

Amsterdam University of Applied Sciences

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Publication date

2020

Document Version

Author accepted manuscript (AAM)

Published in

Climate resilient urban areas

[Link to publication](#)

Citation for published version (APA):

Kluck, J., & Boogaard, F. (2020). Climate resilient urban retrofit at street level. In R. de Graaf-van Dinther (Ed.), *Climate resilient urban areas : covernance, design and development in coastal delta cities* Palgrave Macmillan.

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Climate Resilient Urban Retrofit at Street Level

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Abstract

For a successful transition of existing urban areas towards climate resilience, it is essential that macro level policies and conceptual approaches find their way to every street and neighbourhood through urban retrofit projects. This chapter illustrates how technology, research and urban design can assist and inform this transformation process towards climate resilient streets. It describes three important steps for improving the uptake of climate resilient design in practice:

1. Implementation of design guidelines for climate resilience
2. Show that climate resilient designs are possible, not complicated and affordable
3. Show international ~~existing~~ examples ~~in~~ from practice

These steps are presented by (a) a book of example climate resilient designs for characteristic urban typologies with life cycle costs analyses and (b) a worldwide climate mapping platform presenting many ~~existing~~ ~~implemented~~ projects. With guidelines *implemented* and the knowledge that climate adaptation is *affordable* and has been done before it should become evident that most urban reconstruction projects can and should be climate resilient projects.

Keywords

Climate resilient design

Urban typologies

~~SUDS~~ Climate adaptation platform

3.1. Introduction

In order to stay livable, cities need to adapt to the changing climate. In fact cities have been designed and built for the climate of the past and are not prepared for the coming weather conditions (GCA 2019). The frequency and damage of storm water flooding will ~~rise~~increase as the urban water system is not designed for the ~~increase~~intensification of extreme rainfall events (IPCC 2019). More periods of drought will increase damage on green and infrastructure. And increase of heatwaves will result in a range of problems from an unattractive urban environment to health problems (Klok and Kluck 2018). In addition to climate change impacts, cities are changing—mostly growing, generally ~~increasing~~amplifying the above problems because green and pervious areas are replaced by impervious areas, reducing water storage, discharge, infiltration and evaporation, and reducing cool green spots (Majidi et al. 2019). Because of the expected problems, Dutch municipalities have the task to take climate adaptation into account and to use all urban development projects and retrofitting or refurbishing of existing urban areas to step by step make all cities climate proof (Deltaprogramma 2014). But for a successful transition of existing urban areas towards climate resilience, it is essential that macro level policies and conceptual approaches find their way to every street and neighbourhood in the urban retrofit projects.

The Dutch Association of Municipalities has agreed with the national government that from 2020 on all municipalities will reconstruct urban areas in a climate resilient way. As most urban streets are reconstructed only once in 30 years' time, all existing urban areas ~~could~~can be climate resilient by 2050. A timeline has been set up ~~in which all~~ for all municipalities ~~will have~~ to do climate risk assessments, risk dialogues and finally start implementing measures. To facilitate this process, knowledge on climate resilient design is being shared on a national climate services portal (CAS 2020) and many consultancies have picked up this opportunity to show their expertise and offer climate resilience studies to municipalities.

In practice municipalities have so many tasks to fulfil when retrofitting an area that the extra task of climate adaptation is easily dropped. Professionals at frontrunning

Dutch municipalities expressed the feeling that many solutions are available but that the difficulty is how to convince others to implement them.

Both Amsterdam University of Applied Sciences and Hanze University of Applied Sciences Groningen have interdisciplinary knowledge centres focusing on urban climate adaptation with and for municipalities. In recent years they have in close contact with Dutch municipalities picked up the issue of how to retrofit urban areas in a climate resilient way. Based on the cooperation with those municipalities the authors of this chapter have defined three important steps for improving the uptake of climate resilient design in practice.

1. Implementation of design guidelines for climate resilience
2. Show that climate resilient designs are possible, not complicated and affordable
3. Show international ~~existing~~ examples ~~in~~-from practice

With guidelines *implemented* and the knowledge that climate adaptation is *affordable* and has been done before it is increasingly accepted that urban reconstruction projects ~~can and~~ should be climate resilient projects.

3.2. Guidelines

In the Netherlands there are clear and very high standards for coastal and river flood safety (e.g. once in 5,000 to 12,000 years). For urban pluvial flooding and heat stress, such *binding* standards have not been set. Currently urban designers/developers/managers who are dealing with climate resilient design in the Netherlands are busy discussing on design goals, thresholds and design rules. There is no national *binding* standard for the acceptable levels of pluvial flooding or heat in the urban space. Municipalities have to make their own choice, and they are experimenting with different levels of safety. Several municipalities cluster together to assist each other and exchange knowledge. Some municipalities or groups of municipalities have recently adopted some design rules or guidelines aiming at climate resilience in new developments and reconstruction projects or they are experimenting with such design rules.

Guidelines would certainly be an important enabling factor in making every project for reconstruction or retrofitting an urban area a climate resilient project. With ~~a~~ clear design guidelines, municipalities can ~~have their designs~~ take into account

climate resilience **in their designs**. However, the problem in the Netherlands is that for many of the climate risks there is no consensus at all on what would be sufficiently climate resilient. Authorities first want to know how large the risks are, what are the costs for possible solutions and who is going to pay for it. **As The difficulty is that** storm water flood risk and damage, and costs of interventions **can vary greatly per municipality**, ~~, might be very different on each location. Therefore,~~ local municipalities do not want to be instructed what **measure interventions** to choose. At present, some agreement seems to arise slowly on storm water flooding standards. **E.g. For example, the municipality of Amsterdam requires that rainfall of 60 mm/hour** should not lead to flooding of buildings (Kluck et al. 2015). On urban heat progress is made as well, but this is even more difficult as the goals for a climate resilient urban space are very unclear. Unlike storm water flooding (where it is possible to estimate which rainfall intensity will cause flooding in a building), for urban heat there is no clear threshold above which urban space is unlivable. The higher the temperature during a heatwave the more people will suffer.

AQ1

Without clear guidelines many reconstruction projects will lack the required direction to achieve climate resilience. Fortunately, quite some municipalities are already using or experimenting with their own guidelines: for instance Amsterdam, as mentioned, and Eindhoven with a prescribed percentage of green for urban projects.

3.3. Standard Solutions

In request of professionals at frontrunning Dutch municipalities, who expressed the feeling that many solutions for climate resilient are available but that the difficulty is how to convince their colleagues, a project has been set up to create and compare alternative climate resilient designs to the standard (non-climate resilient) design.

The approach of this project was to use characteristic urban typologies as a starting point. Ten case studies within these typologies were selected. And for each case study, a standard design was compared to several more flood resilient variant designs. To compare the variants, for each variant, costs and benefits were estimated.

3.3.1. Urban Typologies

Street design in the Netherlands is often based on a particular philosophy of its time. Ideas and technologies that were available at the time of constructing are

captured in the authentic details of these streets, such as the size of the houses, gardens, public space for greens and playgrounds, the width of the streets and the architecture of the buildings (Kleerekoper 2016). Kleerekoper (2016) also describes a set of neighbourhood typologies for urban climate adaptation (Fig. 3.1 and Table 3.1). The typological variants give direction to the approach to combat more extreme climate effects. For instance, the abundance of public space in post-war neighbourhoods can easily be employed for climate adaptation, whereas in the dense urban housing blocks and pre-war blocks, underground solutions are more important. The structure of garden cities offers space for swales to absorb heavy rainfall locally. Knowledge of the neighbourhood typology, gradient (flat or sloping), type of soil and the groundwater level enables us to give a reliable projection of the possibilities and effectivity of local climate adaptation. The typologies apply to many of the streets and neighbourhoods across the Netherlands. In every country common typologies can be determined to present climate adaptations that generally fit in. Throughout Europe typologies will vary strongly, especially from North to South due to difference in climate. Northern countries tend to have more spacious streets to allow sunlight entering the houses during winter.

Fig. 3.1

(a–c) Three of the Dutch neighbourhood typologies (Kluck et al. 2018)

**Table 3.1**

Dutch neighbourhood typologies, based on (Kleerekoper 2016)

Dutch neighbourhood typology	Period	Features
Urban city block	Before 1930	No front garden nor green skirting, 4–5 layers
Pre-war city block	1900–1940	Occasional front garden, 3–4 layers, wider streets than urban blocks and occasional green skirting
Garden village	1910–1930	Spacious front and back garden, 2–3 layers, ample parking space, 1930s' architecture, limited public green and rarely street trees
Working-class neighbourhood	1930–1940	No front garden, little public green, 2–3 layers, single-family units
Low-rise post-war garden city	1945–1955	Open building block with ample green, 2–3 layers, single-family units
High-rise post-war garden city	1950–1960	Open building blocks with ample green, 4–6 layers, apartments, storage on the ground level

Dutch neighbourhood typology	Period	Features
Post-war neighbourhood	1940–1990	Front and back garden, 2–3 layers, single-family terraced houses, semi-detached or detached
Community neighbourhood	1975–1980	Single-family unit with front- and back garden, meandering street pattern, courtyards, wide green skirting around the neighbourhood
High-rise city centre	1960–present	More than 10 layers in grid formation
Suburbanization—Vinex	1990–2005	Single-family unit, terraced, semi-detached or detached apartments

3.3.2. Ten Examples with Variants

Ten examples of streets in neighbourhoods that are typical and representative of the Dutch infrastructure (e.g. the urban city block, post-war garden cities and community neighbourhoods) were selected. They include flat and sloping surfaces, and differences in soil permeability and groundwater levels, and represent Dutch situations. The ground water tables are generally high, the Dutch soil is predominantly sandy with clay or peat (Kluck et al. 2018), and the Netherlands has a predominantly flat surface with some sloping areas in the eastern- and southern regions. Six of the ten examples were in a flat area. The other four were in a mild hilly area.

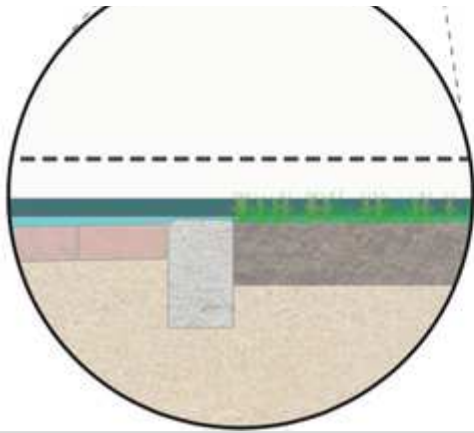
For each example, a traditional (standard) design and three climate resilient variants have been worked out. Variant 0 is the traditional design, whereas variants 1–3 are more climate resilient to extreme rainfall (Fig. 3.2). Additionally, some examples include a particularly green variant.

Fig. 3.2

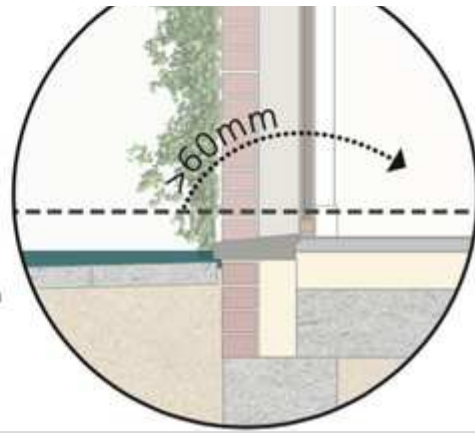
Example of standard design and 3 more climate resilient variants for case ‘low rise post war garden city’ in flat urban area (Kluck et al. 2018).





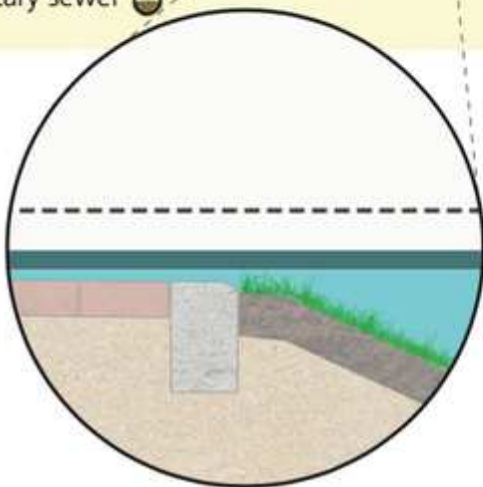


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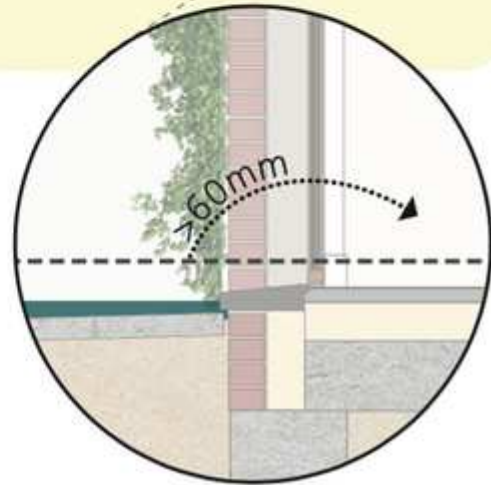


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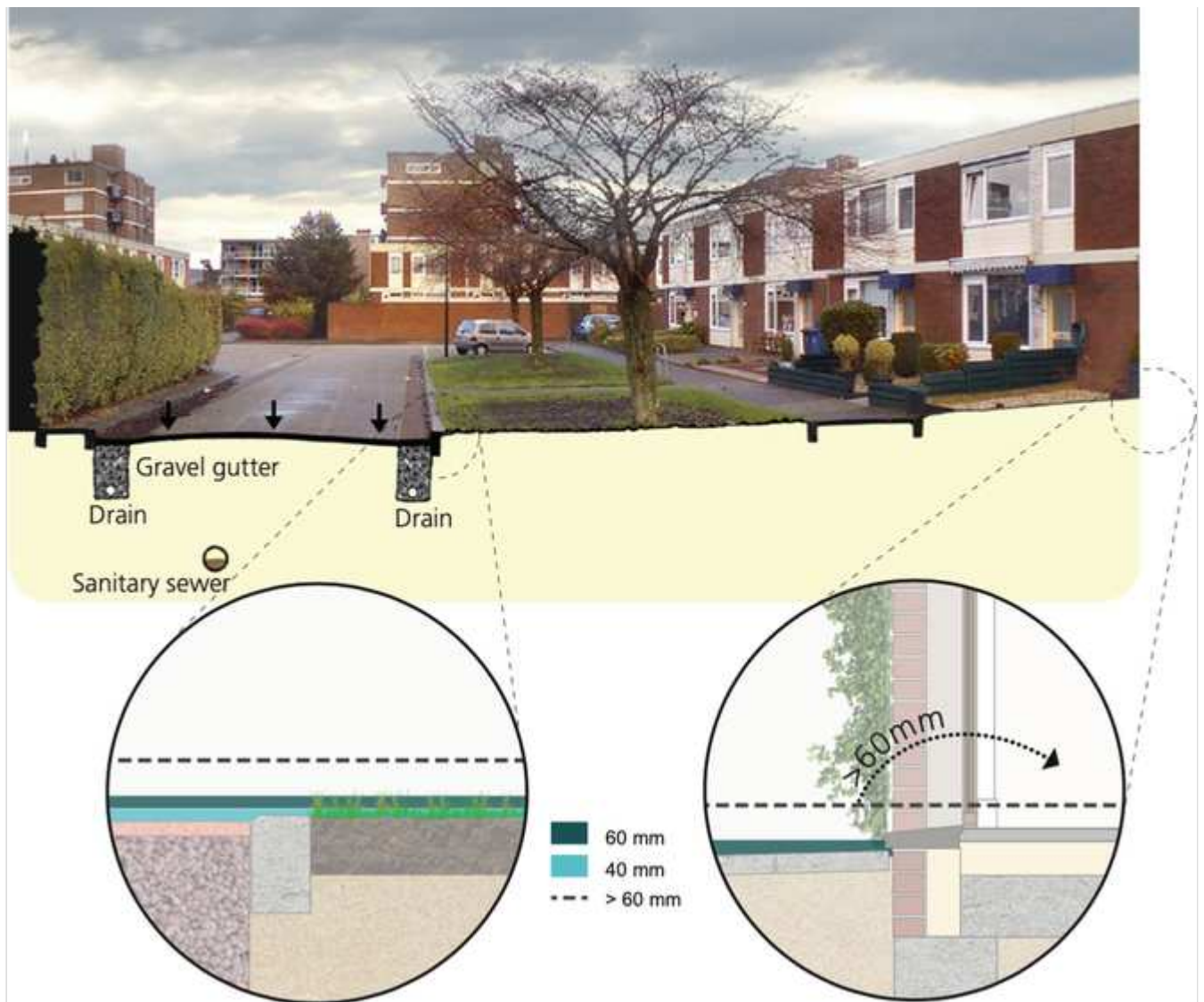
Sanitary sewer



60 mm
40 mm
- - - > 60 mm



3



Variants were tested on their sensitivity to flooding, assuming that flood damage occurs when water enters the houses. For that purpose we calculated for different volumes of extreme rainfall in one hour if water would enter the houses. These different extreme volumes of rainfall are linked to estimations of frequency of occurrence.

3.3.3. Costs and Benefits

Next the lifetime costs and benefits of each variant were estimated by a methodology described in Kluck et al. (2018). This methodology includes flood damage costs and life cycle costs (i.e. construction and maintenance costs) of, for example, sewer systems and permeable paving. Furthermore, it includes variation in the lifespan of particular refurbishments. Calculations were based on the cost ratios of the Dutch Sewer Guidelines (Stichting Rioned 2015) as well as empirical evidence provided by individual municipalities. Kluck (2017⁶) gives more

background documentation on the methodology and a calculation sheet. All investments have been based on a 100-year statistical return period to provide a realistic comparison of variants with differences in maintenance costs. This should provide a deeper insight into the financial consequences of various options to allow policy makers, designers, administrators and other experts to make well-informed decisions.

AQ2

Climate resilient refurbishment of public space has certain benefits. The calculations include the quantifiable cost-effective measures. The most important are the reduced flood damage costs which were also expressed in costs per annum based on estimated frequency and the magnitude of the disruption. Other benefits which were calculated are the reduction in maintenance costs of the urban drainage system and—in case of a combined sewer system—reduction in wastewater treatment costs. There are more benefits that were not quantified, such as reduced or delayed drainage to surface water, groundwater recharge, heat stress reduction, and increased water availability for urban green.

In addition to advantages to the water system (such as increased rainwater infiltration), greening public space improves public comfort and health, water quality, and reduction of energy consumption, and it increases biodiversity. These benefits were studied and quantified with the TEEB-city-method ('The Economics of Ecosystems and Biodiversity' Buck Consultants International 2016).

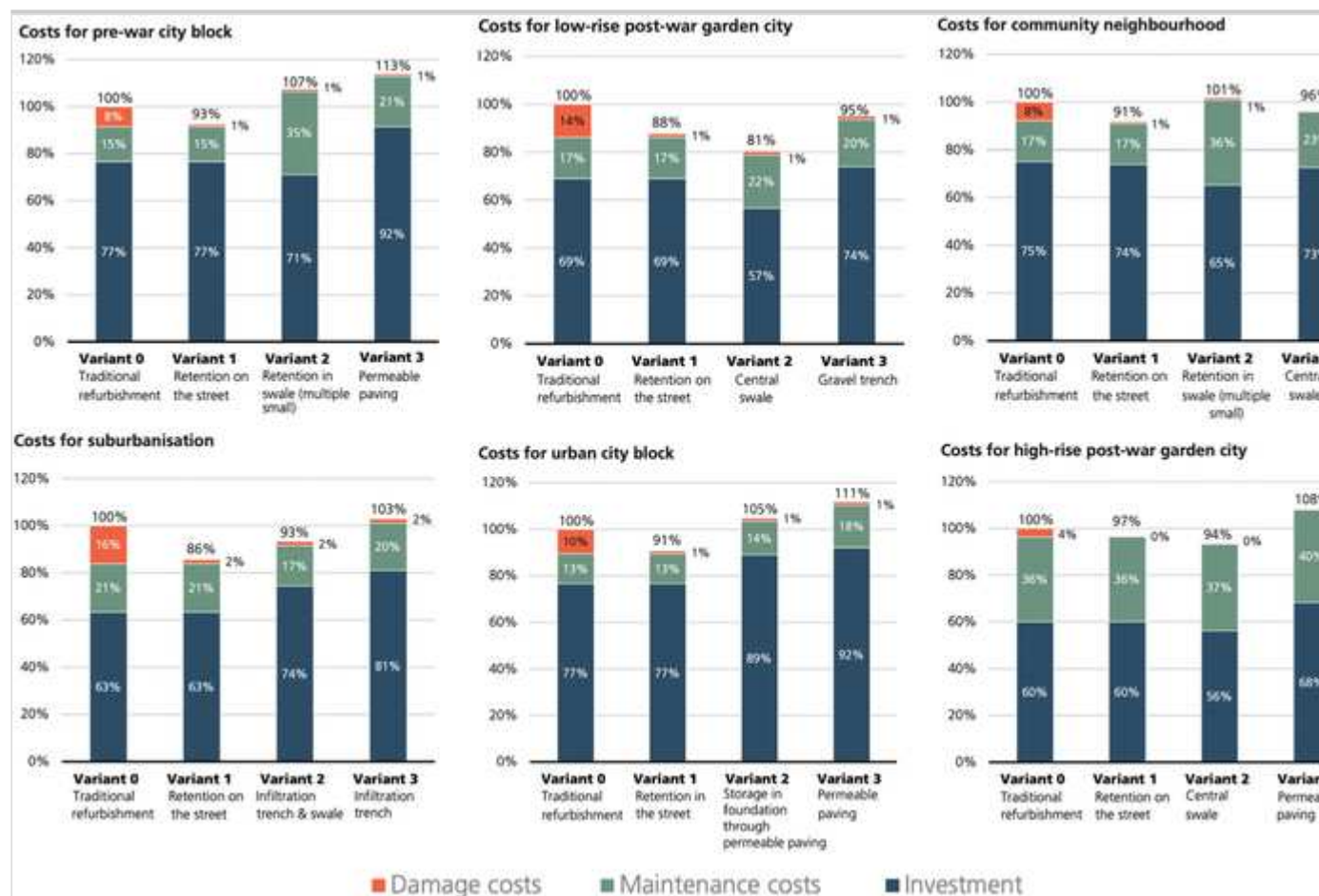
To sum it up: We have compared variants for the costs of maintenance and implementation as well as the benefits of reduced or prevented flood damage and greening. Benefits that we have so far not been able to quantify sufficiently have not been included.

3.3.4. Results

The comparison of the variants shows that the climate resilient variants are not necessarily more costly than the standard situation. Moreover, they are relatively easy to implement when they can piggyback on planned urban refurbishment and maintenance operations. Figure 3.3 presents a comparison of the average yearly lifetime costs for storm water flood damage, construction costs and maintenance costs.

Fig. 3.3

Comparison of lifetime costs (damage, maintenance and construction cost) for rainwater resilient design versus standard design for six urban typology cases adapted from (Kluck et al. 2018)



The examples with the comparison of costs and benefits have been published in a book of examples (Kluck et al. 2018) targeted at urban professionals. ~~The~~ This book of examples (Kluck et al. 2018) shows how ordinary residential streets can be made climate resilient in practice. Explaining that solutions are possible and that the costs are often about the same can help to convince municipalities to choose for a climate resilient design.

AQ3

However, since showing designs of specific interventions might not be sufficiently convincing, also showing interventions which have been implemented before is important. Web-based portals such as ClimateScan (see next paragraph) could also contribute to accelerated uptake of climate resilience measures.

3.4. Existing Solutions Presented in Climate Adaptation Platforms

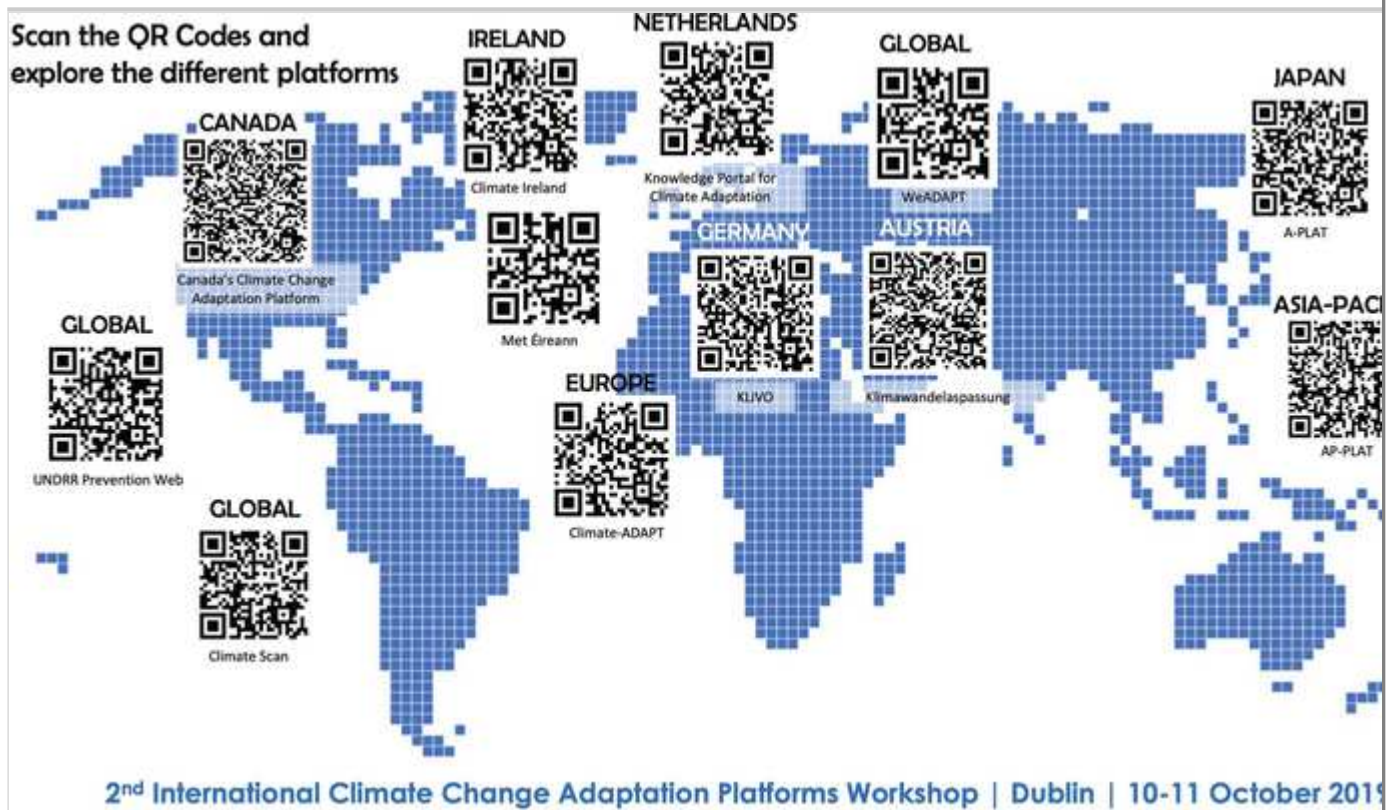
3.4.1. Introduction to Climate Adaptation Platforms

There is an increasing demand for a collaborative knowledge-sharing on climate adaptation and mitigation. Climate resilient solutions are often already available, but their multiple benefits are often unknown. The aim of most Climate Change Adaptation Platforms is (inter)national knowledge exchange and raising awareness about climate adaptation in urban areas and to promote solutions such as Nature-Based Solutions (NBS), Best Management Practices, water-sensitive urban design (WSUD) and Sustainable urban Drainage Systems (SuDS).

Climate adaptation platforms are available for several regions or countries around the world offering information to different target groups. Most of the platforms are country or continent specific, and some are global (Fig. 3.4). Examples of Dutch climate adaptation platforms ~~used for climate adaptation~~ are CAS (2020) and ClimateScan (2020) which offer examples of climate adaptation in the Netherlands. The open-source platform ClimateScan is a global platform and is focussed on street level and will be discussed in this chapter.

Fig. 3.4

Global Climate Change Adaptation Platforms as presented during 2nd international climate change adaptation platform workshop in Dublin October 2019 (Climate Ireland 2019)



3.4.2. ClimateScan Platform

ClimateScan, a web-based international knowledge exchange tool on urban resilience, is a citizen science tool created through ‘learning by doing’ (Boogaard et al. 2017). Since the implementation in 2014, the platform is in continuous development as more data is uploaded, and improvements are made to respond to feedback from users. In the early stage of ClimateScan, the tool was evaluated by semi-structured interviews in the ClimateScan community with the following recommendations:

Most stakeholders (Dutch municipalities and water authorities) would like to have tools that are (Tipping et al. 2015):

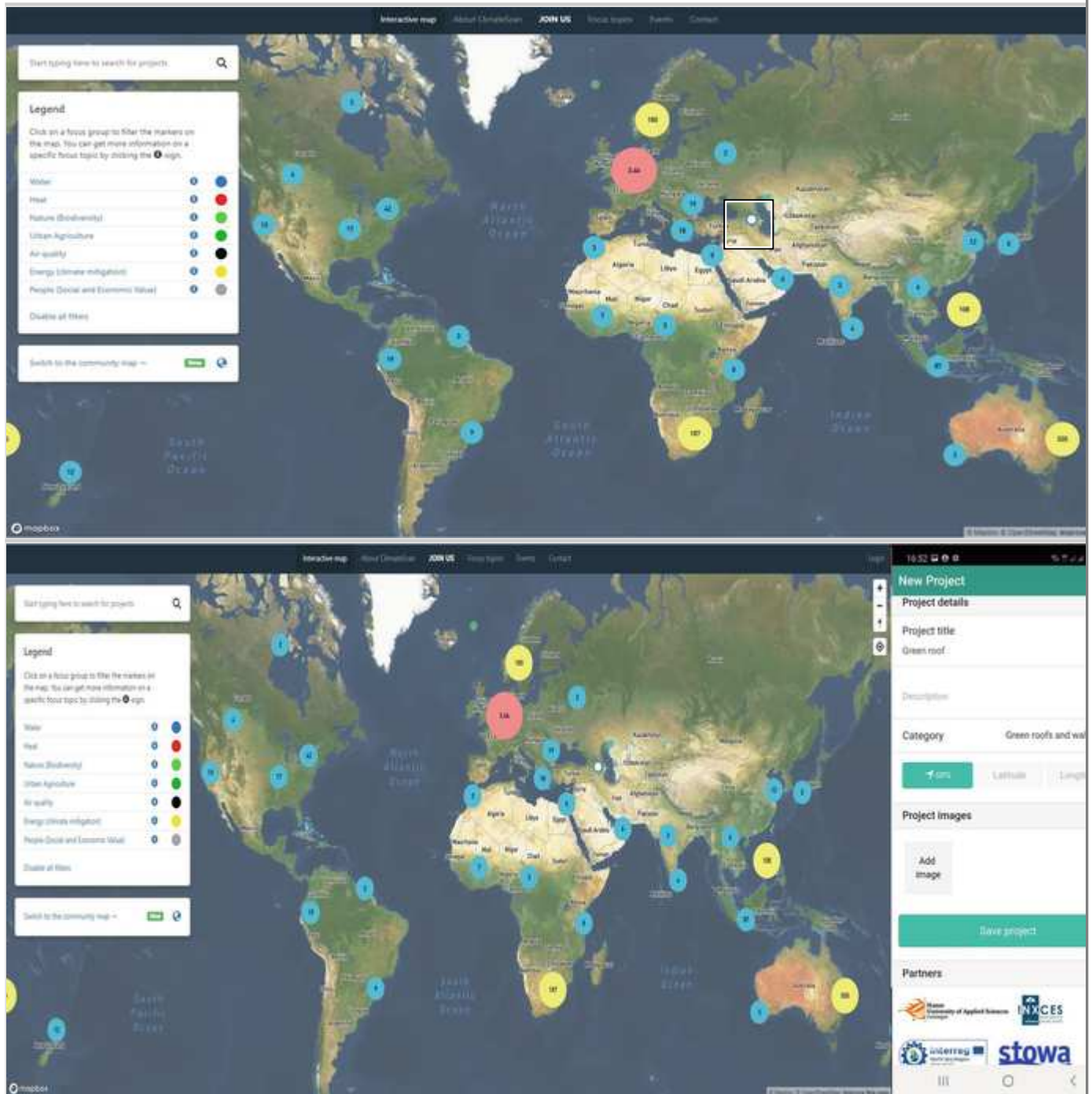
1. interactive;
2. open source;
3. provide more detailed information (location, free photo and film material);
4. link to scientific research outcomes for that specific location;
5. local examples and international examples.

In 2020, ClimateScan has grown into an interactive web-based map application for international knowledge exchange on ‘blue-green’ projects around the globe. The platform has evolved into a ‘solutions-broker’. This role can assist in mobilizing action in the field of climate adaptation. For instance, by creating a network of collaborators and by providing these collaborators with a resource for assistance in their efforts towards achieving resilience. With its existing widespread user base and its diverse portfolio of climate adaptation and mitigation projects, it is a widely used support tool for climate adaptation.

One of the unique features of ClimateScan is its open-source character which allowed users to record and map climate adaptation of their own solutions. The ClimateScan app that can be downloaded in the app store is mostly used for uploading climate adaptation examples all over the world (Fig. 3.5). Unlike other knowledge dissemination platforms, ClimateScan is global in its approach and scope. Most other databases are either restricted in their geographical scope or they have a singular focus on one kind of adaptation solution. The diversity in topics and its global outreach has enabled it to gain a widespread user base, becoming particularly popular among young practitioners and academicians.

Fig. 3.5

ClimateScan.org platform with around 5000 projects around the world



Climate scan collects climate adaptation locations from all over the world **and classifies adaptation solutions into different categories** (Table 3.2) **as Water, People Nature**. The global platform can be used as a first step to collect data by the means of citizen science and share the knowledge on realized climate adaption measures of that region and compare this to other parts of the world. ClimateScan focuses mainly on the topics surrounding the areas of urban resilience, climate proofing and climate adaptation. The main objective of **this e** interactive international open access platform is knowledge exchange on climate adaptation projects through the platform itself and the connected social media channels as twitter and Facebook.

Table 3.2

ClimateScan categories most used in The Netherlands with **definitions** **examples**

Category	Definition
Swale	A shallow vegetated channel designed to conduct, infiltrate and retain water, but may also permit infiltration . The vegetation filters particulate matter.
Constructed wetland	Wetland: Flooded area in which the water is shallow enough to enable the growth of bottom-rooted plants. Wetlands are constructed in urban areas to store water after storm water water -events and improve water quality.
Green roofs	A roof with plants growing on its surface, which contributes to local biodiversity. The vegetated surface provides a degree of retention, attenuation and treatment of rainwater, and promotes evapotranspiration.
Floating urbanization	Floating or amphibious constructions as floating homes will adapt to variation of water levels (flooding, drought). Floating homes are constructed around the world to adapt to climate adaptation change .
Permeable pavement	A permeable surface that is paved and drains through voids between solid parts of the pavement. A permeable pavement is a surface that is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration of water.
Hollow gully free roads	Roads that are constructed as drainage. An example is a surface flood pathway: Routes in which exceedance water flows are conveyed on the ground. Also referred to as 'hollow' or 'gully free' roads.
Sub-surface infiltration	A sub-surface structure into which storm water is conveyed, designed to promote infiltration to restore groundwater levels.
Heat stress measures	An upcoming category linked to implementation of green and blue measures in previous categories (swales, green roofs and walls, rain gardens, etc.) implemented to cool down the city and mitigate heat stress.

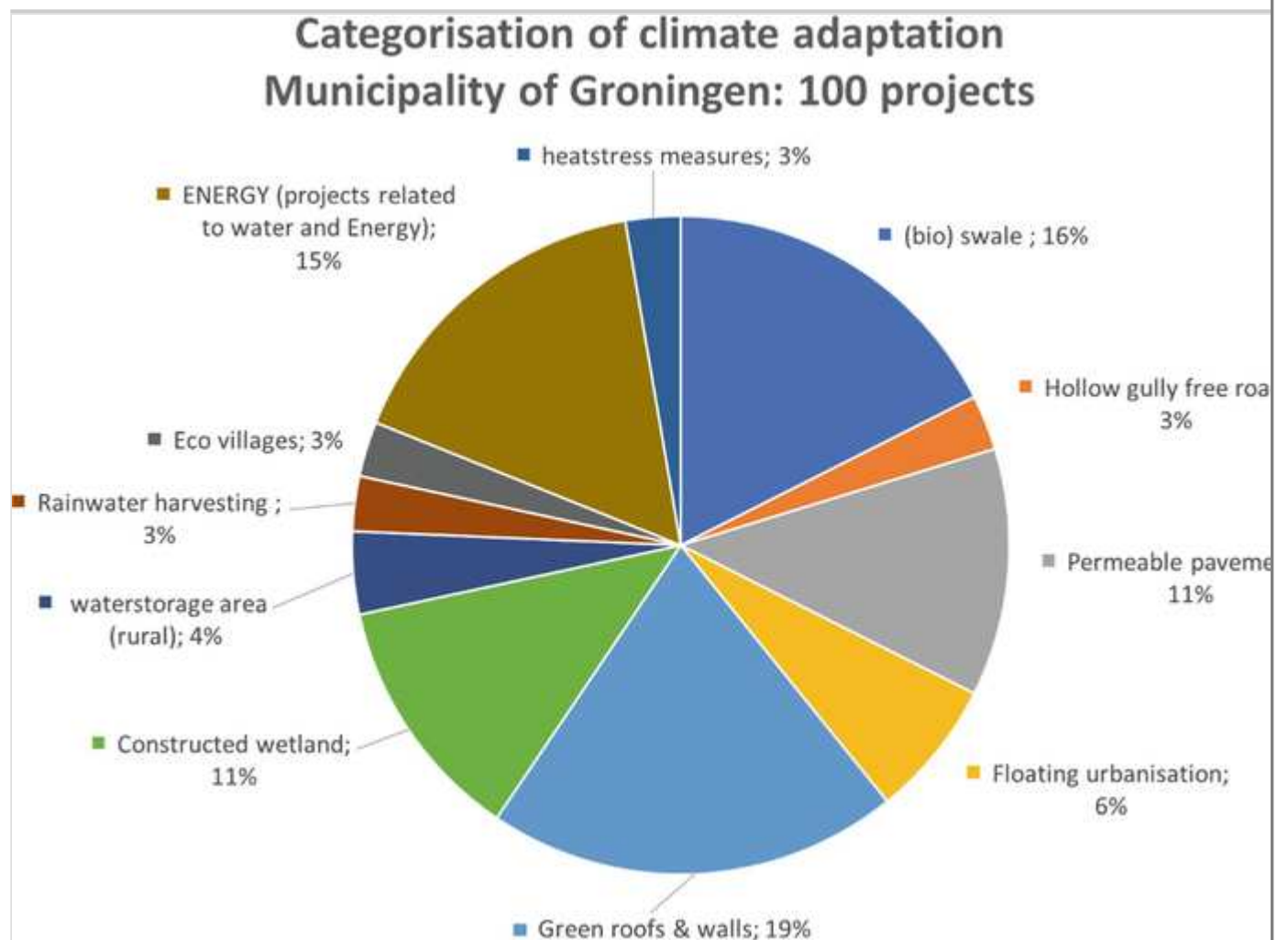
Due to the method of citizen science the platform can raise awareness **and builds** capacity **building** (Wamsler and Riggers 2018) and with an increasing number of users and categories, the platform is under constant change. The current status of the ClimateScan has about 1000 registered users that (can) upload projects around the world. More than 60% of the users are younger than 34, and 51% of users are female. With over 5000 uploaded projects, the platform is considered to be the biggest inventory of 'blue-green' projects around the globe for international knowledge exchange. Currently, all the data points are categorized into 7 sub-groups (Water, People, Nature, Heat, Energy, Urban Agriculture and Air quality) holding over 20 categories, which are each assigned a different colour as shown in the legend to the left of the webpage (Fig. 3.5). Users of ClimateScan can create their own climate adaptation categories.

Most of the uploaded projects belong to categories related to NBS, SuDS, WSU&D and BMPs that are designed to reduce the rate and quantity of surface water runoff from developed areas and to improve runoff water quality. Uploads on ClimateScan include: constructed wetlands, bio swales, green roofs and walls, permeable pavements, rainwater gardens, and floating structures on public and private property (Table 3.2). Along with uploading climate adaptation measures, problem areas are also mapped, where solutions can be implemented.

One of the Dutch medium size cities in The Netherlands that uses the ClimateScan platform is Groningen. Over 100 projects in the municipality of Groningen have been uploaded and categorized (see Fig. 3.6). Every city can use this platform to engage partners to upload climate adaptation measures and analyse their own situation as in Fig. 3.6.

Fig. 3.6

dDistribution of 100 projects in categories of the city Groningen, The Netherlands

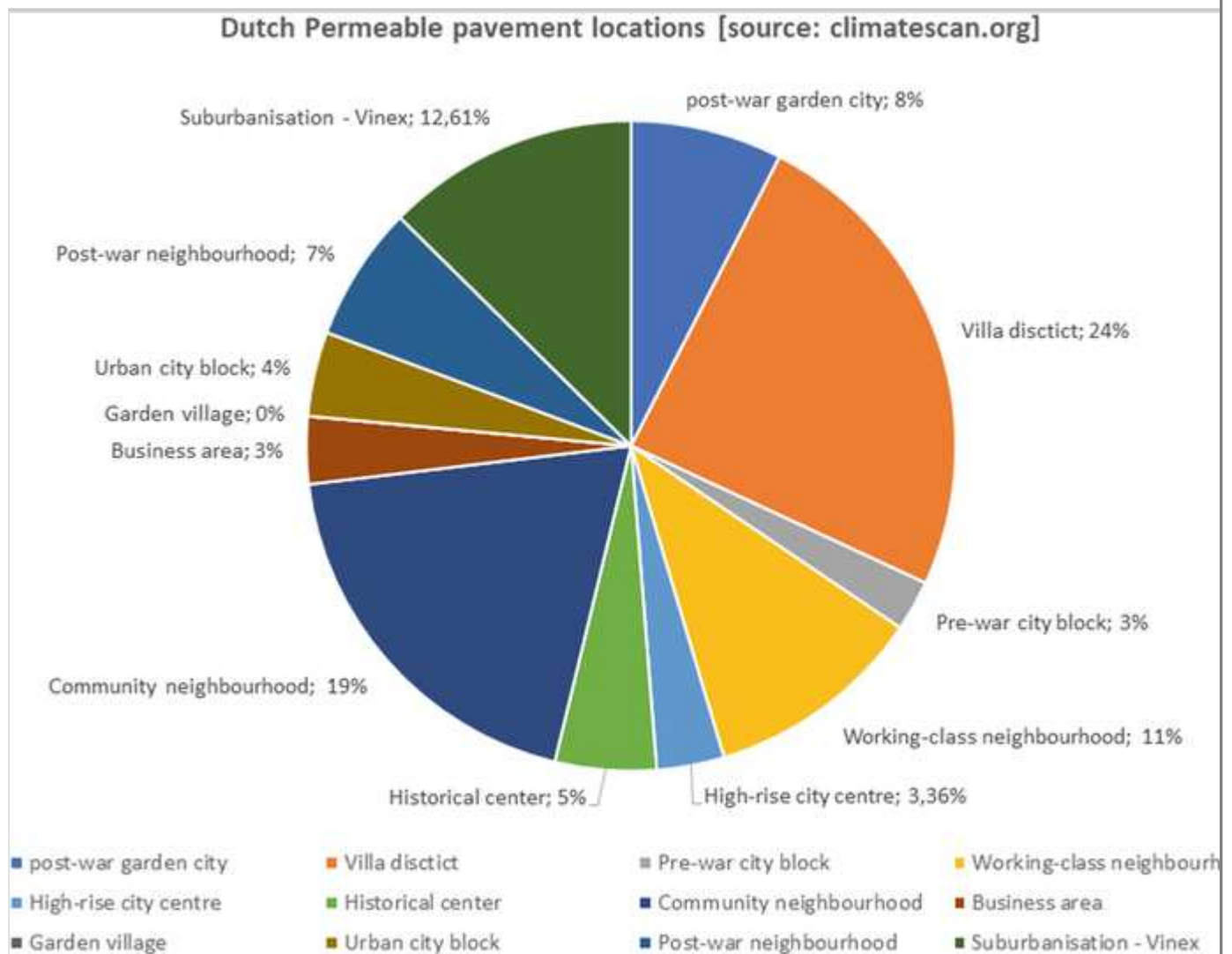


ClimateScan is used in the international Young leaders programme from the GCA (based in Groningen and Rotterdam) for young professionals to get acquainted with global mitigation and adaptation projects.

ClimateScan allows analysing climate adaptation on a national level using the Dutch neighbourhood typologies as presented in Fig. 3.1 and Table 3.1. As an example, Fig. 3.7 illustrates that over 50% of the 168 locations of permeable pavement are located in the three more spacious and newer types of urban areas: villa district, community neighbourhood and suburbanization area. However, it shows as well that permeable pavement is also present in densely built up areas like working-class neighbourhood and historical centre. This information gives an evidence-based proof to urban planners that permeable pavement is implemented in any type of district but mostly is constructed in spacious districts built after 1970. Furthermore, examples of storm water infiltration projects in low-lying districts with high groundwater tables and low permeable soil in challenging can be found also in densely built up areas. This should inspire urban planners and storm water managers to design, plan and implement climate resilient measures with more confidence.

Fig. 3.7

Dutch neighbourhood typologies related to implemented Dutch permeable pavement



The ClimateScan platform is developed with support from several international projects serving the need of different stakeholders creating maps on climate resilience in different regions of the world. The platform is applied in international city Climatecafés (Boogaard and Venvik 2019) and workshops in Semarang, Indonesia (Adi et al. 2020), and Johannesburg, Africa (Leal et al. 2020), targeting young professionals that were very helpful with uploading several projects around the world (Africa, Europe, Asia and South America), and the platform will be used in various new projects and ClimateCafés in the near future.

Climate Change Adaptation Platforms such as ClimateScan are an inspiration to stakeholders to make their cities more resilient to climate change. Challenges are reaching the public and stakeholders and keeping the content up to date. Potential [topics for](#) upgrades of these platforms have been identified with stakeholders. As mentioned, ClimateScan is a ‘learning by doing’ platform, and this comes with challenges. ClimateScan is depending on enthusiastic registered users uploading

projects and categories. Some projects only have a location with a short description. The fact that anybody can upload projects (citizen science) makes quality control important. This is now done by volunteers that check and adjust new projects and categories out of their own interest.

3.5. Reflection on Five Pillars of Resilience

The discussed urban climate adaptation relies on threshold, coping and adaption capacity. The main path for reconstruction and retrofitting urban areas is aiming at **threshold capacity**. More and more Dutch municipalities have chosen to require that only above a certain amount of rainfall in a short timespan flooding of buildings is allowed. For example, no flooding of houses at 60 mm of rainfall within 1 hour (estimated return period of 50–100 years).

Next to this **coping capacity** is important. Flooding of streets is currently and will stay allowed at a much higher frequency than the above threshold. In fact, in practice, municipalities accept flooded streets once every 1–2 years (~~more than~~ 20 mm–30 mm of rainfall within one hour). Note: for important streets the threshold will be higher and lower frequencies will be requested. It is expected that society has sufficient coping capacity to deal with those situations.

Lastly, **adaptive capacity** will be strengthened because people will learn from extreme weather conditions. After experiencing a local flooding or heat wave they might make more resilient choices in their professional and private lives. In an unexpected way, the approach of allowing water on the streets every 2 years might prove to be an effective way to reduce future damage to climate change. Finally, because streets are redesigned every 15–30 years, there are recurring possibilities to further adapt to future developments of weather extremes.

3.6. Conclusions

Because of the expected problems, Dutch municipalities have the task to take climate adaptation into account and to use all urban development projects and retrofitting or refurbishing of existing urban areas to step by step make the whole urban areas climate proof. However, because there are so many other important requirements which need to be fulfilled when reconstructing a road or an urban area, climate resilience is often forgotten, or not fully implemented. It is argued that clear guidelines would help to meet the goals of climate resilient (re)design. Next to guidelines, two ways have been identified to encourage municipalities to choose for climate resilient projects. Both (a) the presentation of example designs for

retrofitting streets with comparison of life cycle costs and benefits and (b) the access to real project examples seem to meet a need of local professionals. *The examples have been combined in a book which was widely requested and was reprinted twice. The book* is however not a guideline for how to act, but rather a book to show possibilities, after which municipalities still have to decide how they want to implement climate adaptation.

To show that climate resilient intervention has been implemented before, the platform ClimateScan with access to real project examples has been created. This and other platforms of examples can inspire different stakeholders that other designs than the ‘standard solutions’ are possible and can be more effective (larger storage volume, higher hydraulic capacity, etc.). Uploading projects by stakeholders themselves and sharing these examples show a high participation and will stimulate repetition of innovating solutions in the urban area to make cities resilient. Analysing the ClimateScan database, where solutions can be linked to the Dutch Neighbourhood typologies, allows to monitor the national progress of climate adaptation in The Netherlands and to identify opportunities for climate adaptation. The database gives an evidence-based proof to urban planners that over 2000 Dutch projects are implemented in any type of district. The results of this study will help urban planners and storm water managers with the designing, planning, climate adaptation measures with more confidence.

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