8 Typological design solutions in the path to climate resilience supported by urban surface analysis [12]

In the previous chapter the role of the urban microclimate in the design process is discussed. This chapter assists planners and designers to increase the role of the microclimate in their design. To merge microclimate solutions with urban design challeges, this chapter explores the spatial implication of climate adaptation measures in specific Dutch neighbourhood typologies. The research question adressed is: How can neighbourhoods become climate robust considering the morphology of Dutch neighbourhood typologies?

The scale is a determining aspect in the decision-making process regarding climate adaptation measures. Usually the neighbourhood scale is chosen because this can be managed by municipalities or housing corporations. However, the effects of measures in the first place is on the local street scale. Because many neighbourhoods have a characteristic building typology and organisation of the public space it is possible to give a general statement of the most appropriate measures. For example, historic urban areas have a completely different starting point than garden cities.

In this chapter a new categorisation of neighbourhoods is presented to combine microclimate indicators with traditional urban typologies. A qualitative method based on case studies is used to come to general climate adaptation measures or strategies per microclimate category. All neighbourhood case studies start with an analysis of the physical properties, followed by at least one design solution or strategy. The design solutions and strategies are input for the general conclusions per microclimate category. This part of the thesis can be described as 'typological research' according to the scheme made by de Jong & Voordt (2002), presented in Figure 8.1. In the case studies the context is variable (different neighbourhoods) and the object is determined (different cases per microclimate category). Each separate case study is, however, a 'design study' in itself, with one specific neighbourhood and thus determined context and variable climate adaptation solutions (objects),

12 The content of this chapter is accepted for publication in the proceedings of the North Amerocan Symposium on Climate Adaptation: Kleerekoper, L., Kluck, J., & Dobbelsteen, A.A.J.F. v.d. (2016), "Selection support framework fostering resilience based on neighbourhood typologies"..

	OBJECT Determined	Variable
CONTEXT Determined	Design research	Design study
Variable	Typological research	Study by design

FIGURE 8.1 Types of design related study by de Jong & Voordt (2002).

§ 8.1 Microclimate categories based on common urban typologies

For the analysis of the microclimate of a specific location or area several methods exist. However, these methods require specialist input data and often make use of complex calculation models or time-consuming interviews. More information about these methods can be found in chapter 2. The method described in this section allows a first indication of the most appropriate microclimate measures without the use of extensive data-analysis or computer modelling. The classification of the neighbourhoods in a category can be based on many characteristics. For the ultimate goal of formulating design guidelines a generalisation of urban areas is required. This section describes the translation of urban typologies to microclimate categories.

Traditionally, urban typologies are classified in relation to their construction period, built form and organisation of the public and private space (Wassenberg, 1993, Ibelings, 1999, Baeten et al., 2004, Lorzing et al., 2008). Besides, the common urban typologies other methods of classification have emerged to support decision makers with the appropriate data about their cities and regions. In 1998 a classification of residential environments was made according to the level of urbanity by the *Woonbehoefte-onderzoek* (WBO). The result is three main typologies from urban, to suburban, to village and rural environments (ABF, 2006). In the beginning of the twentieth century the reflection on a period of fifty years of constructing for housing shortage asked for more insight in the quality of urban areas. The *Rosetta-methode* redefines the WBO residential areas into five main typologies: highly urban, urban, suburban, village and rural (Prins et al., 2010). Although this recent classification offers insight in the quality and ambiance of an urban area it does not offer a differentiation of the main aspects that are required to improve the microclimate.

For the microclimate there are many parameters of interest such as the size of paved surface, type of material, colour, amount and type of vegetation, amount and type of water, height and width of the streets and inner courtyards, openness, orientation and built form. More background information about the urban microclimate is available in chapter 2For cities in the US a climate classification according to physical parameters have been made by Stewart & Oke (2012). Here many parameters are needed to come to a classification, some features are overlapping or indicating the same process. To increase the accessibility for urban designers and planners working with the urban microclimate, this study brought the amount of parameters down from ten to three, see text box Table 8.1. The three most important determinants for the microclimate in which Dutch neighbourhoods distinguish themselves are building height, form of footprint and the percentage of green/water in relation to the urban surface, as given in Table 8.2. These three parameters are also selected as indicators by an extensive typological research in Dutch urban types by Berghauser Pont & Haupt (2009). The three parameters enable a classification based on microclimate categories and on traditional urban typologies used by urban designer and planners.

PARAMETERS BY STEWART & OKE (2012) FOR US CITIES	PARAMETERS DUTCH NEIGHBOURHOOD CLASSIFICATION			
	Building height	Footprint	Percentage green/water	Argumentation parameter selection
Sky view factor	x	x		Sky view factor, canyon aspect ratio and mean building height are all indicators for radiation loads and air flow patterns. The building height in combination with the type of footprint alone, is however, sufficient to make a classification for the common neighbourhoods in The Netherlands. Nevertheless, the height to width ratio (canyon aspect ratio) is certainly needed in the design process where choices for adaptation measures need to be made.
Canyon aspect ratio	x	x		
Mean building height	x			
Building surface fraction		x	x	Building surface fraction, impervious surface fraction and pervious surface fraction are all indicators for evaporation rate, heat storage, reflection and water infiltration. The combination of the type of footprint and the percentage of green or water is sufficient to determine a classification. Nevertheless, the fraction of stony and natural surface is certainly needed in the design process where choices for adaptation measures need to be made.
Impervious surface fraction			x	
Pervious surface fraction		x	x	
Terrain roughness class				No distinctive role in Dutch neighbourhoods
Surface admittance				Minor distinctive role in Dutch neighbourhood typologies
Surface albedo				Minor distinctive role in Dutch neighbourhood typologies
Anthropogenic heat flux				No distinctive role in Dutch neighbourhoods

TABLE 8.1 Important determinants for the microclimate in which Dutch neighbourhoods distinguish themselves.

BUILDING HEIGHT	FOOTPRINT	PERCENTAGE GREEN/WATER
Low (up to 3 layers)	Strip	Little green (0-10%)
Middle high (4-6 layers)	Open urban block	Moderate green (10-30%)
High (7-10 layers)	Closed urban block	Much green (30-50%)
High-rise (9 and more layers)	Spread buildings	Abundant green (50-100%)

TABLE 8.2 Categorization of urban types (based on Berghauser Pont & Haupt 2009) in relation to the microclimate

The relationship between the paved ground surface and the roof and wall surface varies per building morphology and density and is a valuable indicator for the urban microclimate. The heat accumulation in the stony materials, reflection of radiation between these surfaces are for a large extend responsible for urban heating. In American cities wall and roof surfaces in areas of tall, densely spaced buildings exceed the ground surface. Conversely, wall and roof areas of low density single-family detached houses form only a small proportion of the ground surface area (Ellefsen, 1991). In Canada walls are 28% to 54% of the total surface area in the city (Voogt & Oke, 1997).

The parameters given in Table 8.2 are determined using a combination of GIS (ArcMap) mapping, Google Earth aerial images and personal photographs or Google Street view. The source map for the analysis is the TOP10NL (Middel, 2002). The building height is based on the average height and the form of footprint on the TOP10NL. The percentage of green and water requires a combination of different sources: the municipal green ground surface can simply be calculated from the TOP10NL maps, for green roofs and private gardens Google Earth is used to determine a percentage of the private area that can be counted as green. A complete overview of the urban surface analysis is presented in Appendix F.

In addition to the three parameters given above also land use, height/width ratio, function (residential, mixed urban functions, industry, city centre, office park, agriculture, sports and recreation), density (inhabitants per hectare, dwellings per ha, FSI, GSI) and street trees are important for the urban microclimate. These are not directly part of the categories, but are appointed by the explanation per microclimate category in sections 8.2 – 8.9.

Form the additional parameters in the paragraph above, especially street trees are an important issue. In the percentage of green/water the municipal green on the ground surface, green on roofs and private green in gardens are all included. However, street trees were not included in the balance because not all municipalities could provide GIS data with street trees and their properties.

To provide a clear idea of the characteristics of the microclimate categories they are coupled to common urban typologies and their period of origin in Table 8.3. The urban typologies that are related to the microclimate categories in this chapter are mainly based on the typology description in 'An urban typology' (Lorzing et al., 2008). For example: the *historical city blocks constructed before 1910* pertain to the category *middle high closed urban block with little greenery* and the *post-war garden city with low-rise*, which dominate the Western part of Amsterdam, pertain to the category *low open urban block with moderate to much greenery*.

URBAN TYPOLOGY		MICROCLIMATE CATEGORY		
Typology	Period	Height	Footprint	Green
Historical city block & pre-war city block	before 1910 '10-'30	Middle high	**Closed urban block**	Little green
Garden town	'10-'30	Low	Closed urban block	Moderate to much green
Residential housing	'30-'40	Low	Closed urban block	Little green
Post-war garden city low-rise	'45-'55	Low	Open urban block	Moderate to much green
Post-war garden city high-rise	'50-'60	Middle high/high	Open urban block	Moderate to much green
Community neighbour-hood	'75-'80	Low	Strips Open urban block	Little to moderate green
Sub-urban expansion - Vinex	'90-'05	Low	Strips Closed urban block	Moderate green
High-rise city centre	'60-present	high-rise	Spread buildings	Little green

TABLE 8.3 Relation between microclimate category and urban typology

Before 1910 the urban architecture was mainly focused on the traditional closed urban block. These blocks are constructed per plot by mainly private parties. After 1910 the development of complete urban blocks started with the influence of housing corporations. In the 10-30s city expansions were built according to the garden city idea (here referred to as garden towns), based on the ideas of Howard, who strived to provide the working population a better dwelling environment than the unhealthy industrial metropolis. In subsequent years, the garden city concept was left to make way for residential housing that was mainly aimed at providing a home for as many families as possible without much attention to social services and green.

After the second world war a lot of extra living space had to be built because of the bombings, the stagnated construction of dwellings during the war and the rapidly growing population thereafter. In the years 50-60s, the first high-rise housing arose. The basic idea was to create more light, air and space, in spite of the high density. The post-war garden cities can be divided into four different types: strips, stamps, courts and high-rise. To limit the amount of microclimate categories the four typologies are merged to two; strips and stamps are represented by *post-war garden cities low-rise* and courts and high-rise are represented by *post-war garden cities high-rise*. The most distinctive element of the low-rise typology is the transformation from street to stamps where the inner-courtyard becomes part of the public space. The high-rise typology is yet a step further into the free use of (green) space around buildings, with a totally autonomous traffic system.

Ten years later, the community neighbourhood was introduced as a safe place for children to grow up, and there were many so-called 'cauliflower districts' developed. 'Cauliflower' relates to the characteristic pattern of complex forms and meandering streets with low traffic zones. These neighbourhoods often have both private gardens and a relatively large amount of municipal green. Also, there was a tendency to develop concentrated growth areas outside the city.

In the years 1980 - 1990, the compact city was trending, this is still an important aspect of the development strategies today. These densification developments do not form a uniform microclimate category, nor can they be studied as a complete neighbourhood. Therefore, this is not included in the classification.

Next to the compact city the subsequent Vinex (translated: Fourth Note on Spatial Planning Extra) expansions emerged. The Vinex areas or sites which are designated for large-scale construction along the edges of big cities are the most recent effectuation of the desire of most Dutch to live in a land-based house with a private garden. The first Vinex locations were purely focused on housing which meant travelling to and from the city for many activities such as working, shopping and cultural. The recent urban areas are realised with a lot of attention for greenery and water to create an attractive environment.

The Dutch cities will continue to grow due to population growth, but also because of ongoing migrating from the countryside to the city. Highly urbanized areas in town centres have to deal with more users and, where possible, cities strive for more compactness. When redeveloping city cores it is important to keep a focus on the future quality of life.

§ 8.1.1 Case study selection and methodology

The qualitative research method used in this chapter is based on case studies. These case studies are located in the four major cities of the Netherlands: Amsterdam, Rotterdam, The Hague and Utrecht. The municipalities of these four cities are stakeholders within the research project and have the role in the process of providing data, indicating problem areas from their point of view and respond with feedback on design solutions and strategies. In this section the methodology and the selection of case studies is further explained.

The case studies presented in this section provide insight in the type of adaptation measures that are fit for a certain microclimate category. For each category at least two neighbourhoods are analysed and elaborated with a design solution or strategy. In Table 8.4 the case studies are presented in an overview with the neighbourhood typology and microclimate category as explained in the previous section.

Typology		**Microclimate category**			**neighbourhood 1**	**neighbourhood 2**	**neighbourhood 3**
		height	**urban block**	**green**			
Post-war garden city low-rise	'45-'55	low	open	moderate to much green	Slotermeer, Couperusbuurt *Amsterdam*	Watergraafsmeer Jeruzalem* *Amsterdam*	
Garden town	'10-'30		closed	moderate to much green	Tuindorp, *Utrecht*	Tuindorp Nieuwendam* *Amsterdam*	Tuindorp Oostzaan* *Amsterdam*
Residential housing	'30-'40			little green	Ondiep *Utrecht*	Transvaal *Den Haag*	Rivierenwijk *Utrecht*
Sub-urban expansion - Vinex	'90-'05			moderate green	Leidsche Rijn, *Utrecht*	Ypenburg* *Den Haag*	
Community neighbourhood	'75-'80		strokes	little to moderate green	Lunetten *Utrecht*	Zevenkamp* *Rotterdam*	
			spread				
		middle-high	open				
Historical city block & pre-war city block	before 1910 '10-'30		closed	little green	City Centre, Geertebuurt *Utrecht*	Bergpolder-Zuid *Rotterdam*	Zuidwal *Den Haag*
			strokes				
			spread				
Post-war garden city high-rise	'50-'60	high	open	moderate to much green	Overvecht *Utrecht*	Kanaleneiland *Utrecht*	Schiebroek Zuid *Rotterdam* jaren 60
			closed				
			strokes				
			spread				
		high-rise	open				
			closed				
			strokes				
High-rise city centre	'60-present		spread	little green	Station area, *Den Haag*	Lijnbaan* *Rotterdam*	

** this neighbourhood is analysed only on urban surfaces, no location specific adaptation options are proposed*

TABLE 8.4 Selection of case study neighbourhoods based on microclimate categories

As can be seen in the Table above, the categories have two or three case studies. The aim in the beginning of the study was to select at least two neighbourhoods for all categories to come to a stronger general conclusion. However, due to a limit in time and collaboration and education possibilities not all neighbourhoods are elaborated with a design. Therefore, general conclusions about these microclimate categories should be read with this limitation in mind.

As inevitable in conducting practical case study research, there are unpredictable factors determining the course of the process. As a result, the case studies differ in size, the presented section of a neighbourhood does not always exactly match the area presented in the design solution(s) and there is quite some difference in the elaboration detail of the design solutions. These inequalities are a result from the different ways the design solutions are developed. Some case studies are done by the author, some by students (MSc, BSc and grammar school) and others by colleague researchers of the CPC programme. However, the area chosen for the analyses of the land and urban surfaces always is a representative section with, for example, a representative amount of green at the border and a homogenous or mixed building type. Already with the development of castles and its community and facilities the occupancy and land use of this type was very characteristic (Tummers & Tummers-Zuurmond, 1997). In Figure 8.2 the castle and the surrounding formal gardens and buildings are shown. In Table 8.5 the case study details are presented.

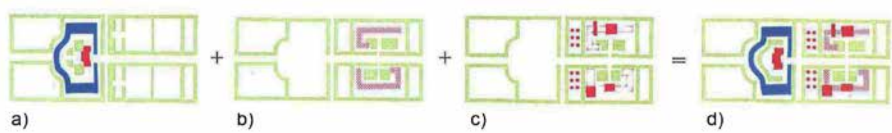


FIGURE 8.2 The castle within the formal garden (a), plus the dwellings for the castle community (b), plus the facilities (c), together form the characteristic castle typology (d) (Tummers & Tummers-Zuurmond, 1997).

SECTION	NEIGHBOURHOOD	CITY	AREA IN HA	LEVEL OF DETAIL	TYPE OF DESIGNER
6.2.1	Slotermeer, Coupe-rusbuurt	Amsterdam	27	location specific design proposal(s)	urban designer/re-searcher (author)
6.2.2	Watergraafsmeer, Jerusalem	Amsterdam	30	not applicable	
6.3.1	Tuindorp	Utrecht	55	general ideas for microclimate category	
6.3.2	Tuindorp Nieuwen-dam	Amsterdam	47	not applicable	
6.3.3	Tuindorp Oostzaan	Amsterdam	56	not applicable	
6.4.1	Ondiep	Utrecht	49	elaborate neigh-bourhood design	urban designer/re-searcher (author)
6.4.2	Transvaal	Den Haag	82	elaborate neigh-bourhood design	urban designer/re-searcher (author)
6.4.3	Rivierenwijk	Utrecht	77	location specific design proposal(s)	Msc students land-scape architecture
6.5.1	Leidsche Rijn, Parkwijk	Utrecht	42	location specific design proposal(s)	Msc students land-scape architecture
6.5.2	Ypenburg	Den Haag	57	not applicable	
6.6.1	Lunetten	Utrecht	127	location specific design proposal(s)	students Lyceum
6.6.2	Zevenkamp	Rotterdam	124	not applicable	
6.7.1	Centrum, Geertebuurt	Utrecht	19	location specific design proposal(s)	Msc students land-scape architecture
6.7.2	Bergpolder Zuid	Den Haag	38	general ideas for microclimate cat-egory and location specific design proposal(s)	researchers CPC
6.7.3	Zuidwal	Den Haag	51	location specific and neighbour-hood design(s)	urban designer/re-searcher (author)
6.8.1	Overvecht	Utrecht	43	location specific design proposal(s)	Msc students land-scape architecture
6.8.2	Kanaleneiland	Utrecht	67	location specific design proposal(s)	Msc students land-scape architecture
6.8.3	Schiebroek-Zuid	Rotterdam	69	location specific design proposal(s)	urban designer
6.9.1	Station area, Uile-bomen	Den Haag	29	location specific design proposal(s)	urban designer/re-searcher (author)
6.9.2	Lijnbaan, Cool	Rotterdam	61	not applicable	

TABLE 8.5 Case study details, including: size, level of detail and type of designer per case.

In the following sections, the microclimate categories are discussed individually. There is a brief description of the level of heat accumulation and its causes in these neighbourhoods. Including an indication of the ventilation and solar radiation load due to the height-to-width ratio (H/W ratio) of street canopies and inner courtyards and green elements. In addition, the type of green and the public and private character of green is discussed. The general introduction of microclimate categories are followed by practical case studies. Each case study is introduced based on its location in the city and an analysis of the relation of natural and stony land surface and urban surface. The latter urban surface analysis, adds an important dimension: the included vertical surfaces receive a lot of radiation due to the relative low sun angle in the Netherlands. Transforming these vertical surfaces have a large effect and therefore should be visible in the relation stony versus natural before and after the transformation. After this short introduction one or more design solution(s) are presented. The individual case studies are summarized in a general discussion about the applicability of measures and the most appropriate measures for that particular microclimate category.

§ 8.2 Low open urban block with moderate to much green

The garden city has a particular urban plan that breaks with the traditional urban block in which the inner courtyard is private property, Figure 8.3. There are several variations of urban blocks in the low-rise neighbourhoods, such as the L-shaped blocks that form semi-enclosed squares, but also straight strips. Entrances of dwellings are situated at both the outside and inside of the blocks. The strip buildings often have a park along the back side. The streets between the blocks have an average width of 15 meters. The inner courtyard has a size of 40 * 60 meters and is surrounded by buildings of two layers and a roof, inside the inner courtyard winds a public road. The H/W ratio is thus between 0.6 and 0.3. The open interior without fences and predominantly grass provides a better ventilation.

FIGURE 8.3 Example of a low open urban block with moderate to much green in West Amsterdam.

§ 8.2.1 Couperusbuurt, Amsterdam

The Couperusbuurt is part of Slotermeer on the West of Amsterdam. It's garden city roots very well emerge looking at the land surface cover in Figure 8.4. Almost half of the area has a natural surface, which is a large achievement definitely taking into account the quite high Floor Space Index (FSI) of 0.6 due to the six layer buildings at the South-East part of the area. The facades form a relatively large part of the stony surface.

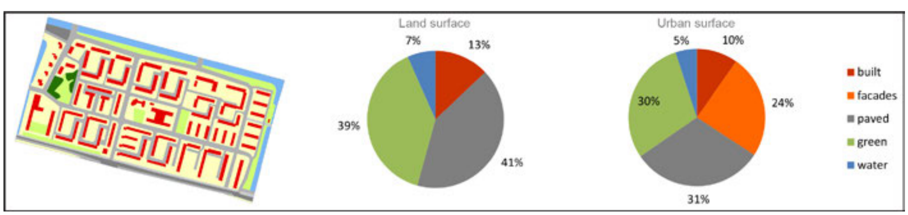


FIGURE 8.4 The relation between stony and natural surfaces in the Couperusbuurt neighbourhood, Amsterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The neighbourhood is on the list of the municipality for redevelopment. Dwellings need to be upgraded and, as an extension of the upgrade, also the amount of parking places should increase. There are several ways to achieve this goal, however, the most apparent option is to use the inner courtyards. Chapter 5 describes the simulations and results of the effect of this change in function. Figure 8.5 shows an impression of a situation in which the courtyard is used for parking without a decrease in thermal comfort. This can be achieved by planting trees in the middle, using permeable concrete grass tiles and changing the roof colour to light and reflective and the façade colour to a middle-dark tint.

FIGURE 8.5 Above: existing semi-public inner courtyard. Underneath: Adaptation measures which improve thermal comfort and increase parking space are light roofs, middle-dark facades, additional trees and permeable pavement with grass.

In the proceeding chapter, section 9.2, the strategy for the Couperusbuurt is elaborated further. An important feature of the strategy is determining an appropriate additional user function of the inner courtyard to increase the value for both residents and passers-by. For a more sustainable water system the courtyards could additionally function as water retention and infiltration points. The small apartments could be transformed into more spacious dwellings without decreasing indoor and outdoor comfort by taking into account solar access. As a result of the transformation from two apartments into one-family houses the need for additional parking space is reduced drastically. As part of the redevelopment strategy energy opportunities such as solar panels or seasonal storage will increase the real estate value and lifespan.

§ 8.2.2 Jeruzalem, Amsterdam

The Jeruzalem neighbourhood is situated in a polder named Watergraafsmeer and was constructed directly after the second world war. Compared to Couperusbuurt this neighbourhood has somewhat more built surface and less open water. However, the relation between stony and natural urban surfaces is very similar, see Figure 8.6. The achieved FSI in this neighbourhood is with 0.4 a bit lower compared to the Couperusbuurt because Jeruzalem has more two storey buildings.

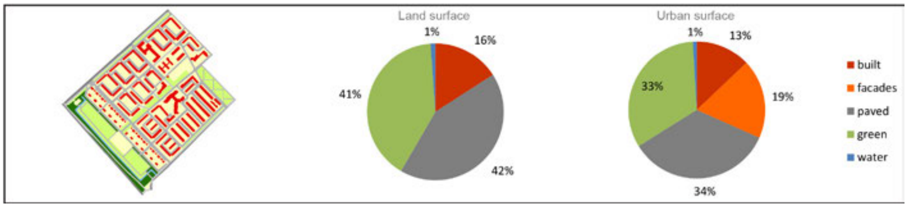


FIGURE 8.6 The relation between stony and natural surfaces in the Jeruzalem neighbourhood, Amsterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with the other garden city. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion at the end of this section.

The garden cities have sufficient green space and the challenge is to preserve this. However, when redeveloping these areas especially this green is in danger of disappearing. In the garden cities most of the green is semi-public and managed by the municipality, this is in contrast to the garden towns presented in the preceding section where the green is predominantly private area. Often the quality of the semi-public green is low and there are few functions linked to the green. This could be part of the solution: by improving the quality of the green and linking multiple functions to it the value of the green will increase and it will not simply be dismissed.

The semi-public inner courtyards have a green meadow in the middle of about 30*50m. The functions linked to this area cannot be confined to residents only because it would blur the public character. Even so, public functions are not in place either because the residents can experience that as an infringement of their privacy. After all, it concerns their backyard. When a social function of peaceful nature and attracts just a small number of people at the same time it will give less friction. For example a route to walk the dogs, water storage, butterfly and bee gardens, fruit and nut orchards, etc.

§ 8.3 Low closed urban block with moderate to much green

In the garden town you will find mostly single-family homes with two to three building layers. The streets have a sufficiently width of about 15-20 meters that offers place for front gardens on both sides of the street, see Figure 8.7. The inner courtyards have an average width of 25 meters, here the aspect ratio is 0.6 to 0.36. In these streets, the green in the front possibly has a lot of influence on the air flow, it may slow down the wind.

FIGURE 8.7 Example of a low closed urban block with moderate to much green, Tuindorp neighbourhood, Utrecht.

In this type of neighbourhood, there is only a moderate risk of heat stress because there is a lot of greenery in general. However, this green is mostly situated in the private front and back gardens. Therefore, the most important focus here is maintaining the private green. The current trend of paving extensive parts of the garden will have more impact here than in other neighbourhoods where many municipal green is present in the streets. The strategy in these neighbourhoods may include the promotion of greenery in private gardens and the addition of street trees in strategic locations.

§ 8.3.1 Tuindorp, Utrecht

Situated at the North side of the city centre of Utrecht Tuindorp is a very popular neighbourhood, only separated from the historical city centre by the Griftpark. The neighbourhood has a typical relation between green, paved, built and facade surface as well as a common FSI for this category of 0.5, see Figure 8.8.

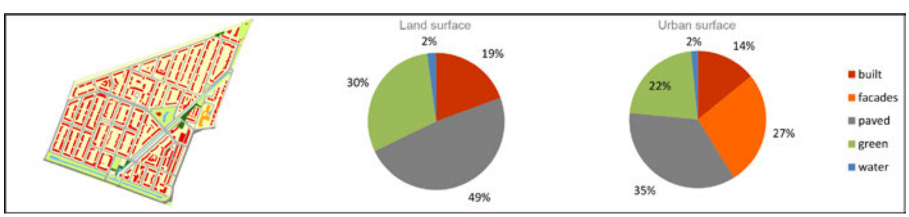


FIGURE 8.8 The relation between stony and natural surfaces in the Tuindorp neighbourhood,Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The relatively large amount of green in the garden town is not due to municipal green. In Figure 8.9 the black hatched areas indicate municipal green. All other green is privately owned in the front and back gardens attached to dwellings. To stimulate house owners to plant a tree the municipality could offer to plant an almost mature tree for free. A variety of tree species to choose from will give people the feeling of self-control and increases the biodiversity in a street canopy. Figure 8.10 shows an example of a tree in a front garden in Tuindorp Utrecht.

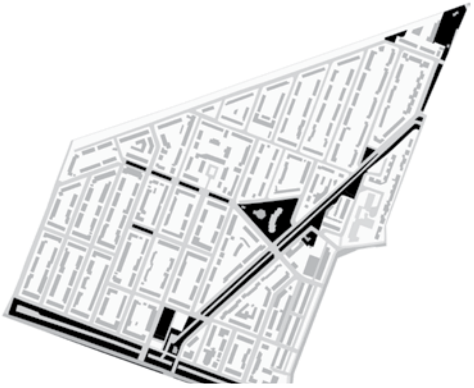


FIGURE 8.9 The black hatched areas indicate municipal green and water.

FIGURE 8.10 A large tree in the front garden compensates lack of trees in the street.

Since there is almost no municipal green in the street canopies infiltration of rainwater has to be realised on or under the road and sidewalks or in the private gardens. The latter option could be feasible in this garden town because people are rather engaged with their gardens. Encourage people to act through a discount on the water tax when all rain water from their lot is infiltrated and provide them with inspiring examples.

For the road permeable pavement is an option to increase infiltration, however, this does not prevent nuisance with heavy rainfall events and is not a visible element. It is important people can see water treatment devices to increase their awareness and engagement. An alternative option to cope with the water is to install infiltration units with a large storage capacity along the sidewalks. Water is temporarily stored here, and while infiltrating into the ground the water is purified with a filter. Still, an overflow to the sewage is needed for the extreme rainfall events. Instead of the overflow the choice can be made to accept water nuisance on the street for the few occasions this happens. In this neighbourhood streets are lower than the sidewalks and front gardens which prevents water to flow inside basements and front doors. The overflow to the sewage can also be an intermediate solution until most private gardens do not discharge their rainwater to the street and sewage. Figure 8.11 shows an impression of possible water storage and infiltration units.

1

2

FIGURE 8.11 Existing street (1) and impression of water infiltration units (2).

§ 8.3.2 Tuindorp Nieuwendam, Amsterdam

On the North-East side of Amsterdam Tuindorp Nieuwendam is surrounded with parks and large water bodies. As presented in Figure 8.12 the percentage of green is similar to other garden towns, whilst the direct surroundings comprise a lot of green and therefore a large cooling potential. Because the Schellingwouderbreek lake partly belongs to the neighbourhood the area of water is relatively large. The FSI of 0.4 does not deviated a lot from the other garden towns.

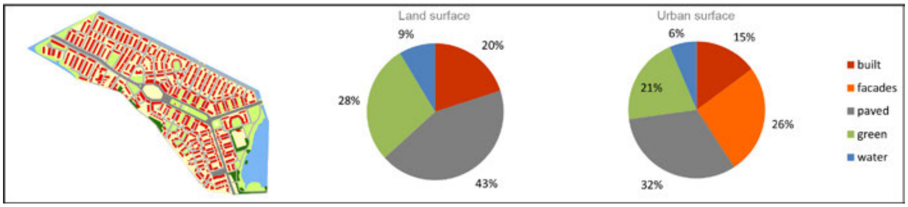


FIGURE 8.12 The relation between stony and natural surfaces in the Tuindorp Nieuwendam neighbourhood, Amsterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with the other two garden towns. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion at the end of this section.

§ 8.3.3 Tuindorp Oostzaan, Amsterdam

Tuindorp Oostzaan is also situated at the North of Amsterdam, but more to the West. This neighbourhood is not surrounded by parks and water bodies just as with Tuindorp Nieuwendam. However, it is within close distance to the rural polder area. As the previous two garden towns, also Tuindorp Oostzaan has a typical relation between green, paved, built and facade surface as well as a common FSI of 0.5 for this category, presented in Figure 8.13.

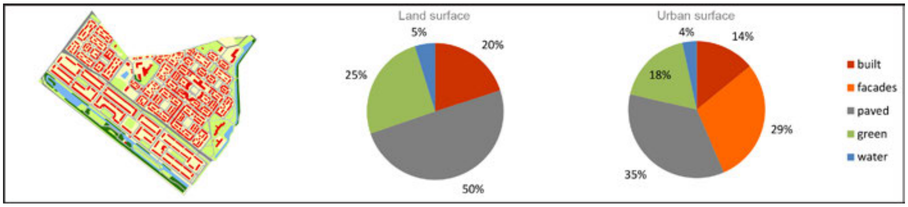


FIGURE 8.13 The relation between stony and natural surfaces in the Tuindorp Oostzaan neighbourhood, Amsterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with the other two garden towns. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion below.

As is the case with the garden cities, the garden towns have sufficient green space and the challenge is to preserve this. The difference with the garden cities is the owner of green: in the garden cities the major part of green is private. Strategies should be aimed at private owners to conserve green. Promoting green in a subtle manner is to inspire people and to create awareness about the importance and benefits of green. Another option is to offer trees, hedges or plants for free to the inhabitants. Through the water board or council tax charges can be adjusted to the degree of pavement in gardens, or charge less taxes when rainwater is collected and infiltrated on site.

§ 8.4 Low closed urban block with little green

The urban residential areas with single family houses of two to three layers are characterized by the relatively narrow streets with little greenery, see Figure 8.14. The streets have an average width of 10 m, where the many parking lots leave little room for street trees. The H/W ratio of the streets is 0.9 and 0.6 and of the inner courtyards 0.4 to 0.6. This provides only limited ventilation and is particularly a problem in the streets with heavy traffic. Front gardens and backyards are paved to a great extent. The total amount of paving in this neighbourhood category is very high.

FIGURE 8.14 Example of a low closed urban block with little green, Heesterbuurt and Transvaal neighbourhood, The Hague.

§ 8.4.1 Ondiep, Utrecht

Ondiep is a working class neighbourhood situated along the river Vecht at the North side of the city centre of Utrecht. As presented in Figure 8.16 Ondiep is a very stony neighbourhood with over 3/4th of hard surface. In this category the percentage of green is not even that low because of the sport fields at the border of the area. The FSI varies a lot within this category, depending on the building height. In Ondiep the FSI is 0.4 with on average two to three building layers.

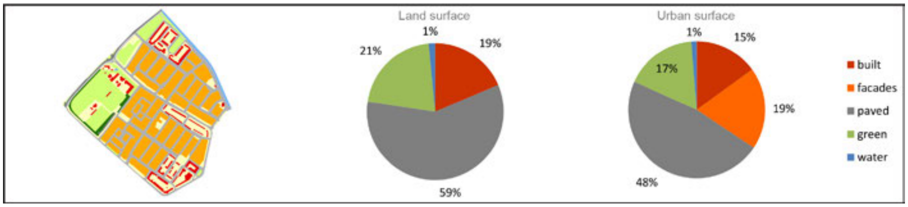


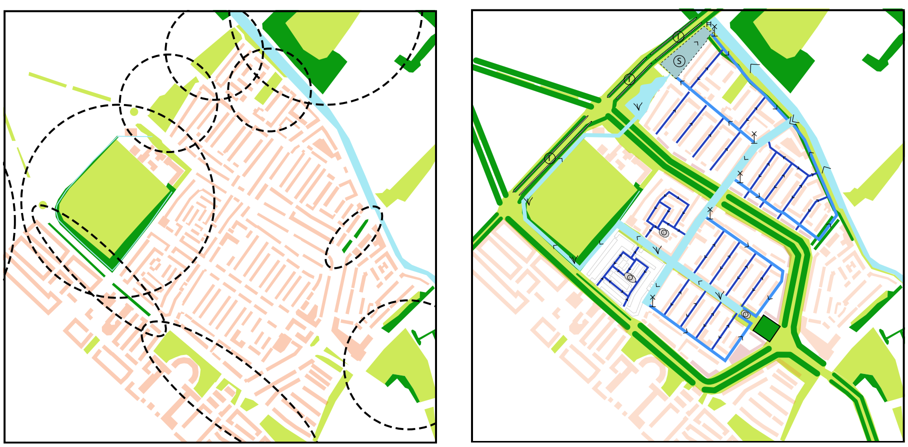
FIGURE 8.15 The relation between stony and natural surfaces in the Ondiep neighbourhood,Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The case study Ondiep is done parallel to the case study Transvaal, the latter one will be described in the following section 8.4.2. Based on an extensive literature review, design criteria were formulated to enable an assessment of the designs. The criteria are the following:

- All dwellings are to be situated within 200m from a green area with a minimum size of 0.15 ha;
- The preferred street orientation is perpendicular to green areas;
- Green filter are to be placed in streets with a high traffic pressure;

- New dwellings should replace an equal amount of dwellings or more, but with a larger dwelling surface;
- Combinations of green with water should be made where possible;
- A lack of greening possibilities in streets should be compensated with surface water, green façades and permeable pavements;
- Flat roofs should be transformed to green roofs or be covered with a reflecting light surface;
- Slanted roofs should have PV-T panels or a reflecting light surface.

Considering the criterion 'all dwellings are to be situated within 200m from a green area', a large part in the middle of the neighbourhood does not meet this standard in the current situation, see Figure 8.16. The design plan for Ondiep is based on improving the routings with green zones and waterways in combination with other heat diminishing measures. Important for the renovation plan is to keep the demolition of dwellings to a minimum.



1 2

FIGURE 8.16 *1*. Green in Ondiep with a circle of 200 meters from the green; 2. Design for green zones and an integral water system.

The building plan for Ondiep provides more space for green along the main route by transforming closed building blocks along this route into single buildings with two additional layers. In this way, both the amount of living space and the H/W ratio is preserved.

The additional green along the main routes, has an important cooling function, but also needs to filter out air pollution. This is illustrated in Figure 8.17 deciduous trees are placed close to the buildings because they let through sunlight in winter and coniferous trees keep their air filtering capacity year round. A water storage under the pavement provides trees with water to keep their cooling capacity during dry periods. The other green zones have a more intimate and quiet character, these improve thermal comfort, offer more recreational space and routings.

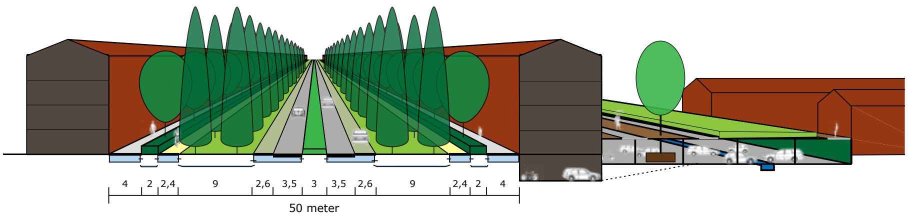


FIGURE 8.17 Section of the car and bus route through the neighbourhood.

In the design for Ondiep the main function of water applications is to supply trees with enough water to maximise their cooling capacity. Additionally, the water that runs through the streets absorbs heat. An integral water plan is calculated to incorporate other aspects of a sustainable water system; the dwellings discharge all wastewater, except for toilet flushing, onto the surface water where helophyte plants clean it. The water system has a fluctuation of 800 mm to deal with heavy rainfall. Seasonal storage and water supply for trees and households is all taken into account in the space needed for storage.

Water needs to circulate in order to preserve a good quality. Water also demands a lot of space, especially when the edges need to be natural slopes. In many streets this space is simply not available. However, there are other possibilities; for example lift the water up to street level. This so called 'shallow water' has to be pumped up from the surface water to a shallow canal, that in this way, ensures a water circulation. Rainwater from roofs and pavement streams into a drain at surface level and is collected in the shallow canals.

The design plan for the Ondiep neighbourhood shows how the design criteria can be applied in a practical situation. The applied measures might not be the most effective ones with regard to minimizing heat accumulation, but the best in relation to the existing spatial situation and the impact on social and financial aspects.

The literature review, methodology and the adaptation strategy for Ondiep and Transvaal were published in 'How to make a city climate-proof, addressing the urban heat island effect' (Kleerekoper et al., 2012) and 'A Heat Robust City. Case study designs for two neighbourhoods in the Netherlands' (Kleerekoper et al., 2011). A detailed description of the neighbourhood design can be found in 'Design principles for Urban Heat Management in the Netherlands' (Kleerekoper, 2009).

§ 8.4.2 Transvaal, The Hague

Transvaal has a central location in the city The Hague. Within this category with little green the percentage of green is even lower: only six percent of the total urban surface is natural surface. Interesting in the relation between pavement, roofs and facades is that they all have an equal share of about 30% which comes close to the category of middle-high closed urban blocks with little green in the historical city centres, see Figure 8.18. In line with the large façade surface, also the FSI of 1.8 is the largest within this category.

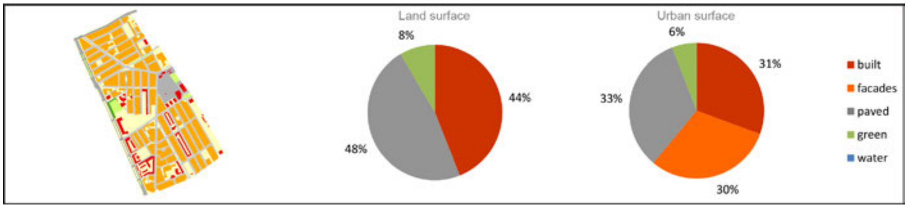
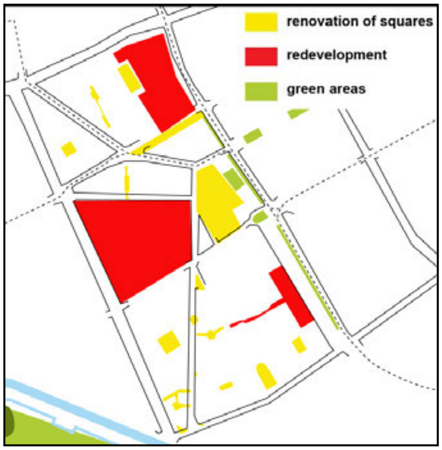


FIGURE 8.18 The relation between stony and natural surfaces in Transvaal in The Hague, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The case study Transvaal is done parallel to the case study Ondiep, described in the previous section 8.4.1. Ondiep and Transvaal are both constructed in the same period. Both have social issues, but there is an essential difference. The dwelling density in Ondiep is quite high: 44 dwellings per hectare. However, this is low in comparison to Transvaal where 98 dwellings occupy a hectare. As for the more lively and multicultural Transvaal neighbourhood, another approach is chosen to test if the design principles are generically applicable. There is a high pressure on public space, quite some litter on the streets and hardly any green except for some lonely young trees, in Figure 8.19 the green space are indicated next to the squares and redevelopment areas.

1



2

FIGURE 8.19 1. Green in Transvaal with strategic renovation plan; 2. Transvaal with green squares, green roofs, new building typology in the middle and the water system. .

In Transvaal the renovation process has already started with the main square and some housing projects. The new square is working quite well in social respect, but in terms of heat accumulation it is a missed chance. Especially regarding the name of the square, 'Wijkpark' (district park), you would expect much more green. The most cost-effective measure for this square is to maintain the layout and to fill the large paved open space with water and add water jets that switch on when it is a warm day.

In the rest of the neighbourhood there are many stony open spaces. Streets have no green, no front gardens, just pavement and cars. The little green in the squares is too tiny to hold out against the intense (ab)use. As a consequence squares are designed with only stony elements and have no shelter from sun, wind or rain. These areas can become cooling islands if they are designed with more green, water and shading. There are quite a lot of little squares spread over the whole neighbourhood. More than 95% of the buildings have a flat roof, which creates the potential to form a green roof landscape. When the measures of greening the squares and creating green roofs are combined the area will meet the criteria '200m from green'. An extra advantage of roof gardens in this neighbourhood is the creation of more outdoor living space. The integral design is presented in Figure 8.19.

In addition to green roofs and extra vegetation on squares there is an excellent solution for this busy neighbourhood in green facades. There are some alleys cutting through building blocks that can transform into an oasis of peace - surrounding the citizens with green and flowering walls.

At the South-East side a building block will be demolished to create space for a public park. A green walkway cutting through building blocks connects the rest of the neighbourhood to the park and the Haagsche market. The demolished dwellings will be compensated for at the North side of Transvaal that is now a pavement desert with some industrial activities. The current activities like paper recycling, a bakery, etc. do not conflict with dwellings. The ground floor space will mainly be occupied by these light industrial activities, and on top of this layer seven storeys with apartments with a view over the green roof landscape are added. . The new apartment buildings have a green façade (a vertical garden) so that they become part of the green roof landscape.

In Transvaal, the introduction of water connects the *Zuiderpark* at the South with a canal in the North. Just like in Ondiep there is not enough space for the implementation of surface water. Here too the water is pumped up into shallow canals, but the canals are not as wide as in Ondiep and do not run through grass but through paved surface, see Figure 8.20 for two examples. At crossings and busy areas the canal is covered with a decorative grill. The shallow canals lead the water to some squares along the main street where it is pumped up by fountains or other water elements.

1 *2*

FIGURE 8.20 *1.* Shallow water in commercial street Amiens, France; 2. Shallow water in Park 't Loo, Apeldoorn, The Netherlands.

A part of the middle of the neighbourhood will be demolished and newly built. This brings the opportunity to reserve space for seasonal water storage that allows trees to cool at their maximum. The new structure of the site differs a lot from the rest of Transvaal. Instead of closed building blocks apartment buildings of three to four storeys high are surrounded by deciduous trees, allowing sunlight through in winter and shading facades and windows in summer.

TOC

§ 8.4.3 Rivierenwijk, Utrecht

Rivierenwijk is again a working class neighbourhood situated at the south of the city centre of Utrecht. More than 80% of the urban surface is stony material, conform this category, see Figure 8.21. However, this neighbourhood has a relatively low percentage of façade surface because the buildings only have one to two layers. Therefore, also the FSI of 0.2 is low for this category.

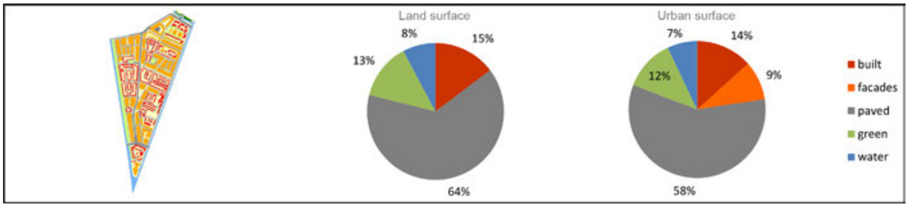


FIGURE 8.21 The relation between stony and natural surfaces in the Rivierenwijk neighbourhood, Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

Rivierenwijk is a neighbourhood with low closed urban blocks with little green. Compared to Ondiep and Transvaal the streets have somewhat more small trees and the buildings have more aesthetical value. Therefore rigorous redevelopments would affect the attractive neighbourhood characteristics. Instead smaller interventions are more appropriate, such as, removing tiles along the facades for flowers or climbing plants, green facades, change the type of pavement to permeable and light coloured and improve dwellings with larger overhangs and roof insulation. See Fgure 8.22 for an impression.

1

2

FIGURE 8.22 1: existing situation Geulstraat in the Rivierenbuurt neighbourhood, Utrecht; 2: impression of the street when tiles are removed for plants and additional pedestrian space is created by removing the parking places at one side of the street.

Rivierenwijk has an additional asset that can contribute to alleviate heat stress. Along the West side of the neighbourhood runs the Merwede canal with a long stretched green belt, the Merwedeplantsoen. However, the space is not used as such by the inhabitants because of the bad accessibility and because housing boats close off the view on the canal. Figure 8.23 and 8.24 show a plan that opens up some spots along the water where a path or a platform facilitates extra experience of the water. The same path provides an attractive routing through the green without disturbing the additional functions like a soccer field or sheltered place with seating's.

1

2

FIGURE 8.23 *1*. Neighbourhood border (dashed line) and the Merwedeplantsoen (dotted line); 2: the re-design of the green belt by Yuche Liu, WUR

1

2

FIGURE 8.24 1: Existing situation of the Merwedeplantsoen in the Rivierenbuurt neighbourhood, Utrecht; 2: impression of the re-design of the green belt by Yuche Liu, WUR.

The target measures in these neighbourhoods are tiny gardens along the facade, green facades, the type of pavement and parking solutions combined with a structure for climbing plants. Because of the many flat roofs at a low height in these neighbourhoods the roof surface can be used to improve thermal comfort at street level. By providing roofs with a white reflective coating solar radiation is reflected which prevents up heating on street level and contributes to a cooler indoor environment, especially on the top floor. Also green roofs with a sufficiently thick substrate layer contribute to cooling on both street level and indoor space. In addition, green roofs have a positive effect on rain water discharge, biodiversity, and extend the life of your roof. In case there is no possibility to add more green the generation of ventilation is especially important. This can, for example, be done by more height differences of the buildings or by using the principle of 'hot' and 'cool' places between which the air will be moving.

When a parking or mobility solution can be found which leaves more space in streets free, a double line of trees can be planted or trees at the side that receives most solar radiation. In some cases, trees as espaliers can provide a solution when the position of the tree cannot be placed far enough from a building wall. Many of these neighbourhoods do have green spaces in between or along the urban blocks. These green spaces can function as a cool spot where people seek comfort when the right facilities are present.

§ 8.5 Low closed urban block and strips with moderate green

In the latest expansion areas, called VINEX districts, there is more space in the street profile for green strips and trees, see Figure 8.25. The streets are on average 20 meters wide, with buildings of two to four and up to eight storeys. The average H/W ratio is 0.5, which means there probably is a moderate ventilation of the streets.

FIGURE 8.25 Example of a low closed urban block and strips with moderate green, Ypenburg district, The Hague.

§ 8.5.1 Parkwijk, Leidsche Rijn, Utrecht

Parkwijk-Zuid is a recent development in the Leidsche Rijn district on the West side of Utrecht. Even though the name presumes a large amount of green in the form of parks, the amount of green does not match the garden towns nor garden cities presented in sections 8.2 and 8.3. The large amount of pavement as shown in Figure 8.26 can be attributed to few green in the street and private gardens. The FSI is 0.4 which is a normal average for single-family row houses.

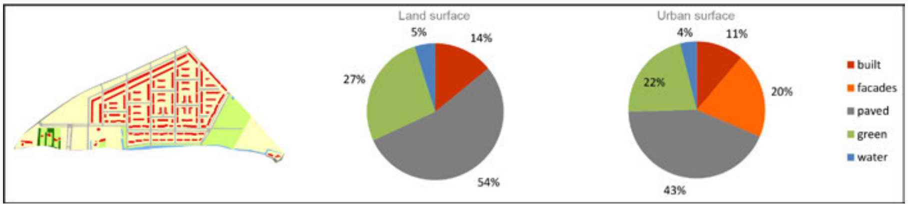


FIGURE 8.26 The relation between stony and natural surfaces in the Parkwijk neighbourhood of the Leidsche Rijn district in Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

With Leidsche Rijn Utrecht made a step over the large barrier with the Amsterdam-Rijnkanaal and the A2 highway in 2006. In 2014 the area had grown to 28.700 inhabitants. Due to stagnating housing prizes from 2008 the projection of 80.000 inhabitants will not be achieved soon. By the time it has, Leidsche Rijn will cover about 25% of the inhabitants of the city Utrecht. The aim is to connect the Leidsche Rijn with the city centre by a one kilometre long roof park over the highway, see the impression in Figure 8.27.

FIGURE 8.27 The Leidsche Rijn roof park designed by DS Landschapsarchitecten (destadutrecht.nl 2012).

Between the roof park and the Amsterdam-Rijnkanaal there is space for the development of new dwellings. This new area can profit from the microclimate qualities of both, the park and the water front. A boulevard along the water would provide a scenic route to the city centre for inhabitants in the Leidsche Rijn, a fresh stroll for people living in the new area and a new experience of their city for people living on the other side, see Figure 8.28 for an impression.

FIGURE 8.28 Boulevard along the Amsterdam-Rijnkanaal by Rosanne Schrijver, WUR (Schrijver et al., 2014).

Because Leidsche Rijn is such a large new area a community needs to be founded. Functions such as playgrounds, sport fields and recreation are accommodated for throughout the whole area. These places are for everyone to make use of, however, a location where people can develop something together is not foreseen yet. The central location of the Prinses Amalia Park is a perfect location to improve the sense of community through urban agriculture. Figure 8.29 shows a way of organizing such an initiative.

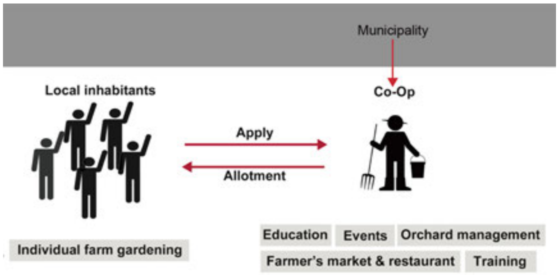


FIGURE 8.29 Urban agriculture as basis for a local community by Changsoon Choi, WUR.

The park has special restrictions due to archaeological remains, this is translated in only grass field in the present situation. These underground conditions can also provide a structure for a varied landscape: some places are fit for fruit trees, others only for allotment gardens with additional soil protection and others for local farmer's market, restaurant and events, see Figure 8.30 for an impression. Adding trees contribute to the microclimate conditions in the park and drawing on people to spend their time here will improve their thermal comfort perception.

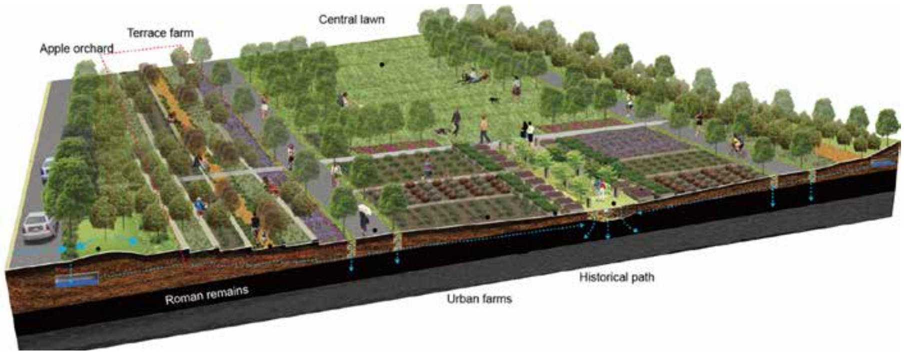


FIGURE 8.30 Boulevard along the Amsterdam-Rijnkanaal by Changsoon Choi, WUR.

§ 8.5.2 Singels, Ypenburg, The Hague

Singels is part of the new development area on the North-East of The Hague, named Ypenburg. This neighbourhood lives up to its name and has a single encircling the neighbourhood. In this neighbourhood the green areas are more spread through the area than in Parkwijk presented in the previous section. However, the amount of green within the street profile and private gardens is very similar, see Figure 8.31. The FSI is lower compared to Parkwijk because on average buildings have one floor less.

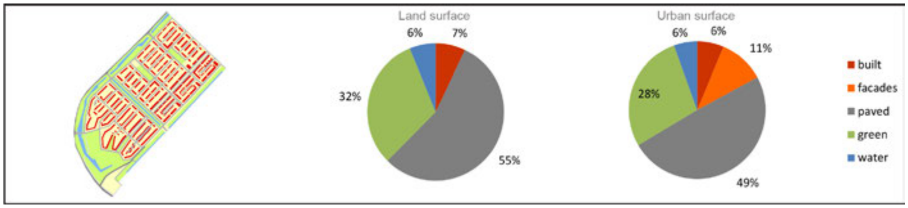


FIGURE 8.31 The relation between stony and natural surfaces in the Singels neighbourhood, in the Ypenburg district of The Hague, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with the other VINEX neighbouhood. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion below.

The VINEX districts are usually designed with more attention for greenery and water. In particular between quarters and along roads there is a lot of greenery and water, but also the residential streets have a single or double row of trees. Nevertheless, the degree of pavement is quite high because of the many parking lots, and above all the lack of trees in the private gardens which are paved to a large extend with dark anthracite tiles. In fact, a similar approach is needed as for the garden towns: inspire people and create awareness about all benefits and important functions green has to offer. Think of a way to stimulate planting additional green by distributing trees, hedges or plants for free, or adjust water board and council tax charges to the degree of pavement in gardens or collecting rainwater on site.

§ 8.6 Low strips and open urban blocks with little to moderate green

In the community neighbourhoods (in Dutch referred to as cauliflower neighbourhoods) streets have an average width of 18 meters with an inner courtyard of about 35 meters. Buildings have 2 to 3 floors, which gives a H/W ratio of 0.5 to 0.3. This results in somewhat more ventilation and more green than in urban residential neighbourhoods described in section 8.4. With the establishment of the neighbourhood many green strips of grass, trees and / or shrubs were designed. Dwellings often have a front garden, the private back gardens are relatively small, which leaves space for a shared courtyard, see Figure 8.32. Here, too, the trend of extensive paving is clearly visible. The distinctive design of the cauliflower neighbourhood as with courtyards and secluded places provides a varied microclimate and no immediate risk of heat stress. Yet even here the emerging pavement is a threat for a comfortable microclimate. There have been coming lots of cars since the 1970s, when these neighbourhoods were developed. The once so charming streets and courtyards have been seized by the car.

FIGURE 8.32 Example of low strips and open urban blocks with little to moderate green, in Maarssen.

§ 8.6.1 Lunetten, Utrecht

Lunetten is a so-called 'cauliflower' neighbourhood situated on the South border of Utrecht. The neighbourhood has a green belt around it as a buffer between the houses and two highways. Due to this green belt the amount of natural surface in the neighbourhood is quite high, more than 40% as presented in Figure 8.33. In addition, green is also incorporated in the open urban blocks and between blocks. On the other hand, the space in the streets is mainly dedicated to the car. The FSI is 0.3 which is lower than average one-family dwellings. The low FSI can be explained by the large green belt around the area. This is a typical green structure for this typology (Ubink & Steeg, 2011). Within the green belt surrounding the dwelling area there are five forts dating from 1822 which are part of the famous Dutch water defence line. Water played an important role in the defence function of the forts. The challenge in Lunetten is to expand the possibilities to experience and use the green belt and to improve the direct surroundings of the dwellings that are very stony.

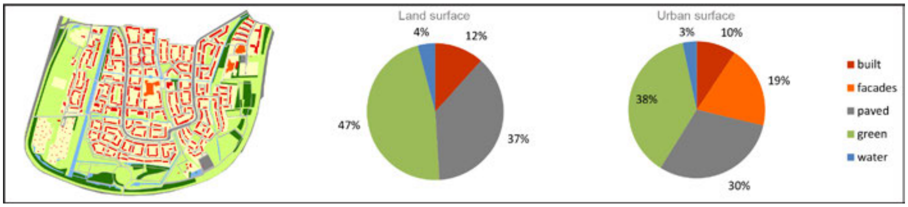


FIGURE 8.33 The relation between stony and natural surfaces in the Lunetten neighbourhood, Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The large amount of stony surface in the street canopies in this neighbourhood has to be reduced and replaced by green to improve the outdoor climate. The parking space for cars is hardly sufficient in the current situation. Therefore, additional green should to be combined with car parking or additional parking place elsewhere. There is a large variety in the organisation of parking around the building blocks. In Figure 8.34 an example is given of a car parking possibility just beneath ground level with a semi-public garden on top with picnic and BBQ facilities. The additional trees provide shading of the facades. In Figure 8.35 the street does not provide enough possibilities to combine additional trees and green with parking. To improve the local climate the parking zone is transformed in a lowered green zone with flowers where water infiltrates slowly. To compensate the parking places additional parking places are realised along the ring road (Figure 8.36). Here the parallel road is transformed in a double deck parking with green walls. Under the deck is only accessible for inhabitants that have a permit, on top of the deck visitors can place their vehicle. Figure 8.38 shows an impression of the ring road with additional parking.

1 *2*

FIGURE 8.34 1. Existing parking place; 2. Impression of combined parking and roof garden unit.

1 *2*

FIGURE 8.35 1. Existing street with parking; 2. Impression of a street with calm traffic due to a narrow trail next to grass tiles, wadi and street trees.

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2

FIGURE 8.36 1: Existing situation of the Simplonbaan in the Lunetten neighbourhood, Utrecht; 2: impression of additional parking on the parallel street.

FIGURE 8.37 Parking facility along the Simplonbaan to create space for green and water close to dwellings.

In the existing situation the green belt surrounding the urban blocks is used to stroll, bike, play sports, picnic, sunbathing and walking the dog. The water canals in this green belt provides a place to fish, swim, play with small boats and ice skating in winter. Thus for many the green offers a cool spot to spend leisure time. Nevertheless, the most vulnerable people, elderly and babies, have less access to the green because most paths are not wheelchair and baby stroller friendly. A solid routing through the green belt with many benches, fitness equipment for especially elderly and kids will increase the accessibility for this vulnerable group. Space for community activities is lacking in the existing situation. With fruit gardens with berries and fruit trees Lunetten can make their own marmalade and with a tent construction summer evenings with music, dance, pancakes and workshops can be organised.

In the heart of the neighbourhood a grass field functions as park, meeting place and soccer field. To improve the contribution of the park as cool spot for the inhabitants it can be transformed into a water square according to the designs of the Urbanisten (Boer et al., 2010) that have realised such a system on the Benthemplein in Rotterdam. Besides a cool spot, the water square for Lunetten is also a means to retain precipitation water. Retaining water and infiltrating it locally alleviates the sewage, canals and rivers in times of heavy rainfall. Moreover, it supplements the groundwater level which provides trees with sufficient water in dry and warm periods. The water square for Lunetten could be divided into two areas: a small playground that fills up with the first rain shower, a second large basin normally functions as a soccer field and transforms into a lake with persistent rainfall. Cools et al. (2015) show an impression of the water square in Figure 8.38.

FIGURE 8.38 Impression water square (Copyright scale model and photo: Cools, T., Gent, A. and Kools, V. (Cools et al., 2015))

To prevent overheating inside dwellings a relatively cheap and simple option is to paint the roof tiles white. When a roof is directed to the South, South-West or South-East PVT-panels (photovoltaic and thermal) can serve as shading device and roof cooling device (AIVC, 2013, by Vasilis C Kapsalis) at the same time. Windows should be equipped by flexible sunscreens and facades can be shaded by vegetation. The latter option provides cooling for both the indoor and outdoor climate.

§ 8.6.2 Zevenkamp, Rotterdam

The Zevenkamp neighbourhood is situated to the North-East of Rotterdam. The neighbourhood is separated by the highway A28 to the South and touches the Wollenfopperpark and the Zevenhuizerplas along the North side. The neighbourhood does not have such a large amount of green around the dwelling area as Lunetten in the previous section, but still a larger percentage of green than most garden towns have, see Figure 8.39. The FSI of 0.5 is common for one-family dwellings.

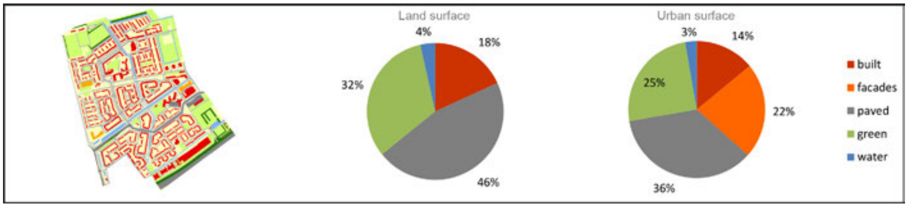

FIGURE 8.39 The relation between stony and natural surfaces in the Zevenkamp neighbourhood, Rotterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with Lunetten. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion below.

This type of neighbourhood mostly benefits from solutions that combines car parking with greenery and shading elements. Reducing the number of cars is not directly an option here because the neighbourhoods are often at a great distance from the centre. One could think of (electric) car sharing or parking on the edge of several building blocks. Thus when more space becomes available it can be used for additional playgrounds, more trees, rainwater harvesting and infiltration meadows. Also here white roofs and green walls can be used to improve thermal comfort.

§ 8.7 Middle-high closed urban block with little green

Historic city centres in the Netherlands have a high density and a lot of pavement in the public domain, see Figure 8.40. On the contrary, the inner courtyards are often an oasis of green and regularly contain large mature trees. Unfortunately, these courtyards are becoming more stony as well with terraces, parking or additional constructions.

TOC

This urban typology concerns in the Netherlands often a height of about 12 meters (3-5 storeys) with a street width of 5-12 m and a block width of about 30 meters. The inner courtyards are often packed for more than half with building extensions and sheds, which makes the height to width ratio vary. The H/W ratio between building height and width of the street and the inner courtyard is thus around 2.4 and 0.4.

FIGURE 8.40 Example of a middle-high closed urban block with little green, the historical city centre of Utrecht.

With a H/W ratio above 1.5 and a wind direction perpendicular to the street, there is almost no mixing between the air in the street and the layer above. Therefore the fresh air supply will be bad here. In the wider road sections, the air mixing is reasonable, this is also depending on the wind speed. Furthermore, the north-south oriented streets have sufficient shading in the morning and afternoon of the narrow street width. At noon, there is hardly any shadow because the streets offer little room for trees with a broad crown. East-west streets have a larger solar heat load on the facades facing south, it may heat up considerably, especially in the afternoon.

§ 8.7.1 City centre Utrecht

The historical city centre of Utrecht is relatively green for this category. 16% of natural urban surface, presented in Figure 8.41, is formed by the wide single with park around the centre, a canal through the centre and the inner courtyards which are relatively green. The façade surface covers most of the urban surface, which is a common appearance in this category. The FSI of 1.4 is a common density for city-centre neighbourhoods in the Netherlands.

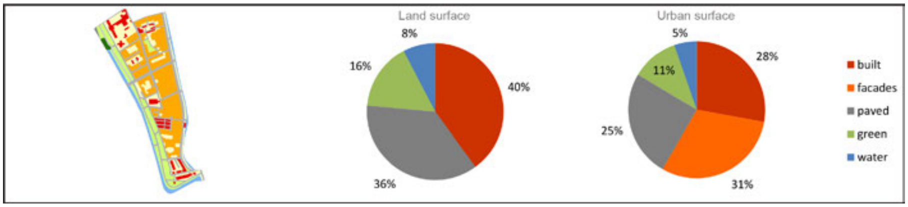

FIGURE 8.41 The relation between stony and natural surfaces in the Geertebuurt neighbourhood, Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

To get rid of accumulated heat in compact city centres ventilation in streets or squares can be increased. For the Vredenburgplein next to the central station in Utrecht three variants of solar chimneys are presented in Figure 8.42. A solar chimney generates a draft of air because the air in the chimney heats up and then rises. The first variant is a large central chimney that draws air from 4 directions, in the second variant multiple solar chimney are attached to the south façade and the third variant is a composition of smaller solar chimneys that have a very local effect and interact with each other.

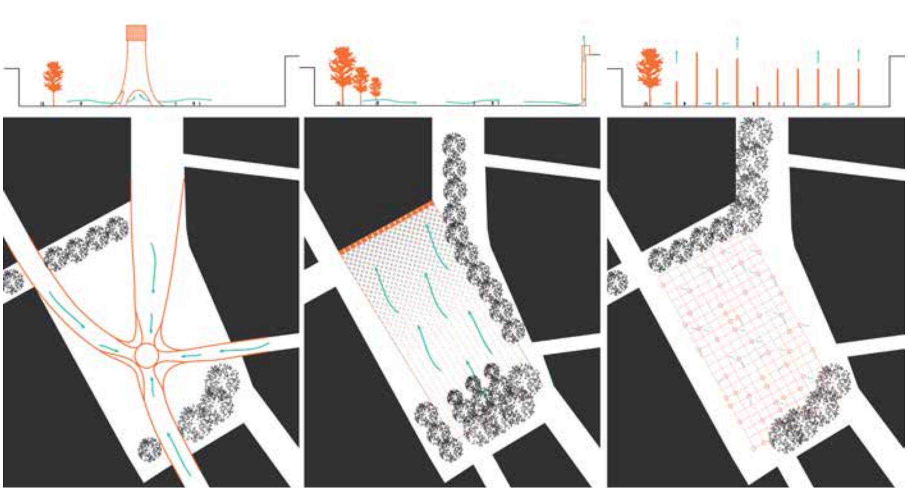

FIGURE 8.42 Three variants of ventilating solar chimneys by Vincent Peters (Schrijver et al., 2014).

For the design of the square the smaller individual poles offer the most opportunities. In Figure 8.43 and 8.44 the solar chimneys play a big role in the square composition, the poles also offer a structure for the market stalls and can include street lighting.

FIGURE 8.43 Vredenburghplein with ventilating solar chimneys by Vincent Peters, WUR.

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FIGURE 8.44 Impression of different use of the Vredenburghplein by Vincent Peters, WUR.

§ 8.7.2 Bergpolder-Zuid, Rotterdam

Bergpolder is a central neighbourhood in Rotterdam and part of Het Oude Noorden (the old northern part of the city). Almost 95% of the urban surface is hard stony material. The little amount of green presented in Figure 8.45 is mainly related to the lack of green in the street, private inner courtyards and very little park space. However, the official neighbourhood contour does not include the Bergsingel and the Bergselaan along the edges of the neighbourhood. These roads contain a broad green and/or water element. Although these are half the size of the single around the centre of Utrecht, they do balance out the relation between the urban surfaces closer to the values for the city centre of Utrecht. In addition, the FSI is the same for these two neighbourhoods, which is 1.4, and the façade surface is again the dominant urban surface.

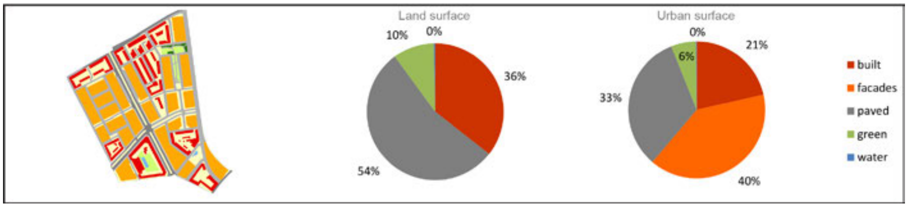

FIGURE 8.45 The relation between stony and natural surfaces in Bergpolder in Rotterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

Interesting about the neighbourhood is its feasibility and attractiveness for young people; more than half of the inhabitants is younger than 34 years. There actually is almost no possibility to stay within the neighbourhood once you form a family because of the small, relatively cheap apartments. The housing corporation Vestia and the municipality of Rotterdam have developed a master plan to improve the housing quality and increase the variety in housing stock for a better mix of inhabitants. The redevelopment also involves energy reduction, improvement of social functions, green and parking (Ginter et al., 2011). Figure 8.46 presents an illustration of additional green.

FIGURE 8.46 Illustrative image for additional green from the master plan (Ginter et al., 2011).

The CPC research programme, which is the overall project under which this thesis resides, selected this neighbourhood as an integration case where all projects could bring in expertise and add to each other's work. The additional studies for Bergpolder are described further in the following chapter, section 9.4.

§ 8.7.3 Zuidwal, The Hague

In The Hague the Zuidwal neighbourhood is a mix of historical dwellings and some post-war dwellings with many commercial activities. In Figure 8.47 the relation between natural and stony land and urban surface is presented. The neighbourhood has, with more than 95%, an even larger share of stony urban surface than the previous two cases in this category. And the share of the façade surface is almost 3/4th of the urban surface. In line with the more dominant façade surface the FSI of 2.8 is higher as well.

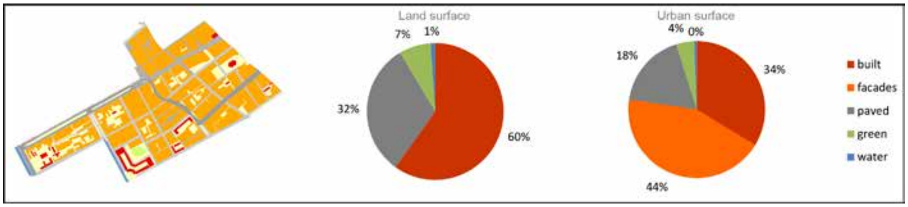

FIGURE 8.47 The relation between stony and natural surfaces in the Zuidwal neighbourhood, The Hague, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

In one of the central shopping streets of The Hague, the Grotemarktstraat, the outdoor climate is not regulated to provide a thermally comfortable place for shopping or passing through. However, applying measures is a big challenge: every square metre is occupied; on the ground, the facades, the underground and even in the air. Planting trees is extremely difficult due to the underground tunnel underneath and the lack of space on the ground floor. Even though cabling runs through because of the tram, high up in the canopy, space is still available. There already is a support system for Christmas decoration, with some additional attachment points, this could also held up canvas sheets to provide shade on hot sunny days.

In the proceeding chapter, section 9.3, the strategy for Zuidwal is elaborated further.

This typology is characterised by the great pressure on public space and limited options in historical or monumental buildings and protected townscapes. Where planting trees is extremely difficult because the parking pressure is too high or large numbers of shoppers and market stalls prevent this, there are other options that can provide for a better thermal comfort during hot days. Creating a comfortable environment can be critical for entrepreneurs and their business.

The opportunities to improve thermal comfort in this highly urbanised areas can be divided into temporary and flexible measures and into solid and robust measures. Temporary and flexible measures are for example canvas sheets above streets and plazas, the spraying of fine water droplets at pedestrian routes, watering the streets to reduce the radiant heat from stony surfaces, seating elements shaded in summer and protected from wind in winter and place elements that can generate ventilation during hot periods. By temporarily putting up canvas sheets above streets or squares the radiation load decreases. Canvas sheets are not suitable in streets with motorized traffic because the exhaust will be trapped in the canopy. The decrease of air circulation due to the canvas sheets is also in the evening a delaying factor in cooling down. This is not necessarily a problem if it is an area with mostly commercial functions. An additional advantage is that the canvas can protect against rain also. In addition, note that it is important to offer different microclimates within the neighbourhood. Therefore, be selective in the streets that are equipped with a canvas covering.

Among fixed robust measures are included pergolas covered with deciduous climbers, arcades along south facades, coverings over a part of the street or a walkway, shallow water streams through the street (see example Freiburg in chapter 3), fountains, white roofs, green roofs, facade vegetation (climbers) or green facade (many individual plants), individual trees with large crowns and preventing heat exhaust or seasonal storage system. With arcades people always have the choice to walk in the shelter from sun and rain in summer and from wind and rain in winter. Nevertheless, in the interior behind the arcade more artificial light will be needed. For all fixed robust measures considering the winter situation is especially important. Hence, the importance of deciduous climbing plants.

§ 8.8 Middle-high/high open urban block with moderate to much green

The typical garden city with high-rise buildings is spaciously designed with a lot of greenery and often water elements between buildings, see Figure 8.48. The high-rise buildings with an average of 30 meters are usually mixed with low terraced housing. The distance between the tall buildings is about 100 meters and between the terraced houses 21 m. The H/W ratio is thus successively 0.3 and 0.4. This gives the impression that the ventilation is limited, however this is not the case because the tall buildings are staggered relative to each other and thus do not form a closed 'street profile'. Moreover, those tall buildings actually increase wind speed at street level because they partially deflect the stronger winds from above.

FIGURE 8.48 Example of a middle-high/high open urban block with moderate to much green, Ommoord in Rotterdam.

§ 8.8.1 Overvecht, Utrecht

North of Utrecht, Overvecht covers a large area with high-rise garden city blocks. The official district *Zambesidreef and surroundings* presented in Figure 8.49 is a representative part of the area. The percentage of natural urban surface is lower compared to the low-rise garden city presented in section 6.2. Instead, it is similar to the percentage of natural urban surface in the low-rise garden towns in section 6.3. The paved and façade surface have an almost equal share in this category. Despite the large height of some of the buildings, the façade surface is not dominating. The FSI of this category is with 0.8 quite high compared to other suburban neighbourhoods.

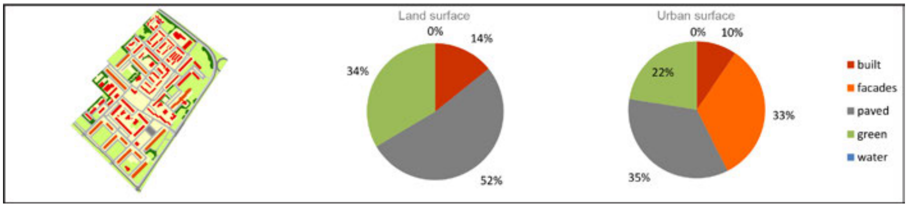

FIGURE 8.49 The relation between stony and natural surfaces in the Overvecht neighbourhood, Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The Overvecht garden city has abundant (semi-)public space, but does not provide people with a comfortable outdoor space. By re-designing the semi-public space of the inner courtyards with the concept of 'personalisation and identity' both the micro climate and the social cohesion can be improved. The design comprises three main interventions: allocate a plot (or shared plots) in the inner courtyard to each household (or group of households), transform ground floor into semi-public space and extend the greening of courtyards to other building blocks, linking the semi-public green to the large green structure (Beer et al., 2003).

In Figure 8.50 a design plan for the inner courtyard is given, the existing trees are preserved, a public path provides access to and a walkway through the courtyard. Adding green and providing people the possibility to create their own outdoor space improves the outdoor comfort. In addition the ventilation in the courtyard can be improved by opening up the ground floor (partially), see Figure 8.51. With the latter measure the winter situation should be taken into account, where flexible openings can be a solution. By linking the open courtyards to the large green structure more diversity in routings is created and more people can find a suitable outdoor space according their preference, see the green structure in Figure 8.52.

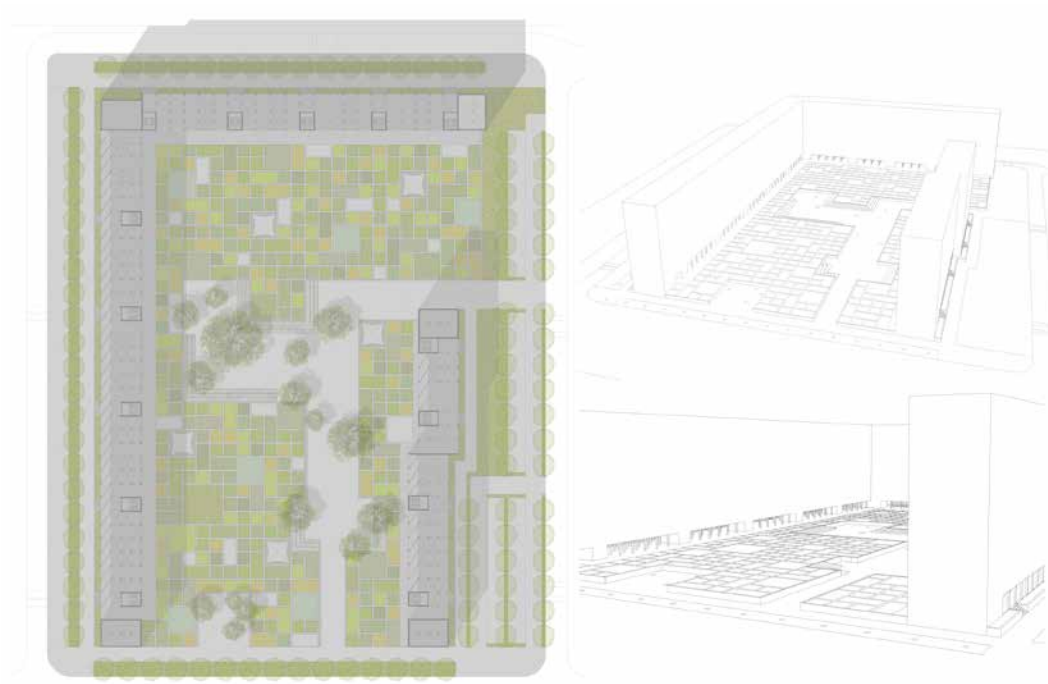

FIGURE 8.50 Private allotment gardens in the semi-public inner courtyard by Frederico Lia, WUR.

FIGURE 8.51 Opening up the ground floor for ventilation and sheltered community space by Frederico Lia (Schrijver et al., 2014)

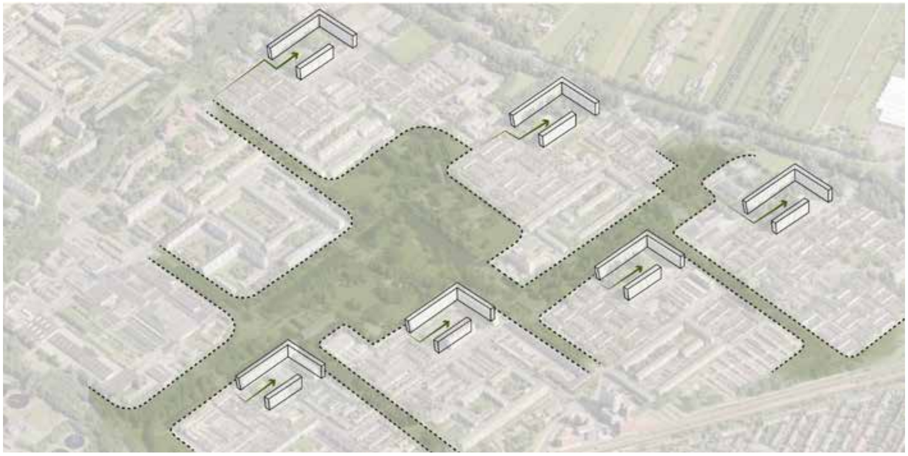

FIGURE 8.52 Extending green structure Overvecht by Frederico Lia, WUR.

§ 8.8.2 Kanaleneiland, Utrecht

Kanaleneiland is a neighbourhood situated on the West side of Utrecht. It is very similar to the previous neighbourhood in urban surface cover, where the main difference is a larger percentage of water, see Figure 8.53. The FSI is with 0.7 a little lower, but still higher than other suburban areas.

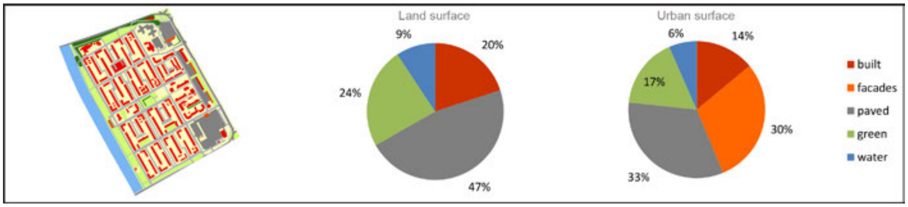

FIGURE 8.53 The relation between stony and natural surfaces in the Kanaleneiland neighbourhood, Utrecht, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

Kanaleneiland is somewhat different from Overvecht: Buildings are lower, generally 18 m high and are placed parallel and often form a street canopy. And instead of only public green, there are semi-public gardens and parks in the inner courtyards, see Figure 8.54. These differences presume less ventilation and less urban green for recreation. Students from Wageningen interviewed inhabitants about their thermal comfort and found that especially the indoor conditions and the public space at the building entrance was experienced too warm and uncomfortable.

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FIGURE 8.54 *1.* Photo of the front side of a building in Kanaleneiland; 2. An analyses of the building blocks and the green by Jules Neefjes, WUR.

In order to improve the microclimate of the buildings and the outdoor space in front of the buildings, flexible and temporary elements can be used that people can position themselves. For the building different kind of structures onto which green climbing plants can grow upwards can give diversity in shadow and appearance, see Figure 8.55 for an impression.

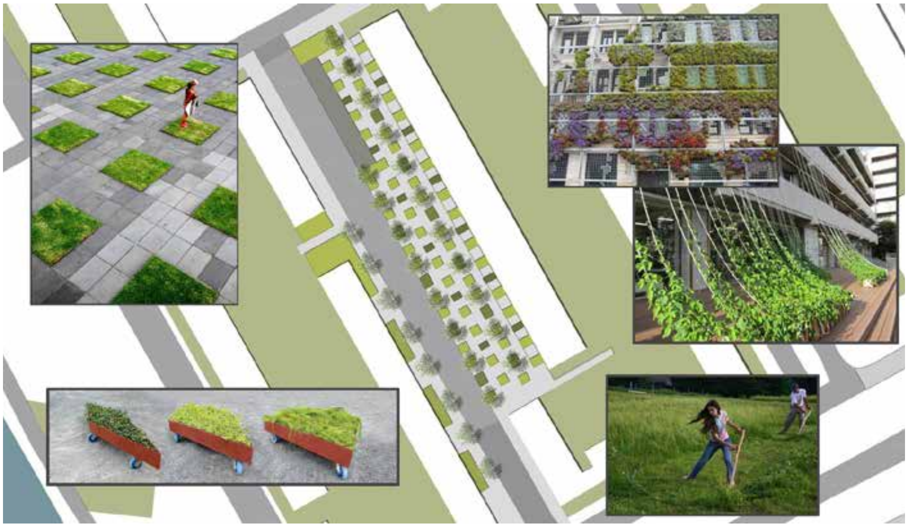

FIGURE 8.55 Greening plan of a building front by Sander Smits, WUR.

§ 8.8.3 Schiebroek-Zuid, Rotterdam

Schiebroek is situated on the North-West side of Rotterdam. The urban surface cover, presented in Figure 8.56, varies with the previous neighbourhoods in this category in the amount of natural and paved surface. The percentage of pavement is smaller and percentage of natural surface larger. Nevertheless the achieved FSI of 0.8 is still high.

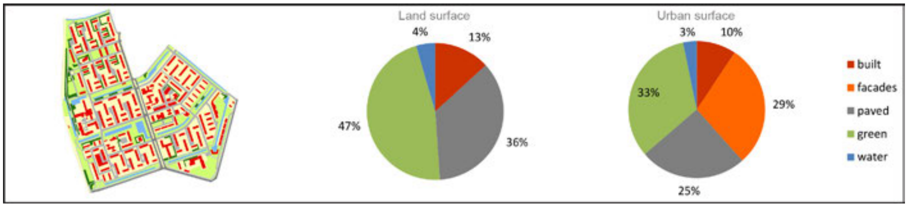

FIGURE 8.56 The relation between stony and natural surfaces in the Schiebroek neighbourhood, Rotterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

Schiebroek-Zuid has a similar building typology as Kanaleneiland, however the available green space is much larger. Here the housing association Vestia initiated a redevelopment programme, called 'Beautiful and sustainable Schiebroek-Zuid'. A design studio showed the possibilities of enhancing urban agriculture in the neighbourhood, see Figure 8.57. The comprehensive ambition is to combine professional urban agriculture with private initiatives by inhabitants.

FIGURE 8.57 Impression of sheltered promenade and urban agriculture in Schiebroek-Zuid (Bosschaert, 2010).

With appointing a project leader, Vestia initiated the redevelopment program. Local inhabitants can request assistance in developing a kitchen garden. The corporation facilitates the small fences, tools, fruit trees, compost and a glass house was constructed. The project turns out to be very popular and people love to take care of their herbs, vegetables and flowers, see Figure 8.58. Children often want to participate and when the products are ready, proudly bring their yield home. The deal is: who helps who can harvest. Together a yearly harvest market is organised, with the returns people want to invest in their garden and organize events for the children.

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FIGURE 8.58 Inhabitants work in the communal gardens (1) and cook an 'iftar meal' for their neighbours (2) in Schiebroek-Zuid (Zeevat, 2014).

The large size (70*100m) of the public inner courtyards are very suitable for special functions, such as water treatment area with reed plants, mixed cropping (urban agriculture or vegetable gardens), a petting farm, water playground, dog training field, lawn or events area with fixed barbecues and permissions for ice cream, snack or Dutch doughnut stand. Throughout the neighbourhood one can think of: walking paths, paved paths for cycling and inline skating, trail for mountain bikers.

§ 8.9 High-rise with little green

The highly urbanised areas in the Netherlands are not numerous, but when there, they are used very intensively, see Figure 8.59. Meaning many people benefit from a comfortable outdoor space in these areas. The building height varies between 50 to 100 meters and the average street width is about 12 meters. This means a H/W ratio of 4 to 8 in some places. This H/W ratio is in the street profile somewhat lower because many high-rise buildings have a wide foot of a number of floors around the high-rise tower. This building foot additionally provides protection from the deflected wind by the high-rise towers.

The large amount of pavement and high building density are factors that increase up heating. There is quite some shadow from buildings, but that does not eliminate up heating, and once heated, these areas retain the heat for a long time. On the other hand, the great variety in building heights relatively provides a lot of ventilation. This also causes strong wind gusts with stormy weather.

FIGURE 8.59 Example of high-rise with little green, Turfmarkt neighbourhood in The Hague.

§ 8.9.1 Central station area, The Hague

The central station area in The Hague connects the public transport hub with the inner city. The official district name is Uilebomen. In the Netherlands districts like this, with many high-rise buildings, are not very common. However, many people from inside and outside the city use the area, which means the microclimate affects many people. In this category the urban surface cover consist almost completely of stony materials. With a very dominant façade surface covering almost 60% of the urban surface, see Figure 8.60. Not surprisingly, the FSI in Uilebomen of 3.2 is the highest among all case neighbourhoods in this study.

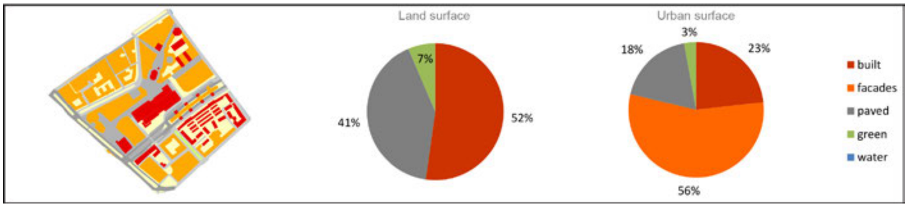

FIGURE 8.60 The relation between stony and natural surfaces in Uilebomen, the Station area in The Hague, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

The large amount of dark surfaces of the Spuiplein in The Hague offers the possibility to harvest heat and/or electricity from the pavement and facades. Figure 8.61 shows options to harvest heat from facades. The façade can produce 100% of the heat demand of the theatre or 30% of the electricity demand of the theatre. The square could provide heat for 60 households per year.

FIGURE 8.61 Three images left: examples of thermal solar collectors with semi-transparent façade. Right: Spuiplein and Theatre, The Hague.

Because of the high altitude of the buildings along the Turfmarkt wind can be used to generate electricity. The common turbines are depending on a certain wind direction. A small wind turbine type called Turby also transits vertical airflow. In order to increase the efficiency even more other techniques can be used, such as the EWICON developed by the TU Delft, which is based on moving water droplets or the Wind Dam by Chetwood Associates which catches and channels the wind. Figure 8.62 shows the two wind energy generators.

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FIGURE 8.62 *1.* energy generation from water droplets with the EWICON; 2. Wind Dam by Chetwood Associates

From the central station in The Hague an underpass leads to the city centre. This underpass has no issues during hot weather, but wind drafts make it an uncomfortable place during the cold periods of the year. With a porous wall or urban curtains you can create a wind barrier to improve thermal comfort. In Figure 8.63 the underpass is inspired on the wind portals by Najla El Zein.

FIGURE 8.63 Wind portals in the underpass from the central station to the Turfmarkt in The Hague.

§ 8.9.2 Lijnbaan, Rotterdam

The Lijnbaan in Rotterdam is the heart of the city. In Figure 8.64 the land and urban surface cover is presented. Again the amount of natural surface cover is extremely low. The relation between pavement and built land surface is different from the station area in The Hague, resulting in a lower FSI of 1.6.

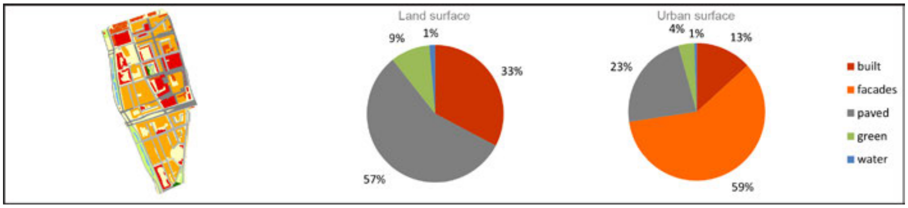

FIGURE 8.64 The relation between stony and natural surfaces in Cool, the Lijnbaan in Rotterdam, with and without the vertical façade surface, map source TOP10NL (Middel, 2002).

For this neighbourhood no design is made. The above diagrams and map show the large similarity with the other highly urbanised city centre. The expectation is that similar measures will be appropriate here. This needs to be confirmed to strengthen the conclusion below.

Applicability of solutions for heat stress are very dependent on the function of the area. Locations that serve as an outdoor living area need to offer both shade for pedestrians and sunny spots for terraces or benches. Because these areas attract many people from inside and outside the city (such as employees, passengers and tourists), it is important to offer a diversity of places: sheltered spots out of the wind, shady spots and perhaps places covered from rain.

Here it is important to reduce the extensive amount of pavement, for example, by realizing roof parks, but these large surfaces can also be used to transform solar energy into thermal energy or electricity. In sub-section 9.3.2 follows a sample calculation of solar collectors in the pavement of the Spuiplein and the facade of the adjacent theatre. Besides capturing heat in paving and facades, the prevention of the exhaust of anthropogenic heat is important in these areas. This does not so much concern the cooling towers on top of high buildings, but mostly the heat exhaust of motorized traffic and refrigeration installations in restaurants and food shops on ground level. It would be better if all exhaust air leaves the building at the top.

§ 8.10 Conclusion

The aim of the case study designs in this chapter is to get to a set of general climate adaptation measures per neighbourhood typology. This addresses the sub-research question: How can neighbourhoods become climate robust considering the morphology of Dutch neighbourhood typologies?

In the previous sections the appropriate measures for a specific microclimate category were extracted after the presentation of two or three examples with design solutions, strategies and complete neighbourhood designs. The main design solutions are summarized and presented in a matrix in sub-section 8.10.1.

With the sets of measures given in this chapter urban designers and planners have guidance in appropriate measures for a large part of the existing urban areas in The Netherlands. Herewith, climate sensitive choices in the initial stage of the design process are possible without profound knowledge of the urban microclimate.

Instead of using professional simulation programs or extensive GIS mapping, the urban designer or planner can place an area in one of the microclimate categories introduced in this chapter. These categories are based on building height, form of footprint and the percentage of green/water in relation to the urban surface. With the urban surface also the vertical façade surfaces should be included. It is recommended to include street trees or tree canopy density in future analysis. The current rapid development of geographical data registration of all elements in public space facilitates the inclusion of street trees in future analyses. This subsequently raises a new question: what is the best way to include trees in an urban surface analysis? Counting the crown cover as green surface ignores the surface cover under the tree crown which has a different effect when paved than when covered with vegetation.

In addition to the three physical aspects, the microclimate categories are coupled to common urban typologies (Lorzing et al., 2008) that are often used by urban designers and planners to characterize a neighbourhood. The physical aspects and urban typologies are well-known parameters for urban designers and planners. To strengthen the generic conclusions in this chapter each neighbourhood typology should be complemented with at least three design proposals.

Although this chapter enables categorizing and selecting measures without the necessity of specialised knowledge about the urban microclimate, the actual implementation of measures does require more knowledge and understanding of the field. More insight in heat mitigation measures and their effects is provided in chapter three. In some cases the effect of (a combination of) measures is not obvious. Here simulation of future scenarios can be of importance in the decision making process. In the following chapter the measures proposed per microclimate category are input for three integrated design studies.

§ 8.10.1 Summary of adaptation measures per microclimate category

This sub-section presents a summary of the measures that fitted a neighbourhood typology in the design studies presented in this chapter. In Table 8.6 heat mitigation measures are indicated per neighbourhood category in a matrix. In the case of the residential neighbourhoods, the historical city centres and garden city high-rise neighbourhoods three designs are made. The measures presented for these neighbourhoods can be regarded as generic, while the other presented measures need to be considered as a possible example. More design studies concerning these neighbourhood typologies are needed to come to a generic set of measures.

Low open urban block with moderate to much green (garden city low-rise)

- Promote green in private gardens;
- Increase the value of semi-public green: improving quality of green and attach multiple functions to the green areas. The semi-public inner courtyards have a green lawn of about 30*50m. The functions linked to these areas cannot be confined to residents only because it would blur the public character. Even so, public functions are not in place either because the residents can experience that as an infringement of their privacy. After all, it concerns their backyard. When a social function of peaceful nature attracts just a small number of people at the same time it will give less friction. For example a route to walk the dogs, water storage, butterfly and bee gardens, fruit and nut orchards, etc.

Low closed urban block with moderate to much green (garden town)

- Promoting green in a subtle manner: inspire people and create awareness about the importance and benefits of green. Another option is to offer trees, hedges or plants for free to the inhabitants. Or, through the water board or council tax, charges can be adjusted to the degree of pavement in gardens, or charge less taxes when rainwater is collected and infiltrated on site;
- Add street trees on strategic places.

Low closed urban block with little green (residential neighbourhood)

- Tiny gardens along the facade and green facades;
- Type of pavement: semi-pavement, permeable pavement, light colours;
- Parking solutions combined with a structure for climbing plants;
- Flat roofs can contribute to thermal comfort at street level: a white reflective coating, a green roof with a sufficiently thick substrate layer;
- In case there is no possibility to add more green the generation of ventilation is especially important. This can be achieved through more height differences of the buildings or by using the principle of 'hot' and 'cool' places between which the air will be moving (thermal draft);
- Find parking solutions: streets can be planted with a double line of trees or one line of trees at the side that receives most solar radiation. In some cases, trees as espaliers can provide a solution when the position of the tree cannot be placed far enough from a building wall.

Low closed urban block and strips with moderate green (VINEX)

- Promote green in private gardens, also try to discourage the use of dark anthracite tiles;
- Parking solutions combined with green and shadow elements.

Low strips and open urban blocks with little to moderate green (cauliflauwer neighbourhood)

- Parking solutions combined with green and shadow elements. Reducing the number of cars is not directly an option here because the neighbourhoods are often at a great distance from the centre. One could think of (electric) car sharing or parking on the edge of several building blocks. Thus when more space becomes available it can be used for additional playgrounds, more trees, rainwater harvesting and infiltration meadows;
- Green facades;
- White roofs.

Middle-high closed urban block with little green (historical city centre)

- Temporary and flexible measures: canvas sheets above streets and plazas, the spraying of fine water droplets at pedestrian routes, watering the streets to reduce the radiant heat from stony surfaces, seating elements shaded in summer and protected from wind in winter and place elements that can generate ventilation during hot periods;
- Fixed and robust measures: pergolas covered with deciduous climbers, arcades along south facades, coverings over a part of the street or a walkway, shallow water streams through the street, fountains, white roofs, green roofs, facade vegetation (climbers) or green facades (many individual plants).

Middle-high/high open urban block with moderate to much green (garden city high-rise)

- Promote green in private gardens;
- Increase the value of semi-public and public green. The large size (70*100m) of the public inner courtyards are very suitable for special functions, such as a water treatment area with reed plants, mixed cropping (urban agriculture or vegetable gardens), a petting farm, water playground, dog training field or as an events area with fixed barbecues and permissions for ice cream, snack or Dutch doughnut stand. Throughout the neighborhood one can think of: walking paths, paved paths for cycling and inline skating, trail for mountain bikers.

High-rise with little green (high-rise city centre)

- Offer a diversity of places: sheltered spots out of the wind, shady spots and perhaps places covered from rain;
- Reduce the extensive amount of pavement, for example, by realizing roof parks;
- Large paved or facade surfaces can also be used to transform solar energy into thermal energy or electricity;
- Reduce the exhaust of antropogenic heat: car free zones, design buildgins that do not need air conditioning and make sure all exhaust air leaves the building at the top.

Microklimaat categorie	Middelhoog gesloten bouwblok met weinig groen	Laag gesloten bouwblok met matig tot veel groen	Laag gesloten bouwblok met weinig groen	Laag open bouwblok met matig tot veel groen	Middelhoog/hoog open bouwblok met matig tot veel groen	Lage strokenbouw en open bouwblok met weinig tot matig groen	Lage strokenbouw en gesloten bouwblok met matig groen	Hoogbouw met weinig groen
Wijktypologie	Historische binnenstad	Tuinwijk/dorp	Woonwijk	Tuinsteden laag	Tuinsteden hoog	Bloemkoolwijk	Vinex	Hoogstedelijk centrumgebied
maatregel								
bomen	matig toepasbaar	goed toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar
straatbomen	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar	toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar
parken	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar
groene routes	moelijk toepasbaar	toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar
grasvelden	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	matig toepasbaar
particulier groen stimuleren	goed toepasbaar	goed toepasbaar	toepasbaar	goed toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	moelijk toepasbaar
stadslandbouw	matig toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	matig toepasbaar
vertikaal groen	matig toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar
groengeluidsscherm	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar
begroeide arcades met bladverliezende klimplanten	goed toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar
wadi's	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	moelijk toepasbaar
waterelementen (fontein)	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	goed toepasbaar
water vernevelen	goed toepasbaar	moelijk toepasbaar	matig toepasbaar	moelijk toepasbaar	moelijk toepasbaar	moelijk toepasbaar	moelijk toepasbaar	goed toepasbaar
waterpleinen	matig toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	matig toepasbaar	toepasbaar	goed toepasbaar
waterspeelplekken	moelijk toepasbaar	goed toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	matig toepasbaar
grachten en kanalen behouden of uitbreiden	toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar
afkoppelen regenwater	matig toepasbaar	goed toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	moelijk toepasbaar
regenton/tank	toepasbaar	goed toepasbaar	toepasbaar	goed toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	moelijk toepasbaar
open water (verzonken)	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	matig toepasbaar
infiltratie punten (evt in combi met wadi's)	matig toepasbaar	toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	matig toepasbaar
natuurlijke oevers	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	moelijk toepasbaar
helofyten filter/grijswatersysteem	moelijk toepasbaar	moelijk toepasbaar	moelijk toepasbaar	toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	moelijk toepasbaar
bewateren van de straat	goed toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar
katoenen doeken boven de straat	goed toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar	moelijk toepasbaar	moelijk toepasbaar	matig toepasbaar	toepasbaar
schaduwelement voor zitbank	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	goed toepasbaar
wind beschermingselement	goed toepasbaar	toepasbaar	toepasbaar	toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	goed toepasbaar
vaste arcades langs zuid gevel of als los element	goed toepasbaar	moelijk toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar	matig toepasbaar	goed toepasbaar
orientatie op zon tbv binnenklimaat	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar
bevorderen ventilatie	toepasbaar	matig toepasbaar	goed toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar
reflecterend/licht dak	toepasbaar	matig toepasbaar	toepasbaar	toepasbaar	toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar
groendak	toepasbaar	moelijk toepasbaar	toepasbaar	toepasbaar	toepasbaar	moelijk toepasbaar	matig toepasbaar	toepasbaar
materialen met lage warmte accumulatie	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar
verharding verminderen openbaar terrein	moelijk toepasbaar	matig toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	matig toepasbaar
verharding verminderen prive terrein	toepasbaar	goed toepasbaar	goed toepasbaar	toepasbaar	toepasbaar	goed toepasbaar	goed toepasbaar	matig toepasbaar
permeabele materialen	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar
atropogene warmte productie voorkomen of omzetten	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	toepasbaar	goed toepasbaar
Asfalt/gevel collectoren	toepasbaar	matig toepasbaar	toepasbaar	matig toepasbaar	matig toepasbaar	matig toepasbaar	toepasbaar	toepasbaar
voorlichting klimaatbeheersing	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	matig toepasbaar
koele en veilige plekken in risicogebieden	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar	goed toepasbaar

goed toepasbaar
toepasbaar
matig toepasbaar
moelijk toepasbaar

TABLE 8.6 Matrix with heat mitigation measures per neighbourhood category.

§ 8.11 References

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