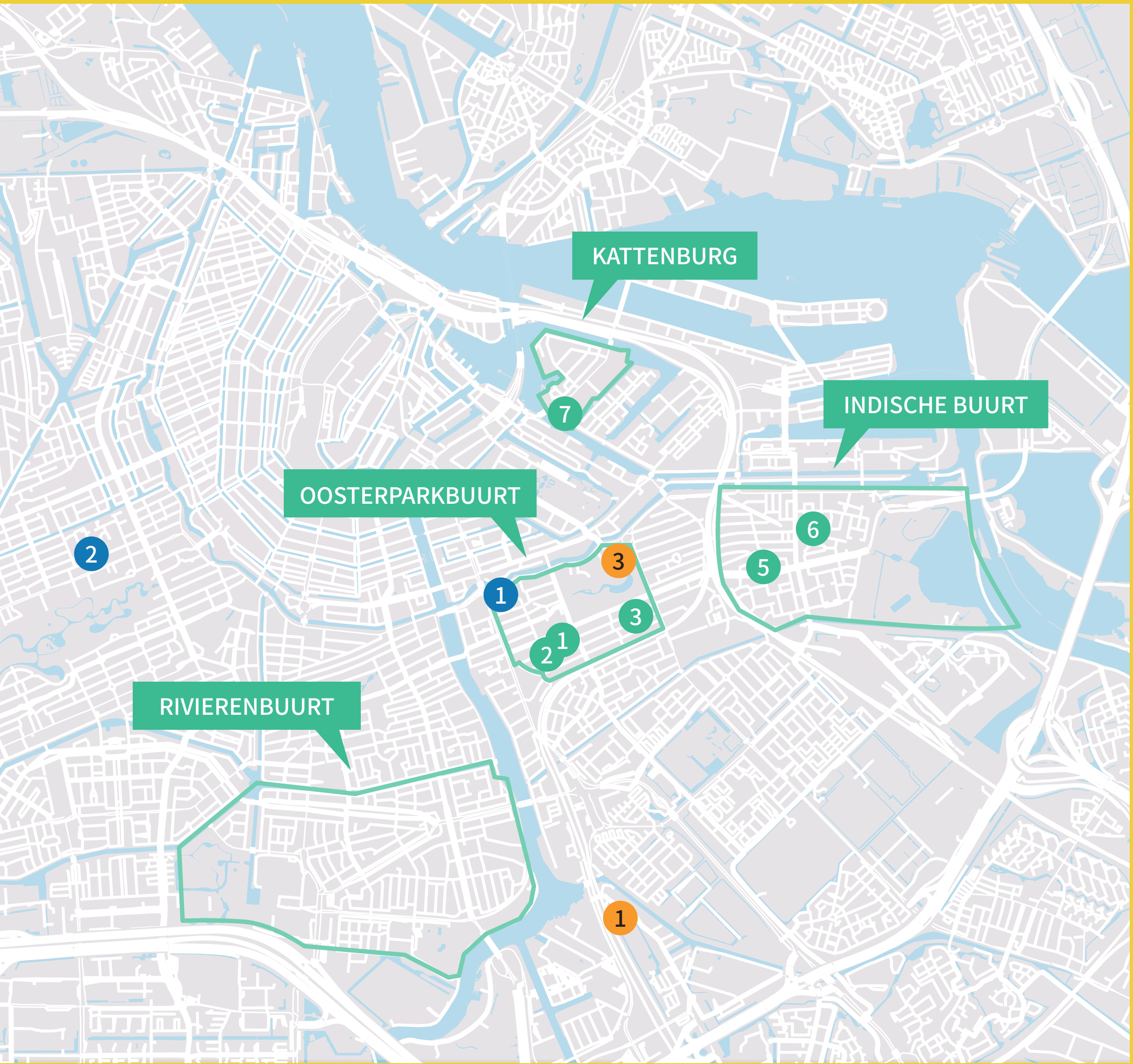

ROOF 6


ROOF 7

ROOF AREA AND RETENTION CAPACITY

1	**STADGENOOT**		
	Sparrenweg 80-100 Tweede Oosterparkstraat 80-86	463 m²	**18,960 L**
2	**STADGENOOT**		
	Derde Oosterparkstraat 39-67 Iepenplein 19-21	935 m²	**55,475 L**
3	**STADGENOOT**		
	Tweede Oosterparkstraat 252-258 Derde Oosterparkstraat 241-253 Kastanjeplein 60	1,160 m²	**45,350 L**
4	**STADGENOOT**		
	Berghoefplantsoen 32-46 Noordzijde 353-423	679 m²	**38,025 L**
5	**DE ALLIANTIE**		
	Riouwstraat	1,151 m²	N/A
6	**DE ALLIANTIE**		
	Makasserstraat 230-296 Javastraat 521-597	1,286 m²	**82,940 L**
7	**LIEVEN DE KEY**		
	Bijltjespad 2-82 Kattenburgerstraat 10-28	1,757 m²	**118,125 L**





INNOVATION LABS

ROOF AREA AND RETENTION CAPACITY

1	**BENNO PREMSELAHUIS**		
	Mauritskade 9-10	450 m^2	32,640 L
2	**ITE BOEREMASTRAAT**		
	Ite Boeremastraat 1-57	700 m^2	25,000 L

GRANT SCHEME ROOFS

1	CPO KOP WEESPERTREKVAART		
	Solitudolaan 414 Lindenhoevestraat 11-81	900 m^2	45,000 L
2	LYCKA (EIGEN HAARD)		
	Lutonhof 3-237 Zaventemweg 67-89	325 m^2	36,000 L
3	ROYAL TROPICAL INSTITUTE DEPOT		
	Linnaeusstraat 2	2,110 m^2	102,000 L
4	VVE BOS EN LOMMER		
	Bos en Lommerplein / Leeuwendalersweg	267 m^2	N/A
5	MANNOURY		
	Koningin Wilhelminaplein 880-1008	491 m^2	N/A

3. CONCEPTUALISING PATHWAYS FOR CHANGE

Innovation Lab Ite Boeremastraat © Wieke Braat

3. CONCEPTUALISING PATHWAYS FOR CHANGE

3.1 ROOFSCAPES

Most of the time, standard flat rooftops of housing estates are covered with a bituminous layer. Its main purpose is to seal off dwellings from the weather (rain, snow, ice, fierce sunshine) in order to secure comfortable living conditions. The RESILIO project was initiated to find out if it were to be possible to transform these rooftops into a new green environment, which could offer different kinds of (eco system) services for Amsterdam and its inhabitants. As a result an existing and undeveloped layer in the city would be disclosed and a network of roofs could create a completely new, high-level urban landscape. This new landscape is sometimes called a ‘roofscape’.

Figure 9: Amsterdam’s roofscape envisioned by Rooftop Revolution. Credits: Alice Wielinga

As explained in chapter 1, the impact of climate change was the main focus for this possible transformation. Can blue-green (BG) roofscapes contribute to the reduction of heat in cities (because they become hotter and hotter as a result of climate change), to water retention opportunities (in order to prevent pluvial flooding) and to biodiversity? The rationale of all RESILIO activities was that European cities will have to counter the negative impact of climate change. Designing and implementing BG roofscapes could be of importance to do just that. However, a roofscape which deals with the challenges as described in chapters 1 and 2, will not be the only solution. The RESILIO project had a specific position within the broader scope of an urban climate adaptation strategy. The ambition of the project was to deliver in-depth practical knowledge about crucial aspects of the transformation of roofscapes by implementing a smart grid of BG rooftops, as a component of that larger strategy.

Within this limited scope, it was still clear that RESILIO would certainly not be a single issue endeavour. RESILIO did not start from scratch. Fundamental research into BG roof systems had already delivered evidence of a number of positive effects. This includes evidence produced by a successful project in Amsterdam, which preceded RESILIO, Smart Roof 2.0 (see chapter 2.2.1). RESILIO could build on the acquired knowledge about the water retention capacity of the crate system, the cooling capacity of the water in this system, combined with the evapotranspiration of the vegetation, and the enhancement of biodiversity. Compared to a traditional green rooftop solution, the accessibility of water in BG roof systems (also in dry periods) allows for a larger variety of plants, grasses and herbs. Research into networks of BG rooftops at a larger urban scale (housing estates, neighbourhoods and city-wide) was not available at the start of RESILIO.

It is important for European cities to know if serious investments in the transformation of our roofscapes are worthwhile: can a new BG roofscape deliver a substantial contribution to adapting to a changing climate, focussed on water retention, heat and biodiversity, as expected and predicted? And equally important: what kind of governance is needed to achieve this and can it be done cost-effectively?

New research, focussing on individual buildings and estates, neighbourhoods and complete towns and cities, is needed to answer these questions. Together, the RESILIO partners decided to facilitate and initiate this type of research. Implementation became the first priority. The quantitative RESILIO target was set at 10,000 m² of new and connected BG rooftops on social housing estates and privately owned property, supported by a municipal grant scheme.

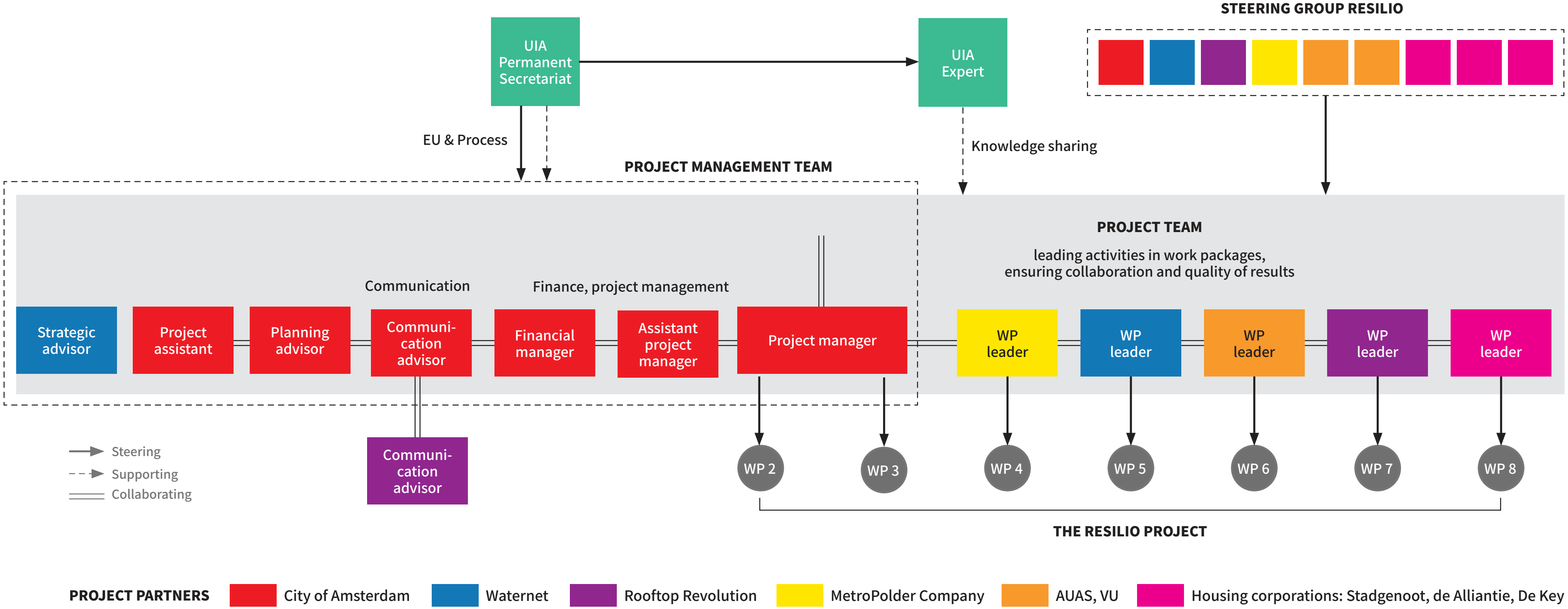


Figure 10: The RESILIO project structure

The RESILIO implementation scheme had a complexity of its own with the involvement and engagement of various direct and indirect stakeholders. Many actions and activities needed to be aligned to achieve the aims and objectives of the project. These included:

- the selection, preparation and construction of the rooftops;
- the installation of the roof systems based on further development and innovation of its components (e.g. the intelligent valve);
- the development of a water platform with a Decision Support System (DSS), Dashboard and user interfaces to enable coordinated steering of the neighbourhood grids of RESILIO roofs;
- communication and participation with tenants and neighbourhood communities

All these activities together created a 'living lab'. The implementation and the study of networks of BG roof systems in this laboratory setting could potentially help other European cities and urban areas with their strategy for dealing with important climate change challenges. Adequate project management and the coordination of partner activities in RESILIO would be a precondition for success. For this purpose a work package (WP) structure was set up, specifying not only activities, deliverables and outputs, but also the necessary cooperation between partners and the allocation of responsibilities to finalise results. All RESILIO partner activity was guided by this intricate and intertwined structure. It proved to be an effective management tool to keep track of all the activities and deliveries.

In a complex project such as RESILIO, priority is quickly given to interdependencies and cooperation, and risks attached to that, to ensure the delivery of the products. The rationale of the project might get lost in the day-to-day activities. It was, therefore, very important to guarantee from the outset of the project that all activities together would achieve the overall goals, as they were set at the beginning. Together with the specification of the management structure, the backbone of the RESILIO WP structure consisted of a conceptual structure which gave coherence and relevance to all the outputs. This RESILIO conceptual structure is shown in figure 10. It visualises how main components in the RESILIO WP structure are tied together in such a way, that its connections support the main ambition of RESILIO. The connections also define a pathway for change. This pathway supports upscaling opportunities by identifying its essential conditions. Lessons learned from the activities in this RESILIO pathway potentially suggest directions for other cities which share similar threats and challenges, and are looking for rational action to meet these challenges in a coherent way. The identification of important conditions for the implementation of BG roofs at city level could be a first step towards incorporating this rational action in a larger urban climate change adaptation strategy.

3.2 THE RESILIO CONCEPTUAL FRAMEWORK

At the top of the diagram, the main ambition of RESILIO is formulated: 'Countering negative climate change impact by the implementation of blue-green roofs'. The layer underneath specifies how RESILIO could contribute to this general ambition. RESILIO identified three major objectives of a climate change adaptation strategy to which the implementation of BG roofs could deliver a positive contribution.

3.2.1 CLIMATE CHANGE ADAPTATION OBJECTIVES

- Prevention of pluvial flooding
- Countering urban heat stress
- Promoting biodiversity

One of RESILIO's innovations is that research could be directed towards a larger scale of implementation: 10,000 m^2 of BG roofs in different neighbourhoods would become available for research.

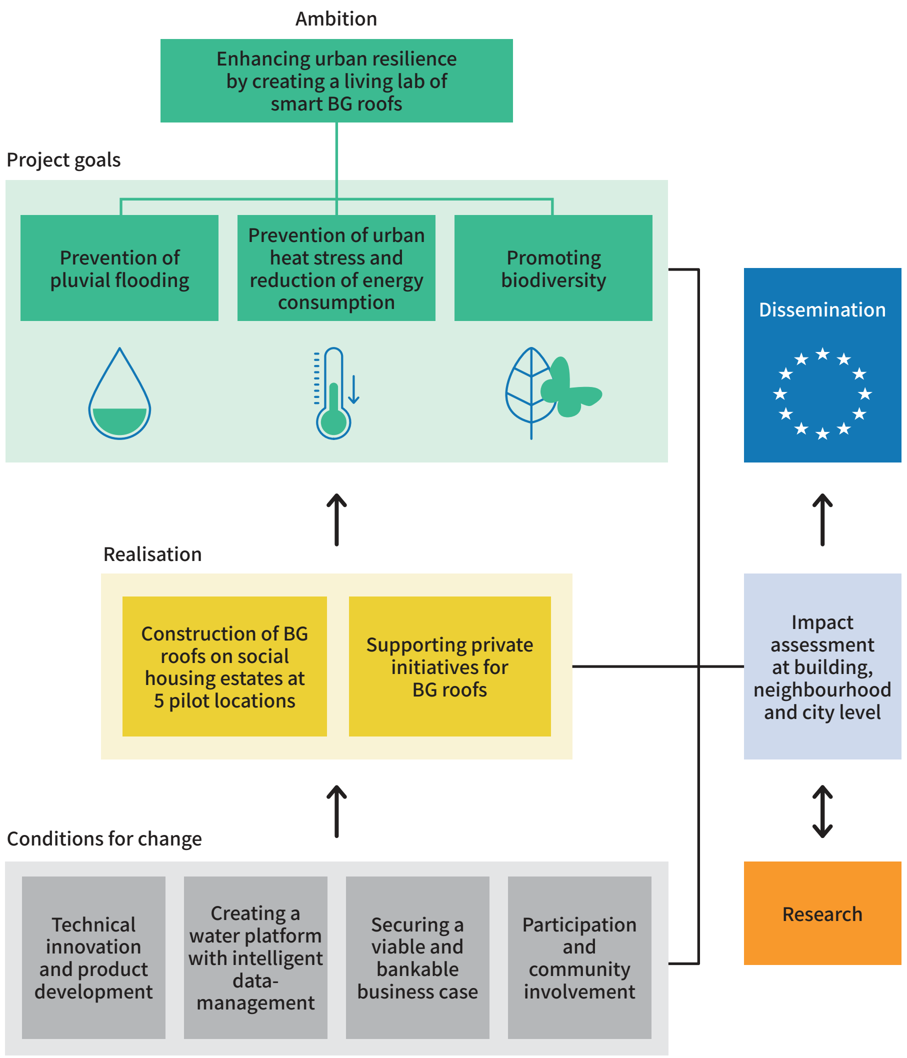


Figure 11: The RESILIO conceptual framework

The Institute for Environmental Studies of the Vrije Universiteit Amsterdam and the Amsterdam University of Applied Sciences specified targeted research activities on heat and water retention, in order to push forward the research agenda on multi-functional roofs. In the initial WP structure no specific research activities were listed to assess the ecological impact of new green infrastructure on roofs. The City of Amsterdam took the initiative to start a study on the ecology of the RESILIO rooftops in cooperation with post-doctoral research of the University of Wageningen. Results of the combined research activities are described in chapter 5.

The research agenda was fully dependent on the realisation of the 10,000 m^2 of BG roofs. They constitute the practical knowledge base of the project. This is visualised in the third layer of the diagram.

3.2.2 A PRACTICAL KNOWLEDGE BASE

- Installing BG roofs on social housing estates
- Supporting private initiatives for BG roofs

Implementing a BG roof system in existing real estate is quite a challenge. Careful preparation is needed before actual construction work can begin. In the selection of roofs which may qualify, the construction of the building has to be assessed in feasibility studies. BG roof systems carry substantial weight. The complete rooftop has to be retrofitted for its new purpose, while the original constructive design of the building never took this into account.

But physical assessments are only one aspect of the preparations. Successful implementation of BG roofs, integrated into a smartly designed water platform with new technology, is not a standard nor widely available product. The housing corporations had to pay specific attention to the procurement of the roofs, before they could select a contractor and formalise assignments. A RESILIO working group with participation of the City of Amsterdam drafted a RESILIO procurement strategy to prepare the tenders and the consecutive assignments. The City of Amsterdam approved a dedicated grant scheme to support private initiatives for BG roofs.

The experiences during and results of the implementation process might be relevant for the upscaling of BG roofs and the dissemination of this solution to other cities. Specific attention to the procurement process and the grant scheme is paid in chapter 7. Several implementation aspects proved to be relevant for the governance of BG roof systems. More on this in chapter 6.

Integrating individual BG roofs into a smart network is not simply a quantitative replication of the implementation of stand-alone roof systems. It requires a meaningful qualitative investment with regard to many parameters of BG roof installation. Together, they are a vital condition to push forward the climate change adaptation strategy to increase the sponge capacity of densified cities with new blue-green infrastructure. To establish these conditions, and to study and assess their impact in a genuine city environment, was as important in RESILIO as the more technical and physical research into primary climate change impact. The RESILIO project focussed on four crucial aspects:

3.2.3 ESTABLISHING CONDITIONS FOR CHANGE

- Technical innovation and product development
- Creating a water platform with intelligent datamanagement
- Securing a viable and bankable business case
- Governance with the people: participation and community involvement

The technical innovation and product development is described in chapter 4. The societal cost- benefit analysis as the foundation of a business case approach is described in chapter 6. Governance in the context of civil society means that steering towards goals is only possible if stakeholders and communities in the implementation context understand and support the proposed solutions. In the context of RESILIO, this implied being present in the neighbourhood. Chapter 9 describes how RESILIO partners met this challenge.

3.2.4 RELEVANCE

The conceptual framework of RESILIO, embedded in its WP structure, gave coherence and relevance to the following project activities:

- implementation activities executed in a transforming city roofscape;
- research into climate change impact of this new roofscape;
- work on technical and governance conditions to optimise this impact at building, neighbourhood and city level.

This way, the framework has been important for establishing connections between research and development, product innovation and governance arrangements, with the ambition to enhance implementation conditions.

The RESILIO project has been completed. This final report informs the reader about the results and outputs. It also tries to assist the reader in answering an important question: is a pathway leading to the introduction of BG rooftops at a larger urban scale already there? The reader can confront his or her judgement with lessons learned, which the RESILIO partners have formulated at the end of each chapter. Recommendations for the next steps are described in the final chapter of this report. It is now up to other cities to decide what to do: follow up, adjust or choose a different route.

FRAME B. INNOVATION LABS

Within the RESILIO project, two Innovation Labs were realised. These were roofs for experimenting with innovative smart BG roof systems. They were also RESILIO's demonstration centre and served as a community space for educational and interactive events. Local universities used the Innovation Labs to design interactive workshops. And datasets from the labs were available for research.

RESEARCH TOPICS

- **The cooling effect** Study of the effect of BG roofs on cooling the surface of the roof and classrooms directly underneath.
- **Watersaving and evaporation** Understanding how much rainwater plants absorb and to what extent the amount of tap water, required to water the plants, can be reduced.
- **Efficiency of solar panels on different roof surfaces** Study of the efficiency of solar panels for different roof types: a classic black bitumen roof, a green roof, a water-retaining blue layer with white gravel roof and a BG roof. Investigation of possible connections between the cooling effect of these roof types and the efficiency of the solar panels.
- **Interaction of solar panels and plants species** The solar panels in the second Innovation Lab were placed in four roof sections at different heights and row distances, plus a fifth section without solar panels – to measure the differences. Study of the effect of light and shade on the development of different plant species

RESULTS

The first technical drawing shows four different plots of the Benno Premselahuis. The underlying layers are (from left to right) conventional green (green), conventional black (black), smart blue-green (yellow) and smart blue (blue). Each plot has its own solar panel (PV).

For an indication of the cooling effect, temperatures of the different surfaces were measured in a specific period, between the 5th and 17th of August 2020. In figure 14 the red line represents air temperature. It is clear that the black bitumen roof heats up the most (up to 55 °C). The green roof reaches a maximum of over 30 °C. The blue roof and the BG roof stay below 30 °C. The smart BG roof shows the best performance.

These results are as expected, as the BG roof has the greatest potential for evaporation. Its cooling effect will result in lower indoor temperatures during hot summers.

Measurements of energy performance of the solar panels, however, show minor differences between the plots. A possible explanation for this outcome is the small sizes of the plots. This is one of the reasons to choose a larger set-up at Ite Boeremastraat (see figures 15-16). Here, research into PV energy performance will be continued from spring 2022.

Figure 12: Set-up Innovation Lab Benno Premselahuis

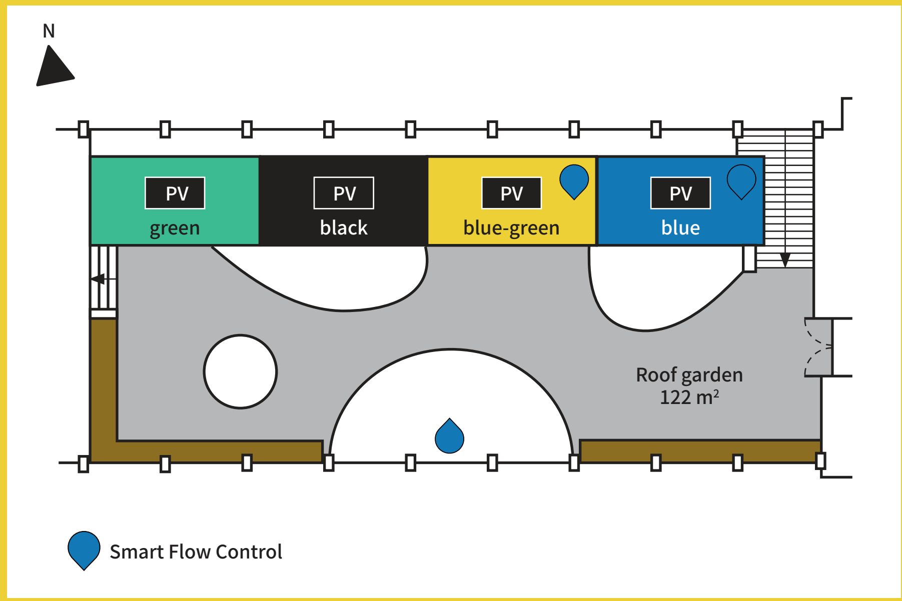


Figure 13: Set-up solar panels Innovation Lab Benno Premselahuis

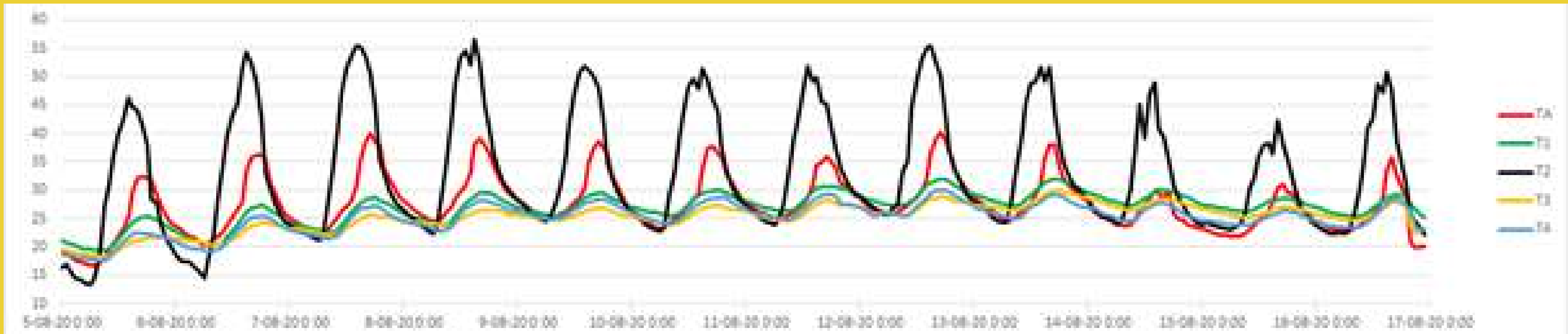


Figure 14: Temperature

Figure 15: Set-up Innovation lab Ite Boeremastraat

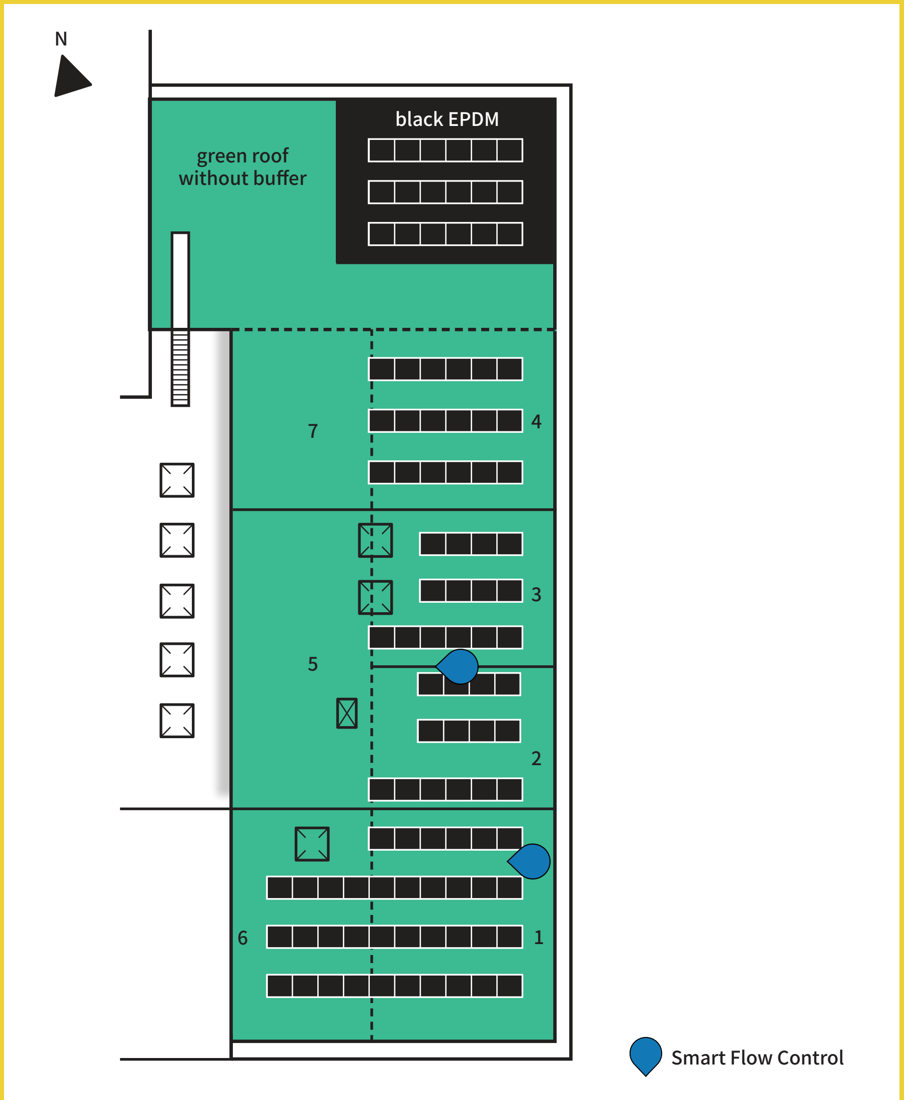


Figure 16: Set-up Innovation lab Ite Boeremastraat

4. TACKLING TECHNICAL ISSUES: RESILIO WATERPLATFORM

Innovation Lab Ite Boeremastraat © Wieke Braat

4. TACKLING TECHNICAL ISSUES: RESILIO WATERPLATFORM

4.1 MICRO WATERMANAGEMENT OF SMALL-SCALE WATERBUFFERS

The Netherlands has a long tradition of watermanagement. Good examples of this are big infrastructure works such as storm surge barriers, sand motors, river projects and dike reinforcements. In the urban landscape the Sponge City, based on blue-green infrastructure (BGI) as explained in chapter 2.1, evolved to accommodate climate change.

The traditional watermanagement in urban areas is static. Rainfall is discharged by a combined system of hardened surface area (public and private), surface water and greenery (BGI) and sewerage infrastructure (pipes). Private roofs can store additional waterbuffers and thereby add BGI to the relative hard surface of the city. This demands a new attitude towards watermanagement, where the private domain interacts with public space. New technologies can enhance the performance of this composed urban drainage system. Object-specific based watermanagement on micro waterbuffers is a key element. Making use of these small-scale buffers on rooftops is called micro watermanagement.

This type of management uses valves and pumps. Its software is based on algorithms and decision rules. As a result, real time data can be processed and adopted to manipulate the newly acquired waterbuffers. They become squeezable sponges: they retain water in periods of drought and heat, squeeze and create storage with expected rainfall. The waterbuffers on private plots and buildings can be seen as extensions of the urban drainage system. A differentiated micro watermanagement strategy optimises public and private engagement and performance. In their new relationship, public and private partners will have to define their distinct roles and responsibilities.

4.2 THE ROLE OF DSS IN MICRO WATERMANAGEMENT

All kinds of practical decisions have to be made in the usage of small scale waterbuffers. A DSS is a key element to help public and private partners to make these types of decisions. Many data have to be considered. To handle these, Waternet has designed a new technical environment, which determines the structure of the DSS. This is visualised in figure 18.

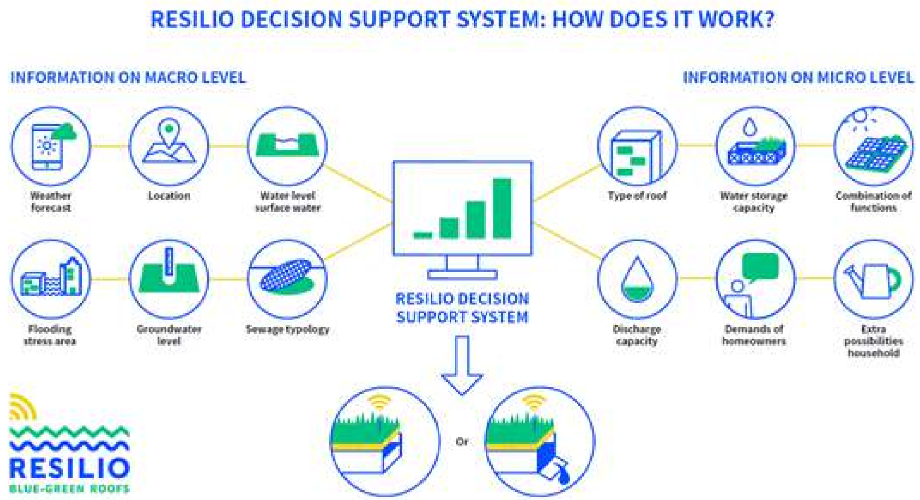


Figure 18: RESILIO Decision Support System (DSS): How does it work?

When heavy rainfall is expected, the DSS signals the smart valve on the blue-green (BG) roof to discharge the retained rainwater, before the expected downpour actually happens. This way, a smart roof can collect the maximum amount of rainwater during a shower. Less pressure is put on the sewerage. During dry periods, the water which has been collected on the roof will not only cool down the building, but the roof decreases the temperature in the surrounding area as well, and the roof will water its own greenery. From the perspective of the owner of the BG roof the captured water can be used for a number of functions. A secondary internal water system for toilet flushing and washing can reduce the use of high quality drinking water and costs.

The decision rules in the DSS are fed with macro watermanagement data and micro object-based settings, mainly controlled by the private roof owner. The next paragraph explains in more detail which data at these different levels are involved and how support rules operate.

4.2.1 MACRO LEVEL DATA

Weather forecasts

The continual development of high grade and high resolution precipitation forecasts can help to optimise buffer capacity in the roof systems. The roof can be drained before the expected rainfall, in order to accommodate storm water volumes. After the occurrence of the rainfall the storage facility will be completely full. With a longer drought in the weather forecast, retention of water is the driving ambition to facilitate the availability of water for the vegetation layer and cool the roof and environment through evapotranspiration.

Seasonal settings

The growing season (April to October) demands the availability of water. The standard setting is a closed valve, which maximises the stored volume of water. Outside the growing season, water availability and cooling power through evaporation is less relevant and the valve is set towards a slow release of the water (1 mm/h). In the winter (or when temperatures drop below 2 °C) an open valve is standard, to prevent freezing of the water and causing damage to the construction.

Sewerage system

Water retention on the roof is key, when the combined sewerage system is not permitting extra water volumes from roofs. This way, overflow towards the surface is prevented. In an urban water stress location the flow of stored water in microbuffers is managed accordingly. No release is intended during rainfall to prevent the buildup of water on the stress location.

Surface water

The release of rainwater towards the surface water system can be reduced or prevented when the receiving waterbody has high or critical water levels. The micro watermanagement strategy on the BG roofs is designed to deliver this performance.

Ground water

Depending on the local urban drainage system, groundwater can be a receiving waterbody for roof-captured water. When the ground water level is high, release through infiltration systems is unwanted. The feed of water towards the ground water table in times of drought and heat is a feature which adds quality to the urban environment and local vegetation. The possibility of a directing element (towards infiltration, sewerage or surface water) in the micro waterbuffer system is not yet developed, but is expected to be incorporated in the DSS in the foreseeable future.

4.2.2 MICRO LEVEL DATA

The roof
Each roof has its own characteristics. Depending on carrying capacity, the stored volume of water can be bigger or smaller. A larger storage capacity can overcome larger periods of drought and heat stress. Evapo(transpi)ration may differ depending on the shading, vegetation and other functions (terraces, solar panels).

Roof owner
A roof or building owner can contribute to watermanagement for the micro waterbuffer. When additional vegetation (at ground level/ garden) has to be watered with captured rain water, extra storage in the growing season is feasible. When flushing toilets or other usage of rain water is wanted, a higher minimal drainage can be set. This way, a robust volume of water for these functions is achieved.

Discharge
The discharge capacity of a filled roof system depends on the surroundings and private infrastructure (rain pipes, vicinity of surface water, infiltration capacity). This has a connection with the reaction time of the roof system, when substantial rainfall is expected and needs to be processed by the DSS.

With the rules, parameters and settings of the DSS, the BG roofs can respond to weather forecasts. The system determines how much water can, may or must be retained on a roof. The ambition of RESILIO was to build a DSS within an Amsterdam setting of available watermanagement data, governance principles and the specific context of seasonal and climate characteristics. DSS is an open model which can be adapted to any location. In Amsterdam the DSS is built and managed by Waternet – the Public Water Authority working on behalf of the City of Amsterdam and the Regional Water Authority Amstel, Gooi en Vecht.

4.3 DISSEMINATION AND LOCALISATION

The possibilities of micro watermanagement adopting a DSS can differ from city to city (and country to country), due to differences in climate (hot and dry versus cool and wet), vegetation needs, tap water pricing, construction (building and technical) regulations and governance in general.

With a holistic approach, other issues pop up. The complete envisioned architecture consists of hardware (smart valves) from different developers and suppliers, integrated with different software and data systems. Each supplier and maintenance contractor for the private BG roof infrastructure will use an independent system to monitor performance. A public-based DSS uses publicly accessible and real-time watermanagement data to match the object-defined parameter settings. Through Application Programming Interfaces (APIs) different systems and programmes can exchange data and information. This creates the possibility to connect different systems (pumps/valves) from different suppliers to the DSS.

Next to the software/hardware integration, the authority of the different system components needs a sharply defined governance protocol. A clear response for each system component is needed when failures occur, connections get lost or stress situations demand a shift from automatic to direct control. Transparency in responsibilities for each partner and system in the architecture of the micro watermanagement is essential. The responsibilities and expectations between the different partners can be clearly defined with a Micro Watermanagement Contract.

4.4 MEASURING RESULTS AND MAKING THEM VISIBLE: THE RESILIO DASHBOARD

Combining macro data from the public watermanagement authority, the local parameter settings and system set-up, combined with the weather forecasts, opens up a perspective for a DSS with a dynamic response profile. In reality, a direct signal for change (‘valve open’) can be expected just once or twice a year. Direct intervention is only necessary when expected rainfall is to expected to be bigger than the available storage capacity. The benefits and mechanisms of retention and evapotranspiration balance out with the help of the substantial storage capability of the BG roof system. Chapter 5.1 will explain how modelling results support the values and benefits of smart water retention.

A dashboard connected to the DSS informs the owner of the BG roof about the performance of the system. This is essential for the acceptance of the innovation of micro watermanagement in the private domain. The dashboard visualises the span of control of diverse governance options. These options are given by answering the following questions: who is in control, who is responsible, and who owns the system and the water?

The DSS advises about the water level in the micro waterbuffer. It is up to the owner to accept this advice. There is always a possibility to disconnect from DSS. This gives the public watermanagement authority an incentive to come up with ‘an offer you can’t refuse’ towards the roof owners. In RESILIO a conservative setting of governance interactions has been chosen. The roofs financed through the RESILIO funds are obliged to connect to the DSS.

RESILIO offers an escape route of DSS settings. An emergency button enables direct drainage of the system, to encounter leakage stress or start maintenance activities. There is an option to change parameter settings, as well as an option for higher levels of water storage, if additional water needs have to be serviced. Direct control by the building owner or maintenance contractors can also be facilitated.

The dashboard displays a timeline with information about how the DSS processed relevant data in relation to the roof system. Transparency on decision support rules enhances understanding of the interaction between data and system settings. Changes in the growing rule set of the DSS (fine-tuning) can be made visible. The owner or dedicated maintenance contractor can be directly informed about a performance glitch through an additional message service (SMS/text/e-mail). The data from the DSS and specific roof settings can be made more valuable by informing tenants and users (via narrowcasting) about the quality of the roof, its ambitions and performance and the value for the building and environment.

4.5 LESSONS LEARNED

The micro watermanagement system is complex and encompasses public macro data, private responsibilities, new governance protocols, funding principles, hardware, software and datastreams. After a project span of three years, the RESILIO ambition to have a fully operational new system turned out to be feasible. But processing all the demands of a broad consortium of partners with different roles, responsibilities and perspectives, within one holistic approach, was too ambitious. With RESILIO now finished, the data architecture has been fully designed, but integration of all results and deliverables of the RESILIO WPs has not yet been completed.

A key element in the development of a micro watermanagement strategy is a new definition of the governance of watermanagement. This specifically concerns the distribution of responsibilities and authorities regarding the public/private interface of rainwater discharge. A comparison and analysis of cities and countries on this issue might be valuable for further dissemination of the philosophy of the Dynamic Sponge City, incorporated in micro watermanagement.

Existing (or developing) legislation on obligations of rainwater management have a direct effect on the business case and cost-benefit analyses. A regulatory framework, such as the Amsterdam Rain Water Ordenance, has a direct impact on financial governance. Societal Cost Benefits and transfer mechanisms within the context of a business case approach are discussed in chapter 6.

Micro watermanagement can be viewed as an ecosystem of its own. In RESILIO many valuable lessons were learned about the complexity of this system. A bottom-up approach guided by activities in a WP structure sometimes led to difficulties in the integration of all the necessary information. For this, a shared language, which is understood by all contributing partners, is a precondition. Perhaps such a language must be defined top-down. The development of a complete architecture of the ecosystem must progress step by step, with input from all relevant partners. The challenge is to build a rich and complete system by integrating different layers of information on data, governance and economics.

5. DOING RESEARCH

Biodiversity at BG RESILIO roof Javastraat/Makasserstraat © Wieke Braat

5. DOING RESEARCH

Smart blue-green (BG) roofs offer a climate adaptation solution which aims to address the impact of extreme rainfall and heat, while simultaneously increasing urban greenery and biodiversity. However, BG roofs are still at the innovation stage of technological development. More research is needed into the performance of BG roofs on buildings and upscaled to entire neighbourhoods and cities.

Within the RESILIO project, the knowledge partners addressed several key research questions regarding BG roofs. How much rainfall can the roofs store, while at the same time keeping water available for the green layer? How much do BG roofs contribute to the insulation of roofs? Once scaled up to city level, how much can BG roofs contribute to the reduction of rainfall bottlenecks, and how much can they reduce the urban heat island (UHI) effect? And how do BG roofs contribute to increasing biodiversity? This chapter summarises recent research by the knowledge partners (Vrije Universiteit Amsterdam [VU], Amsterdam University of Applied Sciences [AUAS] on rainfall and heat, as well as biodiversity research by the City of Amsterdam. For the in-depth research reports, see RESILIO 2021[xx].

5.1 WATER (VU RESEARCH)

5.1.1 BUILDING LEVEL

As outlined in chapter 1, BG roofs generally consist of a blue layer for water storage, and a green layer consisting of a plant layer and a substrate layer. From a water perspective, the BG roof has two goals: (1) to maximise water storage during and after extreme rainfall, (2) to maximise available water for the plants, for the sake of the plants themselves and for biodiversity, and because evapotranspiration from plants has a cooling effect. These goals are conflicting, as the first requires the blue layer to be as empty as possible, while the latter requires the blue layer to be as full as possible. Within RESILIO, VU researched how the smart BG roof can use weather forecasts to achieve an optimal level of water and reach both goals.

For this, two approaches were combined. Firstly, MetroPolder Company equipped the RESILIO roofs with sensors for measuring water levels, rainfall and temperature. These sensors allowed for tracking the performance of the BG roofs under current operating regimes. Secondly, as the measurements covered only a short time span, VU developed a computer model which represents BG roofs. In doing so, the analysis of the BG roof performance could be extended to a longer period (2013-2019), and more importantly now also included historical extreme events. The model enabled an analysis of how different weather forecasts can be used to optimise water storage capacity and water availability under normal conditions and under extreme rainfall or extreme heat conditions. The final results were compared to two reference cases: a simple green roof, and a BG roof without a smart valve (i.e. a blue-green ‘bucket’).

Results of this study [13/14] provide an in-depth analysis of the hydrological performance of smart BG roofs. Combining the sensor measurements on the RESILIO roofs with the computer model confirmed that the model adequately represents the hydrological performance. The model shows that under all operating regimes, smart BG roofs outperform green roofs and blue-green ‘bucket’ roofs for both storing extreme rainfall and water availability. While the results indicate that green roofs could capture 30% of rainfall over the analysed period, blue-green buckets could capture 50% and smart BG roofs could capture 90% or more. Based on the most extreme weather forecast, water storage capacity could be increased further, but this can result in ‘false alarms’, which leads to draining of the blue layer, without a rainfall event that could fill it back up. In turn, this reduces the water availability for the plants and consequently leads to a reduction in evaporative cooling. Overall, the results show that the hydrological performance for smart BG roofs is high for both water storage and water availability, using a range of different weather forecasts.

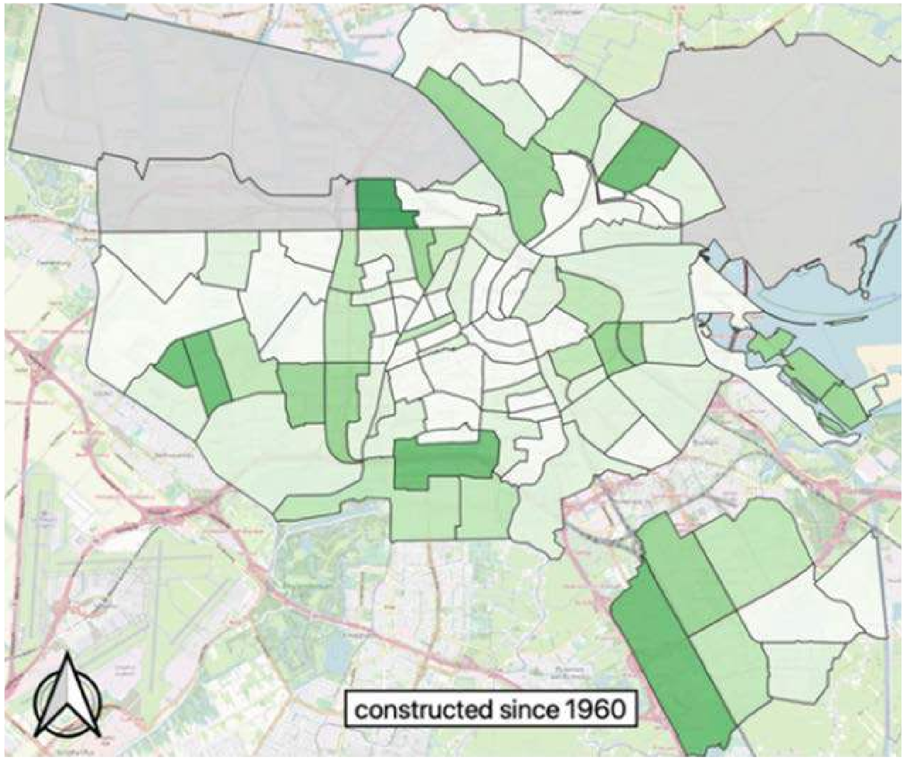
5.1.2 CITY SCALE

While 5.1.1 shows high potential of smart roofs at building level, a key question within RESILIO is whether or not the concept can be scaled up to neighbourhood or city level, and what the effect of this upscaling would be on water storage. Within RESILIO, VU answered these key questions by analysing (1) which roofs in Amsterdam might be suitable for implementing smart BG roofs, and (2) once implemented, how much do these roofs contribute to alleviating rainfall bottlenecks? Relating to water and upscaling, the focus is on water storage for extreme rainfall events, as that is the main goal for implementing BG roofs at this scale.

To determine which roofs could be suitable for implementing smart BG roofs, VU performed a spatial analysis of all buildings in Amsterdam using three different scenarios.

- In the first scenario, called the ‘base scenario’, it is assumed that roofs should be relatively flat (with a slope of under 8.6 degrees) and that the surface of the roof should be more than 200m2, as it is otherwise not deemed cost-efficient to install and operate a smart valve.
- The second scenario, the ‘constructed after 1960 scenario’, uses the same assumptions as the base scenario, but only houses which were built after 1960 are selected. The reason for this is that houses from before 1960 often do not have sufficient carrying capacity, while buildings from after 1960 often do.
- A final analysis was done for an ‘all roofs scenario’, wich includes roofs of all sizes and building ages, as long as they are relatively flat. This scenario is representative of a situation in which costs of the smart valve are reduced, so that small roof surfaces are also eligible, and a situation with sufficient advances in technology, so that there are no restrictions on carying capacity of roofs.

As an example, figure 20 shows the suitable areas per district in Amsterdam for the ‘constructed after 1960 scenario’.



Suitable areas per district area (%)

- 0-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-12
- 14-16
- excluded

Figure 20: Suitable roof areas for implementation of smart BG roofs in Amsterdam. The map shows the surface area relative to total neighbourhood area (in %) for buildings constructed after 1960.

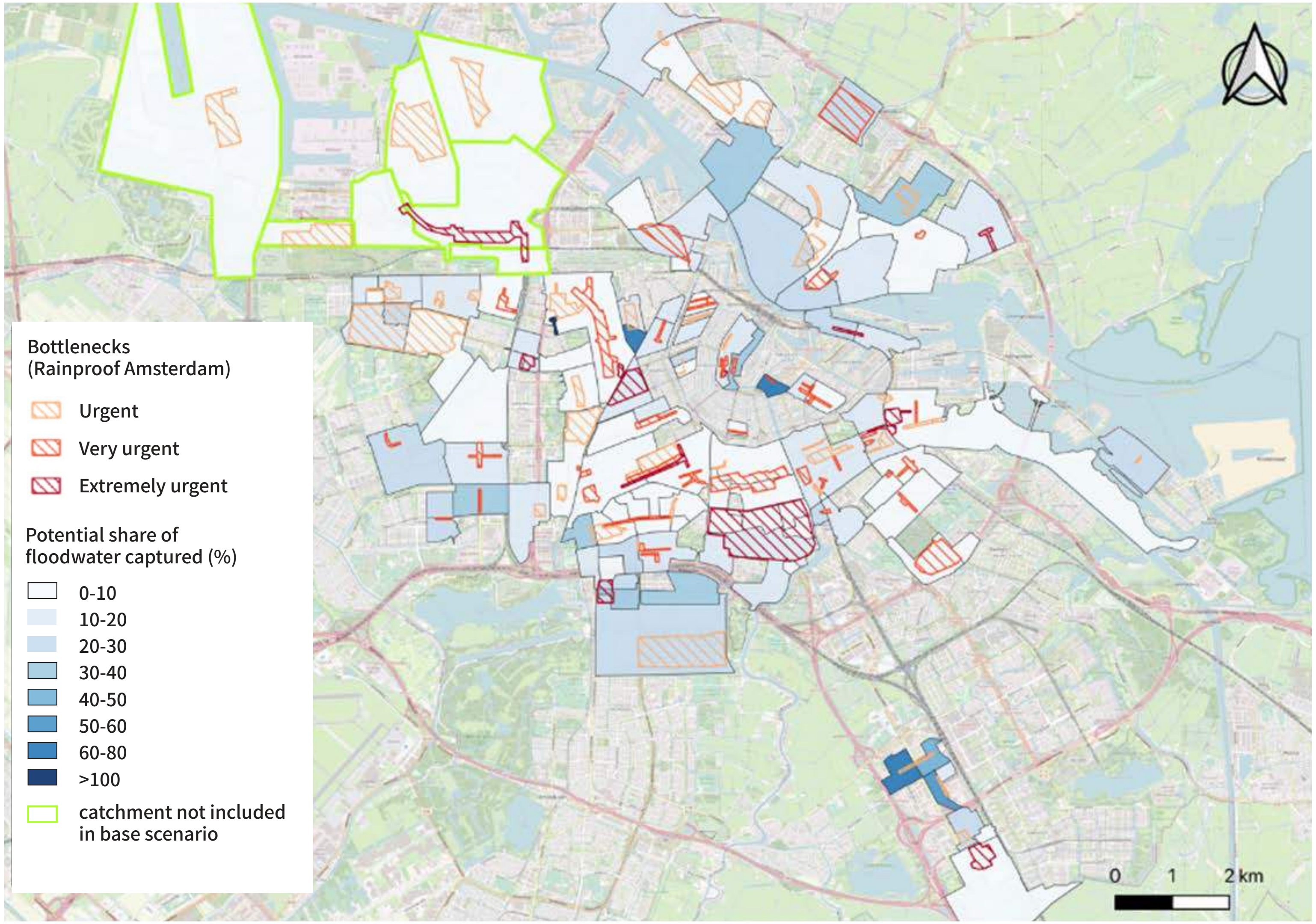


Figure 21: Reduction in pluvial flooding (in cm water) per catchment area (constructed after 1960 scenario). Catchment areas where all excessive rainwater can potentially be stored by blue-green roofs are indicated with coloured hatching.

Following the analysis of roof suitability, the next question was: if the full potential of suitable roof areas for smart BG roofs is used, how much excess rainfall can be prevented in the streets? To answer this, a flood map was used, showing how much water remains in the streets during an extreme rainfall event of 60mm in one hour, after the sewerage system has reached its capacity. The assumption was that all roofs in all scenarios are equipped with smart BG roofs, and that individual BG roofs perform as outlined in 5.1.1.

Next, a calculation was made of the reduction of water in the streets during an extreme rainfall event. The results of this study [15] show that, depending on the suitability of the roofs, between 11% and 19% of the water volume which remains in the streets during an extreme rainfall event can be prevented. In the bottleneck areas, identified by the City of Amsterdam (see 2.2.1), on average 9% to 27% of the flood water can be stored (depending on the scenario), a figure which can be considerably higher (or lower) in specific bottlenecks (see figure 21).

This analysis shows that smart BG roofs may not provide all the answers, but that they can play an important role in dealing with climate extremities in cities.

5.2 HEAT (AUAS RESEARCH)

5.2.1 BUILDING LEVEL

Within RESILIO, Amsterdam University of Applied Sciences (AUAS) has researched the cooling and insulating effect of BG roofs on indoor temperatures. The project was a unique opportunity to compare newly installed BG roofs to more ‘traditional’ roofs located nearby. This gave an insight into the performance of different types of roofs. To assess the effect of BG roofs on roof surface temperatures, indoor temperatures and insulation, measurements were carried out, but outside and indoors, in both summer and winter.

The thermal impact of BG roofs at building level has been examined using four RESILIO BG roofs, four reference roofs (black bitumen or gray gravel) and two conventional sedum covered green roofs. On each roof, temperatures were measured at and above the roof surface, together with air and ceiling temperatures inside the building (see figure 22). The aim of this was to investigate both the thermal effects on the inside environment and on the outside surface of the building. The measurements were done during a warm period (>20 °C for seven consecutive days) and a cold period (< 5 °C for seven consecutive days), to investigate the cooling effect and the insulative effect of BG roofs.

Results of this study [16] shows different thermal behaviour across different types of roofs. In summer, the temperature of the substrate underneath the vegetation was only a few degrees lower than the temperature of the gravel roofs. This indicates that the cooling capacity of the green layer alone is relatively limited. On the other hand, the temperature inside the water crate layer was more stable (during both warm and cold periods) than other measured surfaces, which indicates that the additional water layer only present in blue-green roofs function can act as a temperature buffer.

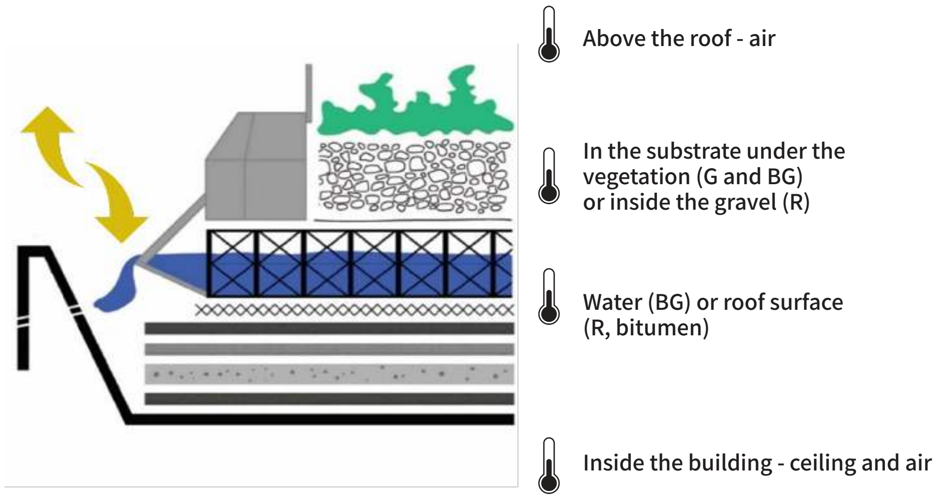


Figure 22: Overview of the placed measurement devices at the research sites for green roofs (G), blue-green roofs (BG) and reference roofs (R).

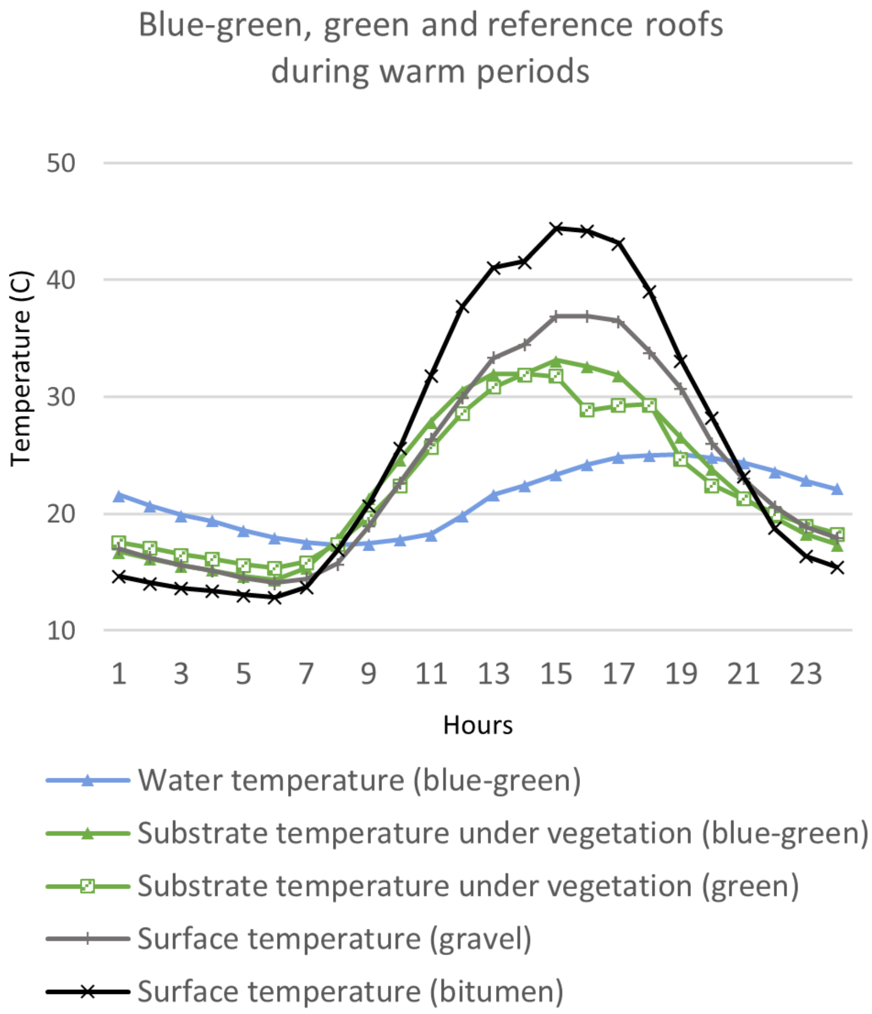


Figure 23: Graphic of the hourly averages of measured temperatures during the three warm periods (4-16 June, 16-27 July, 6 -10 September 2021) for the research locations in Amsterdam's Oosterparkbuurt.

Figure 16 shows the relatively stable temperature of the water compared to other surfaces in summer. This stability is caused by the fact that water heats up much more slowly than bitumen, gravel, or even the substrate of BG roofs. However, water also cools down much more slowly. This is visible in the night temperatures when water stays the warmest from all measured surfaces. This buffering effect might be beneficial during daytime, but might negatively affect the heat transfer from inside to outside the building and delay the cooling-down of the building after a long heatwave.

During a cold period, the crate layer remains empty. Nonetheless, it still functions as a buffer to the lower outside temperatures. Research measurements showed that the stagnant air layer in the water crates was up to 3 °C warmer at night than other measured surfaces.

The effect of the water layer was also measured inside the building. Average indoor temperatures showed that rooms under BG roofs were colder during summer and warmer in winter compared to reference roofs, indicating year-long benefits of BG roofs when it comes to a comfortable atmosphere inside the building. Moreover, the measurement results show that inside temperatures under BG roofs are less sensitive to outside air temperature changes than temperatures under reference roofs.

The insulation capacity of buildings, by computing the R-values for the whole roof, was also examined. In construction practice, R-values are used to indicate the insulation properties of materials. The R-value calculated for the BG roof was higher than the expected R-value based on the applied insulation material (3.5 versus 4.8). This was not the case for the reference roof, where the calculated R-value resulted in more similar values to those given by the insulation material (2.0 versus 2.3). This suggests that the blue-green layer on top of the roof contributes to the insulation properties of the building.

Roof type	Insulation layer properties	Measurement period	R-value (m^2 x K/W)
Blue-green	Isomix 160-170 mm, R value 3.5	2021 - Winter	4.8
Reference (gravel)	XPS 60 mm, R value 2.0	2021 - Winter	2.3

Table 1: Insulation properties of a BG roof and a reference roof at the Oosterparkbuurt location. The Insulation layer properties column shows the type of insulation material in the roof and consequently the expected insulation of the whole roof. U- and R- values are calculated insulation values of the roof based on temperature differences inside and outside of the building.

All indoor measurements showed a small but systematic effect of BG roofs on indoor temperatures. But at this point it cannot be precisely specified how strong this effect is. Both average temperatures and variations in temperatures were small and might not be perceived by humans. However, the increased insulation values for BG roofs suggest that the additional blue-green layer might potentially influence the heating/cooling costs. The exact effect of the BG roofs on the air temperature inside the building and consequently the thermal comfort of the residents is unclear and requires more research.

5.2.2 CITY SCALE

To research what the effect of BG roofs can be on a larger city scale, in terms of reducing heat stress, a literature study was conducted and an expert session organised. This enabled an investigation into the effect of BG roofs on air temperatures at street level, in a city such as Amsterdam, during summer.

Modelling studies about a potential effect of (B)G roofs at city level, with a similar climate and characteristics as Amsterdam, show a potential cooling of up to 0.4 to 1 °C. These values, however, are calculated for a city where all roofs are covered by vegetation. If the upscaling potential of BG roofs in Amsterdam is taken into consideration and compared to the literature, the figure becomes 0.3 °C. This cooling effect was modelled in an earlier study [17] where 30% of the rooftops in a city, with characteristics similar to Amsterdam, are replaced with well-watered vegetation.

In addition to the potential upscaling effect, the neighbourhood typology also plays an important role in assessing the effect of BG roofs on temperatures at street level. Several studies showed that a low rise urban environment – typical for many residential locations in Amsterdam – can benefit the most from green roof implementation.

The results of the literature review were also discussed by a panel of experts consisting of meteorologists, experts on BG roofs, an urban climate modelling expert and climate adaptation experts. The panel discussion led to the conclusion that the potential effect of BG roofs in Amsterdam might be very small, even if all suitable roofs are used. The effect of 0.3 °C that has been found in the literature was agreed to be the maximum potential effect, while the actual effect would probably be much smaller. When it comes to the varying benefits of BG roofs for different neighbourhoods, the experts agreed that the potential availability of the roofs for BG roof implementation, as well as the general neighbourhood typology, will play a role in the resulting effect. Nonetheless, as the effect varies by only tenths of a degree, the differences can be considered negligible when it comes to the overall cooling of a city or neighbourhood.

In conclusion, the experts agreed that BG roofs will only have a small effect on Amsterdam's urban climate, or no effect at all, even if all suitable roofs are used. However, this should not discourage from implementing (B)G roofs. It remains a fact that increasing the vegetated surface cover alongside other green measures in a city is the best way to combat urban heat. BG roofs are part of this general strategy.

5.3 BIODIVERSITY

5.3.1 BUILDING LEVEL

Green roofs are often divided into three categories: sedum roofs, herbaceous roofs and roof gardens (see figure 24). The latter two show a significantly higher diversity of insects, with herbaceous roofs even showing a slightly higher diversity of certain insect groups compared to roof gardens. This is because herbaceous roofs and roof gardens allow for a much higher diversity of plants. Herbaceous roofs are also often referred to as nature roofs, as they contain native plants and are often not accessible to the public. As these nature roofs contribute significantly to biodiversity, they have even been made compulsory in Basel, Switzerland, where green roofs are built with soil and seeds from the surrounding green area.

For all these reasons, a list of native plant species was made by the City of Amsterdam's ecologist Geert Timmermans and Van Ginkel, a specialised green roof company focused on biodiversity (see table 2).

By April 2022, this vegetation will have sprouted on all RESILIO roofs. From this moment onwards an inventory of the biodiversity will start. This will be done in the first year by an ecological consultancy (Bureau Stadsnatuur Rotterdam) and will be continued by a PhD student (Eva Drukker) from Wageningen University & Research (WUR), specialising in the diversity of insects on green roofs. The monitoring will involve the identification of plants and all insect groups, from soil fauna to bees, butterflies and moths and the possible interaction with swifts and bats.

Figure 24: Example cross sections showing the different layers of three types of green roofs:
a) Sedum roofs have a vegetation layer with the succulent plant sedum and mosses. These roofs require only a shallow substrate as sedum can withstand long periods of drought and exposure to sun.
b) Herbaceous roofs usually have a combination of mosses, sedum, and many species of herbs which require a more constant amount of water and a deeper substrate.
c) Roof gardens have a deep substrate depth, starting at 15 cm. They can host shrubs and even small trees. They are often multifunctional, meaning that they can also be used for recreational purposes and to locate solar panels.

PLANT SPECIES (LATIN NAME)	
Achillea millefolium	Linaria vulgaris
Allium schoenoprasum	Lotus corniculatus
Anthoxanthum odoratum	Origanum vulgare
Armeria maritima	Plantago media
Campanula rotundifolia	Potentilla argentea
Clinopodium vulgare	Potentilla tabernaemontai
Dianthus armeria	Prunella vulgaris
Dianthus carthusianorum	Rumex acetosella
Dianthus deltoides	Sedum acre
Erigeron acer	Sedum album
Erodium cicutarium	Sedum rupestre
Festuca ovina	Silene vulgaris
Festuca rubra	Thymus pulegioides
Galium verum	Trifolium arvense
Hieracium pilosella	Arabidopsis arenosa
Jasione montana	Pilosella aurantiaca

Table 2: Plant species suggested by the City of Amsterdam, to plant on RESILIO roofs.

5.3.2 CITY SCALE

RESILIO's original work plan did not include research into biodiversity. In collaboration with one of the City of Amsterdam's main ecologists, additional activities were set up. These will result in first insights into biodiversity at building level, as explained in 5.3.1. The bulk of this research will be done after RESILIO's official closing date, as the vegetation has only recently been planted due to delays in the delivery of most roofs. At city scale, biodiversity has not been researched in the RESILIO project. Potentially, a network of roofs could contribute to a more liveable city.

In fact, greenery is an important condition for urban life itself. According to Amsterdam's Main Green Structure (Hoofdgroenstructuur [18]) it is not a luxury but a necessity, and a crucial part of a global survival strategy. Roofs can be part of a city's public space. And no single roof should be looked at on its own, but as a part of a larger system. The green space can offer a resting or foraging place for animals and can therefore act as a stepping stone in the ecological main structure. [19] This is an interesting topic for further research.

Figure 25: Achillea millefolium at grant scheme roof Kop Weespertrekvaart

5.4 LESSONS LEARNED

Within the RESILIO project, the knowledge partners contributed to the technical analysis of how smart BG roofs perform during extreme rainfall, and can contribute to reducing extreme rainfall, reducing heat and increasing biodiversity.

For water (5.1), research shows that when using weather forecasts, smart BG roofs have a high potential for capturing water from extreme rainfall, while maintaining the availability of water for the plant layer and evaporative cooling. The performance of smart BG roofs on water storage and evaporative cooling is better than that of green roofs, or blue-green 'bucket' roofs (i.e. blue-green roofs without smart operation). Moreover, when scaling up to city level, research within RESILIO shows that smart BG roofs can significantly contribute to reducing water in the streets under a range of assumptions on flatness, size and carrying capacity of the roofs.

For heat (5.2), BG roofs showed a potential temperature buffering effect inside buildings. Measurement data show that, in summer, BG roofs experience lower roof surface temperatures than conventional (gravel or bitumen) roofs. This is particularly noticeable in the water temperatures, which remain very stable with only small daily changes. As a consequence, the temperature inside a building with a BG roof fluctuated less than in buildings with other roof types.

The BG roof also had an effect on the insulation properties of buildings during the winter months, which suggests potential benefits to thermal regulation, and consequently energy consumption, across the whole year. Unfortunately, the beneficial thermal effects of BG roofs do not reach much further than at building level. On a neighbourhood and city scale the potential effect of BG roofs on Amsterdam's urban climate has been found to be negligible.

For biodiversity (5.3) substantive results at building level will follow in the coming years, after the RESILIO end date and when the vegetation has sprouted.

While the research within RESILIO yields insights into the performance of smart BG roofs, there were also lessons learned regarding the process. Within RESILIO, the contracting, implementation and research were executed simultaneously. Delays in contracting and implementation considerably hindered research on the roofs. The knowledge partners solved this by using computer models, using expert analysis and other approaches. However, an advice for other projects, which combine implementation and research, is to plan carefully, in light of potential delays and other contingencies.

Finally, RESILIO aimed at investigating the potential of smart BG roofs as a way of dealing with the effects of extreme rainfall, heat and loss of biodiversity. The project's research has shown that these roofs can indeed contribute to reducing said impacts. However, smart BG roofs are among the many different adaptation options a city can implement. Each city, each neighbourhood, each street and each building could benefit from including smart BG roofs as a solution. But other adaptation options can be just as viable, or even more viable, depending on the local situation. Both future research, as well as actual adaptation planning, should consider the wide range of adaptation options available, including smart BG roofs.

6. BUILDING A BUSINESS CASE FOR BLUE-GREEN (BG) ROOFS

Innovation Lab Ite Boeremastraat © Wieke Braat

6. BUILDING A BUSINESS CASE FOR BLUE-GREEN (BG) ROOFS

For the wider diffusion of smart BG roofs in society, and scaling up beyond the boundaries of the RESILIO project, insight into the total cost of ownership (TCO), as well as the economic, environmental and social benefits is essential, and a basis for exploring how to build a business case for BG roof investments. This chapter summarises key insights based on the societal cost-benefit analysis (SCBA) in 6.1 and the business case in 6.2, conducted as part of the RESILIO project (please check the published research reports for more in-depth information on each theme).

6.1 SOCIETAL COST-BENEFIT ANALYSIS

By quantifying benefits and costs for BG roofs, the RESILIO project offers insights into the societal benefits of this innovative solution. The SCBA offers a tool to gather information about the range of costs and benefits which can be associated with the implementation of BG roofs. It allows for a comparison and prioritisation of implementation strategies, by considering the uncertainties in monetising water storage, biodiversity and heat reduction. The SCBA should not be used for a yes/no decision. Instead, the final decision should be made in a holistic way, taking non-monetary factors and societal considerations into account.

To investigate a range of realistic outcomes, the SCBA is performed for six different scenarios varying in timing of construction of BG roofs, including or excluding climate change, using different methods for quantifying benefits (see table 3).

The lifespan of a BG roof is assumed to be 60 years, while a conventional roof is expected to last 30 years. The majority of the estimated costs are obtained from the actual expenditures from Lieven de Key, de Alliantie and Stadgenoot, and cost estimates from MetroPolder Company.

SCENARIO VARIABLES FOR THE SCBA		
Renovating roof	Replacing roof	Installing a BG roof can be done either when the current roof is at the end of its lifespan, or when the current roof is scheduled for major maintenance. Renovating the roof means overlaying the roof with a new black layer (bitumen) and adding a blue-green layer on top. Replacing the roof means dismantling the old roofing and replacing it with a BG roof.
Water damage estimate	Shadow price of alternatives	For water storage, which is the main goal of the RESILIO project, two different methods for calculating the benefits are analysed: direct water damage estimates, which are based on the information from the Klimaatschadeschatter (2020) and shadow prices, where the costs for not being able to store water on the roof are investigated, and instead public space has to be used, for instance by creating bioswales (channels designed for concentrating and conveying rainwater).
Current climate	Future climate	To highlight the effect of climate change on the cost-benefit analysis, benefits are analysed for both for the current climate as well as for a changing future climate, with more extreme precipitation and more heatwaves.

Table 3: Scenario variables for the SCBA.

To monetise the benefits, methods such as Willingness to Pay, potential damages and shadow pricing were used. The full range of potential costs and benefits is shown (e.g. low-costs/high benefits, high costs/low benefits). In the SCBA, the costs and benefits of a conventional roof are included as a comparison correction, meaning that a positive Net Present Value (NPV) indicates that the BG roof is more economically desirable than a conventional roof.

The costs and benefits can be adapted in the calculation model for the RESILIO project (see [20]). Note that the shadow pricing method is based on a fixed water storage volume. For instance: comparing the cost of implementing 800 liter water storage from BG roofs to the cost of storing 800 liter in bioswales, retention basins or other infrastructure, as the shadow prices are based on a fixed volume, the results are independent from climate change.

When installing a new roof, the costs are higher because of the required constructions. When installing a BG roof during a renovation, the overall costs are lower, as the overlaying procedure is less costly and fewer roof preparations are necessary.

The regular maintenance costs, which include green maintenance, gutter maintenance, maintenance of the smart roof weir/drop system and re-inspection, make up a large and important share of the costs.

The most favorable scenarios are those with renovating through overlaying. In these scenarios, construction costs are lowest and a sequential construction of a completely new roof 30 years later is prevented.

Scenarios 1-4 quantify the benefits for water storage based on avoided direct and indirect damage. While this is appropriate and informative, determining direct and indirect damage is also relatively uncertain. To avoid this uncertainty, scenarios 5 and 6 are based on a shadow price method for the benefit of water storage through BG roofs instead of other water storage solutions. Note that both direct/indirect damage calculations and shadow pricing yield similar results. Furthermore, the results indicate that using BG roofs is a cheaper and more cost-effective measure than using alternative water storage options in the urban environment.

The NPV has a large range, resulting from different possible combinations between low, medium and high costs and benefits, and differs from a net positive NPV to a strongly negative NPV. In the least favorable case of low benefits and high costs, the NPV will be significantly negative across all scenarios. In the most favorable case of high benefits and low costs, the NPV will be significantly positive across all scenarios.

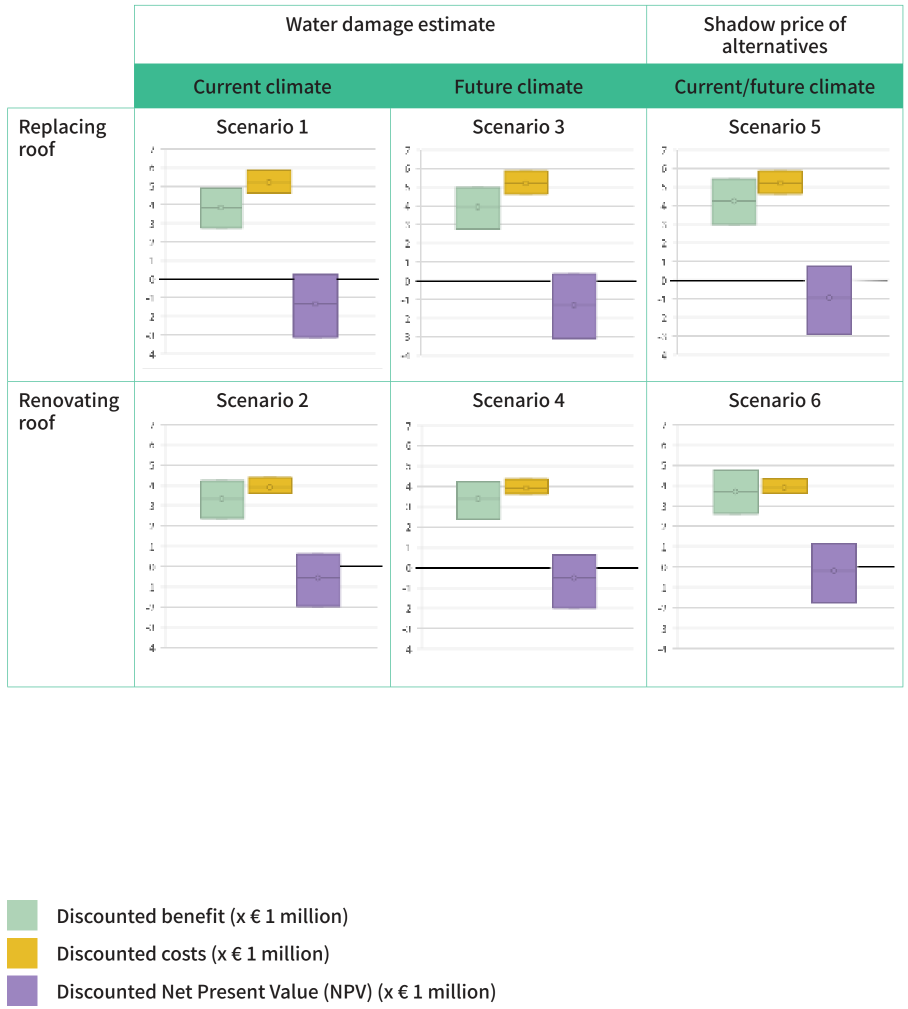


Figure 26: Net Present Value for (1) different timing moments for installing BG roofs, (2) current or future climate scenarios, and (3) different valuation methods for the benefits of water storage.

The SCBA is promising as it shows that, even before economy of scale can be achieved, the net present value can turn positive. In this research key opportunities for smart BG roofs to achieve an overall positive SCBA were identified:

- **Multi-functionality**: within RESILIO, BG roofs are implemented on buildings of the social housing cooperations, and access to the roof is limited for safety and maintenance reasons. However, when BG roofs are combined with accessible roof gardens or recreational areas, there is a great opportunity to add value to the functionality of the roof. Literature shows that accessible (B)G roofs can add up to 21% to the property value, which is especially the case in densely built cities like Amsterdam. Of course, adding recreational space reduces the space that can be used for water storage, so there is a trade-off between added economic value and achieving the targets for water nuisance reduction.

- **Reduced green maintenance costs**: the green maintenance costs are now between 26% and 44% of the total net present cost, depending on the scenario. The current costs are based on €4/m^2 per year. If trough economy of scale this can be reduced to €2/m^2, most scenarios would turn to positive net present values under all assumptions. Achieving this reduction of costs seems realistic according to Life@Urban Roofs [21] and Groendak.

- **Upscaling of BG roofs**: the RESILIO project installed roughly 10.000m^2 of smart BG roofs in Amsterdam, which is a sizeable amount but relatively small on a city scale. Upscaling will increase the potential of smart release of water to the sewerage system, will increase the effectiveness in reducing the Urban Heat Island (UHI) effect, and will increase biodiversity effects. Moreover, through economy of scale, costs can be reduced, all together probably leading to a positive net present value for the SCBA.

6.2 TOWARDS A BUSINESS CASE FOR BG ROOFS

In developing a business case for BG roof investments, a transfer mechanism for costs and benefits is identified, with three categories:

1. integrating co-investments and/or (in)direct payments between stakeholders who benefit from BG roof investments based on the SCBA, and/or
2. expanding the benefits of the BG roof by incorporating value-adding features, and/or
3. reducing investment and/or maintenance costs based on the total cost of ownership (TCO) during the lifespan of the roof.

By using the calculation module based on the SCBA [22/23], specific interventions translate into a neutral or positive NPV, thus showing different pathways towards a potential business case.

Transfer mechanism	Category	Description	Main conditions and/or examples
Co-investments	1	Co-investments in the construction costs of BG roofs from stakeholders which benefit from BG roofs, but have no (or very limited) responsibility for the TCO for the roof owner as principal investor.	Willingness to pay and take responsibility for TCO / construction costs based on monetized benefits and sustainable impact on society and urban development.
Direct payments	1	Direct payments for maintenance costs of BG roofs from stakeholders which benefit from BG roofs, but have no (or very limited) responsibility for the TCO for the roof owner as principal investor.	Willingness to pay and take responsibility for TCO / maintenance cost based on monetized benefits and sustainable impact on society and urban development.
Subsidies	1	Subsidies for the construction and/or maintenance costs for the roof owner as principal investor (or collective of owners), to stimulate the uptake of BG roofs as a sustainable solution for urban climate change adaption.	The replacement of the 80% EU-UIA subsidization that has financially underpinned the RESILIO project, for the sustainable impact on urban development and citizen welfare.
Tax differentiation	1	Tax incentives based on exemptions/differentiation for the roof owner as principal investor (or collective of owners), to offset some of the TCO based on impact of BG roof investment.	Changes and/or exemptions to tax policy for specific benefits (e.g. water tax, sewage tax, or any applicable impact area of BG roof investments).
Volume-based reimbursements	1	Water retention and storage facilities for urban water management are created through BG roof investments, for which volume-based reimbursements could be provided to the roof owner as principal investor (or collective of owners), to offset some of the TCO based on impact of BG roof investment.	All BG roofs need to be connected to an interconnected system of BG roofs in order to become part of urban water management, and the scale of retention/storage facilities needs to be substantial enough to have a meaningful impact in the overall water management system.
Lease/rent of accessible rooftop space	2	For accessible rooftops, the roof's design could allow for the (non-) commercial exploitation by the roof owner or contracted third parties, for which lease/rent is charged to offset some of the TCO	Accessible rooftop space which can be accessed on a regular/continuo-us basis, for options such as urban farming, outside bars or restaurants, or (catered) meeting and socializing places.
Pay-for-benefit or pay-for-use roof of accessible rooftop space	2	For accessible rooftops, occupants of the building could pay for access to an (attractive) rooftop area, or pay for specific benefits such as indoor heat reduction in the floor directly under the BG roof (related to the cooling impact of the BG roof).	Accessible rooftop space which can be accessed by occupants of the building for recreational purposes (not the case in RESILIO); legal option to increase rents and/or ask a premium for specific residents based on benefits (which is very difficult for social housing in RESILIO).
Integrate value-adding solutions to rooftop space	2	BG roofs are part of a wider portfolio of sustainable solutions for the urban build environment, potential for combining combinations can add value to the rooftop environment.	Combination with (transparent) solar panels for sustainable energy production at the building level (not the case in RESILIO); impossible in Resilio due to technical constraints in the building load bearing capacity.
Reducing construction costs and/or maintenance costs	3	Reduction of different types of costs associated with the TCO over the roof's lifespan for the roof owner as principal investor, including the one-time construction costs and reoccurring maintenance costs.	Realistic options for costs reductions can be taken into account to move towards a neutral or positive NPV for BG roof investments; technology development may have a impact on the lowering of costs over time, due to its increased maturity stage and wider diffusion .

Table 4: Transfer mechanisms for BG roof investments identified in RESILIO.

In addressing how the transfer mechanisms in Table 4 enable the development of a business case for BG roofs, there are governance-related issues. These concern the (re-)distribution of costs and benefits amongst public and private stakeholders, as well as opportunities to enlarge benefits and/or identify opportunities to decrease the TCO during the lifespan of the roof. In this research, key considerations were identified in order to move towards a business case for BG roofs based on the SCBA and the calculation module:

- **Embracing the perspective of the principal investor:** how to achieve co-funding from the beneficiaries of BG roofs: it is important that public and private stakeholders, who benefit from BG roof investments, act as potential co-investors alongside the roof owner (who is responsible for the TCO as principal investor), and assess which monetised benefits associated with BG roof investments could translate into co-investments towards a positive NPV. During an expert meeting as part of the RESILIO project, several scenarios to make stakeholders/beneficiaries pay for the societal benefits of BG roofs were discussed:
  1) the owner of the building is fully responsible;
  2) the City of Amsterdam and the public watermanagement organisation (Waternet) are fully responsible;
  3) a proportional split between the owner, the City and the watermanagement organisation.

Whilst stakeholders in the project have different opinions on this (ranging from no subsidy to full subsidisation as the baseline, depending on the stakeholder), the overall consensus was that the third option is most promising for a business case.

- **Key stakeholders' willingness to pay:** the willingness to pay for benefits by stakeholders is an essential part in moving towards a business case for BG roofs, given that a positive NPV for BG roof investments without any of the transfer mechanisms being adopted is very challenging in this early stage of technological development. Hence, a sustainable urban development orientation from key stakeholders such as the City council and the public watermanagement organisation, as well as for other urban stakeholders who could be potential investors based on their sustainability mission to contribute to urban development, is central for a positive NPV.

While the SCBA reflects that, at present, the TCO outweighs the economic benefits from a financial point of view (under the specific conditions in the RESILIO project), willingness to pay for non-economic benefits for sustainable development and increasing the resilience of the urban environment to climate change, can be a lever for investments.

- **Paradigm shift for urban roofscapes:** from a value creation perspective, it is helpful to conceptually think of rooftop environments in (densely populated) cities as potential new parts of urban spaces – fundamentally different from the traditional way of thinking where a roof is merely 'covering the top of the building' without any additional functionality. The transfer mechanisms are potentially value-adding opportunities for BG roofs. Pay-for-use, pay-for-benefit or lease/rent constructions could be an important opportunity for the roof owner to offset (part of) the maintenance costs, which in turn can have a substantial impact on the TCO and creation of a positive NPV. This is especially the case in urban locations where green spaces are scarce and hard to create in alternative ways, as well as in locations which are most promising and potent from a flooding and heat stress perspective (see 5.1.2 for upscaling potential of BG roofs in Amsterdam).

- **Supportive policy frameworks and institutional arrangements for BG roof investments:** in decision-making for BG roof investments, environmental and social benefits tend to prevail over economic benefits. Therefore, some kind of co-investment, subsidisation scheme, tax incentives, and/or standardised reimbursements for roof owners, as part of a wider policy framework for sustainable investments, is essential in this stage of development to stimulate the wider uptake of BG roofs.

As the SCBA has identified that the TCO on larger roofs have lower costs per m2 than for smaller roofs, it is important to analyse which conditions for the investments need to be part of such a framework, in order to reap the benefits of BG roofs beyond the roof and building level (i.e. for climate change adaptation and watermanagement for the city in its entirety). Policy framework should ideally be aligned with other regulatory frameworks, such as a rainwater ordinance for water storage on new private property (as is the case in Amsterdam).

- **Economic value creation and property value increase:** the SCBA monetise environmental and social benefits, which are central drivers for BG roof investments from a societal perspective. The main economic benefit, an increase in property value, as well as other potential value-adding features of accessible rooftops (lease/rent for exploitation by a third party, pay-for-use rooftop garden, solar panels for power generation) can be central drivers for a business case to scale up BG roofs.

Smart BG roofs are a relatively new technology, which has not yet seen widespread installment – exemplified by the fact that the EU-UIA has subsidised the RESILIO project to develop, test and validate the solution in Amsterdam. This has made the creation of a clear-cut and scalable business case a challenge, particularly because the main benefits are societal (ecological and social) rather than economic, as well as having several context-specific dimensions (existing built-up environment, non-accessible roofs, limitations to the load-bearing capacity, social housing focus).

However, the SCBA and adoption of the transfer mechanism provide promising avenues for a positive NPV and scalable business cases, as further specified in the research result documents.

6.3 LESSONS LEARNED

From the analysis presented in the SCBA and the exploration of opportunities to develop a business case for BG roofs, the main lessons learned are:

- The SCBA offers a realistic range of costs and benefits, but the decision process for BG roof investments needs to be supplemented with non-monetary and societal considerations, focusing on the wider resilience and adaptation to climate change of the urban environment.

- Depending on the scenarios and taking into account uncertainties, the NPV for BG roofs currently ranges from positive to negative, whereby willingness to pay for non-economic benefits by key stakeholders is a basic principle in moving towards a positive NPV. An integrated perspective amongst key urban stakeholders on value creation, which incorporates economic, environmental and social value creation, is therefore important in scaling up BG roofs.

- Whilst the smart technology for BG roofs is still in an early stage of adoption, there are multiple ways of developing a business case for BG roofs: by adopting one or more transfer mechanisms which financially support the roof owner who is responsible for the TCO based on the SCBA (i.e. the (re-)distribution of costs and benefits); by incorporating value-adding features to the roof environment (e.g. rooftop terrace, solar panels, commercial exploitation, depending on the characteristics of the roof); and by cost reduction during the lifespan of the roof (construction and/or maintenance costs).

- Favourable city-level frameworks supporting BG roof investments, as well as regulatory frameworks (such as a rainwater ordinance, which is in place in Amsterdam), are important drivers for the development of a business case for BG roofs. A supportive institutional setting and public policy for climate change adaptation and mitigation investments, and the availability of favourable national/regional/local frameworks to support investments in sustainability-oriented solutions (particularly with a focus on stimulating blue and green investments), can be an important driver for scaling up BG roofs in individual cities.

- The SCBA in the RESILIO project has primarily focused on BG roofs for the existing built-up environment, specifically for the replacement or renovation of existing roofs. While BG roofs for new buildings have therefore not been within the scope of the SCBA, it can be expected that the business case for BG roofs on new buildings will be more positive than for replacement and/or renovation in the existing environment, as the construction costs (which make up a significant portion of the TCO for the roof owner) are part of the overall investment in the building when the BG roof is incorporated in the building's design.

- Upscaling is promising, as the general trend is increasing benefits and decreasing costs with a larger roof area, as reflected in the SCBA. Hence, increasing BG roofs in an existing environment as well as for new buildings through public policies and supportive frameworks, can be drivers for scaling up BG roofs in the urban environment.

7. IMPLEMENTATION STRATEGY: PROCUREMENT AND GRANT SCHEME

Construction of grant scheme roof at Royal Tropical Institute Depot © Wieke Braat

7. IMPLEMENTATION STRATEGY: PROCUREMENT AND GRANT SCHEME

7.1 INTRODUCTION: PROCUREMENT AND GRANTS AS A DELIVERY MECHANISM FOR BLUE-GREEN (BG) ROOFS

As explained in chapter 3, the actual implementation of blue-green (BG) roofs was a priority of the RESILIO project. Chapter 6 demonstrated that a sound cost-benefit analysis underpins a business case approach towards the implementation of BG roofs at a larger scale.

This chapter focuses on specific delivery mechanisms which could be decisive within the framework of a business case approach in the actual stage of development. In RESILIO two types of delivery mechanisms played a key role: the procurement of 8,000 m² of BG roofs by the RESILIO housing corporations and the implementation of 2,000 m² of RESILIO-roofs by private companies, but supported by a municipal grant scheme. How did RESILIO partners decide on the details of both the procurement strategy and the municipal BG roof subsidy, and how effective were they? The most important findings are summarised in the ‘Lessons learned’ paragraph.

7.2 PROCURING FOR RESULTS: THE RESILIO PROCUREMENT STRATEGY

7.2.1 PROCUREMENT AS A CHALLENGE

After the roof selection by the RESILIO housing corporations the project entered a new phase: the actual installation of the BG roofs on the selected estates, as innovations as well as part of planned renovations of the rooftops (bituminous or grey gravel top layers). Housing corporations in Amsterdam have asset maintenance schemes to decide on the appropriate timing of these kind of renovations.

An important question had to be addressed: how can this complex operation be assigned to a competent and trustworthy company and result in value for money? A blue-green system is not a simple commodity which real estate owners can buy on the open market. Initially there was even a discussion about whether the procurement should be targeted as a product or as the delivery of a service, for example water storage.

Traditional bitumen rooftop maintenance is not a demanding, high-frequent task. The main priority is the prevention of leakages. New energy saving regulations for housing corporations’ real estate also demand high insulation values of the building shell, including rooftop insulation materials. Sensitive to these new regulations and demands, housing corporations base their calculations and capitalisation of maintenance investments for rooftops on an average replacement term of 30 years. Investments in roofs are part of the TCO. To minimise costs, local housing corporations have agreed to long-term maintenance contracts with a limited selection of companies, specialised in rooftop maintenance. The corporations call these companies their ‘roof partners’ (‘dakpartners’).

In The Netherlands, housing corporations are legally obliged to invest in social housing only. Their main objective is to build and rent out affordable housing. At the same time, they are part of the private sector and are, therefore, free to choose their own investment strategy, within the legal framework of the Dutch Housing Law. They can make their own decisions on procurement. Procurement rules for public authorities do not apply.

Not all long-term rooftop maintenance contracts of the RESILIO housing corporations are procured publicly. Some of them are framework assignments with preferred partners, with regular adjustments of the prices of the contracted work, based on market conformity testing.

The legal status of Dutch housing corporations and their long-term contracts with roof partners created an important context for the assigning of the implementation and installation of the RESILIO BG roofs. The public European funding by the UIA required that RESILIO BG roofs had to be procured in compliance with European and national regulations. The RESILIO housing corporations Lieven de Key, Stadgenoot and de Alliantie pleaded that the BG roofs would become part of the regular maintenance schemes after the assignment and realisation. This should lead to a connection to or an adjustment of the long-term maintenance contracts with trusted roof partners. Working with trusted partners, who are knowledgeable in all aspects of regular rooftop maintenance, would guarantee that lessons learned during the implementation of BG roofs could be incorporated in the overall maintenance contracts.

The decision for a suitable procurement process within this context created a challenge for the RESILIO partnership. But it was also an excellent learning opportunity from a unique procurement environment. The most important stakeholders, active in the niche market for innovative development of BG roofs on existing real estate, were all represented in the RESILIO consortium (see 2.2.2): housing corporations (acting as companies in the private sector), public authorities, a specialised small or medium-sized entreprise on roof technology, a non-governmental organisation promoting sustainable development on roofscapes, knowledge institutes and a rooftop maintenance company.

To benefit from this opportunity, the RESILIO partners joined forces to draft a guiding procurement strategy. This strategy would be sensitive to long-term interests of the assigning housing corporations, but would also capture lessons learned about the procurement strategy for such an innovative product.

7.2.2 DECISIONS IN THE RESILIO PROCUREMENT STRATEGY

The RESILIO consortium decided to choose a limited tendering procedure, in which each housing corporation invited three of its roof partners to submit offers in competition. This would guarantee a transparent and fair procurement procedure. This limited tendering process complies with the European and national procurement rules and with the procurement policies of the City of Amsterdam. The process aimed for a contract with an estimated value below the thresholds for open, public tendering at the national level (€ 1,500,000). The estimated values for contracted BG roofs by each housing corporation were:

- Stadgenoot: € 700,000
- de Alliantie: € 525,000
- Lieven de Key: € 600,000

RESILIO opted for a contract form based on ‘Uniform Administrative Conditions for integrated contracts’ (UAV-GC). This contract form refrains from detailed technical specifications in the procurement process. Implementation standards for BG roofs on existing real estate are not yet developed.

The implementation of RESILIO BG rooftops would be a challenge for each contractor. By choosing a functional specification of demands and requirements, the assigning housing corporation triggered each contractor to find innovative, practical and cost-effective solutions to meet these demands. It was not feasible to procure solutions on the open market for the Smart Flow Control (SFC). As RESILIO partner, MetroPolder Company would further develop and innovate the smart valve as the crucial instrument to facilitate SFC and connect this to the Decision Support System (DSS), which would be developed by RESILIO partner Waternet.

The consortium decided in its procurement strategy that each roof partner, that would submit an offer for a RESILIO BG rooftop contract, would be obliged to sub-contract MetroPolder Company for the installation of the SFC. The procurement strategy determined a fixed price in advance for the installation and the consecutive maintenance contract of the smart valve for eight years, thereby conforming to the UIA fund guidance that funded products would be maintained for at least five years.

This element in the RESILIO procurement strategy demonstrates tensions, as encountered by innovative projects when they develop new innovative solutions which are not yet available on the open market. They have to find solutions to meet procurement rules and, on top of that, they might be restricted by specific criteria if they receive additional funding. This was the case in RESILIO, as the project received a grant from the EU's 'Urban Innovative Action' fund.

Another piece of the procurement puzzle was Consolidated, a rooftop maintenance partner of the RESILIO housing corporations – in this position a (sub)contractor of local housing corporations. Consolidated was also a knowledge partner of RESILIO. The database on maintenance characteristics of Amsterdam rooftops (Dakota) was crucial for the selection of RESILIO BG roofs on housing corporation estates (see 2.3). In the procurement strategy, a potential conflict of interest and an advantage of information regarding the tendering process was identified. This could occur, if Consolidated were to submit an offer in the BG rooftop tendering process. Consolidated signed the RESILIO partnership agreement as a precondition to receive UIA funding. To prevent a potential advantage for Consolidated during the RESILIO tendering process, a strict separation was built in between its potential role as a (sub)contractor for the implementation of RESILIO roofs and its role as a partner in RESILIO - a 'Chinese Wall' between those two roles. In the actual proceeding of the project, this provision turned out not to be feasible, mainly because of additional UIA subsidy contract regulations.

7.2.3 THE RESULTS OF THE RESILIO PROCUREMENT PROCESS

At the end of the RESILIO project, the conclusion can be that the tendering processes for the eight RESILIO rooftops have all been successfully initiated. Selected roof partners have submitted their quotations according to the rules of the limited tendering processes. For seven out of eight tenders, contracts were awarded. The tendering procedure for the implementation of a BG roof on the social housing estate at Wittenburgerkade, owned by the RESILIO housing corporation Lieven de Key, did not lead to a contract. All registered offers in this tender exceeded the available budget for a BG roof. Although the tendering process for this assignment in itself had proceeded without problems, the frustrating outcome implied that one RESILIO rooftop project had to be cancelled.

This was a setback. However, the majority of the roofs have been implemented successfully within the budget framework. There were other unexpected outcomes of the tendering process. Some of them were a result of the decisions made in the procurement strategy. Analysing and discussing some of them may lead to valuable insights for future procurement of BG roofs.

1. Functional versus technical specifications

There was consensus that a functional specification of requirements was a better option than detailed technical specifications. In the preparation of the first tender, there was some doubt about the prices that could be expected in registered offers. To anticipate this, a detailed engineering exercise of the first RESILIO roof was executed. This revealed that certified insulation options, as the second rooftop layer underneath the crate system, could be very costly.

There is some tension between an engineering attitude, to get a better grip on expected costs, and the philosophy of functional specification of contracts. A presumption of that philosophy is that market-oriented companies will come up with cost-effective innovative solutions, if they are offered the opportunity in a competitive environment. In RESILIO this tension led to delays in finalising the tender documents, specifically the requirements specifications (on both product and process).

Because of expected high prices for the first roofs, Lieven de Key postponed the start of the tendering processes, and Stadgenoot became the first housing corporation to submit a RESILIO tender. Stadgenoot decided to tender out all their roofs in one procedure. This led to adjustments in the tendering process. Housing corporation de Alliantie also customised its tender documents to their specific roof situation. The ongoing active exchanges between housing corporations proved that RESILIO offered a fruitful environment for active learning. As a consequence, the procurement strategy was substantially adjusted in the consecutive RESILIO tendering processes, leading to mixed tendering documents, with functionally and technically specified elements.

2. Complex contract situations

Consolidated left the RESILIO consortium when it was awarded a contract for BG rooftop installation on the Stadgenoot housing estates. Even though the 'Chinese Wall' between its RESILIO partnership and its role as a contractor for the work on Stadgenoot's roofs secured a fair tendering process, additional demands of the UIA fund (regulations regarding invoices between consortium partners) created a complex puzzle.

The subcontracting position of MetroPolder Company also created some difficulties in the preparation and execution of the assigned work. SFC is a key element in the total design and construction of the BG roof system. Although the selected contractor leads the assignment, the smart components of the BG roof system affect the execution of the complete job. This can lead to friction or imbalance in the actual work planning. The work of the main contractor depends heavily on the work of the subcontractor.

3. Black, blue-green and grey

The rooftop maintenance industry is not yet accustomed to implement intelligent BG roof systems on existing real estate on a large scale. The situation might be different with new buildings. In the design of a new building or a larger housing complex, BG roof systems can be fully integrated in advance. The implementation of BG roofs on existing housing complexes amounts to an often costly retrofitting of the roofscape. BG rooftops actually introduce completely new functions in the roof environment (ecosystem services delivered by BG infrastructure), which exceed traditional rooftop renovation.

The rooftop maintenance industry offers standard products and calculations for classic rooftop renovation. In the RESILIO procurement strategy the rooftop maintenance sector was invited to submit offers in a (limited) tendering process. Currently there are no other companies which could deliver this 'product'. An important implication is that there should be a clear differentiation between 'regular' rooftop renovation costs and costs connected to the implementation of the BG system. In the RESILIO work plan these costs were clearly distinguished: regular renovation is within the scope of pre-construction work and the implementation of BG systems is called construction work.

In the procurement strategy and the tendering process it became clear that there is no clear division between various cost categories in the complete work of BG roof systems implementation. In the RESILIO project standard costs of renovation would be funded by the housing corporations' maintenance programmes. In practice, they cannot always be separated from costs of BG rooftop installation. Because of this, it was decided that standard renovation costs would be called 'black' (the colour of standard bitumen layers) and BG roofsystem costs 'blue-green'. Intermediate costs were to be called 'grey'. The implementation of a BG rooftop can lead to higher costs in necessary standard renovation work (e.g. other types of insulation). The other way around, renovation demands which result from specific rooftop characteristics (e.g. existing roof drainage, presence of chimneys and pipes, etc.) may lead to higher BG roof implementation costs, compared to the implementation on new real estate. These extra costs and other additional costs were allocated to a category called 'grey costs'.

Still, in practice it turned out to be very difficult to disentangle these costs in a complete, assigned job. Upfront, there were no clear decisions on how to separate these costs in the functional and technical requirements of the tendering documents.

Therefore, it was decided to perform a cost analysis afterwards, based on the awarded quotations. A general comparison between black, grey and blue-green costs turned out to be impossible. As mentioned: demands on the separation of these costs were not formulated in the specifications of requirements in the tendering documents, and tenders were adjusted by each housing corporation because of lessons learned in the RESILIO process.

4. 'Life is like a box of chocolates…

… you never know what you're going to get'. Forrest Gump, the main character in the eponymous movie, learned this proverb from his grandmother. In the RESILIO procurement strategy it was almost known what the 'getting' would be like. And because of steering on that during the tendering processes, this turned out to be (almost) true. But a project sometimes resembles real life, and this led to some surprises...

With the help of the Dakota maintenance data base on rooftop characteristics, the construction of each selected RESILIO roof was assessed. The contractor of the roof for de Alliantie in the Rivierenbuurt neighbourhood found out, during his pre-construction work, that there was a heavy cement layer on the roof. This was not documented in the construction information. Removal of this layer was not possible. After an elaborate study of all remaining options, de Alliantie had to conclude that a BG system on this housing complex would not be feasible. A completely new tendering procedure had to be started for a replacement social housing block at Riouwstraat. Understandably this was a serious setback, with substantial delays. It is questionable, though, whether this could have been prevented within the framework of the procurement strategy.

Another category of surprises had to do with requirements that had to be met, but were not part of the assignment of the work – leading to extra costs. In the engineering design, delivered by both the roof partners and MetroPolder Company, it became clear that a 'static valve', not connected to DSS, would also be necessary – in order to discharge the water into the sewerage in case of overload. This should have been part of the functional and technical requirements of the tendering documents. This was also the case for specific requirements on the vegetation, related to biodiversity, which were specified by the city's urban ecologists.

And finally the choice of the crate system led to some debate. This had to do with the necessity of the connection between the water layer and the substrate of the plants. There must be a capillary transport of water towards the vegetation, especially in longer periods of drought. This is facilitated by capillary cones in the crates. The capillary transport was a clear demand in the functional specifications of the tender... but still there was some discussion about which crates would satisfy this demand.

7.2.4 LESSONS LEARNED

The RESILIO consortium learned a good number of lessons from the results of the procurement strategy. AUAS conducted a more general study of the procurement and assignment process. This has led to very helpful recommendations in Dutch. [24] More specific lessons learned on the procurement technique are:

- **BG roof systems are not yet established as a regular procurable product in the market.**
  BG roof systems introduce new functions on our roofscapes. A procurement strategy for existing real estate has to take this into account, specifically because the rooftop maintenance sector is only just starting to learn about these new requirements.

- **It is crucial to draft a procurement strategy which makes a choice on product selection, processes and allowed contracts before entering the BG rooftop tendering process.**
  In tendering procedures a choice has to be made between Uniform Administrative Conditions (UAV) or Uniform Administrative Conditions for integrated contracts (UAV-GC). RESILIO's experience with the assignments of BG roofs may lead to the conclusion that a clear specification of technical requirements is perhaps preferable, at this stage.

- **Cooperation between contractors and subcontractors has to be specified upfront, because traditional roof companies will have to sub-contract the delivery of the micro watermanagement technology, but do not (yet) know enough about the integration of this technology in the complete roof system.**
  The roofers involved are generally subcontractors and not the main contractors. As many subcontractors are involved in the realisation, and parties do not yet have much experience with the construction, the construction process took much longer than anticipated. Planning should be more flexible. Working on the implementation of an innovative product such as a BG roof, in a developing market, is demanding. All partners involved in a contract situation like this should develop new skills to respond to these demands adequately: commissioning parties, such as housing corporations, should become more knowledgeable about their roof situation, main contractors should be more aware of their commissioning role towards subcontractors, and subcontractors should be more flexible in their work planning.

- **A specification of costs, which are within the scope of regular rooftop maintenance, and costs which are attributed to the BG roof system, can be helpful to assess offers of subcontractors.**
  A very practical, procedural solution might be to tender out two options for contracts simultaneously: one offer for a standard renovation and another offer for the implementation of a BG roof system, including necessary renovation work.

- **Professional and realistic milestone planning of the entire procurement process is necessary to be able to steer the implementation. Even then, one should count on delays and hickups.**

7.3 GRANT SCHEME

7.3.1 DEVELOPMENT OF THE GRANT SCHEME

To facilitate investments in BG rooftops the idea of creating a grant scheme took hold. The logic was that a grant scheme would benefit roof owners across the city, including in the identified bottleneck pilot areas, to overcome financial hurdles for investing in a BG roof.

Funding guidelines were developed in accordance with UIA guidelines and local legislation. For this, both the City's legal and financial department as well as its Subsidy Bureau helped out. Amsterdam already had a green roof subsidy scheme in place. Politically, the alderman in place was not very keen on developing another scheme for the city. Ideally, the blue part should have been integrated with the already existing grant scheme. But due to the innovative character and UIA fund requirements this turned out not to be feasible. The scheme would also have a limited lead time, matching the RESILIO project period. It was also decided that the BG roof grant scheme could also be used for newly built property in the city, whereas the green subsidy roof scheme could only be used for existing property.

After the guidelines and organisational structure of the grant scheme had been established at the
administrative level, City Council approval needed to be ensured. This decision-making took several months and was completed on the 24th of March 2020. The subsidy cap was set at € 500,000. In February 2021, another council decision was made to extend the deadline of applications for this grant by six months, as the subsidy cap had not yet been met and the RESILIO project end date had also been extended due to the delays in rooftop implementation by the housing corporations.

As the grant scheme was rather innovative, the aforementioned decision-making process in the Council was used for a change in the conditions of the ruling. In the original ruling one of the applicants had to be denied, because they already received financial support for other activities, going beyond the 'de minimis threshold'. However, it appeared that under European Commission Regulation No 651/2014 an exception to state aid provisions can be made for certain organisations, allowing more of them to qualify for the BG roof grant scheme. To make this possible, the text of the original subsidy scheme needed to be amended.

7.3.2 ELIGIBLE ACTIVITIES AND COSTS

The Council decided that applicants had to meet the following conditions:

a. a minimum area of 200 m^2 connected roof surface;
b. with a slope of up to 1%;
c. a minimum water storage capacity of an average of 60 liters per square meter, with at least half of the water storage surface intended for greenery.

Eligible costs for the construction of the BG roof are costs which are directly necessary for the realisation of the roof. The already existing green roof grant scheme had a maximum of 50% of the total eligible costs which were covered by the subsidy. It was decided that the subsidy for BG roofs would go up to a maximum of 75% of the total eligible costs with a maximum total amount per subsidy application of € 150,000. This 75% was chosen because of the innovative character of the solution, whereby the amount of the grant was calculated on the basis of the following criteria:

a. construction costs of BG roofs are subsidised for a maximum of 50% of eligible costs up to a maximum of € 150 per m², excluding the costs for the smart roof valve and management and maintenance;
b. costs of the smart roof valve including installation costs are 100% subsidised up to a maximum of € 3,000 per valve;
c. cost management and maintenance of the smart roof valve are subsidised for a maximum of five years, whereby the costs are 100% eligible up to a maximum amount of € 1,200 per year for the first valve and a maximum of € 200 per year for each subsequent valve.

7.3.3 RESULTS

The grant scheme functioned efficiently, as multiple property owners applied and more than 3,000 m² of BG roofs were realised on private property, as such creating additional space for water storage in a densely populated city. The tested model can therefore be called a success for the purpose of RESILIO (micro watermanagement on private property).

An interesting aspect is that most applicants use their new rooftop space multifunctionally: in addition to the blue and green layer they added recreational space. In fact, they added extra value to their living environments. This is an interesting development: this way BG roofs can potentially offer:

- socialisation opportunities to combat isolation and loneliness;
- urban gardening opportunities, which contribute to a community spirit;
- exercise space, including safe playgrounds for children;
- accessible areas for cooling down on hot summer days.

Figure 28: Subsidised roofs which are also used for recreational space

Figure 29: Subsidised roofs which are also used for recreational space

7.3.4 LESSONS LEARNED

Even though more than 3,000 m² of BG roofs were realised on private property, actively engaging with the market did result in a degree of disappointment. It turned out that the concept of urban micro watermanagement is still hard to grasp for private owners. Innovations take time and the subsidy scheme was not in place for such a long period. However, with more real estate being delivered over time, people can actually see the results, and confidence within society will grow. Long-term subsidy schemes, instead of fast and often changing schemes, could offer property owners more certainty.

Another lesson was that applying for this grant was rather difficult for roof owners, as a lot of technical details were needed. It was difficult to reach the original target group (residents associations) in existing property. Most applicants realised BG roofs on new buildings. The only roof owner who applied for subsidy on existing property was helped by an expert (from RESILIO partner Rooftop Revolutions) to submit the application.

In the future, it might be interesting to explore the possibilities of a ‘dakloket’, a one stop shop where owners can get help with their applications and ask questions. In addition, in the development of the grant scheme the primary focus was on the watermanagement settings. In the future, the grant scheme could pay more attention to the greenery, for example by including a list of native plant species – so that roof owners can plant these and contribute to biodiversity in the city.

Unfortunately, a grant scheme which compensates a maximum of 75% of the total costs is not sustainable in the future, when EU subsidies are no longer available for this. Therefore, the City of Amsterdam needs to reconsider if subsidising BG roofs is the way forward. Perhaps the City should focus more on an area-based approach. Whether new funds will become available is also a political decision.

8. BEING PRESENT IN THE NEIGHBOURHOOD

Creative workshop in Slotermeer © Rooftop Revolution

8. BEING PRESENT IN THE NEIGHBOURHOOD

8.1 WHY DID WE ORGANISE CITIZEN PARTICIPATION IN RESILIO?

The overall goal of citizen participation in RESILIO was to create a wider support base for the implementation of blue-green (BG) roofs. Consequently, this could lead to a higher awareness of the issue of climate change, and with that an increased willingness to contribute to climate adaptation measures. A stronger support base is also a crucial condition for the upscaling of BG roofs, which was a central goal of RESILIO. The participation processes and the appropriate means of communication were therefore not limited to the residents of the housing corporations' premises, but also focused on the wider neighbourhoods.

In February 2020 the Covid-19 pandemic reached The Netherlands. This had a serious negative impact on the execution of our participation strategy. Live events and face-to-face contacts were not possible during the many lockdowns, and continually changing restrictions had to be taken into account. Many of the planned activities were cancelled and, especially in the beginning of the pandemic, people were mostly preoccupied with the urgency of the crisis. This affected the level of participation and the quantity of our efforts. RESILIO's presence in the project's neighbourhoods had to be restricted significantly and, as a result, a smaller number of residents were actively engaged in the project.

8.2 THE IMPLEMENTATION IN THE NEIGHBOURHOODS

8.2.1 MAPPING THE SOCIAL STRUCTURE

To gain a better understanding of the neighbourhoods, their main characteristics and the relevant issues, firstly the social structure was mapped, based on existing data from local government. In addition, more experiential knowledge was obtained about residents from key local stakeholders, such as local area managers of housing corporations and the local government, residents' initiatives and neighbourhood organisations. These organisations often have a better understanding of how to reach residents and have a significant network in the neighbourhood. This approach helped in harvesting local knowledge on needs and motivations of residents and to gain insight into which events were organised by the local initiatives.

A number of times RESILIO was able to 'plug in' on those events to get to know the residents and showcase the project. In addition, short street surveys were conducted by students from the Amsterdam University of Applied Sciences (AUAS), which assessed residents' concerns about climate change and their willingness to act.

The information gathered provided relevant insights in the different neighbourhoods and the residents living in the buildings, which was helpful in adapting a participation strategy per area. By gathering this information, RESILIO started to be present in the neighbourhood and engage with local stakeholders. Although similar in many respects (socially mixed areas with a proportion of residents in disadvantaged positions, where the designated buildings all contained social housing), there were some differences between the RESILIO neighbourhoods which influenced the type of participation activities (see the case descriptions at page X).
The initial idea was to have specific strategies per neighbourhood,

which would be executed subsequently and would range in levels of participation (from informing to more co-creating), due to different types of ownership (housing corporation or a condominium residents association). However, in the end, only social housing owned by housing corporations was part of the research, which meant the objective of participation was mostly informing.

With the changing circumstances, and the set-up of the project as such, the whole process was characterised as ‘learning-by-doing’. RESILIO constantly evaluated its activities and tools with the project team and the housing corporations, in order to adapt and improve the strategy.

8.2.2 DEVELOPING PERSONAS

To better target the participation activities, personas were developed. A persona is a fictional character which represents a specific type of target group. The personas were helpful for the specification of area based approaches. The design of the personas was based on the interviews and data from the neighbourhood analysis. [25]

The personas were distinguished according to three variables, based on motivations for engaging in climate adaptation measures.

- Personal situation both entails the type of property (owner-occupied or rental) and the personal socio-economic situation. Ownership of a property is an important factor in the motivation and ability to act. The socio-economic situation is relevant since this affects a person’s ability to act (and take measures) and to be engaged with the subject of climate adaptation, as other issues are more urgent. Language skills were added, as these were seen as a potential barrier in the communication towards residents (for example in the Indische Buurt).

- Attitude towards the topic which concerns the persons affinity and awareness of climate adaptation measures. Residents who already have a higher awareness of the consequences of climate change are probably more inclined to engage in the project.

- Social neighbourhood participation entails the personal level of existing interaction and rootedness in the neighbourhood. Residents who engage in neighbourhood activities, who have lived there for a longer period and who are satisfied about the area often have a higher motivation to participate in improving their area (for example, making it greener).

In the end, three main personas could be identified for engagement with the RESILIO project:

1. Renter of social housing with a lower socio-economic position. Low level of interest in the topic of climate change, but high level of interest in making the area greener. Lower level of social interaction in the area and/or the building.

2. Renter of social housing with a lower socio-economic position. High level of interest in making the area greener. Main difference is the high level of interest in installing BG roofs due to experienced heat stress and/or water leakages/flooding, and mostly because of living directly under a roof. Sometimes associated with a general interest in the issue of climate adaptation.

3. Resident (both renter or owner) with an interest in climate change issues and a higher ability and willingness to act. Sometimes they have already undertaken their own actions for climate adaptation (such as a ‘façade’ garden or a rain barrel).

Although the personas turned out to be quite useful in communicating RESILIO's approach to the project team and the housing corporations, they proved to be less useful in tailoring an approach to the target groups. The reason for this were the restrictions, caused by the pandemic, to engage with different residents in the neighbourhoods.

8.2.3 PARTICIPATION ACTIVITIES

Based upon the social analysis of the neighbourhoods and residents of the buildings, several participation activities were organised.

1. INFORMATION MEETINGS

Meetings with experts were organised (live and online) for each neighbourhood to inform residents of the buildings and in the neighbourhood about the RESILIO project and what it meant for the specific building block where they lived. The first activity was the onsite opening of the first Innovation Lab (see frame B). Among the invitees were residents from two RESILIO neighbourhoods. Experts from the RESILIO partners explained the benefits of BG roofs. An alderman from the City of Amsterdam officially opened the lab, and the city poet recited a poem especially made for the occasion.

"I was afraid that the roof would cause leakages and that it would attract many mosquitoes, but after explanations from everybody here, I am mostly excited about the blue-green roof. A greener street is nice."- resident Uiterwaardenstraat during the opening of the Innovation Lab.

Because the opening of the Innovation Lab was very successful, in the sense that residents seemed to appreciate the knowledge that was shared, a similar programme in an online format was developed for residents of the Oosterparkbuurt, the Indische Buurt and the Rivierenbuurt. Representatives from the housing corporations also joined this meeting and offered residents the possibility to ask questions and share their concerns about issues such as roof leakage and nuisance caused by the construction activities.

Despite extensive promotion through flyers and a manual explanation of how to take part in a digital meeting, the meeting attendance was limited, with just seven residents turning up. The online meeting with the student-residents at the Oostelijke Eilanden (Kattenburg) was better attended, as students were already used to the online meetings due to the Covid-19 lockdowns and – in general – have better digital skills.

To increase the interaction with residents, issues were chosen which they would be able to influence. The initial idea was to give residents a choice in the type of plants. But this turned out to be practically impossible, because of procurement conditions (see 7.2). Another (online) event in Kattenburg was organised for residents to co-decide on certain aspects of the construction work. The housing corporation thought this was a fruitful exercise, since it provided them with relevant information for the building process and was an easy way to communicate with interested residents.

FACE-TO-FACE COMMUNICATION

In cooperation with the housing corporation, physical and digital information letters were sent. For events flyers were distributed (in person or in letterboxes) and posters were put up in the buildings to inform the residents and the wider neighbourhood about the BG roofs. Face-to-face communication was always the preferred option, as most residents indicated they had not read the information letter.

"If you really want to communicate your message, you need to go and see the residents. Ring their doors with a very strong presentation. Really take the time to let them understand the project." - local area manager in Slotermeer.

2. PARTICIPATION IN LOCAL EVENTS (MARKETS AND FESTIVALS) WITH THE BG 'ROOF BIKE' IN KATTENBURG, INDISCHE BUURT, SLOTERMEER AND RIVIERENBUURT

On a number of occasions, the RESILIO team participated in local events. The aim was to engage with residents in the neighbourhoods and to gain a wider reach through linking the project to other activities and projects. Respective examples included an autumn market in the Rivierenbuurt, a day market at the Oostelijke Eilanden (Kattenburg) and a neighbourhood festival in the Indische Buurt.

RESILIO's physical presence provided good opportunities to meet residents and answer their questions in a straightforward manner. To educate people on the principles of a BG roof, a working model of the system was installed on a Dutch cargo bike. This 'roof bike' attracted a lot of interest from residents. Most residents the project engaged with on these occasions were people who already had some interest in making their area greener, in green roofs, or in other sustainability ambitions. By creating a link with existing activities, the project was able to reach out to more residents, and organising the event and communicating about it took up less time and manpower. On these occasions, it became clear that the concept of BG roofs was new to everyone, but that the concept of a green roof was familiar to most of them. Several residents showed interest in having their own green roof and were referred to Rooftop Revolution for further advice.

Figure 31: In the Indische Buurt RESILIO joined a local festival with a 'roof bike' to create awareness of the BG innovations.

Figure 32: At the Oostelijke Eilanden (Kattenburg), RESILIO ‘plugged in’ on a local event, a day market.

BRING THE ROOF DOWN TO STREET LEVEL

A fun and sympathetic way to introduce BG roofs to residents and bring it to street level, was the ‘roof bike’, a cargo bicycle with a box at the front containing a miniature BG installation. The bike attracted many people and helped them towards a better understanding of how a BG roof works.

Other ways to give residents an impression of what was going on above their heads were time lapse videos and artist’s impressions. The videos were shared through the RESILIO website and the social media accounts and local online platforms of the City of Amsterdam. With a GoPro camera on top of a roof, ‘the making of’ different BG roofs in Amsterdam was filmed, to share with different target audiences. Additionally, an information film was made to explain every step in the construction of a BG roof.

USE COMMUNICATION CHANNELS OF LOCAL STAKEHOLDERS

Through Jungle, a local organisation in the Oosterparkbuurt which focuses on sustainability, the concept of a BG roof was demonstrated in their video journal, which could be watched by anybody in their local network. At the Oostelijke Eilanden, RESILIO teamed up with the De Witte Boei community centre, which aims to strengthen social cohesion and supports residents in many ways. One of its staff oversees green initiatives in the neighbourhood. She gives support to all kinds of green citizen initiatives and produces a bi-monthly newsletter to inform about the latest developments. The project featured in the October 2021 newsletter which was distributed shortly before ‘ day’, where RESILIO was present with a market stall directly in front of the community centre (see picture X).

3. CREATIVE WORKSHOP WITH CHILDREN IN SLOTERMEER

To increase the level of interaction with residents, RESILIO teamed up with the Bookstore Project, a community project for creative artists. Together with a local artist, children could paint their own vision and interpretation of a green city on a large canvas. The canvas was a means to interact with residents and gather knowledge of their perceptions and wishes in making their neighbourhood greener.

RESILIO organised this creative workshop in Slotermeer because most local households have children. And many residents in this area are difficult to reach in conventional ways, according to the local area manager. While the children were painting, the project team was able to engage with their parents and provide them with information on BG roofs in an informal and interactive way.

4. EVENT TO MARK THE COMPLETION OF THE BG ROOF IN THE INDISCHE BUURT

RESILIO celebrated the completion of the roof with a small gathering in the inner garden of the building. Residents were invited to view the roof, the city poet recited one of his poems (especially made for this event) and there were drinks and snacks. To increase the level of participation, residents could vote for the words they preferred on the façade of their building (see 9.3.5 for the result). Although these painted words were a small gesture towards residents, they facilitated a truly fun way of interacting with each other.

5. NEIGHBOURHOOD STORIES

Neighbourhood stories are personal accounts from residents in the five pilot areas. The stories were published every other month on the RESILIO website. They were inspired by the ‘Humans of New York’ concept. They consisted of a short interview with questions about the neighbourhood, climate change, BG roofs and RESILIO, accompanied by a photo of the local resident, taken outdoors to strengthen the connection with the neighbourhood.

By putting residents in the spotlight, RESILIO made the project more personal, with the aim to get a positive attitude from the neighbourhood and residents of Amsterdam towards the project. For some residents the RESILIO project also offered a platform for themselves and/or their initiative, which made the benefits reciprocal. In Frame C one of the neighbourhood stories is published.

Figure 34: Final event to mark the completion of the BG roof at the Javastraat (Indische Buurt).

FRAME C. ATEF ABDALLA, COMMUNITY CENTRE VOLUNTEER

We have a chat with Atef (65) at ‘De Witte Boei’, the community centre at the Oostelijke Eilanden, where he is a veritable jack-of-all-trades. Since 2006 Atef has lived around the corner, near Kattenburg – and before that at Jacob van Lennepkade in Amsterdam-West. Full of enthusiasm he talks about the people in his neighbourhood, his role within the community centre and the ongoing local initiatives, to which he is happily contributing.

Cosy, village-like neighbourhood with a lot of creative people

Atef talks of a special and cosy neighbourhood. “A lot of creative people live here: artists, dancers, you name it. I know just about everybody, including young kids and children.” It feels like a village, he says, which was not really the case in Amsterdam-West. “Over there, I felt like a guest in my neighbourhood, I felt a certain distance. Everybody had their own spot, you said hello and goodbye, but that was it. Here it’s really different, it really is a village. Oostelijke Eilanden contains five areas and everybody knows everybody. You bump into each other in the supermarket and there are a lot of neighbourhood activities.”

From cookery lessons to green projects

For a living, Atef was a marketing director. But now he enjoys a well-deserved retirement. He spends a lot of his time in the community centre. “At Oostelijke Eilanden I am a connector between young and old. I participate in a lot of activities in the neighbourhood, ranging from cookery lessons to dancing practice. I am a member of the neighbourhood committee for Oostelijke Eilanden, and of the ‘Islands Conference’, and I am connected to the citizens’ initiative ‘Stadsdorp’.” He can also tell a lot about the local projects which aim to make the neighbourhood greener. “We have been doing this here for two years now, led by Brenda. A number of green projects are going really well. We help elderly people with the maintenance of their gardens and we try to make barren streets greener, which is subsidised by the City of Amsterdam. There is also a community allotment. And we now have spades! Everybody can borrow one.”

Green pyramids in Alexandria

In his house, Atef suffers from heat stress. “I live on the third floor, right underneath the roof. The heat can really drive me crazy. Luckily, I have a big window and a balcony. And I am used to a degree of heat, as it is pretty common in Alexandria, Egypt, where I hail from.”
Atef says that Alexandria has a lot of green roofs. “Many roofs are green, there is enough rainfall for maintaining the plants and it makes for a nicer outlook.” He adds that Alexandria is a trailblazer. “In the olden days, Alexandria only had small houses and a lot of greenery. When the population began to grow, space to live became scarcer. They only began to construct buildings of more than five storeys high, but people still wanted a garden. Therefore, they started making gardens on their roofs. There are also buildings which resemble the pyramids. Each apartment has a garden, which is located on the roof of the apartment below. And some sloping roofs contain little parks, just like the one on top of the Albert Heijn supermarket at Museumplein in Amsterdam. In Alexandria, people can use these parks for a picnic, to play in, or even cycle down them.”

Looking out on greenery makes people happy!

Atef has a clear vision on how to enthuse people about green roofs. “Start with low roofs, the ones that most people look out on. People who live above them will see these roofs, and it will make them enthusiastic and willing to have a green roof themselves. It has to be something that is being felt by the whole neighbourhood and not just by the owner of the roof. Looking out on greenery makes people happy! You prefer to look at a person with a nice haircut, over one with a bald head, right? It’s the same with roofs! It’s healthy too, to look at greenery, and of course it’s better for the environment.”

Atef finishes with an idea. “I think it would be lovely to produce a nice poster, with an image of how the roof is going to look – and to put that up in the neighbourhood, for example in the community centre or in a church. An open day, where people can get information, would also be nice, but corona might make that difficult at the moment.”

OOSTERPARKBUURT

Oosterparkbuurt is a mixed neighbourhood, with a high poverty rate. In the specific area where the buildings are located, the average household income is low and unemployment rates are high. The residents of the buildings are mostly concerned with affordability and financial worries. According to the local area manager, residents are not well-organised and social cohesion is lacking, especially compared to surrounding areas where there are more residents' collectives and initiatives. The number of green public spaces is relatively low, due to the many inner gardens, and public areas are quite gritty. An important priority of the local government is to engage residents in making their environment greener and stimulate sustainability measures.

Lessons learned
Reaching residents in the Oosterparkbuurt was difficult. Several explanations can be given here, one being that RESILIO entered this neighbourhood during the first lockdown and residents really had more urgent worries about health and their economic situation. In addition, there was no real key figure present in the area who the project could engage with. For example, the local area manager of the housing corporation had no time to work with RESILIO, something that did happen in other areas. This made it more difficult to meet residents.

INDISCHE BUURT

The BG roof building is located at Makassarplein. Most residents are seniors from different ethnic backgrounds. A lack of Dutch language skills posed barriers for social interaction with the tenants. The surrounding neighbourhood is characterised by poverty, certainly in comparison with other neighbourhoods in the Indische Buurt. Many residents experience the area as gritty. Making it greener is an important priority of the local government (Gebiedsagenda 2019-2022). Instead of flooding, heat stress is causing more nuisance for residents who participated in the students' surveys. For them, making the area greener and better home insulation are perceived as important measures in climate adaptation.

Lessons learned
The efforts RESILIO made in promoting the project were extensive and the general turnout at events was low. The local area manager of the housing corporation was essential in reaching more residents. She is known and was trustworthy for residents and was able to engage with a number of them.

SLOTERMEER

Slotermeer is an area where most of the residents are from a non-western migrant background and have a low socio-economic position. Many households consist of families, with a quarter of the residents younger than 18. There is a high proportion of social housing, and many residents are not satisfied with their home and the neighbourhood. Many residents are not fluent in Dutch. Main priorities for the local government are improving residents' health and economic situation. The local government wants a better engagement with residents on issues such as climate adaptation and the energy transition. Compared to flooding, heat stress is causing more nuisance for residents, as is the outcome of surveys conducted by students from AUAS. Therefore, better home insulation and making the area greener are perceived as important measures in climate adaptation.

Lessons learned
Residents in this area are more distrustful towards formal organisations such as the local government and the housing corporations. Key community-based organisations are essential in getting the message across. A continuous presence is needed to build this level of trust.

KATTENBURG

Kattenburg is a neighbourhood with a mix of young families, elderly people and students living in student housing blocks. The share of social housing is above the city average. Repeatedly, residents have shown a pro-active attitude towards the City of Amsterdam and are successful in lobbying. Taking climate adaptation measures is an explicit goal according to the neighbourhood agenda drawn up by the local authority (Gebiedsagenda 2019-2022). 'Greenification' is considered to achieve this goal. Residents have taken several initiatives to make the neighbourhood greener and are actively supported in this by the neighbourhood centre De Witte Boei.

Lessons learned
RESILIO's presence at a local festival made clear that there is potential for more BG roofs in this neighbourhood.

RIVIERENBUURT

Rivierenbuurt is an older neighbourhood with a considerable socio-economic divide between people with higher incomes and those who struggle to make ends meet. Making the neighbourhood more sustainable is an important goal of the local authority (Gebiedsagenda 2019-2023). Several residents are involved in initiatives to make the neighbourhood greener. They are (pro-)actively supported in this by the sustainability focused neighbourhood centre Natuur-en Milieuteam Zuid. Water nuisance is recognised as a major problem.

The Rivierenbuurt roof needed to be cancelled after construction had already started: the condition of the roof did not allow for the construction of a BG rooftop (see 7.2).

Lessons learned
Begin to communicate with residents and users of surrounding buildings at an early stage, i.e. during project preparations. And provide residents with contact details of persons they can turn to, in case of nuisance or concerns caused by the building activities.

8.3 RESULTS OF THE PARTICIPATION STRATEGY

At the start of the project, RESILIO explored how it could collect quantitative data in the relevant neighbourhoods, in order to perform a proper baseline measurement. However, this seemed a challenging task because of the highly innovative character of the project, combined with low levels of familiarity of residents with climate adaptation measures and BG roofs.

The project team's efforts to invite residents to react to an online survey did not generate sufficient response. Instead, insights about residents were collected through participant observation: how did people respond and interact during participation activities, and what were their experiences and perceptions? As a follow-up to every activity an evaluation was done: how did residents who participated in the activities experience this, and to what extent did they appreciate the innovation of the BG roof?

Residents were especially triggered to the notion of reducing heat stress which was experienced by many (most recently in the summer of 2019), as BG roofs can potentially diminish this type of nuisance. In addition, most residents were keen on the idea of a greener area, even though they could not see the roof. Their enthusiasm increased even more when they watched the time lapse videos.

However, sensitisation of residents to climate adaptation issues does take a lot of time and effort. During the event to celebrate the completion of the roof in the Indische Buurt it became clear that the residents of the building had no understanding whatsoever of what a BG roof actually is. At that particular point in time an online information meeting had already been organised, as well as a physical meeting in the Innovation Lab, and communication via flyers, posters, postcards and letters. Apparently, these efforts had remained unnoticed.

Residents who already had some level of interest in climate change were more interested in – and some of them were even fascinated by – the concept of BG roofs. These residents were mostly reached through existing neighbourhood activities.

The general conclusion can be that engaging residents in RESILIO was rather difficult (apart from being in a pandemic/crisis with many restrictions on social activities), simply because residents could not really influence the implementation of the BG roof itself. The level of engagement was limited to receiving appropriate information. Residents' input was not asked for in terms of roof design, choice of plants or planning of the building activities. Instead, they were invited to be informed and not to co-create or even influence any part of the process or its outcome. Through various activities the project tried to involve them in some parts of the process, but it is questionable if this resulted in a higher sense of ownership or a greater motivation to act. It is debatable if having a say should always be the goal of participation, but in any case a higher level of interaction will increase people's awareness on the issues of climate change adaptation. And to reach a certain level of interaction, residents need to have the feeling that they are listened to and that their input can potentially affect the (outcome of the) process.

"We are in a good location, right between the Flevopark and the Oosterpark, a perfect stopover for birds and insects. We have a beautiful roof. Let's make good use of it!"
- resident Javastraat

"I am not too bothered about a roof like this. But for the folks there on the top floor it's way too hot, so it is good for them."
- resident Makassarplein

8.4 LESSONS LEARNED

Some lessons from the participation strategy can be worthwhile for similar projects.

- Being present in the neighbourhood as early as possible and connecting respectfully with residents is key to creating support for a BG project and make a success of the participation activities. To start with, it helps to pay regular visits to the area, map the situation, find out what the issues are in the neighbourhood, its social structure, its institutions and its relationship with local government. When involving residents of social housing blocks, always cooperate with the housing corporations in the communication towards their residents. When different parties are involved in communication, residents can become more distrustful.

- Residents tend to become more interested and more strongly committed to a BG roof project if they have a say in decisions about the design of the project (e.g. choice of plants, access to the roof, planning). Therefore, it is wise to involve them in some aspects of the decision-making process.

- Engaging with local stakeholders in neighbourhoods through local area organisations/initiatives is an effective strategy, especially when the topic of climate adaptation is not high on people's agendas. Furthermore, local stakeholders can act as ambassadors who share the story of the project with other residents in their network. These ambassadors are more trustworthy for residents than third parties. To facilitate cooperation, it makes sense to reserve money in the budget for the assistance of local organisations in participation activities.

- Making the roof visible for residents is a powerful tool to raise awareness about the concept of BG roofs. Most residents will never see the roof with their own eyes. It is therefore important to use other media and/or means to create a better understanding of how it works and what it looks like.

9. COMMUNICATION AND DISSEMINATION

Grant scheme roof Lycka (Sloterdijk-Centrum) © Wieke Braat

9. COMMUNICATION AND DISSEMINATION

9.1 ENHANCING AWARENESS

To enhance awareness of the blue-green (BG) roofs solution residents and other stakeholders need to be well informed. Therefore RESILIO strived for efficient communication within the project and with stakeholders outside of it. As the project was co-financed by the European Regional Development Fund through the Urban Innovative Actions Initiative (UIA), an initiative which provides urban areas throughout Europe with resources to test new and unproven solutions for addressing urban challenges, the knowledge gained in the project should also be transferable and relevant to other urban authorities in Europe, dealing with climate change.

To kick-start this process of transferring knowledge, a communication strategy was developed in the first months of the project. In addition, the UIA provided an external expert on climate resilience and adaptation, Leon Kapetas, to help bring the international dissemination of the project forward.

The goal was to:
1. inform and activate the target groups (see 9.2) about BG roofs and their impact on heat stress and flooding;
2. generate involvement in the realisation of BG roofs in the selected neighbourhoods;
3. reach 30% knowledge of RESILIO within the professional target groups, 30% amongst the tenants living in the relevant buildings, 30% amongst the citizens living in the selected neighbourhoods and 10% amongst Amsterdam residents;
4. raise awareness regarding the urgency to make cities sustainable;
5. raise awareness of how BG roofs offer a solution for climate adaptation;
6. increase the visibility of the rooftop landscape.

9.2 TARGET GROUPS

Eight different target groups were identified:
1. residents of buildings and neighbourhoods (see chapter 8);
2. residents of Amsterdam;
3. local and national policy makers, involved in climate adaptation;
4. professionals and representatives of European cities, engaged in climate adaptation;
5. local networks and organisations involved in climate adaptation;
6. science and research in sustainability and climate adaptation;
7. real estate industry;
8. professionals in the roof and garden industry.

In order to reach the different target groups, different activities were organised and developed.

9.2.1 RESIDENTS OF AMSTERDAM

To reach the residents of Amsterdam, RESILIO was presented frequently at events hosted by Pakhuis De Zwijger non-profit organization. Their programs discuss societal issues about the city, the country and the world of the future. The project for example joined an event in March 2022 called ‘We Make The City Green’. Here, RESILIO premiered its final report and presented the project results.

Figure 36: Event at ARCAM in 2019 with Marie Morel (researcher AUAS) who discusses participation with the audience.

9.2.2 LOCAL AND NATIONAL POLICY MAKERS, INVOLVED IN CLIMATE ADAPTATION

For Amsterdam policy makers it is essential to understand which barriers exist for rooftop owners. For that reason, RESILIO partners Rooftop Revolution and MetroPolder Company organised a workshop with a diverse range of local partners, working in the roof industry, and documented their conclusions in a report [26] . The report focused on both new buildings and existing property in Amsterdam and presented key challenges and recommendations for possible solutions. Civil servants from the City of Amsterdam used this document as valuable input for their newly designed approach to come to an integral and multifunctional roof landscape.

On a national level, a number of RESILIO partners are members of the National Roof Plan. This a coalition of partners (governments, private sector, knowledge partners and umbrella organisations) who see opportunities on roofs for tackling national challenges such as climate adaptation, urbanisation and densification, sustainable energy consumption, biodiversity and wellbeing. RESILIO has often shared experiences with this coalition, so that other cities can learn from what we do.

9.2.3 PROFESSIONALS AND REPRESENTATIVES OF EUROPEAN CITIES, ENGAGED IN CLIMATE ADAPTATION

Smart BG roofs are fit for introduction in other major cities. RESILIO wanted to share its knowledge with cities and professionals, involved in climate adaptation worldwide.

One of the main dissemination activities was RESILIO's contribution to the Amsterdam International Water Week in November 2021. The project organised a dedicated RESILIO session and shared its findings with an international audience, involved in water related topics.

A small delegation of the RESILIO consortium also joined the integrated leaders forum, in which solutions were discussed. The Dutch water envoy Henk Ovink received the closing statement of this forum and took it to the COP26 climate conference in Glasgow, in November 2021. The core of the statement was to add ‘blue’ to the ‘Green Deals’, in order to connect regions, industries and communities.

RESILIO also joined another important international event. In January 2021, the Dutch government hosted the international online Climate Adaptation Summit. This summit was attended by high-level representatives such as the former and current secretary-general of the United Nations, Ban Ki-moon and António Guterres respectively, and IMF managing director Kristalina Georgieva. RESILIO was proudly included in a number of fringe events of this online gathering, for example participating in the documentary ‘How to solve the urban water challenges?’ – in which water experts from four major cities around the world shared their insights. [27] Additionally, the City of Amsterdam produced a short film about how public and private space is used to make the city more climate adaptive. RESILIO is a prominent project in this film. [28]

In addition to reaching water and climate adaptation experts, RESILIO believes that for optimal dissemination of its results a broader international audience should be targeted. For that reason, the team travelled to Barcelona in November 2021 to join the Smart City Expo World Congress, as part of the official Dutch delegation. RESILIO hosted a session on smart multifunctional roofs and organised a ‘rooftop tour’ together with local partner Coincidencies, which is part of the European Creative Rooftop Network.

Furthermore, in August 2021, RESILIO contributed online to the Blue Green Technologies for Urban Design Symposium hosted by Green Roofs for Healthy Cities, a North-American non-profit professional industry association, whose ambition it is to make the green roof and wall industry throughout North America bigger.

Figure 37: RESILIO’s assistant projectmanager Joyce Langewen presents the project’s results during the Amsterdam International Water Week in November 2021


Figure 38: Dutch water envoy Henk Ovink receives the closing statement of the integrated leaders forum at the Hermitage Museum in Amsterdam

Figure 39: Smart City Expo Barcelona

Figure 40: Smart City Expo Barcelona in November 2021, including a panel discussion about multifunctional roofs with Jan Henk Tigelaar from Rooftop Revolution and Kasper Spaan from Waternet

Figure 41: Roof excursion: visit to the biodiverse roof of the Musea de Ciènces Naturals de Barcelona

Figure 42: Roof excursion in Barcelona in November 2021, during which RESILIO’s assistant projectmanager Joyce Langewen was interviewed for the Mayors Manual Podcast, which explores solutions for urban challenges.

9.2.4 LOCAL NETWORKS AND ORGANISATIONS INVOLVED IN CLIMATE ADAPTATION

RESILIO teamed up with a number of (international) network organisations. For example, by producing a movie about the Innovation Lab with the Regional Public Water Authority Amstel, Gooi and Vecht [29]. And also by regularly working together with Amsterdam Rainproof, a network organisation which prepares the city for extreme cloudbursts.

In 2020 and 2021 RESILIO teamed up with ROEF, the Rooftop Festival in Amsterdam. This event raised awareness of the transformation of the Amsterdam roofscape, for example towards climate adaptation, and brought local residents together (see figure 43).

Lastly, in a combined effort, the City of Amsterdam, Rooftop Revolution and AUAS contributed to a course on Climate Adaptation and Local Resilience from the The Hague Academy of Local Governance. Thirty participants took part in this course. RESILIO shared with them how it aims to involve citizens in mitigating and adapting to climate change.

9.2.5 SCIENCE AND RESEARCH IN SUSTAINABILITY AND CLIMATE ADAPTATION

- Tim Busker, researcher at Vrije Universiteit Amsterdam (VU), presented his research findings about the effectiveness of BG roofs with forecast-based operations during an academic conference in Potsdam, Germany (see figure 44).

Figure 43:. Anne Molenaar from Rooftop Revolution explains the concept of a BG roof at the ROEF Rooftop Festival 2020

Figure 44: Tim Busker (VU) presenting his research findings on forecast-based operations during an academic conference in Potsdamacademic conference in Potsdam

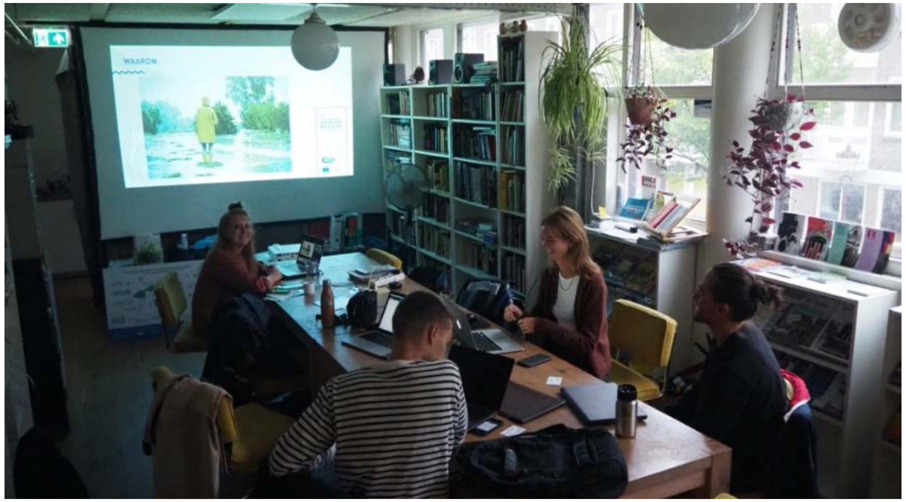


Figure 45: Presentation by Rosanne Nieuwesteeg from Rooftop Revolution to students from the Amsterdam Institute for Advanced Metropolitan Solutions

Figure 46: Presentation for real estate developer Dalpha by Joost Jacobi from MetroPolder Company.

- Rooftop Revolution, the City of Amsterdam and housing corporation Lieven de Key participated in an academic research project, organised by students from the Amsterdam Institute for Advanced Metropolitan Solutions (see figure 45). They investigated the potential of multifunctional roofs in a neighbourhood in the eastern part of Amsterdam, by conducting interviews and hosting a co-creating session with residents.

9.2.6 REAL ESTATE INDUSTRY

RESILIO informed private property owners, residents associations, entrepreneurs and houseboat owners to apply for a subsidy to realise a RESILIO BG roof. To get a better understanding of what motivated applicants, a number of interviews with new BG roof owners was conducted – for example with Tom Kuster (see Frame D).

RESILIO also presented itself to Dutch real estate developers and showed them around in the Innovation Lab.

9.2.7 PROFESSIONALS IN THE ROOF AND GARDEN INDUSTRY

To realise the BG roofs, RESILIO teamed up with a number of green contractors and gardeners. They were asked for advice regarding the plants to grow on the roofs. This advice was used to write articles and inform the tenants and private homeowners.

Furthermore, during the Rooftop Symposium 2020 (for policymakers, real estate owners and professionals in the roof and garden industry) the RESILIO project received a lot of attention from roof and garden professionals. RESILIO connected with them and discussed long-term opportunities. Lodewijk Hoekstra, a Dutch celebrity TV gardener and industry expert, was also willing to present RESILIO on camera. [30]

FRAME D. TOM (34) REALISED HIS OWN SUSTAINABLE HOUSE WITH A RESILIO ROOF

In 2017, Tom Kuster (34), his partner and a few other locals applied for a building plot in the Bajeskwartier in Amsterdam East through a CPC, a collective private commissioning. This is a form of private ‘build your own’ in which a group of future residents is organised as a non-profit legal entity. They are the clients for the self-build of more than one new house where they themselves will live. This set-up allowed Tom to work with a group of like-minded people to build homes which they could completely customise and build sustainably. In 2020, a complex with 32 apartments was completed. The icing on the cake was a BG roof of 900 m², partially funded by a grant from the RESILIO project.

How to get from a barren piece of land to a sublime, sustainable apartment complex with a huge RESILIO roof? Tom explains, on a sundrenched summer morning on his roof right next to where the Bijlmer prison once stood.

Sustainable living dream

Tom is an account manager at Signify – a Dutch multinational lighting corporation – and his work also involves sustainability. Nevertheless, Tom’s idea to build his own house was not only sustainability-driven: “The plan to start a self-build project was initially price-driven. The prices for existing buildings have been skyrocketing for years and if you want to renovate in a sustainable way, it is financially almost impossible to achieve. The fact that with a self-build we could create our own home entirely according to our own ideas on sustainability, that we could get a subsidy, and that we could do this with a competent and enterprising group, made us decide to go for it.”

> “The plan to start a self-build project was initially price-driven. The fact that with a self-build we could create our own home entirely according to our own ideas on sustainability, with a subsidy and an enterprising group, made us decide to go for it.”

Challenging process

Together with a number of other self-builders, Tom was part of the core group of the private initiative. Tom: “What struck me was that self-building doesn’t necessarily mean you can think of everything yourself, especially when you’re building such a large complex with 32 homes. That can be a pitfall. There are shafts, bearing walls, noise standards and a thousand other architectural and technical things you have to take into account. So we did have to temper our expectations at times!”

From grey water to tinted glass

What the entire group continually steered toward is that sustainability should be a priority in design and construction at all times. The homes therefore have quite a few sustainable features. The entire complex is gasless and is heated and cooled with heat pumps. Another ingenious detail: a heat recovery system which uses grey water from the shower to heat the incoming cold water of that same shower, so you end up using less hot water. In addition, each house makes use of the solar panels on the roof, tinted glass and, for example, a larger boiler could be chosen. The group also very deliberately chose a BG roof. It contains terraces which provide space for recreation, especially for the residents of the upper floors. The flourishing, water-storing roof also cranks up the number of sustainable features. “We use the water storage on the roof to water the flower boxes along the façades, and this is digitally controlled”, explains Tom. “The nice thing is that this water storage also has a cooling effect on the building in the summer.”

> “We use the water storage on the roof to water the flower boxes along the façades, and this is digitally controlled.”

The crowning glory: a biodiverse, BG RESILIO roof

Tom’s and his fellow residents’ smart BG RESILIO roof is a fantastic garden where one can get a very good idea of what the roofs of the future might look like. The rooftop garden is located next to the skyscrapers of the Amstel Quarter and the Bajes Quarter, which is still under construction. In the distance the tall trees of the Diemerbos can be seen, with IJburg laying behind them.

"It is a secret garden far above the city. But it is alive: everything grows and hums", says Tom. "The roof itself is divided into two sections: the rooftop garden with grasses, for instance various types of yarrow and ironwood, and the section with the extra heavy solar panels with sedum growing in between. This roof attracts many species of bees and bumblebees and is much more interesting to these animals than a 'simple' sedum roof. Two bumblebee species (Bombus Pascuorum and Bombus Lucorem) fly around happily. They feast on the nectar of the flowers. Such a roof is an important source of food for insects in a city full of bricks and concrete, and acts as a link between various nature areas."

"The rooftop garden is located next to the skyscrapers of the Amstel Quarter and the Bajes Quarter. It is a secret garden far above the city. But it is alive: everything grows and hums."

A real garden

The rooftop garden by the Weespertrekvaart canal is really treated as a garden: the residents remove weeds and everything is neatly kept. This is where it differs from a so-called natural roof, where the weeds are not removed. The residents followed a special course on basic maintenance at roof gardening company 'The Roof Doctors'.

Tom again: "The sedum roof is maintained only sporadically. Yet that is a pity: the growth of clovers and other 'weed plants' is important for various species of butterflies and other small insects. So you can also choose not to remove many of these so-called weeds. The more you leave standing, the happier the insects, and by the way, that goes for those planters on your balcony as well!"

Scoring on sustainable roofs

"The City of Amsterdam's ambition is to achieve a certain sustainability score for new construction projects," explains Tom. "Because we chose a sustainable RESILIO roof and heavier solar panels, we achieved an even better score." But it's not just the roof that scores well on sustainability, he adds: the bond with his s is also quite sustainable. "We all built our own house in four years. As a result, I do not only have a very special bond with my house, but also with all my s. If I forget to buy something, like tools, or if I need a hand, there is always a I can count on. Everyone is very social with each other. For example, we watched the European Football Championship on our roof. That was a huge success – well, for us, not so much the Dutch team."

"We all built our own house in four years. As a result, I do not only have a very special bond with my house, but also with all my neighbours."

Figure 22: Tom Kuster

9.3 VISIBILITY: TOOLS AND MATERIALS

9.3.1 THE RESILIO WEBSITE

Written content material was published on the RESILIO website. The goal of the website is to inform target groups about BG roofs. The website provides information about the system behind the BG roofs, how it works, why this project is so necessary and who the partners are.

Each RESILIO neighbourhood has its own page on the website. These include updates regarding the BG roofs and the activities organised in the neighbourhood. They also contain neighbourhood stories, which are fun and easy to read, about people living in the RESILIO buildings or in the neighbourhoods, to get to know the sentiment of the neighbourhood and to make the project more attractive.

9.3.2 ONLINE COMMUNITY ENGAGEMENT

As the pandemic evolved during 2020 and social distancing became the norm, the focus shifted to communications with the professional community on LinkedIn.

Growing a vivid online community is pre-eminently the way to generate involvement and commitment on several levels, and in times of a pandemic the only way. In June 2021 RESILIO launched its own LinkedIn account, and ever since it has seen a steady growth. The number of views for each post varies between 50 and 3,000 and the project responds to people who have questions. The main language is English.

9.3.3 SOCIAL MEDIA POSTS

By branding RESILIO as a smart and practical way to tackle the challenge described in 1.1, the project used different types of content to inform target groups and ideally encourage them to act. Twitter and LinkedIn were used to reach a more professional target audience such as policy makers, researchers and real estate professionals, and Facebook to inform the residents in the neighbourhoods.

The types of content were RESILIO-related long reads, reports of RESILIO events, RESILIO Rooftop status updates, articles on other climate adaptive initiatives focused on roofs or micro watermanagement, reposts of messages from partners and neighbourhood stories.

In general, RESILIO posted weekly on Tuesday and Thursday mornings. The tone of the posts was light and engaging. Using relevant hashtags, such as #sustainability, #Bluegreenroofs and #watermanagement helped enlarging engagement with particular themes, especially BG roofs.

Usually, all partners and stakeholders (profiles of organisations and personal ones) were tagged and occasionally relevant entities, depending on the scope of the information. In some situations, paid content was created and advertisements were made, to reach specific target groups such as citizens living in a particular neighbourhood or to give the project's LinkedIn account a boost.

9.3.4 VISIBILITY ON STREET LEVEL

RESILIO improved its visibility by putting banners on buildings with a RESILIO roof during the installation. When BG rooftops were complete, a plaque was attached to the wall of the building.

Housing corporation de Alliantie made it possible to put some words on the wall of a recently renovated building with a BG roof. The words came from a poem, written by Amsterdam's city poet Gershwin Bonevacia. The residents of the building chose the actual words, as one of the participation activities which were described in 8.2.3.

Figure 23: Plaque on the façade of a RESILIO building from housing corporation Stadgenoot

FIgure 24: 'Lobi ask amor' ('love' in Surinamese, Turkish and Spanish and Portuguese) on the façade of the RESILIO building from housing corporation de Alliantie in the Indische Buurt.

9.3.5 OTHER FORMS OF PUBLICITY AND RECOGNITION

RESILIO's BG roofs - lush, green homes to many birds and insects - are a sustainability initiative with great likability. The topic was suitable for encouraging people to elevate their awareness of sustainability in general via channels such as the City of Amsterdam's own local newspaper, Amsterdam Rainproof and other channels of the City of Amsterdam. The project received publicity in a number of newspapers (see figure 25) and made it onto the main news channel on Dutch television (NOS). Please check an overview of all publications in the media here and RESILIO's press releases here.

RESILIO also gained international attention and recognition. For example, it won the 'BiodiverCities Challenge' 2022 from the World Economic Forum. This was a global call for innovative solutions which are enabling cities to become nature-positive and fulfill their potential as engines of equitable and sustainable development, resilience and well-being. Here's to restoring nature in our cities!

In addition, RESILIO was a finalist for the 'Innovation in Politics Award' 2021 in the ecology category. This award recognises creative politicians from across Europe who have the courage to break new ground to find innovative solutions for today's challenges. A citizens' jury comprising over 1,000 Europeans evaluated the projects.


Amsterdam gaat voor droge voeten en een koel hoofd

Groen schoolplein in Venserpolder

Blauw-groene RESILIO daken op sociale huurwoningen

100 groene plekken extra in de stad

Wat u zelf kunt doen

De langste geveltuin van de Indische buurt

Rainproof experimenteren

Nieuwe riolering en een betere waterafvoer

Tegels eruit, groen erin

Proef met zoutbestendige planten

Bouwen voor het klimaat van de toekomst

Figure 25: City of Amsterdam newspaper from November 2021 with a feature on climate adaptation, including RESILIO.

Figure 26: Webpage Innovation in Politics Award

9.3.6 CONCLUSIONS

The conclusion can be that RESILIO's exposure has been bigger than expected. By being broadcast on national TV and by winning a number of awards the project stepped out of the Covid-19 shadow, after – especially at the start of the pandemic – it had been difficult to reach an audience. The project changed its strategy and aimed for more online visibility, and focused on manifesting RESILIO online through existing networks. This was done by sharing online content via the project's social media channels.

The strategy to reach target groups was focused on brand recognition. RESILIO also reported about the climate adaptive approach of its partners and stakeholders. This also appealed to an overall awareness of climate adaptive measures amongst the target groups.

In general, posts with an update on rooftops were by far the most popular category. Photography was used as the main eye catcher. The total feedback on posts via Facebook was obviously higher when it regarded events in the neighbourhood. The same tendency was seen in the professional field: the more people who are involved in referenced projects were mentioned, the more likes were generated.

Every six weeks, RESILIO's communication team discussed the most relevant and important content to share with the partners' communication advisors. The creation of the LinkedIn account helped a lot to reach target groups better. Connecting with street coaches and other professionals in the neighbourhood also helped in finding appealing and relevant local content.

A challenge for the communication team was dealing with delays in the realisation of the rooftops. The aim was to post content and pictures and write stories about the animals that were spotted on the roofs and the different plants that had started to grow. However, with roofs being delayed, this content was not yet available for publication.

BG RESILIO roof at Javastraat/Makasserstraat © Wieke Braat

9.4 LESSONS LEARNED

In the communication about the project it was important to emphasise the ‘cuddly’ elements of RESILIO: there is hardly anyone who could be against bees, birds or plants. Some people do not see pluvial flooding as a great climate risk, even though RESILIO is beneficial for dealing with this. Depending on the target group, one should pick the most appealing aspects. Residents, in general, are more interested in green than in blue.

Please check chapter 8 for a more extensive explanation about the strategies used to reach the residents of the different RESILIO-linked neighbourhoods. In general audiences in a neighbourhood with higher incomes are more active online. Professional target groups are abundantly present on LinkedIn and therefore easy to access by adding hashtags and by constantly updating this network.

Another valuable lesson was that photography is an effective communication tool to draw attention and to show finalisation of the roofs for all audiences. It is important to use local markers in visual content. But in hindsight it was a bit naive to think of writing articles about greenery, flowers and animals immediately after delivery of the roofs. For example, whenever seeds were sown on those new roofs in Amsterdam, birds notice them and happily use them in their nests. It therefore takes a longer period of time until the roofs actually start to blossom. Another interesting discovery, and this was confirmed by Amsterdam’s city ecologist, was that ring-necked parakeets are not very keen on a changing environment and therefore simply demolish the plants on the new roofs.

10. RECOMMENDATIONS

BG RESILIO roof at Javastraat/Makasserstraat © Wieke Braat

10. RECOMMENDATIONS

The RESILIO project provides a wealth of insights, thoughts, ideas and practical solutions. Here are a number of messages to take home and ten recommendations.

THE IMPLEMENTATION OF A SMART GRID OF BLUE-GREEN (BG) ROOFS AS A CLIMATE ADAPTATION MEASURE

In the past three years, RESILIO has built up considerable experience in implementing a network of BG roofs. RESILIO's main objective was to find out whether a connected system of BG roofs could deliver a substantial contribution to climate adaptation strategies in European cities.

Although the implementation itself has been a challenging 'roof journey', the RESILIO partners have succeeded in installing a new operational micro watermanagement system onto 10,000 m² of rooftops in Amsterdam. The RESILIO research yielded important insights into the performance of smart BG roofs. Based upon this research and practical insights, we can now conclude that a smart grid of BG roofs can be a meaningful component of a city-wide climate adaptation strategy. This leads to recommendations 1 and 2.

1. RESILIO recommends that European cities develop a micro watermanagement system as part of their climate adaptation strategy, and to include BG roofs as a promising watermanagement option. Implementation of the micro watermanagement strategy, which can include BG roofs, should start in neighbourhoods which are most prone to flooding.

Clarification
Large-scale grey infrastructure, such as a traditional sewerage system, is challenged by climate change, because its capacity is pushed to the limit. Cities face negative impacts of climate change in the shape of pluvial flooding, extreme heat and droughts, as well as a loss of biodiversity.

RESILIO has demonstrated, by doing scientific and technical research into the implementation of a smart grid of BG roofs, that their performance delivers a meaningful contribution to counter those negative impacts of climate change. One should realise that, depending on the local context, there are other climate adaptive measures which can be viable as well. Both future research and actual adaptation planning should consider the wide range of available adaptation options. As smart BG roofs address several climate impacts in one solution, RESILIO recommends integrating BG roofs in climate adaptation policy frameworks.

RESILIO's findings can help cities to make better informed assessments of where to implement this solution. For example, geographic information system*-based information on risks and vulnerabilities of pluvial flooding and urban heat islands can support the pre-selection of potentially suitable roofs. The development of maps, which show the upscaling potential, can be helpful to prioritise and make decisions.

2. RESILIO recommends the integration of BG roofs into a multifunctional roofscape strategy.

Clarification
Every city faces a number of challenges to become future-proof. Besides climate change, these – for example – include densification, energy needs and the need to create a healthier and more liveable city.

However, existing public space is often scarce. Adding functions or volumes to rooftops can therefore have its benefits.

RESILIO recommends a multifunctional use of space, as this can create additional value to living environments. RESILIO's second Innovation Lab shows that solar panels can be added to the blue-green layer, as well as recreational space, providing opportunities for sports and urban gardening, which can both contribute to a community spirit.

For policy makers as well as housing corporations it is important to be aware of this multifunctionality of roofs, in order to avoid competition between different policy objectives. RESILIO recommends looking at the roofscape in an integral way. Different combinations might be possible, but it is important to develop an assessment framework for optimal use of the space. For example, as some constructions have a limited carrying capacity, a combination of functions on a single roof is not always possible. And combining functions also increases the costs.

RESEARCH ON THE IMPACTS OF BG ROOFS

RESILIO research shows that micro watermanagement on BG roofs is a valuable tool for overall watermanagement in cities, because smart BG roofs have a high potential for capturing extreme rainfall while maintaining the availability of water for the plant layer and evaporative cooling. Furthermore, RESILIO research demonstrates that, at building level, BG roofs can mitigate heat stress and severe cold in winter by the enhanced buffering qualities of the BG roof system.

On a neighbourhood and city scale, RESILIO shows the upscaling potential to reduce urban flooding. However, the potential effect of BG roofs on heat reduction was found to be negligible at city level. On biodiversity, research results at building level will follow in the coming years, after the RESILIO end date, when the vegetation has sprouted.

All research results discussed in chapter 5 create a relevant base for further research. This leads to recommendation 3.

> 3. When BG roofs are introduced on a large scale, RESILIO research could be followed up by more detailed studies on the reduction of heat by BG roofs, specifically at building level. This new research should include the assessment of impacts related to health of residents inside the building. Additionally, extended empirical measurements on BG roofs are advised to investigate the validity of RESILIO's model-based results. Lastly, research on a city scale should focus on the question whether new green spaces on the roofs can offer a resting or foraging place for animals, and if the roofs as such can act as a stepping stone in the ecological main structure of the city and offer meaningful support for biodiversity.

Clarification

The RESILIO research was based on the implementation of 10,000 m^2 of BG roofs, literature reviews and modelling studies. The research demonstrated promising results on heat and water. The findings of the conducted modelling studies on water retention capacity have been validated by measurements on the RESILIO roofs. However, as the measurement period was short, further measurements are needed to validate the results of the model.

RESILIO's health impact study did not deliver results, because of rooftop delivery delays. But RESILIO's ecology research suggests positive outcomes on biodiversity. Several insects and moths have been detected so far, and hopefully positive impacts on bats and birds will be seen as well. Results of ongoing ecological research will become available after the closure of the RESILIO project. If BG roofs will be introduced on a larger scale, this additional research will be very helpful to make informed decisions on useable plant species.

MICRO WATERMANAGEMENT PLATFORMS

RESILIO has built an operating micro watermanagement architecture, which facilitates intelligent steering by combining characteristics of the BG system (e.g. water level in the crates) and weather forecast data. By the time RESILIO ended, the data architecture had been fully designed, but the integration of relevant macro-level information from the environment of the BG water platform had not yet been completed. An extension of the water platform is needed, to fully benefit from all relevant steering options. In doing so, micro and macro watermanagement data can be connected. This leads to recommendation 4.

4. RESILIO recommends investing in micro watermanagement platforms. DSSes can be upgraded by the integration of macro-level data streams. Public-private partnerships can be strengthened by a concerted effort to set up adequate governance arrangements.

Clarification

New upgrades of DSSes and dashboards will result in enhanced smart connections for large-scale sewerage infrastructure at city level and more sensitive steering options for the BG-roof systems. The investments in the system will have to be guided by a continuation of public-private partnerships. This specifically concerns the distribution of responsibilities and authorities regarding the public-private interface of rainwater discharge. This includes the hosting of an IoT environment, user interfaces and dashboards with essential information on steering options.

RESILIO made it clear that additional attention needs to be paid to decisions about responsibilities related to the running and maintenance of the smart system. In other words: who is responsible when the system does not function properly, and who should pay for the maintenance costs of the smart valves? This is an ongoing debate. A comparison and analysis of cities and countries on this issue might be valuable for a further dissemination of the philosophy of the Dynamic Sponge City as incorporated in micro watermanagement.

GOVERNANCE STRUCTURES AND A SOUND BUSINESS CASE

RESILIO research on governance has provided an inventory of possible transfer mechanisms for the business case. Three categories were identified:

1. integrating co-investments and/or (in)direct payments between stakeholders who benefit from BG roof investments based on the SCBA, and/or
2. expanding the benefits of BG roofs by incorporating value-adding features, and/or
3. reducing investment and/or maintenance costs based on the total cost of ownership (TCO) during the lifespan of the roof..

Each city is defined by its own governance arrangements. Transfer mechanisms which are sensitive to national, regional or local arrangements could be important to build a business case as a context for investments in BG systems. This leads to recommendation 5.

5. RESILIO recommends applying and specifying these transfer mechanisms in business case approaches for the implementation of BG roofs. In the short term, co-investments by public authorities for the implementation of BG roofs on existing real estate will remain necessary.

Clarification
There are multiple ways of developing a business case for BG roofs. To make informed decisions about (upscaling) BG roof implementation, it seems wise to integrate monetised values of environmental and social benefits of BG roof investments into the decision-making process. This would be better than focusing on economic/financial aspects only, given the wider impact on sustainability-related challenges in the urban environment.

For these non-monetary benefits, which help the city and its citizens as a whole, it is recommended that public authorities (e.g. city government, waterboard) support roof owners in relation to the TCO through one of the identified transfer mechanisms (such as co-investments, direct payments, subsidies, tax differentiations and volume-based reimbursements) in the current early stage of development.

Apart from the two Innovation Labs, it was not possible to add value-adding features to the BG rooftops owned by the housing corporations. Still, these might offer valuable options for upscaling BG roofs in city environments. One could think of rooftop terraces, solar panels, commercial exploitation, city farming and (tiny) housing, depending on the characteristics of the roofs.

DELIVERY MECHANISMS FOR BG ROOFS: WIDENING THE SCOPE OF BG ROOF IMPLEMENTATION

Properties in cities worldwide are affected by negative climate impacts. In Amsterdam, bottleneck areas identified by Amsterdam Rainproof are mostly located in the inner city, mainly because public space is scarce and results in limited space for incorporating climate adaptive measures on the ground. As such, RESILIO focused on retrofitting roofscapes on existing property. The housing stock of three housing corporations in Amsterdam was used. That way, the project directly benefited local communities with a limited budget. This is also supported by new public policies on climate justice in Amsterdam.

RESILIO showed that retrofitting existing real estate rooftops is a complex and costly operation, compared to the implementation of BG roofs on newly planned real estate. In the coming decade housing corporations will have to meet new demands for a sustainable future of their real estate. At the same time, they must guarantee that their housing stock will remain affordable for their tenants. This might lead to other priorities than investing in BG roof systems. As part of an upscaling strategy, it seems important to cast the net wider and not only focus on retrofitting existing roofs. The development of new real estate, including newly built social housing, will offer opportunities to stimulate a further growth of the BG roof market.

The realisation of BG roofs within the RESILIO project was done with a twofold delivery mechanism:
1) procuring BG roofs on the market;
2) supporting private initiatives with a municipal grant scheme.
There are also other options and delivery mechanisms for contracting and/or assigning BG roof systems. Taking these into account might be helpful for entering a new phase of implementing BG roofs.

With this in mind and the lessons learned in RESILIO, recommendations 6, 7, and 8 are as follows:

6. Distinguish between BG roof investments in the existing city and new developments. Upscaling scenarios in new development could prioritise the adoption of new regulatory frameworks, such as a municipal rainwater ordinance, making the retaining and re-using of rainwater mandatory on new buildings and buildings that are radically renovated.

Clarification

RESILIO governance research has produced a SCBA for BG roofs. This SCBA has primarily focused on BG roofs for existing buildings, specifically the replacement or renovation of existing roofs. While BG roofs for new buildings have therefore not been within the scope of the SCBA, it can be expected that the business case for BG roofs on new buildings is more positive than for replacement and/or renovation in existing buildings. This is to be expected, as the construction costs – which make up a significant portion of the TCO for the roof owner – are part of the overall investment in the building when a BG roof is incorporated in the building's design. Therefore, the construction of new buildings can be designed in a manner that they are able to support more weight.

As was seen in the applications for the municipal grant scheme, there is a willingness amongst private home owners to invest in BG features. It is an attractive option to combine micro watermanagement with an enlarged living space on private roofs. An uptake of these types of investments would enhance the general acceptance of BG roofs in society. With Amsterdam's rainwater ordinance such investments are stimulated.

7. Procurement is one of the commissioning options available. RESILIO recommends adopting procurement strategies in such a way, that market innovation is promoted.

Clarification

The implementation of the RESILIO procurement strategy has demonstrated that it is a challenge for the rooftop maintenance sector to retrofit the roofscape of cities on a large scale and create a new BG environment. In practice, some roofs turned out not to have the necessary carrying capacity.

Therefore, RESILIO recommends a clear technical specification of requirements which can safeguard solid implementation of BG roof systems. However, it is expected that developments will now accelerate and integrated BG systems will become more and more common, thanks in part to RESILIO's output. To promote this development, it seems important to look for innovation of procurement strategies which guide the market, in order to facilitate the rooftop maintenance sector in developing adequate product portfolios. The aim must be to open up markets for this new development. Local governments can take the lead in this development, by acting as commissioning public authorities and by starting with the retrofitting of their own roofscapes

8. RESILIO recommends to design a roof grant scheme which is multifunctional and can be adjusted to specific local needs. Not everything is possible on all roofs, but something is possible on each roof.

Clarification

In RESILIO, the BG roof grant scheme was only in place for a short period of time. Furthermore, an already existing grant scheme for green roofs was in place in Amsterdam, making it complicated for applicants to understand for which subsidy they had to apply.

RESILIO recommends future grant schemes to be based on performance conditions which integrate different roof functions. For example, besides requirements for the water storage capacity, the grant scheme could also pay attention to 'greening conditions', by including a list of plant species with native varieties, which applicants then need to use to benefit the city's biodiversity. The flipside of this coin could be, however, that for such species the substrate layer possibly needs to be thicker, resulting in additional weight. And on existing real estate, the necessary carrying capacity for this is not

always present…
In addition, it might be interesting to explore the possibilities of a 'dakloket', a one stop shop where owners can get help with their applications and ask questions.
And lastly, long-term subsidy schemes, instead of fast and often changing schemes, could offer property owners more certainty.

PARTICIPATION AND COMMUNICATION

The RESILIO partnership has invested a lot of energy and time in community engagement and involvement. This final report showcases many inspiring examples of this. A wide range of communication materials was developed and used to supply good and understandable information about BG roofs.

Still, the RESILIO planning situation did not allow for much influence on strategic decisions about the choice of roofs and the implementation itself. These were already determined by the approved EU Urban Innovative Actions (UIA) project plan. This leads to the final two recommendations.

9. RESILIO recommends giving direct stakeholders as much influence as possible on the implementation of BG roofs and the accompanying decision-making process.

Clarification
Residents tend to become more interested and more strongly committed to a BG roof project if they have a say in decisions about the design of the project, for example the choice of plants, access to the roof and planning. Therefore, it is wise to involve them in the decision-making process, in matters where can make a difference. Some residents could, however, have demands which create nuisance or safety issues for others, so possibilities will always be limited.

10. Try to make information clear, transparent and manageable and keep your tone light: be hopeful, optimistic and honest.

Clarification
Provide specific and understandable information, tailored for the target audience: how much water is 'heavy rainfall' ? How many liters of water can be captured by a roof? What is biodiversity and why is it important? Try to use relatable terms, such as 'showers' or 'cups of tea'. People often cannot understand certain descriptions without mentioning a comparison quantity.

Adopt a clear framework for messaging about BG roofs: explain how the BG infrastructure attributes to a future society which is healthier, safer and greener, and be honest about the fact that some roofs will not be suitable for a BG layer.

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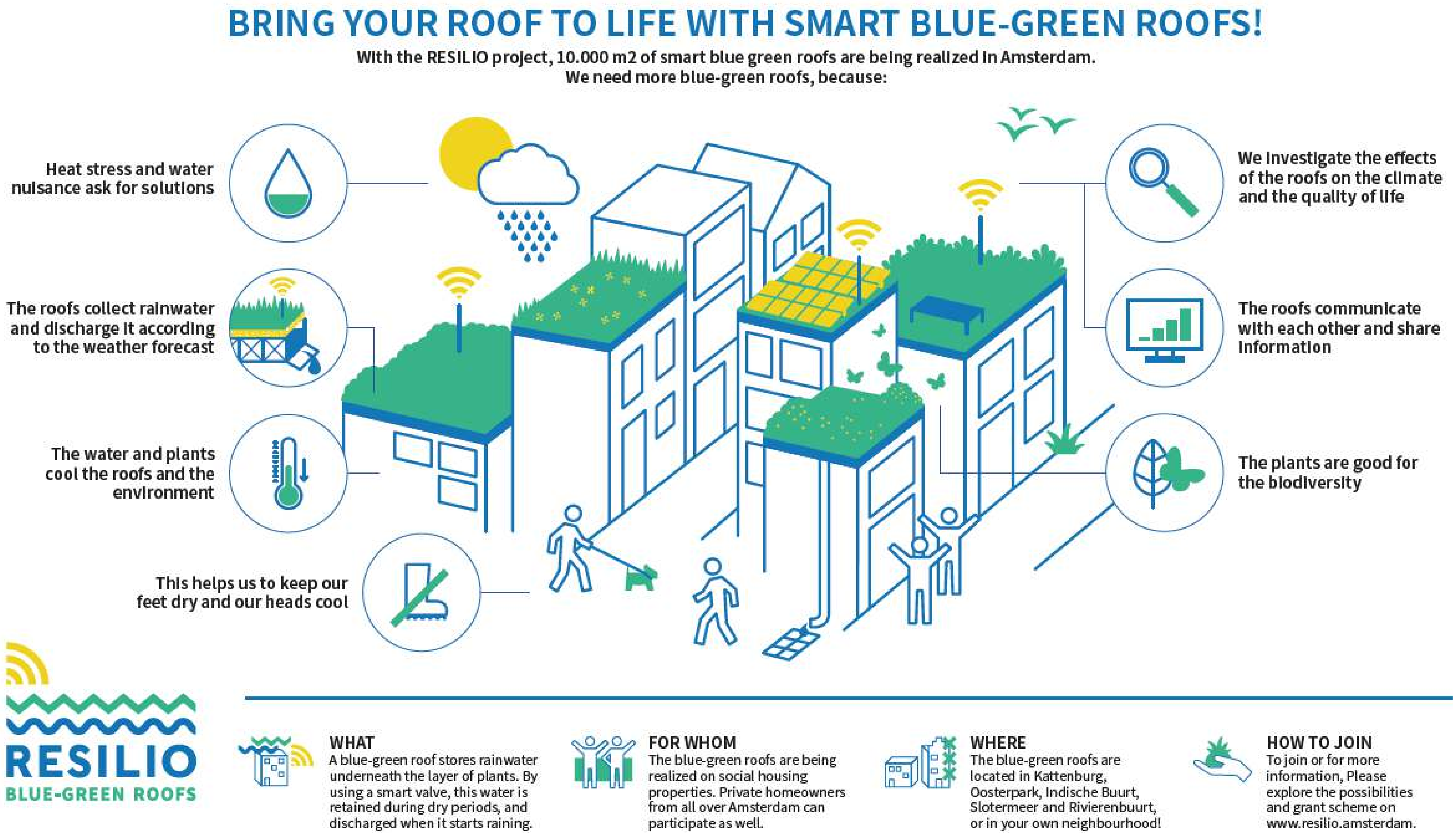
For further reading, visit openresearch.amsterdam/resilio

ANNEX 1: RESILIO INFOGRAPHICS



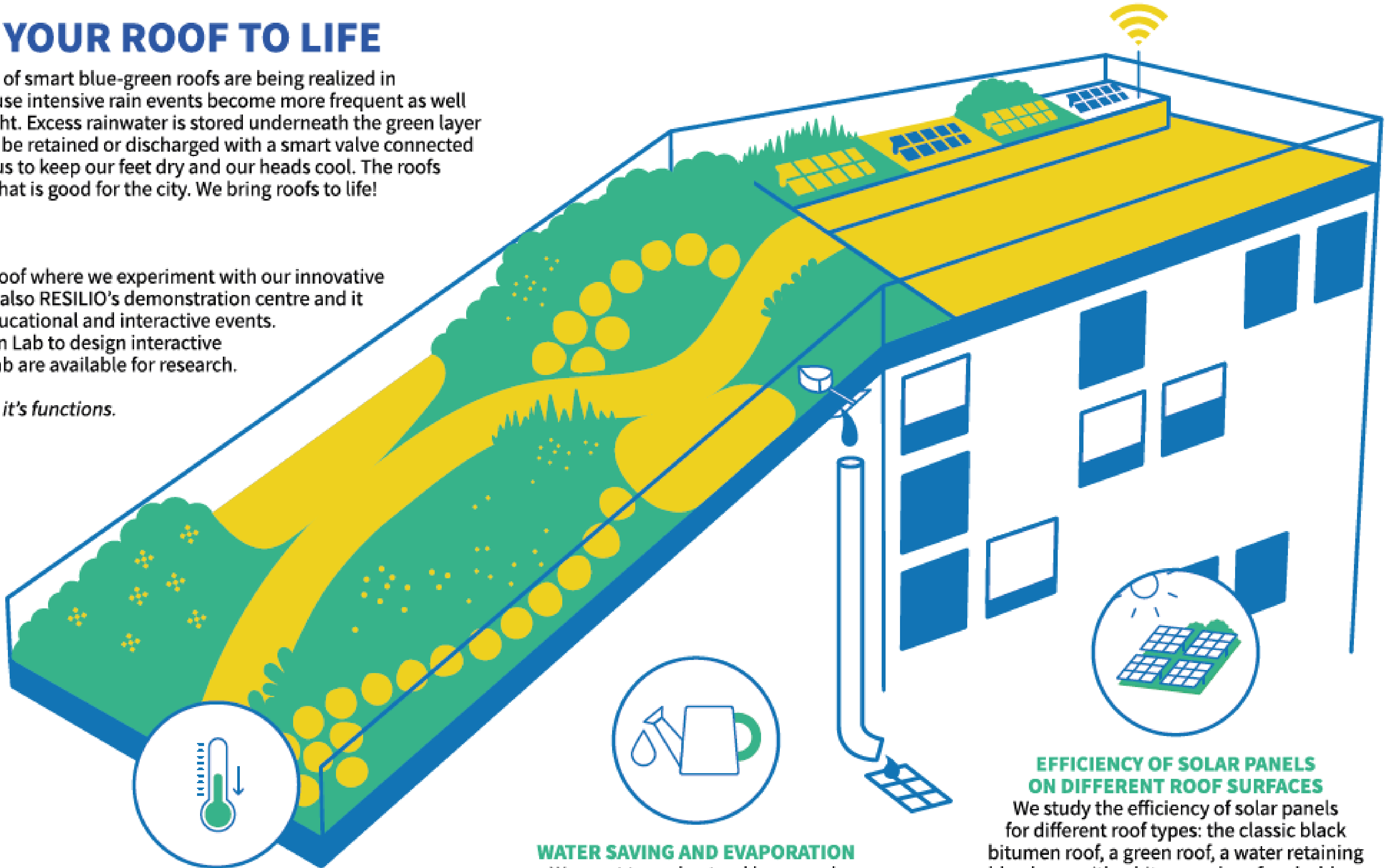
RESILIO: BRING YOUR ROOF TO LIFE

With the RESILIO project, 10.000 m² of smart blue-green roofs are being realized in Amsterdam. This is necessary because intensive rain events become more frequent as well as longer periods of heat and drought. Excess rainwater is stored underneath the green layer of plants on the roof. The water can be retained or discharged with a smart valve connected to the weather forecast. This helps us to keep our feet dry and our heads cool. The roofs provide space for new nature, and that is good for the city. We bring roofs to life!

INNOVATION LAB

This is the innovation lab, a 450m² roof where we experiment with our innovative smart blue-green roof systems. It is also RESILIO's demonstration centre and it serves as a community space for educational and interactive events.
Local universities use the Innovation Lab to design interactive workshops and datasets from our lab are available for research.

This graphic illustrates the roof and it's functions.



THE COOLING EFFECT

We study the effect of blue-green roofs on cooling classrooms directly under the roof.

WATER SAVING AND EVAPORATION

We want to understand how much rainwater plants absorb and, therefore, to what extent we can reduce the amount of tap water required to water the plants.

EFFICIENCY OF SOLAR PANELS ON DIFFERENT ROOF SURFACES

We study the efficiency of solar panels for different roof types: the classic black bitumen roof, a green roof, a water retaining blue layer with white gravel roof and a blue-green roof. We investigate possible relations between the cooling effect of these roof types and the efficiency of the solar panels.

RESILIO
BLUE-GREEN ROOFS

RESILIO: LAAT JE DAK LEVEN

Het regent steeds vaker harder, terwijl het ook heter wordt. Om plensbuien op te vangen en de stad koel te houden hebben we meer groen nodig. Maar ruimte in de stad is schaars. Daarom zet Amsterdam de onbenutte ruimte op de daken op een vindingrijke manier in. Met het RESILIO project wordt 10.000 m2 dakoppervlak veranderd in slimme blauw-groene daken.

INNOVATIELAB 2.0

Dit dak is het tweede onderzoeksdak van RESILIO en noemen we het InnovatieLab 2.0. Het dak is 700 m2 groot en eigendom van de gemeente Amsterdam. De onderzoeksfocus ligt op het technische aspect van de blauw-groene daken. We onderzoeken een slimme combinatie, waarbij waterberging, biodiversiteit, energieopbrengst en de plaatsing van zonnepanelen elkaar versterken. Het onderzoek wordt uitgevoerd door RESILIO-partners MetroPolder Company, gemeente Amsterdam en Hogeschool van Amsterdam in samenwerking met Bureau Stadsnatuur.

OPBRENGST VAN ZONNEPANELEN

Het opgevangen regenwater geeft water aan de beplanting op het dak. Door de verdamping van het water koelt de lucht boven het groen en onder de zonnepanelen af. We onderzoeken of dit zorgt voor een hogere opbrengst van de zonnepanelen.

WISSELWERKING ZONNEPANELEN EN BEPLANTING

De zonnepanelen zijn in vier dakvlakken op verschillende hoogtes en rij-afstanden geplaatst. Daarnaast is er een vijfde vlak zonder zonnepanelen om de verschillen te meten. We onderzoeken op welke manier lichtinval en schaduwwerking invloed heeft op de ontwikkeling van de verschillende plantensoorten.

WATERBERGING

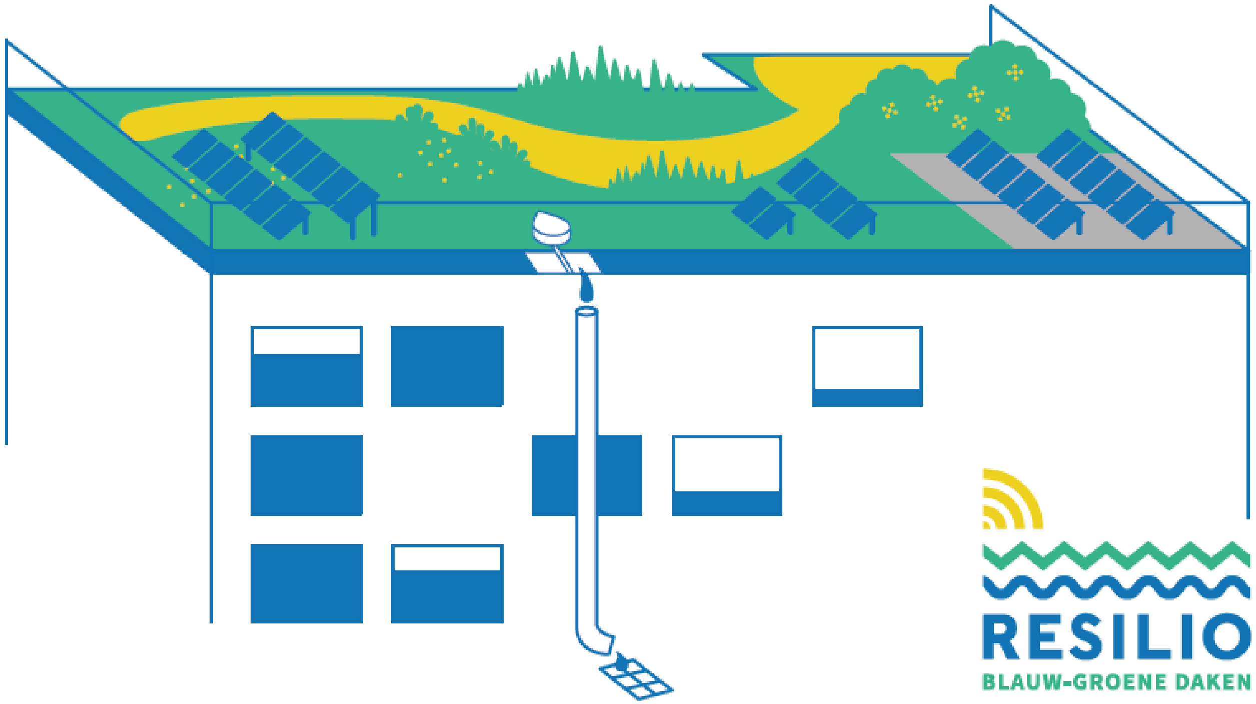
De daken kunnen extra regenwater opvangen en met een slimme klep lozen afhankelijk van de weersvoorspelling. Zo voorkomen we natte voeten op straat.

VERKOELING

Het water en de planten koelen de daken en de omgeving in de heetste en droogste maanden van het jaar.

BIODIVERSITEIT

Door het extra water kunnen planten beter groeien en blijven ze langer groen. Dat is goed voor de biodiversiteit aan planten, vogels en insecten.



RESILIO
BLAUW-GROENE DAKEN

For English: resilio.amsterdam/en