9 Designing for the urban (micro) climate

In this chapter the results of all previous chapters are input for the development of three integrated urban development strategies.

For climate adaptation measures to be part of the 'standard' design process, urban designers and policy makers need to have clear guidelines at their disposal (Pijpers- van Esch, 2015). A first assistance in selecting heat mitigation measures was presented in the previous chapter. Common neighbourhood typologies are classified in relation to heat accumulation and appropriate heat mitigation measures are presented for that specific typology. Using this guide for the pre-selection of adaptation measures does not require an extensive analyses of the urban microclimate and enables urban designers and policymakers to quickly scan the adaptation options for the area. Still, the choice for a particular measure is rather arbitrary.

This chapter tests how heat mitigation measures can be integrated in a planning or design process for three different assignments in different neighbourhoods. The sub-question that will be answered is: How can the transformations proposed per neighbourhood typology be applied in an integrated design assignment, combining various heat mitigation measures, linking water adaptation measures and creating additional value in relation with energy, health, ecological, social and economic issues?

The sub-questions answered in this and the preceding chapter are input for the research question: How can microclimate be integrated into a planning or design process?

§ 9.1 Case study method to integrate adaptation

This section describes the method that is used to integrate climate adaptation measures in the design process for the three case studies presented in this chapter. A method to focus on heat mitigation measures and integrate these in complex redevelopment tasks is the maximisation method presented in the next sub-section. Zooming in, a choice between heat mitigation measures can be made by the proposed strategy to prioritize heat mitigation measures inspired by the 'Trias ecologica' in the second sub-section. Zooming out, the choice for a certain measure is depending on the political field as well. This is explained in the third sub-section.

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§ 9.1.1 Case study method: maximisation

The method of 'research by doing' is used to answer the (sub-)research questions stated above and can be described as 'design research' according to the scheme in Figure 8.1 developed by de Jong & Voordt (2002). They can be placed under 'design research' because for each integration case study the context and the objects (climate adaptation measures) are determined.

A design process, however structured or processed, is always intertwined with unconscious considerations of the designer. Van Dooren et al. (2014) describe designing as a complex, personal, creative and open ended process. To reduce the arbitrariness of design decisions the methods presented in this section form a basic thread in the three integrated design studies.

All three case studies have the aim to improve the outdoor microclimate and climate robustness of an area. This common aim composes a certain level of maximisation in the design process. The maximisation method developed by Duijvestein (2002), schematically presented in Figure 9.1, is a method for urban design that aims to clarify the choices made in the process in relation to selected environmental theme(s). In this research the maximisation theme is thermal comfort. A design process develops from analyses to design within the minds of designers and stakeholders and is often inconceivable. With the maximisation method the spatial consequences are revealed with a one-sided thematic design. The three case studies in this chapter follow the same integration process with the same sub-questions presented in Table 9.1.

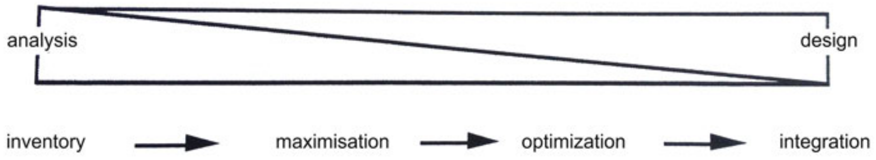

FIGURE 9.1 Environmental aspects provide structure and direction in the transition between analysis and design (Duijvestein, 2002).

ANALYSIS			MAXIMISATION	OPTIMISATION	INTEGRATION
Development task	Adaptation task	Political context	What are best options in relation to thermal comfort and neighbourhood characteristics?	What are best options in combination with other climate adaptation options?	What are best options in combination with other context related aspects?

TABLE 9.1 Design integration process aiming at increasing thermal comfort.

Maximisation of thermal comfort in urban design

The maximisation step requires a choice between heat mitigation measures, while optimisation and integration ask for a broader view and coincide with an increase of complexity. According to Kabat (2010) the chosen measures have a greater feasibility when they are flexible, no-regret and go hand-in-hand with monitoring & ability to incorporate new scientific insights. However, feasibility alone is not a strong enough argument for a choice that influences people their lives. This is in line with the statement of de Jong & Voordt (2002) that within the range of the probable and possible solutions only a part is also desirable, see Figure 9.2. He states that: "*The designer has the task of exploring improbable possibilities, especially when the most probable development is not the one preferred. Because of their improbability, these possibilities are not predictable, one has to design them*" (Jong & Voordt, 2002, page 339). The grey areas in the figure relate to uninteresting possibilities for design with desirable but impossible (1) and desirable, probable and possible (2) scenarios. In the first case scenarios are not realistic and in the second case no additional dedication is needed for realization. The most interesting solutions are, as stated above, the possible, desirable and improbable (3) solutions. In this study, most of the design proposals can be assigned to this scenario as climate adaptation solutions are often not the common solutions and therefore less probable. The probable, possible, but undesirable scenarios (4) need consideration to transform these in a desirable scenario, while scenarios that are possible, but not probable nor desirable, do not need attention because they will simply not happen.

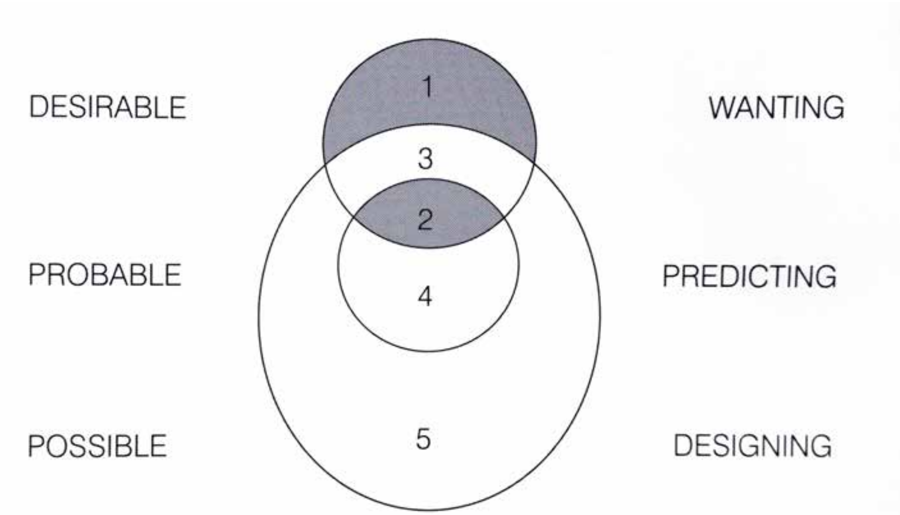

FIGURE 9.2 Views of the future (Jong & Voordt, 2002).

This research has a focus on the relatively new design field of outdoor thermal comfort for hot weather extremes. And therefore the maximisation on thermal comfort is elaborated further than the other steps. In the first instance the effectivity of a measure seems to be of great importance in prioritising measures. In chapter 3 and 4 a search for most effective measures in air temperature and thermal comfort is done through literature review and computer simulations. Due to the great variability in effectiveness within space and context it is not possible to order adaptation measures without ending up with broad ranges that overlap and many exceptions and reservations. An alternative can be to test adaptation measures by simulation of the actual context. This method requires a lot of expert knowledge about the urban microclimate, advanced simulation skills and takes a long time for modelling and calculation time and computer capacity. Such simulations can indicate a difference between effectiveness, but due to unavoidable simplifications in modelling and calculations, results remain inaccurate to a certain extend. And, not all possible solutions can be analysed, this especially counts for innovative ideas. Moreover, urban designers and policy makers generally do not have extensive knowledge about the urban microclimate nor do they have the time, skills and budget to perform computer simulations.

Each case study has been shortly introduced in the preceding chapter concerning physical parameters like built form, H/W ratios and percentages of green and stony surfaces. In this chapter each case study start with a recap of that analyses and a description of the political context of the city. Thereafter, the integral design is thematically discussed indicating whereas the heat mitigation measures prevent heating, cool passively or actively. In the closure the measures from the set of measures for the neighbourhood typology in chapter 8 that are not part of the design are discussed. Integration is not a step afterwards, but already happens in the mind of the designer considering the different maximisation and optimisation options. In section 9.5 the design process is evaluated by discussing the intertwined combinations of heat and other climate adaptation measures (optimisation) and of heat mitigation and other urban development tasks (integration).

Choices within the design process are made by the author in the cases Couperusbuurt and Zuidwal, while adaptation options in Bergpolder are made by different designers and researchers involved in the CPC project.

§ 9.1.2 Approaching heat mitigation as a common sustainability issue

Better safe than sorry, certainly counts when dealing with climate change adaptation. To prevent heat stress related problems in urban areas the possible adaptation measures can be divided into three steps: preventing heating up, use passive cooling

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and active cooling. This three stepped strategy is an alternative version of the 'Trias ecologica' developed by Duijvestein (1993) and presented in Table 9.2. The Trias ecologica is inspired by the work of ecologist van Leeuwen (Jong et al., 2015).

	IN	OUT
Step 1	the prevention of unnecessary consumption	the prevention of waste
Step 2	the use of infinite sources	the recycling of waste
Step 3	the sensible use of finite sources	the processing of waste sensibly

TABLE 9.2 The three-step strategy as described by Prof C.A.J. Duijvestein (Jong et al., 2015).

The Trias ecologica is often used to prioritize measures to maximum environmental benefits for energy, material and water flows. An example is the Ecodevice model that is based on the same type of considerations and is applicable on many scale levels (Tjallingii, 1996). Lysen (1996) changed the three step strategy to 'Trias energetica' with the steps 1: reduce the demand, 2: use renewable resources, 3: solve the resuming demand efficiently and clean. More recently the 'New Stepped Strategy' developed by Dobbelsteen (2008) adapts the 'Trias ecologica' to the building design process with the steps 1: reduce consumption (using intelligent and bioclimatic design), 2: reuse waste energy streams, 3: use renewable energy sources and ensure that waste is reused as food.

For a sound argumentation in the choice of heat mitigation measures an additional strategy to prioritize these measures is needed next to the preselection per neighbourhood typology in chapter 6. Inspired by the 'Trias ecologica' a three step approach to prevent heating up guides the design process and choices for adaptation options in a structured way:

1 Prevent heating up;
Use passive cooling,
Use active cooling considering the 'New Stepped Strategy'.

This approach favours measures from the first step above the second and third. After all, when heating up can be prevented according to step 1, cooling, either passive or active in step 2 and 3, does not need consideration. The steps are described briefly in the following sections, a more elaborated explanation can be found in the online course that is developed with several partners of the CPC project and the Open University (Kleerekoper & Dobbelsteen, 2015).

Preventing heating up

Preventing heating up by the sun has three aspects of which the prevention of solar irradiation from urban to building scale is the first. This can be done by trees, canvas

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sheets above public spaces, increasing the compactness of buildings and equip buildings with sunscreens. The second aspect is to reflect solar radiance back to the atmosphere by increasing roof and pavement albedos. The third aspect is to prevent the absorption of heat by using materials with low heat absorption capacity, apply thin and light façade claddings and use thermal isolation to prevent heat intrusion through the façade.

Preventing heating up by anthropogenic sources aims at reducing the heat people produce with all urban activities, including dwelling, transportation, sports, etc. The heat exhaust from cooling buildings mechanically with air conditioning should be avoided. This is in fact heating up the outdoor temperatures which is again of influence on the indoor temperatures. Buildings with sufficient thermal isolation and sunscreens need less cooling (energy) and have a lower heat emission to the outdoor space. A means to reduce anthropogenic heat is to replace traditional combustion engines with electrical ones. Another way to achieve reduction of heat emission is to re-use waste heat, with for example a pool that receives heat from an ice rink's cooling installation and supplies nearby dwellings with space heating.

Passive cooling

Passive cooling with ventilation should be looked at on different scale levels. On the large scale urban ventilation is depending on types of airflow and wind conditions in The Netherlands. This type of airflow originates from differences in atmospheric pressure. As soon as the airflow arrives at urban areas the flow is influenced by obstacles and transforms into secondary air flows and turbulence. The secondary horizontal air flows can be influenced by creating contrasts in openness and obstruction. Dense tree lines or building volumes can guide or deviate airflows and porous and scattered trees can let airflow penetrate an area. Air flow on street scale can be influenced by creating thermal inducement because of thermal differences. Both, the location where hot air rises and the direction from which cooler air is attracted can be influenced. And finally, on the building scale differences in air pressure and thermal inducement can be used to ventilate indoor spaces. For cooling, the principle of summer-night ventilation can cool down building elements that absorb heat during the day such as concrete floors and walls.

Passive cooling with water basically implies increase of evaporation. Waterbodies such as rivers, lakes, canals and urban water elements often have a relatively small effect on the air temperature. Nevertheless, it can make a large difference in the perception people's thermal comfort when they can see, and even better, touch the water. Also trees cool through evaporation of water, the so-called evapotranspiration process, and thus function as urban air conditioners. Next to waterbodies and trees, also permeable and water absorbing surfaces can contribute to cooling during hot days.

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Active cooling

In order to actively cool with water technological systems are needed. With flexible groundwater level management more rain water can be infiltrated and groundwater can be used in dry periods for vegetation or cooling of urban surfaces (or people). Cooling air through the fine spraying of water is a commonly known effect of fountains, and the recent trend of spraying even finer mist on busy public spaces or terraces is even more effective. Active cooling of buildings can be achieved with water running along roofs and walls absorbing heat, or with water storage on roofs which is covered from the sun during the day and exposed to the sky to accelerate the cooling of water at night.

In the previous paragraph described the cooling effect of evaporation of water. Another active cooling method for urban surfaces is based on the absorption capacity of water. Analogous to heat collector panels on roofs, other urban surfaces can serve as heat collectors where the absorbed solar heat is discharged via water running in tubes through or behind the stony surface. The discharged heat can be used directly, for example pre-heating hot tap water or a nearby swimming pool, or saved for the winter period in a seasonal storage system. This is still an unconventional solution, but with large amounts of stony surfaces in urban areas that contribute to heating up we can make use of and strive for a sustainable energy system in combination with climate adaptation.

§ 9.1.3 Political context: dedicated or mainstreaming adaptation approach

In this thesis the importance of a good microclimate in cities is argued in chapter 2. However, this is hardly ever the most important factor in weighing urban design solutions. Is climate adaptation a goal in itself that must be achieved, or is it one of the many elements that should be addressed properly in achieving a climate resilient urban area? A study about the differences between a dedicated or mainstreaming approach in urban policy is done by Uittenbroek et al. (2014). In this section the findings of this research are summarised and extended to the design process.

Dedicated approach

In the dedicated approach political or client commitment is given directly to climate adaptation. Politicians or clients will provide resources to achieve the objectives. The direct political or client commitment provides opportunities, such as political pressure and new organizational structures, but may also lead to unclear positioning of policies. It can lead to innovative designs and techniques that are an example and inspiration for others. The approach also involves the risk of neglecting other essential elements of urban design or investing a lot of money without the certainty of future extreme changes in climate.

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Mainstreaming approach

In the mainstreaming approach commitment of individual stakeholders to a climate resilient design is a crucial precondition in achieving this. For policy this means "an attempt to obtain indirect political commitment for climate adaptation by framing the issue as an added value to existing policy objectives" (Uittenbroek, 2014) page 71. This approach usually does not lead to changes in the organizational structures and routines. No or limited additional resources are made available and existing resources are difficult to reallocate because they are labelled to another objective. For the design process it implies that, although climate adaptation is one of the general requirements on the design brief, for each planning or design choice climate adaptation has to 'compete' with other aspects. In this way, the achievement of climate adaptation objectives rely on individual choices of the planning and designers involved. In case of a dedicated team of supporters of climate adaptation, the approach can lead to a well-balanced plan that achieves to combine many assets and objectives. On the other hand, without motivation for and knowledge about climate adaptation there is the risk of not achieving a climate resilient development. Friend et al. (2014) have a rather pessimistic view on the potentials in governance and state that: "*...generally there is such a fundamental failure of urban governance that there is often nothing to mainstream into...*".

The three case studies presented in this chapter are all situated in a different political context. Where the Municipality of Amsterdam clearly chose to mainstream climate adaptation into the different departments and organisation layers, the municipality of Rotterdam chose the dedicated approach. In The Hague no conscious decision was made how to approach climate adaptation as an organisation, resulting in a random attention to the subject throughout the organisation.

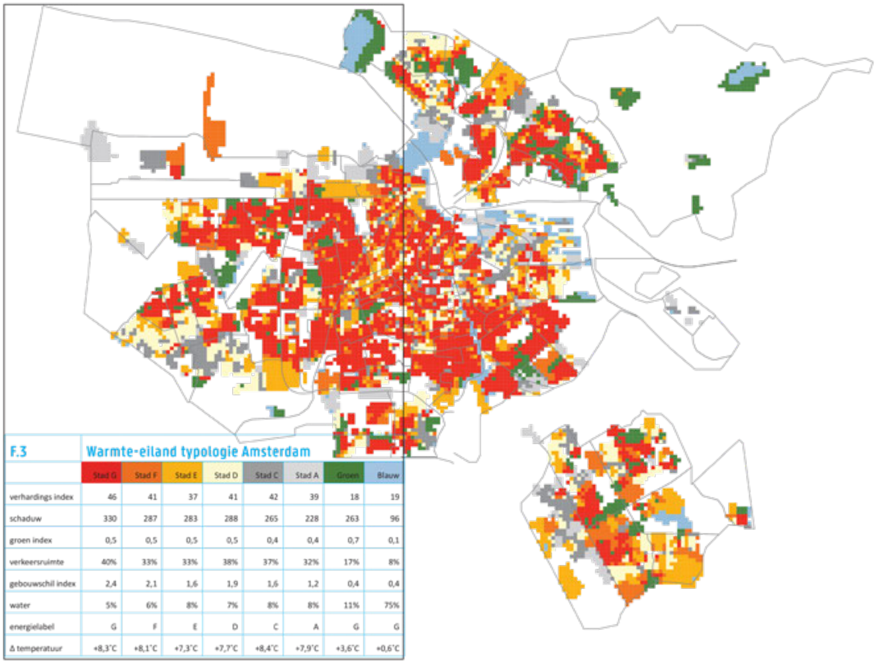
§ 9.2 Couperusbuurt, Amsterdam

This sub-sections presents the case study for the Couperusbuurt neighbourhood, Amsterdam.

§ 9.2.1 Neighbourhood analysis

In the previous chapter the Couperusbuurt neighbourhood was introduced as a non-problematic area in terms of outdoor thermal comfort. However, redevelopments considered by the municipality form a threat for the green characteristics and for the urban microclimate. This section introduces options to improve thermal comfort in combination with other assets for the neighbourhood.

Within the CPC consortium an analyses of the vulnerable areas to heat is made for the city of Amsterdam by Hoeven & Wandl (2013), as introduced in section 2.3.2 in this thesis. With a geographical information system (GIS) the heat island of Amsterdam is based on eight parameters: pavement index, shadow, green index. Infrastructure for traffic, building envelope index, water, energy label and temperature difference. The analyses is presented in figure 9.3, showing a large spreading in hot areas over the whole city. Locations with vulnerable groups such as elderly and babies are located in the outskirts, especially on the western part of the city. While concentrations of labour activities is largest in the city centre. For the Couperusbuurt neighbourhood, which is situated in this western part, this means that liveability for these groups need to be protected.



	Stad G	Stad F	Stad E	Stad D	Stad C	Stad A	Groen	Blauw
verhardings index	46	41	37	41	42	39	18	19
schaduw	330	287	283	288	265	228	263	96
groen index	0,5	0,5	0,5	0,5	0,4	0,4	0,7	0,1
verkeersruimte	40%	33%	33%	38%	37%	32%	17%	8%
gebouwschil index	2,4	2,1	1,6	1,9	1,6	1,2	0,4	0,4
water	5%	6%	8%	7%	8%	8%	11%	75%
energielabel	G	F	E	D	C	A	G	G
Δ temperatuur	+8,3°C	+8,1°C	+7,3°C	+7,7°C	+8,4°C	+7,9°C	+3,6°C	+0,6°C

FIGURE 9.3 Physical heat map of the city of Amsterdam (Hoeven & Wandl, 2013).

Political context of Amsterdam

The municipality of Amsterdam chose not to place climate adaptation on the political agenda in the period 2010-2014 in which the CPC project was running. In a study by Uittenbroek et al. (2014) the political context is described in detail. In short she states that the three main topics receiving political attention were: economic growth, social empowerment and sustainable investments. Although it received less attention, climate change was addressed through climate mitigation actions relating to CO2 reduction and investments in new ways of energy generation. According to the responsible alderman climate adaptation (meaning water management) is not an issue of discussion, opposed to energy transition which is a controversial topic that requires political agenda-setting.

Despite the lack of political dedication to climate adaptation, the issue is addressed in the policy documents of the departments of spatial planning and water. With the compact city approach that is applied in Amsterdam, extra attention is given to the improvement of the green infrastructure and vulnerability of the water system. Pilot projects were based on 'existing' budgets, such as a subsidy for green roofs that was made available from resources to improve the green infrastructure. The political context in Amsterdam did not aim at a specific performance on climate adaptation which makes climate related responses dependent on individuals within the different departments.

§ 9.2.2 Design integration

The design for the Couperusbuurt neighbourhood is described in this sub-section by means of thematic descriptions.

Enlarging floor space delicately

To attract a larger variety of people to the Couperusbuurt neighbourhood, as the municipality strives for, the small houses need to be redeveloped. To meet the current housing needs of the middle class society the floor space per dwelling, energy performance and amount of parking spaces should increase. The redevelopment proposed here provides for the prevention of up heating of the outdoor environment and an increase of floor space. In following sections is dealt with the energy performance and parking spaces.

At the moment there are two type of dwellings surrounding the courtyards: single family houses with two floors and an attic and mostly ground floor apartments with small private garden which have a second apartment with attic on top. Each floor counts around 54m^2, with 108m^2 for a single family house. The average floor space of a contemporary apartment is 78m^2 and a single family dwelling in the Amsterdam region is 125m^2 (CBS, 2013). With one additional building layer or additional dormers on the roof the current buildings can be expanded to spacious single family houses of 162 m^2 and 135 m^2 respectively.

An additional building layer decreases the solar access in the courtyards, and therewith also reduces the risk of heat stress (Kleerekoper et al., 2015). In case the green in the courtyards is maintained, there is no need to reduce the current risk for heat stress. The access of solar radiation in winter and moderately warm days is even very welcome. This would plead for no additional building layers. However, due to the composition of the wide inner courtyards and the position of the roads along the north side of the buildings the additional building layer will have no significant impact on the solar access inside the houses and gardens. It even provides extra shading on the paved road surfaces, see sketch in Figure 9.4. Nevertheless, it will have a significant impact on gardens and buildings along streets that run in between the courtyard blocks, especially the streets running North-South, with a width up to 20 meters. Therefore, these streets will not have an additional building layer, but dormers to transform the attack into a valuable living space. In Figure 9.5 the building strips with dormers and with an additional building layer are indicated. In a few building strips the floor space per apartment remains the same to maximize the variety in housing supply. On the North-East side of the neighbourhood the three courtyards have a different form and size compared to the rest. Here the exception in the redevelopment strategy of no increase in floor space makes sense. The same goes for the two buildings along the *Burgemeester Rendorpstraat*.

FIGURE 9.4 Sketch of solar angle (61.5°) on the 21 of June at noon with two or three building layers in section AA’ in Fig 9.5.

FIGURE 9.5 A redevelopment strategy to increase floor space and the variety in housing supply with attention to solar access indoor and gardens.

Although a higher H/W ratio usually decreases ventilation within a street or courtyard, a differentiation in building heights will increase turbulence and therefore a better mix of air between the canopy layer in streets and courtyards and the boundary layer above the buildings. A better mixing of these layers will accelerate cooling and improve air quality. For the same reason pitched roofs have preference above flat roofs.

Energetic opportunities

First of all, the redeveloped buildings need improved isolation and sunscreens to prevent indoor overheating. When no air-conditioning units will be necessary this also contributes to the prevention of outdoor heat accumulation. With the transformation of, mostly South-East oriented, building strips with an additional building layer an ideal opportunity for solar panels on roofs occurs, for both thermal and electrical panels. Heating energy in winter can be saved by heat and cold storage in the ground per courtyard. A great advantage is the possibility to extract cold from the ground in summer to bring down indoor temperatures without air-conditioning units. In Amsterdam the city heating network can be supplied with additional heat when the seasonal heat and cold demand is not in balance. The building renovation should be adopted to the energy opportunities with for example low temperature heating systems and additional insulation.

Preserving green with courtyard identity

The wish of the municipality to use the inner courtyards for parking is the most economic option to increase parking space. And with some additional measures to the buildings, pavement and additional trees this does not directly decrease thermal comfort. This was concluded from the simulations presented in chapter 5. Nonetheless, the additional paved surface contradicts with the aim to prevent additional heating up in the first place. Moreover, it would be a destructive option regarding the special garden city concept which is carefully designed throughout all scale levels, from courtyard, to neighbourhood, to district, to park city (Feddes, 2011). Typical for the garden city is the 'in-between' scale which are the green strip and the park strip in the green structure and the neighbourhood and district street in the traffic system. These 'in-between' elements are the connecting elements for green and allow a free choice in the routing network. Figure 9.6 schematically illustrates the green structure. The tree structure follows the hierarchic road structure.

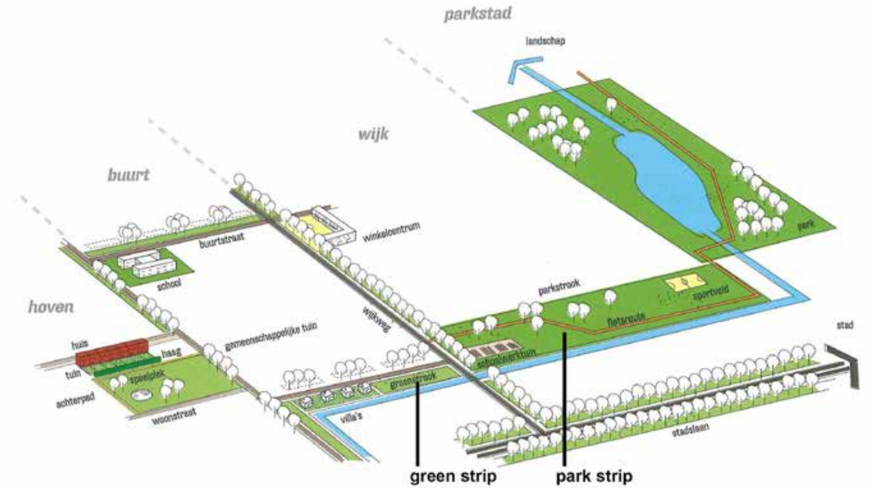


FIGURE 9.6 Schematic illustration of the green structure of most parks in Amsterdam Nieuw-West; they form an entity through different scale levels (Feddes, 2011)

According to the second step, passive cooling needs to be preserved. The chance of preservation can be increased by assigning a function to green space so that the value for inhabitants increases. An alternative function to the inner courtyard should not only enlarge the dwelling comfort, but also fit in the typical green structure where it serves the other scale levels. The additional function to the green is a delicate decision since the dwellers of the courtyard should not be hindered by the new activities. Therefore, a sports field or private allotment gardens would not be appropriate. One can think of a playground, community garden, butterfly and bee garden, water retention basin or infiltration point or fruit and nut orchard.

Increasing parking space

As stated before, additional pavement is not desirable because it leads to an increase in heating up, in this case the additional parking places will also decrease the passive cooling capacity of the grass. This argues not to sacrifice green for parking, especially if there are alternatives to exploit. The current parking space is around 0.6 places per dwelling. With the transformation of two apartments to a single family house the amount of parking space automatically doubles to 1.2 places per dwelling without adding any physical places. No additional parking places are needed, as is explained below.

NO NEED FOR ADDITIONAL PARKING PLACES

The national parking standard per dwelling varies from 1.6 places per dwelling for social housing to 2.3 places for the expensive housing segment (CROW, 2012). This standard does not consider additional factors like public transport possibilities and regulation through parking permits and pay parking which have substantial effect on the parking demand (Bos & Martens, 2015). The Nieuw-West city district has decided to deviate from the national standards weighing the current and projected growth of car ownership and the stimulant they want to create for built parking and alternative initiatives. The parking standard is set to 1.0 places per dwelling for social housing to 1.3 places for the free sector (Gemeente_Amsterdam, 2012).

Travelling by car within Amsterdam is not very attractive because it takes longer than traveling by bike or public transport and parking is a dreadful waste of time and money. On the other hand the alternatives are quite attractive. There is a tram and bus line running along the South side of the neighbourhood. And it takes only 15 minutes by bike to reach the historical centre of Amsterdam and 20 minutes to the central train station. For trips outside the city a car could be more convenient or even indispensable. With the many car sharing companies we can choose from nowadays, the amount of private parking spaces can be further reduced. The high connectivity and density of functions is a unique feature of large metropolitan city like Amsterdam which allows for lower parking standards and offers great opportunities for a different use of the public space.

Another approach to interventions that increase (future) problems with water and heat stress is to demand compensation. This can, for example, be in the form of a green covering over and water storage under the parking or active cooling facilities.

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Integrated water system

The Couperus neighbourhood is enclosed by roads that form a dike ring of about 1.5 meter high. The transition from the higher road to the neighbourhood is done with a slope along the high traffic road and with staircases and green along the road next to the canals, see Figure 9.7. Further improvement of the microclimate can be achieved by regulating the water level within the area. More water infiltration supplies trees with enough water to evaporate and cool at full potential. Independent water regulation starts with disconnecting pluvial water discharge from the sewage. This cannot be achieved by simply discharging to the large body of surface water because of the dike ring. The courtyards, green strips and park strips could be very functional to a more sustainable water system that increases the passive cooling capacity.

1 *2*

FIGURE 9.7 The South side (1) has a sloping edge and the North side (2) has stairs to enter the neighbourhood. Dwellings have a higher entrance level than the door to the back yard.

Figure 9.8 presents a water system for the area. The surplus of water is collected in two main buffers with infiltration points. The water will infiltrate up to a minimum level. The water is directed to the basins by open gutters which only contain water during rain fall. Some are integrated in the street or pedestrian pavement, the main discharge flows are integrated in the green strips along the road. In case the maximum buffer capacity is reached, a pump discharges the water to the surface water on the other side of the dike. In case of extra heavy rainfall an additional overflow discharges to the sewer. The extra water infiltration is only possible if the groundwater level may vary. Most of the buildings in Amsterdam are funded on wooden poles which have the risk of rotting when they extend above the groundwater level. After 1920 the wooden foundation poles have a concrete extensions to keep the wooden pole head under water (Gemeente_Amsterdam, 2010). The Couperusbuurt has no risk of rotting because the foundation poles are entirely made of concrete. Therefore the water level may vary according to amount of precipitation and water consumption by vegetation.

FIGURE 9.8 Design of a new water system for the Couperus neighbourhood to disconnect all rain water from the sewage and infiltrate it in the ground or discharge it to the surface water.

The inner courtyards all have their own buffer or infiltration facilities, as illustrated in Figure 9.9 (a and b). Especially in combination with the alternative function that is addressed to it, interesting new urban spaces can evolve. A butterfly and bee garden could be very well combined with, wet flower beds, small water streams and ponds that eventually dry out after the rain, like the example of.. in Figure 9.9 (c). A playground is much more fun with water elements in it, as shown in the example of a water playground in The Hague in Figure 9.9 (d).


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FIGURE 9.9 Design of water infiltration bodies(1) and water buffer (2) in the courtyards and water garden Darwinpark in Zaandam (Bakker, 2012) (3) and water playground in The Hague (Vos) (4).

Important for an optimal infiltration is to infiltrate at both, the front and the back side of buildings (Votel, 2015). To achieve this the municipal infiltration system described in the previous paragraphs should be complemented with infiltration in private gardens along the roads. Additional benefit in this case can be less pavement and increase of cooling capacity of green close to the dwellings.

§ 9.3 Zuidwal, The Hague

This sub-sections presents the case study for the Zuidwal neighbourhood, The Hague.

§ 9.3.1 Neighbourhood analysis

This neighbourhood was introduced in the previous chapter as part of the historical city centre of The Hague with a commercial character and additional post-war dwellings. The percentage of green and water is very low, less than five percent of the total amount of urban surfaces. Even for this type of neighbourhood, where large pressure on public space and high density of buildings are common, the amount of natural surfaces is relatively low. Street trees are only appearing on squares and along the canal. In the meanwhile, the outdoor space is used intensively, increasing the importance of healthy and comfortable conditions.

In the design process, research and design studies are parallel. Where the design studies raise questions it is sometimes possible to answer or test hypothesis with a research

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study. This particular design process started off with the question which neighbourhood is interesting for the municipality of The Hague as a pilot study? A neighbourhood with a high heat accumulation potential was found most interesting. Therefore a first hotspot analyses was performed by a colleague in the CPC project pointing out Zuidwal as hotspot. The following intermezzo gives a short description of the study.

HOTSPOT ANALYSES

Before leaping to possible solutions, insight in the difference of heating up in this neighbourhood compared to other areas in the city provides a better understanding of the heat accumulation and the possible solutions.

LAND SURFACE TEMPERATURE

Several parameters assessed through remote sensing imagery can be used as UHI indicators. One of these indicators is the diurnal Land Surface Temperature. Diurnal LST images provide an overview of the city areas that tend to heat up during the day. Depending on the heat storage capacity of the material this heat is either released to the atmosphere and/or to the interior of the buildings during day time, or during night time.

The land surface temperature analysis of The Hague has been carried out based on satellite imagery (Landsat 5 TM) retrieved during the heatwave of 2006, on the 16th of July at 10:33 h presented in Figure 9.10.

In the Hague several neighbourhoods present average diurnal LST above 41ºC: Schildersbuurt, Transvaal, Zuidwal, Brinckhorst and Kerketuinen.

STORAGE HEAT FLUX

Another relevant UHI indicator is the storage heat flux. Storage heat flux maps identify public spaces within a city that tend to radiate more heat at night, but also building roofs with higher heat storage capacity, and therefore a higher potential interior discomfort.

The energy balance equation can be written as:
$Rn = G + H + LE$ (Asrar, 1989), where Rn is the net radiant energy absorbed by the surface, G is the storage heat flux, that is the energy dissipated by conduction into the ground or into the building materials, H is the sensible heat flux, that is the energy dissipated by convection into the atmosphere (its behaviour varies depending on whether the surface is warmer or colder than the surrounding air), and LE is the latent heat flux, that is the energy available for evapotranspiration.

For the storage heat flux analysis of The Hague the same satellite imagery used for the land surface temperature has been imported into ATCOR 2/3 (atmospheric topographic correction software for satellite imagery).

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In Figure 9.11 the storage heat flux in The Hague is presented. Two neighbourhoods show an average storage heat flux above 90 W/sqm: Zuidwal and Uilebomen. Zuidwal is (as indicated above) a mix between 17th century Dutch dwellings with post-war dwellings whereas Uilebomen is the high rise district of The Hague.

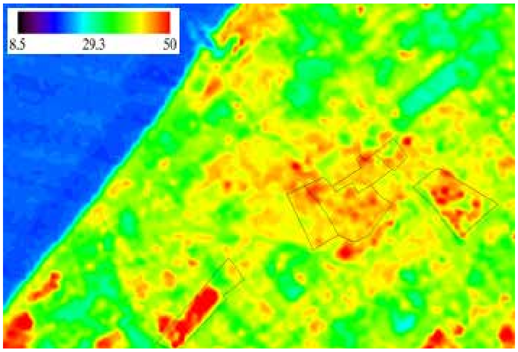

FIGURE 9.10 Land surface temperature image from the16th of July 2006 at 10.33 UTC.

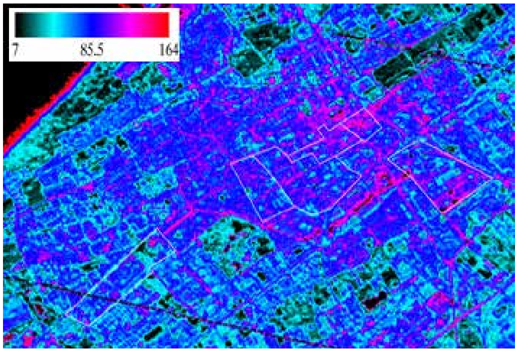

FIGURE 9.11 Storage heat flux image from the16th of July 2006 at 10.33 UTC.

The neighbourhood that has both, a high LST during the day and a large storage heat flux is Zuidwal. In this area temperatures are relatively high at day time and at night it takes a longer time to cool down compared to other neighbourhoods. Regarding the intensive use of the public space in this part city and the partly residential use of the buildings comfort improvement has the potential to effect many people.

This hotspot analyses is carried out by Echevarria Icaza (forthcoming).

The following sub-section shortly describes the political context and the paragraphs thereafter introduce options to improve thermal comfort in combination with other redevelopment themes for the neighbourhood.

Political context of The Hague

While in Amsterdam a clear choice was made to mainstream climate adaptation in the different departments of the municipality, The Hague did not make an explicit choice. According to the two principles of the dedicated and mainstreaming approach neither is applicable to The Hague. The city district *Haaglanden* (Stadsgewest Haaglanden) has established a regional plan (Structuurplan) that presents the ambition to reduce CO2 emissions with 30% by 2020 and become 'climate neutral' by 2050 (Witsen, 2008). In this document, no ambition in relation to climate adaptation is mentioned. Nevertheless, there was interest and cooperation from the municipality in the case

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study projects of the CPC. Continuity of climate related projects and knowledge is insecure since the city district *Haaglanden* has terminated all operations on 1-1-2015. The district will continue partly within the Metropole Rotterdam The Hague.

§ 9.3.2 Design integration

The design for the Zuidwal neighbourhood is described in this sub-section by means of thematic descriptions.

Shading

In one of the central shopping streets of The Hague, the Grotemarktstraat, the outdoor climate is actually 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. In the Mediterranean climate, heating of the outdoor space is often prevented by shading devices that cover the whole canopy.

Although a canvas sheet is a solution that belongs to the first priority to prevent heating, in most streets with traffic running through it is not an option because of the reduction air quality. Besides, the shading device is only in place in summer and has no benefits during the rest of the year. An extra benefit of covering a street is the protection against rain. However, compared to trees that have many additional benefits throughout the year, canvas awnings do not serve that many additional benefits.

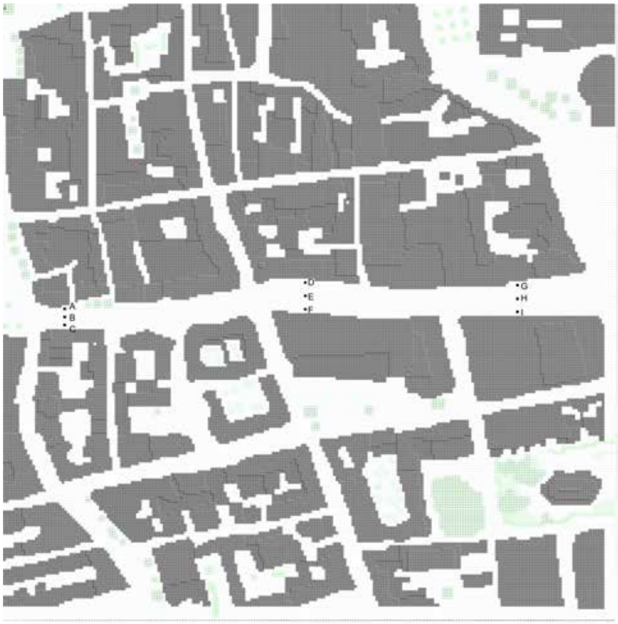
In case of the Grotemarktsstraat planting large trees is not an option. Moreover, the application takes only a minor intervention since there already is a support system for lightening. And the enterprises and municipality are considering an extension of the system for Christmas decoration. With some additional attachment points, the support system could held up canvas sheets to provide shade on hot sunny days and Christmas decoration and lighting in the winter months. In Figure 9.12 an impression of the Grotemarktstraat with the shading device is presented.

FIGURE 9.12 The Grotemarktstraat in The Hague with canvas sheets to improve thermal comfort on hot days.

The canvas sheets are a temporal measure that will be in place during the hottest period of the year. Nevertheless, the street needs sufficient daylight which can be achieved through the use of light colours, some level of translucency and only covering the North side of the street. In any case, a shading device will reduce indoor daylight as well which might lead to more artificial lighting.

SIMULATION OF EFFECTS ON THEMAL COMFORT

To analyse the effect a canvas shading device can have on thermal comfort the street and surrounding area is modelled and simulated in ENVI-met. Together with the existing situation and two other options that could be possible on the location: trees on the North side of the street and light roofs with an albedo of 0.85 instead of 0.3. In Figure 9.13 the modelled area and the receptor points A to I are presented on a map. In Figure 9.14 the outcome of the simulations is presented in a graph.



THE ENVI-MET INPUT PARAMETERS ARE BASED ON A TYPICAL HEAT WAVE DAY THAT HAVE OCCURRED IN THE LAST 50 YEARS:

Start Simulation at Day (DD.MM.YYYY): =21.06.2005
Start Simulation at Time (HH:MM:SS): =05:00:00
Total Simulation Time in Hours: =10.00
Save Model State each ? min =60
Wind Speed in 10 m ab. Ground [m/s] =2.2
Wind Direction (0:N..90:E..180:S..270:W..) =45
Roughness Length z0 at Reference Point =0.1
Initial Temperature Atmosphere [K] =296
Specific Humidity in 2500 m [g Water/kg air] =7
Relative Humidity in 2m [%] =65

FIGURE 9.13 The model input in ENVI-met showing the Grotemarktstraat and surrounding in The Hague with receptor points A to I.

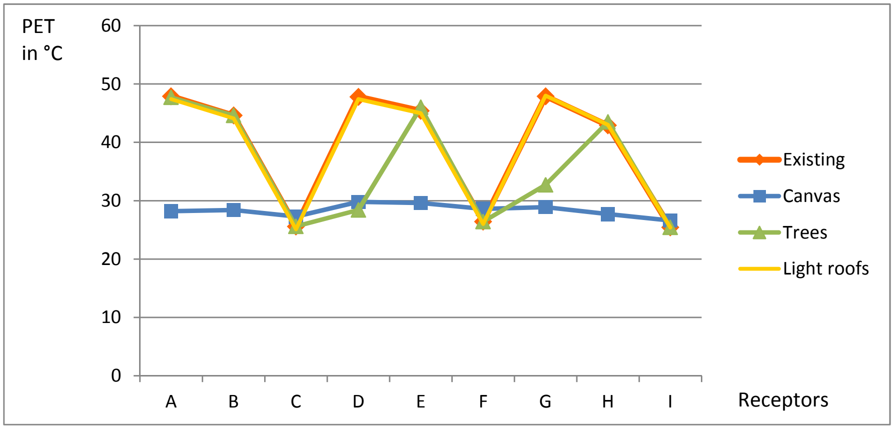


FIGURE 9.14 ENVI-met simulation to analyse the effect of three different adaptation measures on thermal comfort (PET) in the Grotemarktstraat at 13:00 h at a height of 1 meter.

The North side and middle of the street receive the most solar radiation, this is visible in receptor points A, B, D, E, G and H. The canvas sheets lower the PET with about 20 °C. The receptor points C, F and I are already shaded by the adjacent buildings at 13:00 h. Interesting enough the canvas sheets cause a slightly higher PET here of around 2 °C. This can be explained by the reduction in ventilation caused by the covering sheets. The effect of a single row of

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small trees along the North side reduce the PET on this side of the street with 0 to 22°C, depending on the distance from the trees. Light roofs do not significantly reduce the PET. Probably the building height of 15 to 27 meters is too high for an effect on street level. Important to notice is that there is no negative effect at street level either. While for indoor spaces and the city wide UHI the effect can be of importance.

The Zuidwal neighbourhood has many more shopping streets, mainly the streets perpendicular to the Grotemarktstraat. These North-South streets need additional shading devices, such as trees with a wide crown, to keep pedestrians comfortable on the middle of the day. The area knows many narrow streets, these do not provide sufficient ventilation in combination with car emissions. Car use should be avoided in these streets, for example by introducing one way traffic streets or expanding the pedestrian area.

Roofs and façades in control of the urban climate

When the ratio of roof and façade surfaces is much larger than the ground surface they form great potential in controlling the urban climate, but also to produce heat and electricity on a sustainable way. Instead of focussing on one optimal measure that cools passively (reflective or vegetated surfaces) or actively (collectors), a mix of green, white and thermal/electric coverings is a more realistic strategy which enables combinations with user preferences. Depending on the shape of the roof, the construction of the building, the indoor comfort requirements, the electricity and gas consumption and the use of the roof, a choice can be made for the roof or facade covering. In Figure 9.15 the map illustrates adaptation options, including the above mentioned. The other measures presented in the map are dealt with in the following sections.

The use of facades and roofs in conditioning the urban climate can be done passively or actively. Passive measures include stimulating air flow with façade colours or solar chimneys, see chapter 3, section 4 and chapter 6 for more information about these principles. Also increasing the evaporation from these surfaces provides more cooling, for example with green roofs and facades or sponge materials that absorb water. These will be difficult to apply because of the monumental status of most of the buildings. Facades facing a courtyard have less strict regulations, here constructions for climbing plants to shade South and West facing walls are recommended

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Zuidwal Den Haag

---- underground storage for runoff water to supply
trees and spray systems in hot an dry periods
🟦 waterplaza to store water with heavy rainfall

green wall with ivory

green wall with structural support

● ● ● trees or ivy pergola

🟩 green roofs

---- underground storage for runoff water to supply
trees and srpay systems in hot an dry periods
⬚ flexible canvas sheets

▬ energy wall that insulates indoor climate

▬ shadow device for pedestrians and cylists

■ permeable pavement
■ asphalt collectors
🟨 energy roofs, pv panels or boiler panels catch radiation and use solar heat/light
■ existing urban fabric

||||||||| narrow street (H/B > 1,57) NW-SE
car free zone for better air quality
||||||||| narrow street (H/B > 1,57) NE-SW
low car zone for better air quality
||||||||| existing car free zone

⬚ gallery providing shelter for pedestrians
against sun and rain
☐ white roofs cool indoor and outdoor
climate
■ existing urban fabric

FIGURE 9.15 The Zuidwal neighbourhood in The Hague with a wide range of climate adaptation measures to improve thermal comfort on hot days.

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Active cooling measures include the use of running water along roofs and facades or the use of running water within the façade cladding. Especially the latter one could be a realistic option in this historical area because it does not have to show on the outside. With cooling the façade and roof surface both, the outdoor and indoor temperatures are reduced. An energy wall can harvest the heat from the façades in summer to heat up the indoor space in winter. Such a cooling system requires a cold source like a large lake or river or an aquifer for seasonal heat and cold exchange. With using the heated water from the collector wall directly for hot tap water or indirectly for heating in winter the urban climate control system supports indoor climate control and can lead to significant reduction in energy consumption. An alternative is to use an absorption chiller that can use hot water of 55-90°C to cool water to 5-10°C. The cooled water can be used to cool indoor, semi-outdoor spaces and provide cool pavement at places where many people gather or where children play. Another option for the same type of places could be to work with *phase change materials* (PCM's) that absorb energy transforming from solid to liquid. In section 3.4 and 3.5 these energy principles are explained and in the following section the energy potential for a specific location is further elaborated.

Energy producing Spuiplein

To approximate self-sufficiency in energy consumption, which is unavoidable in meeting the national energy agreement before 2020 (SER, 2013), additional options and sources must be used. The first thing to do is: look for possibilities to consume less energy; second: reuse energy; and only as a third step: produce the energy demand that is left with renewable sources (Tillie et al., 2009). In the case of linking climate adaptation to mitigation the first step is already covered in by the previous proposed measures. Indoor comfort and energy consumption have a strong relation in our present-day buildings. Therefore, measures to control the outdoor climate are beneficial in reducing energy consumption for indoor climate control. Vice versa, when no air conditioning units exhaust hot air from inside to the outdoor environment, the first priority to prevent heating is achieved. The second step where the two objectives meet is to re-use heat, which cools the outdoor space in summer (second priority, active cooling) and reduces energy consumption for indoor space heating in winter or other functionalities. Finally, the third step is producing electricity and meanwhile avoiding radiation to reach the roof surface or indoor spaces and to avoid multiple reflection into street canyons (first priority, prevent heating).

The previous paragraphs also tell us that not all roof surface is available for energy production, because another functionality might be preferable. If we look at the potential of the available roof surface when completely dedicated to energy production, only 20% of the electricity and 60% of the heating demand in Zuidwal can be supplied. In Figure 9.16 the energy consumption and in Figure 9.17 the potential production from roofs for heating and electricity is given for 6 hotspot neighbourhoods in The Hague.

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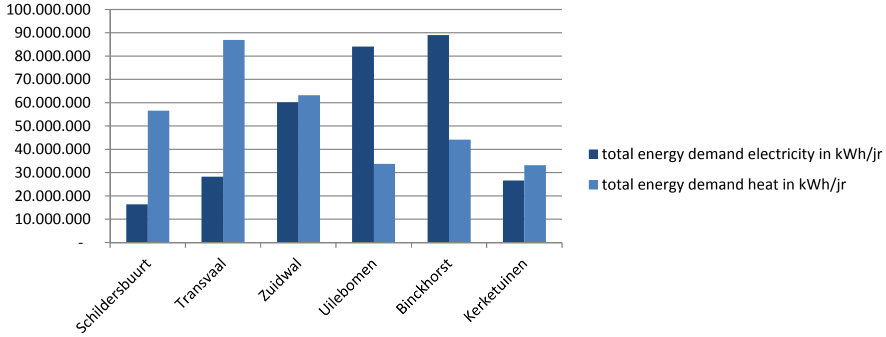

FIGURE 9.16 Total energy demand per neighbourhood for electricity and heat in kWh per year (source municipality of The Hague).

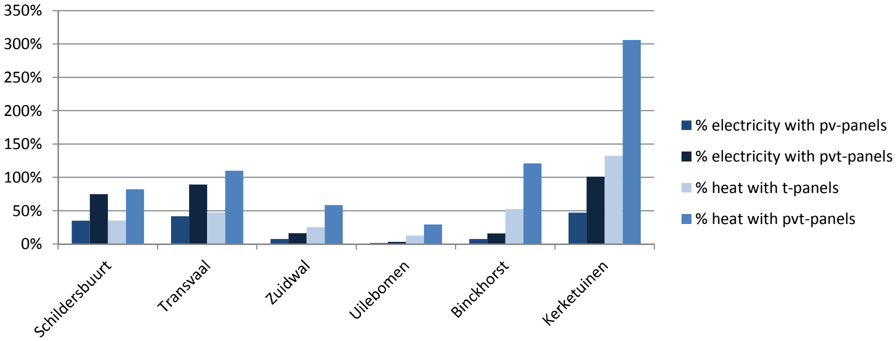

FIGURE 9.17 The potential energy production from the available roof surface in relation to the demand per neighbourhood. The yield is divided in electricity and heat production and shows the difference between using 50% photovoltaic and 50% thermal panels and using a combined panel producing electricity and thermal energy at the same time.

A large square, such as the Spuiplein adjacent to the Zuidwal neighbourhood, has the potential to produce energy. An additional asset, besides the large paved surface of 3600 m^2, is the dark colour of the pavement that absorbs the solar radiation even more, see Figure 9.18. In the Netherlands heat collectors in pavement have an average yield of 268 kWh/m^2 per year (Hoes, 2008, Loomans, 2001). As a hypothetical example this square could produce 882,000 kWh per year and provide enough heat for 60 households.

FIGURE 9.18 The Spuiplein in The Hague (Source picture: Fleur van Paridon).

The buildings surrounding the square and facing the South could be transformed into energy walls. The South-West facing wall of the two theatres have a surface of 840 m^2. Vertical pv-collectors produce 70 kWh/m^2 per year on average (Meer, 2008, Matuska & Sourek, 2006) resulting in a potential energy production of 60 MWh per year. This would cover about 30% of the electricity demand of the theatre (Stimular, 2015). In case there is opted for a heat producing façade, the yield is about 280 kWh/m^2 per year (Matuska & Sourek, 2006). The façade fully compensates the relatively low gas demand of the theatre, of around 17.000 m^3 per year, and additionally covers the demand for 14 households (Stimular, 2015). The Hague has a city heating network that could easily be deployed to use the heat from the asphalt and/or façade collectors in case no seasonal storage will be realised on site.

The calculation for the heat and electricity production of the façade is based on the fully closed façades of the theatres. In addition, the glass facades of the entrance, lobby and foyer could be used. With transparent systems the yield is lower compared to the closed system, but spaces keep their visual connection to the outdoor space, see Figure 9.19.

FIGURE 9.19 multi-functional facade elements with integrated evacuated-tube collectors enable a view outside developed by University of Stuttgart (BINE, 2013).

Water management

Besides the canal running along the edge of the neighbourhood, rainwater has no other way to leave the streets than through the sewage. Due to the intense use of the public space the ground surface is almost completely sealed. When streets need maintenance or complete redevelopment replacing existing pavement with a permeable variant provides trees with more water enabling passive cooling of the third priority. The permeable pavement alleviates the sewage during peak rainfall events. Also green roofs and facades can contribute to less discharge via the sewage system.

A recent development in urban water management is the combination of urban facilities and water retention to cope with peak rainfall events such as the water plaza Benthemplein in Rotterdam. In the Zuidwal neighbourhood the Kerkplein is a relatively small urban square far from any open surface water. The square can be designed to combine underground water storage in tanks and temporal water storage for infiltration. During peak rainfall events the surplus of water is collected in the open basins. Water is slowly discharged to the underground storage tanks and in case the limit in capacity of the basins is reached it can be discharged quickly to the tanks. The tanks can be used for watering the roof gardens and street trees (second priority, passive cooling), create water mist (third priority, active cooling) or even for flushing toilets. The basins are combined with the existing functions on the square. The first rain water drops are collected in the shallow basins along the tram tracks. A basin with a floating terrace is filled up next, which is discharged long after the rain has stopped so you can have a drink in the sun remembering, and even receiving mist from, the rainfall event of a few days before. A second basin can have the form of a small theatre in the open to support live music, theatre play or book readings. The usual function of a water square as a playground for children is not appropriate for this historical city centre location.

§ 9.4 Bergpolder, Rotterdam

This sub-sections presents the case study for the Bergpolder neighbourhood, Rotterdam.

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§ 9.4.1 Neighbourhood analysis

The previous chapter introduced this neighbourhood as one of the old parts of the city centre of Rotterdam. The area has a large ratio of stony surfaces within the urban block structure, while around the neighbourhood the main roads are supported with broad green belts. The following paragraph describes the political context in Rotterdam, the sub-section thereafter introduces options to improve thermal comfort in combination with other assets for the neighbourhood.

The same analyses as presented for Amsterdam in section 9.2.1 is developed for the city of Rotterdam (Hoeven & Wandl, 2015). The analyses is presented in figure 9.20, showing a large spreading in hot areas over the whole city. Locations with vulnerable groups such as elderly and babies are located in the outskirts, especially on the western part of the city. While concentrations of labour activities is largest in the city centre. For the Couperusbuurt neighbourhood, which is situated in this western part, this means that liveability for these groups need to be protected.

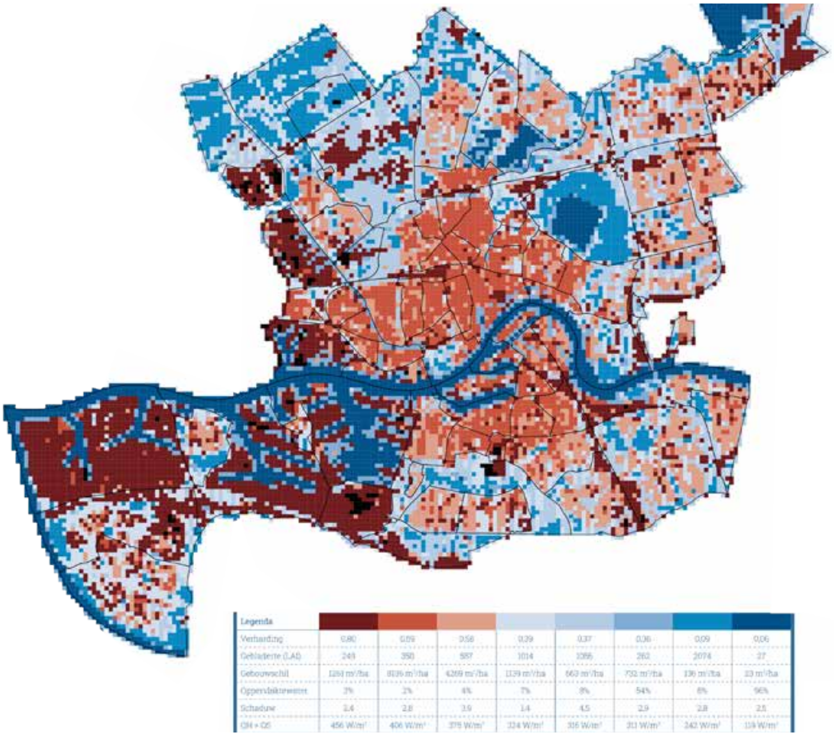

FIGURE 9.20 Physical heat map of the city of Rotterdam (Hoeven & Wandl, 2013).

Political context Rotterdam

The municipality of Rotterdam introduced the Rotterdam Climate Initiative in 2008 from where the Rotterdam Climate Proof (RCP) program was initiated. The RCP program aims for: a reduction of CO_2 emissions by 50 percent by 2025 (in relation to 1990); a 100 percent climate proof city by 2025; and strengthen the city's economy (Molenaar et al., 2010). According to Uittenbroek et al. (2014) this political objective leaded to a dedicated approach. To provide safety, accessibility and a liveable urban environment, there was a need for 'smart water management'. Because this need was framed as a strength that could profile Rotterdam as a leading city in water and climate solutions, politicians were willing to commit to the issue. A budget and responsibility for the RCP program was assigned to the new climate bureau. An important output of the RCP programme is the policy document Rotterdam Adaptation Strategy (RAS) which received input from research and pilot projects initiated and funded by the RCP program. The specific budgets and political objectives enabled the realization of a floating pavilion, water plaza and green roofs. The Bergpolder case can be seen as one of the research projects within the RCP program. In this case study, objectives of the CPC project and RCP program were joint.

§ 9.4.2 Design integration

The design for the Bergpolder neighbourhood is described in this sub-section by means of thematic descriptions.

Integration project of Climate Proof Cities (CPC)

The Bergpolder Zuid neighbourhood was pointed out by the CPC programme as integration project for all CPC partners. Within the integration project workshops were organised for researchers and stakeholders from the municipality of Rotterdam and the housing association Vestia to come to collective research objectives and to discuss intermediate results *(Groot et al., 2014)*. Figure 9.21 presents the timeline of the project.

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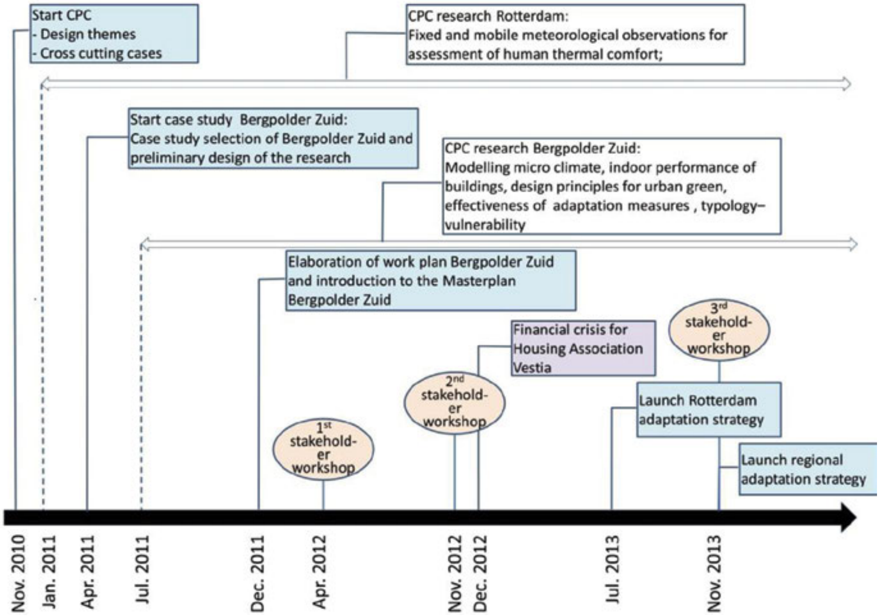


FIGURE 9.21 Timeline presenting the integration project Bergpolder Zuid in the CPC research framework (Groot et al., 2014).

The collaboration of different research groups working on one case provides detailed insight in the effects of a wide range of measures to improve thermal comfort. From measures for indoor to outdoor and for day, night or both. Figure 9.22 presents the range of effect of measures in time of day and type of space. The scheme is useful to keep designers and policy makers aware of the different type of effects that can be achieved instead of only focussing on the magnitude of the cooling effect. If you want to improve thermal comfort in a residential area night ventilation is of greater importance than in an area with offices and shopping streets that is almost deserted at night.

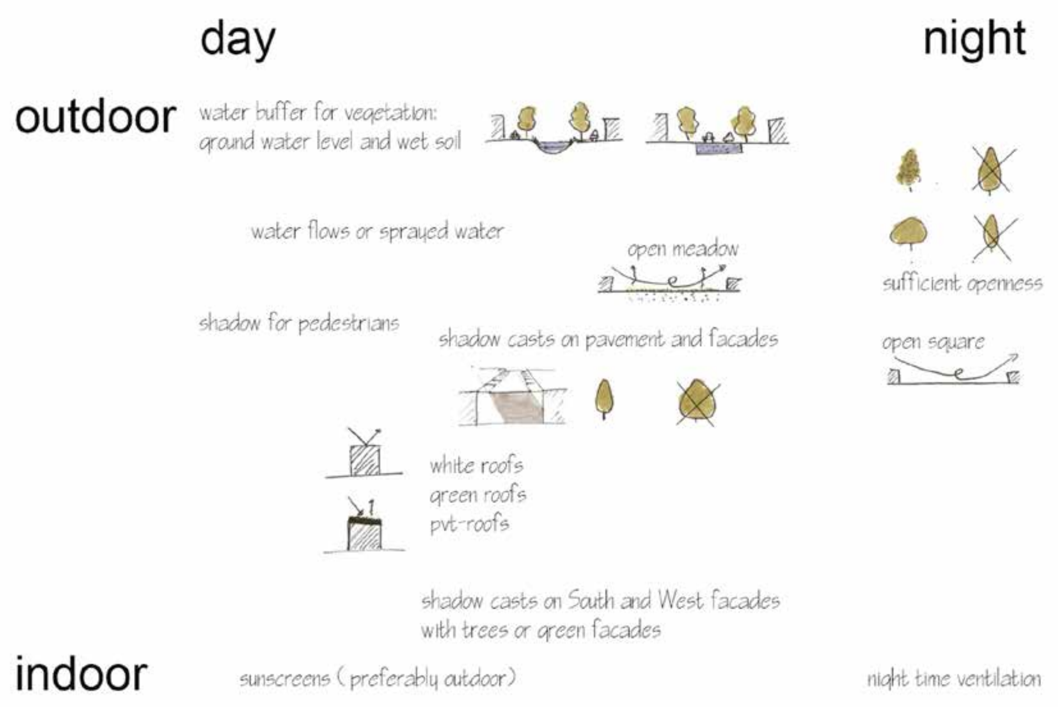


FIGURE 9.22 Overview of climate adaptation measures and their range of effect in time and space.

The integrated research in Bergpolder Zuid started off with observations of the microclimate with fixed and mobile measurements. Compared to the rural surrounding several inner-city areas, including Bergpolder, are over 8˚C warmer in the evening and at night on warm summer days (Hove et al., 2015). The master plan developed by the housing association and the municipality of Rotterdam (Ginter et al., 2011) is simulated in the ENVI-met model to analyse the impact on the air temperature. The results do not indicate a relevant difference as described by Kleerekoper et al. (2012) and presented in Figure 9.23. Therefore, additional measures are needed for a climate proof redevelopment strategy. The following paragraph describes studies into the effect of adaptation measures, mainly water and vegetation, through model simulations and urban design studies by various researchers and designers involved in the integration case.

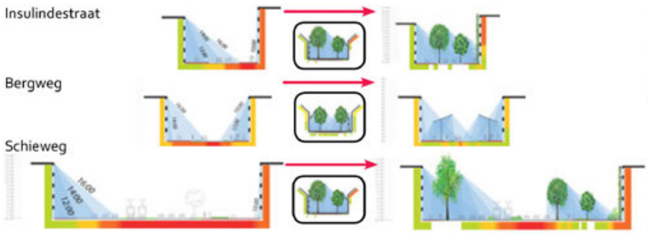
Existing situation

Master plan

FIGURE 9.23 Simulation results by ENVI-met in potential air temperature for 7-8-2013, 13:00h at a height of two meters. Yellow indicates 25.5-26°C and orange 26-26.5°C (Kleerekoper et al., 2012).

Outdoor and Indoor overheating prevention

The orientation and H/W ratio are determining parameters to prevent heating of the outdoor environment (first priority). Regulation of solar access can be further influenced by street trees. Different street profiles and orientation require a different tree planting scheme. In Figure 9.24 the solar exposure is given with an appropriate planting scheme for three streets in Bergpolder-Zuid.



Trees are located as close to the middle of the street as possible to allow solar access to the windows.

Street does not have space to plant trees that is why shading constructions in the shape of umbrella are proposed.

Canyon H to W ratio is very low, it is impossible to shade street with 2 rows of trees complitely, additional trees to shade the surface are added where it is possible.

FIGURE 9.24 Solar exposure, appropriate greening scheme and actual design according to the local conditions for three streets in Bergpolder-Zuid (Hotkevica, 2013)

In Bergpolder-Zuid a mix of building types can be found; from historical, via post war, to present-day architecture. The outdoor climate has an influence on the indoor climate and vice versa when, for example, air conditioning is switched on. Simulations are performed with Building Energy Simulation to determine the most effective adaptation measure in reducing indoor temperatures; see Table 9.3. The effect of insulation decreases with newer construction because they already have good insulation values. Overall the best results can be achieved with a sufficient overhang. Also opening windows, increasing the roof albedo and applying a vegetated roof show substantial effects. Note that increasing the facade albedo is less effective in cooling the indoor temperature than increasing the roof albedo. Moreover, a reflective facade can decrease outdoor thermal comfort due to the extra radiation load, as concluded in chapter 5. Another point worth mentioning is the fact that operable windows only have an effect when the outdoor temperature is lower than indoors.

MEASURE	REDUCTION IN OVERHEATING HOURS (%)			
	TYPE 1	TYPE 2	TYPE 3	TYPE 4
Insulation	-7 - 61	-3 - 44	-2 - 30	-1 - 18
Thermal mass	-4 - 4	-1 - 6	0 - 6	0 - 7
Albedo	49 - 91	35 - 69	25 - 58	20 - 51
Overhang	30 - 67	49 - 95	62 - 98	70 - 99
Opening of windows	55 - 67	77 - 96	82 - 89	83 - 91
Vegetated roof	33 - 66	22 - 64	17 - 57	14 - 47

TABLE 9.3 Simulation results in overheating hours for six adaptation measures for the indoor climate of four different dwelling types: dwelling type 1 is a reference dwelling built before 1974, dwelling type 2 is a reference dwelling from 1974 – 1991 dwelling type 3 is a reference dwelling from 1992 – 2011 and dwelling type 4 represents a new dwelling constructed after 2011 (Haak, 2012)

For all building types a specific structure for greening the façade can be designed, see Figure 9.25 for various solutions. A large advantage of overhangs or a façade structure with deciduous climbing plants is the solar gain in winter when the leaves have dropped.

FIGURE 9.25 Various façade structures for climbing plants: window and balcony with overhang (1 and 3) and whole façade (2 and 4) (Liu & Shan, 2012).

Temperature effects of trees and water in Bergpolder

Water and trees can be applied to achieve a passive cooling effect (second priority). A project directed to study the effect of trees and water on the air temperature used two different measurement methods: a glass fibre cable and sap flow in trees. The study indicates a cooling by trees with an average of 3˚C. And although the effect of the existing surface water is more complicated to measure, the results indicate a cooling effect of about 1˚C (Slingerland, 2012).

To see whether additional surface water could improve thermal comfort in the neighbourhood on warm days, three locations with a water pond are simulated. The simulated ponds are around 600m^2 and have a depth of 0.3m, see Figure 9.26. The water ponds show to decrease the air temperature with 1 to 2˚C at a height of 1.8 metres. The roof pond shows an even higher cooling up to 3.9˚C (Toparlar et al., 2013).

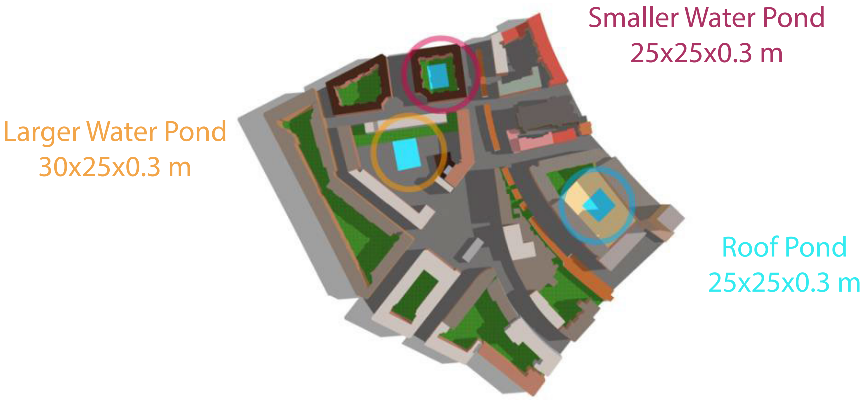


FIGURE 9.26 Water ponds on three locations in Bergpolder-Zuid (Toparlar et al., 2013).

Another cooling option with water is wetting streets, this urban cooling method cools actively (third priority). In Japan this has evolved into an essential tradition called ‘Uchimizu’. A test in Rotterdam shows a substantial cooling effect with wetting streets. But if we want to apply this a large amount of water is required, which should be stored somewhere. Rotterdam already has a large water tank that could be exploited for urban cooling. The water storage of 10.000m^3 in the parking garage of the museum park would be enough to wet the whole city centre four times (Slingerland, 2012). Depending on the weather forecast, this storage space needs to be emptied since its main function is to prevent flooding during heavy rainfall, see Figure 9.27. A difficulty with spraying pavement and roofs is the lack of additional benefits besides cooling. It might be combined with cleaning the streets, but this is usually done with a water saving cleaning car wiping the streets instead of using a water hose.

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FIGURE 9.27 Water storage for heavy rainfall under parking garage Rotterdam (source: IABR.nl)

Cooling breeze on square

A passive cooling method (second priority) can improve thermal comfort on the Insulindeplein and adjacent Insulindestraat. As presented in chapter 6, a dark façade can increase ventilation during warm weather. A former chocolate factory along the Insulindestraat was appointed for redevelopment in the master plan. This opens the opportunity to replace the front façade and apply a multifunctional façade. With a dark colour the façade will reach higher temperatures, causing heating of the air near the façade. The heated air will rise due to the buoyancy effect attracting colder air.

Reference can be made to the former chocolate factory by the use of the dark colour of cacao . In combination with the name of the factory written in the alley an historical value for the neighbourhood is preserved. In Figure 9.28 and 9.29 the building with the dark façade is indicated with the expected generation of air currents.

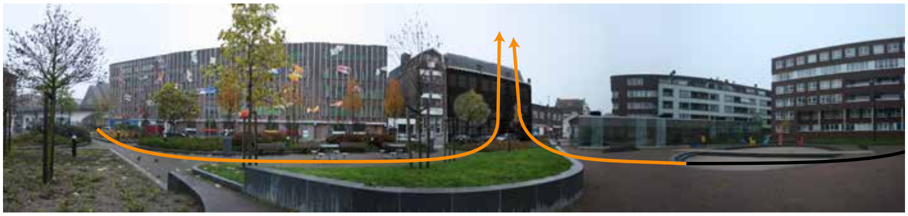

FIGURE 9.28 Expected thermal induced air currents with a dark façade of the old chocolate factory at the Insulindeplein

FIGURE 9.29 Expected thermal induced air currents with a dark façade drawn into the master plan Insulindeplein

The dark façade can have a negative impact on indoor thermal comfort and energy use in summer, whereas it can have a positive effect on both aspects in winter. To improve thermal and energetic conditions in summer a 'smart' façade needs to be developed. A façade with a heat collector to regulate the generation of ventilation and make use of the captured heat can provide the following function: When the radiant force of the sun decreases in the afternoon, the air current is no longer needed. If the collector is switched on at this time of day the accumulated heat in the facade can be extracted cooling both, the indoor and outdoor environment. In any case, the smart façade needs to have additional isolation and sunscreens in front of windows to decrease overheating during the day. The heat collector can harvest heat whole day long in spring and autumn as a regular collector system since in this time of year additional cooling of the outdoor is not needed.

Combining cultural values with cooling measures

Passive cooling measures (second priority) such as additional green can be combined with the preservation of cultural elements in a neighbourhood. In Bergpolder an unused elevated railway track running through the neighbourhood offers opportunities for community green in the form of a stroll path, urban farm land and restaurants and bars, see Figure 9.30. This concept of giving new life to deserted railways proves very successful in other cities. The highline in New York is the most famous example, other examples are the Promenade Plantée in Paris and the Cypres Community Garden in Vancouver.

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FIGURE 9.30 railway park (Liu& Shan, 2012).

In the area biking is a common transportation mode, as goes for all Dutch cities. However, parking places for bicycles are scarce and if they are facilitated they blemish the street view. Figure 9.31 shows the consequences in the Bergpolderstraat. With a smart parking solution for bikes, see Figure 9.32, that also adds green to the street and functions as water infiltration point this becomes a feasible measures to improve thermal comfort.

FIGURE 9.31 Bicycles parked on unintended locations (left) and intended locations are insufficient and chaotic (right).

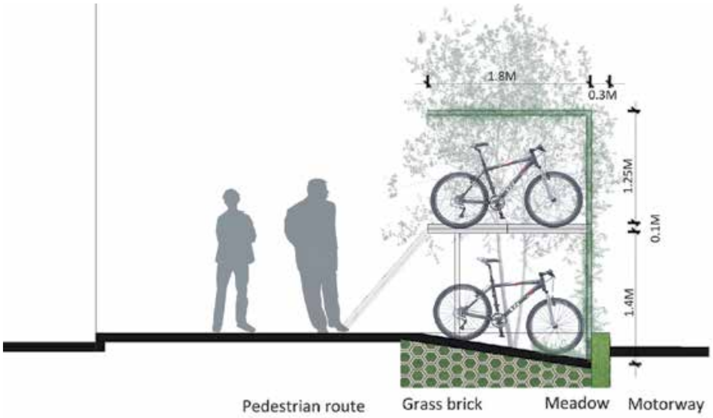

FIGURE 9.32 Smart parking solution for bikes combined with structure for climbing plant (Liu & Shan, 2012).

§ 9.5 Design evaluation

The three integrated design proposals from the previous sections are the output of the followed design process described in section 9.1. The process includes an analysis of the development task, adaptation task and political context, and a maximisation, optimisation and integration step. In Table 9.4 the results of these steps are shortly summarised per case study. Although this design process guides design choices, these choices are still partly based on personal considerations of the designer. This means also other options are possible and can be 'as good'. In fact, this arbitrary aspect is inherent to design and another designer might favour another possibility. The proposed design options therefore are an hypothesis to improve thermal comfort within the specific contexts of the neighbourhoods. This section concludes with reflections on the design processes for each case study.

	NEIGHBOURHOOD AND DESIGNER	COUPERUSBUURT, AMSTERDAM BY AUTHOR	ZUIDWAL, THE HAGUE BY AUTHOR	BERGPOLDER, ROTTERDAM BY AUTHOR AND CPC CONSORTIUM PARTNERS
Analysis	Development task	More variability in housing stock, more parking space	Many constraints: underground track under street, many monuments	More variability in housing stock, increase attractiveness
	Adaptation task	Preserve or compensate green Starting point: preliminary development plans municipality; what are effects on climate resilience of the neighbourhood?	Prevent overheating of shopping customers/ passers-by Starting point: inquiry municipality; which neighbourhoods have high heat stress probability?	Prevent heat stress indoor and outdoor Starting point: master plan housing association and municipality; what are effects on thermal comfort and what are 'quick wins'?
	Political context	Mainstreaming approach	No specific political approach	Dedicated approach
Maximisation	What are best options in relation to thermal comfort and neighbourhood characteristics?	Prevent heating: redevelopment of buildings with additional insulation and sunscreens, increase of shadowed pavement with additional building layer and street trees, offer alternatives for additional pavement for parking; Passive cooling: preserving existing green, add surface water, infiltrate rain water; Active cooling: fluctuating groundwater level.	Prevent heating: shading with urban canvas sheets and street trees, reflective roofs; Passive cooling: green facades and roofs, white roofs; Active cooling: solar collectors in walls, roofs and pavement, water storage on square, spraying water mist.	Prevent heating: shading with street trees on optimal location, redevelopment of buildings with additional insulation and green; Passive cooling: water ponds, greening facades, roofs and street furniture, cooling breeze through dark façade colour; Active cooling: sprinkling water on pavement and/ or roofs.
Optimisation	What are best options in combination with other climate adaptation options?	Extreme precipitation: additional surface water, wadi's, open gutter system, more vegetated and permeable surface; Drought: more rain water infiltration, flexible groundwater level.	Extreme precipitation: water square decreases risk of flooding; Drought: permeable pavement for water infiltration, water storage on square.	Extreme precipitation: water ponds, street trees and additional vegetated surfaces delay water runoff.

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	NEIGHBOURHOOD AND DESIGNER	COUPERUSBUURT, AMSTERDAM BY AUTHOR	ZUIDWAL, THE HAGUE BY AUTHOR	BERGPOLDER, ROTTERDAM BY AUTHOR AND CPC CONSORTIUM PARTNERS
Integration	What are best options in combination with other context related aspects?	Energy: isolation, sunscreens, lower outdoor temperature in summer, limiting parking space (no increase car use), clean production (collectors and PV cells on roofs and walls); Health: mental benefits provided by green, no increase of PM; Ecology: green habitat for flora and fauna, increase biodiversity (variations in green and additional water); Value: preservation of cultural historical characteristics of green structure, increase value and use of green, relief of sewage system (less discharge), additional floor space without decreasing comfort conditions.	Energy: reflective and green roofs, clean production (collectors and PV cells on roofs, walls and square); Health: mental benefits provided by green walls and roofs; Ecology: green habitat for flora and fauna; Value: increase attractiveness shopping streets in summer (improved comfort conditions), roof parks provide additional outdoor space, relief of sewage system (less discharge).	Energy: isolation, sunscreens, green roofs and walls, energy production by smart façade chocolate factory; Health: mental benefits provided by additional street trees, green walls and roofs, high rail park; Ecology: green habitat for flora and fauna; Value: roof parks provide additional outdoor space, redevelopment of building blocks (mix of housing, housing quality), increase attractiveness by additional street trees, redesign of square, parking under square preserves valuable public space.

TABLE 9.4 Overview of results per step within the integrated design process of the case studies

Couperusbuurt, Amsterdam

The starting point for this case study was set by the preliminary plans of the municipality and their request to gain insight in the effects these would have on the climate resilience of the neighbourhood. Parallel to the integrated design process to improve the outdoor thermal comfort, effect studies with computer modelling provided feedback on several adaptation measures.

From the two proposed measures to improve thermal comfort in the set of measures for the *low open urban block with moderate to much green*, preserving the existing green is a feasible option in this neighbourhood. Also additional measures to prevent heating or increase cooling capacity are applicable within the specific urban context. Especially the preservation of the existing green can be combined with many additional benefits. Optimizing climate resilience is possible with adding facilities for water retention, infiltration and buffer storage in the green spaces. Sufficient space within street profiles enables the transportation of water to the green spaces. The additional benefits of the green with water facilities are numerous and include health and

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economic benefits. The renovation of the buildings offer opportunities to increase comfort condition indoor and outdoor in combination with reduction of energy consumption and even energy production.

An important recommendation from this case study is the importance to preserve the ordering principles where the Westelijke Tuinsteden and many other neighbourhoods built between 1950 and 1960 are funded on. These principles have resulted in areas with a comfortable urban microclimate that have the opportunity to adapt to extreme heat waves and heavy rainfall events. From cultural-historical perspective green has a great value, with climate change the same green regains significance.

Zuidwal, The Hague

The municipality of The Hague did not have questions about a particular area, but first needed an indication of the areas that have a high probability of heat stress Thus, a heat risk analyses was the first step to come to a case study location. The heat risk analyses was done by a partner within the CPC project. The Zuidwal neighbourhood is expected to accumulate more heat than other areas and is a intensive used area with high density. Also in this case study computer modelling provided feedback on the effects of measures on thermal comfort. But in contrast to the thorough effect study for Couperusbuurt the modelling for Zuidwal was limited to one street and only a few measures.

The two proposed measures to improve thermal comfort in the set of measures for the *Middle-high closed urban block with little green* both prove to be applicable in the specific context within Zuidwal. The canvas sheet is an example of the temporary and flexible measures and green roofs and facades of fixed and robust measures. Optimizing climate resilience is possible by gradually replacing pavement with permeable materials increasing infiltration, technical and civil water buffers can be combined with other urban function of a square. The integral design is a collection of many individual measures that need consideration per building or street.

Bergpolder, Rotterdam

In Bergpolder the starting point was again different than the former two cases. Here the municipality and housing association already developed a complete master plan. These stakeholders were interested in the effect of the master plan on thermal comfort condition and if there are ‘quick wins’ that could be realised without having to altering the complete design or having to allocate a significant larger budget. Another difference compared to the former cases is that the adaptation measures proposed are a collection of expert studies from the collaborating CPC partners.

The set of measures for Bergpolder are initially the same as for Zuidwal since they both belong to the category *Middle-high closed urban block with little green*. In this case a flexible measure that sprays pavement and roofs with water is proposed, however no additional benefits are linked to this measure. While fixed and robust measures such as a dark façade to generate ventilation and additional vegetation do add other benefits. Optimizing climate resilience did not receive enough attention in this case study due to the separate working groups all focusing on a very specific question. The integral design, that was the starting point of the case study, is further improved by the expert studies in relation to thermal comfort conditions. The proposed measures do not require a complete revision of the master plan and most additional costs imply a larger investment with returns on the building scale.

The collaboration of different research groups working on one case lead to a large variety of results. However, the potential of such a unique combination of experts was not fully exploited. The measurement and modelling studies did not focus on the same locations and used different indices to indicate effects of heat stress. Another difficulty in the process was the change in financial means of the housing association that limited the involvement of the most important stakeholder to a minor role.

Although the Bergpolder case was embedded in the RCP program within the dedicated political approach of the municipality of Rotterdam, the area developments did not reach the status of example project where the city could profile itself with. This can be devoted to the explicit focus on research and the change in the economic situation of the municipality and involved housing association.

General conclusion

From the evaluation above I can conclude that the maximisation on thermal comfort often is specific per neighbourhood and location. Optimisation possibilities regarding heavy rain fall and drought can be combined with many heat mitigation measures. However, this depends a lot on the water system, building fundaments and available space above and under the ground. Integration of measures to improve thermal comfort and deal with heavy rain fall and drought is needed to secure qualitative developments and liveability. In essence, the additional benefits that can be realised together with climate adaptation measures are similar per case study. Reduction of energy demand is an automatic result of lower outdoor and indoor temperatures. Moreover, making use of 'waste heat' through collectors and solar cells clean energy and heat becomes available for other purposes and is a way to prevent heating of the outdoor or indoor space. Using passive and natural cooling techniques, such as ventilation and green, health condition improve i.e. air quality, mental state and more space for outdoor recreation in green. Additional green provides a habitat for flora and fauna and on a larger scale connects habitats. Another common added value of adaptation measures is the possibility to increase the attractiveness of an area and improve aesthetic values.

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§ 9.6 Conclusion and discussion

This chapter proposes the maximisation method and an additional prioritisation method to integrate climate adaptation into the design process. The methods are tested in three different neighbourhood designs.

The transformations proposed per neighbourhood typology in the previous chapter are merely a preselection and do not cover all suitable options. Neither do they provide a way how to integrate the measures into the design process. The sub question addressed in this chapter aims to cover this gap: 'How can the transformations proposed per neighbourhood typology (Q4) be applied in an integrated design assignment, combining various heat mitigation measures, linking water adaptation measures and creating additional value in relation with energy, health, ecological, social and economic issues?'

In the method proposed the maximisation step is one of the components of the integration design process. The process starts with analysing the development and adaptation tasks and the political context or view of the client. As the project progresses the focus shifts from analysing to designing. In the first maximisation step, solutions solely directed towards improving thermal comfort in summer are projected on the area. Within the maximisation step a prioritisation based on the 'Trias ecologica' is proposed: 1) prevent heating up; 2) use passive cooling, 3) use active cooling considering the 'New Stepped Strategy'.

The second optimisation step, is directed at linking the favourable solution for thermal comfort to solutions that increase the total resilience of the area to climate change. In this study the additional adaptation task is confined to heavy rainfall events and drought. Measures against flood due to sea level rise or rivers are generally not dealt with at the neighbourhood level and are covered by an extensive research field already. The third and last integration step, aims to find relations between the thermal comfort and adaptation measures and other development tasks in the area. Increasing the quality of life is an important asset for all neighbourhoods. While increasing variance in housing supply is only relevant for some neighbourhoods. Although the three design steps have an order in complexity, which is increasing from maximisation, via optimisation, to integration, it is an iterative process. Solutions that might not seem very promising in the maximisation step can be a 'quick-win' when combined with a development task in the integration step. The other way around is also possible; a very effective measure in relation to thermal comfort might not have links to other developments and therefore lack argumentation and financial means for realisation.

The three design cases in this study show that the maximisation method is applicable for different cases. A strong element of the method is the freedom it provides in analyses tools, combination of design domains and evaluation tools or criteria. Independent on the available data, mapping and simulation tools, time and expert knowledge the method can still guide the design process. The result is not necessarily the best adaptive design, however a balanced design between climate measures and other assets for a neighbourhood. The method is now tested in three neighbourhoods in the Netherlands. Although they can be seen more as an exercise rather than a real test case since the neighbourhoods did not actually started with redevelopment due to the cuts in public resources of municipalities and housing corporations.

The three design examples represent only two of the seven common neighbourhood typologies presented in the previous chapter. More cases are needed to confirm the applicability of the method in all neighbourhood typologies. In addition it would be interesting to test the method for cases outside the Netherlands. This could be combined with classifying specific neighbourhood typologies for a country or climate zone. Even without a new classification of neighbourhoods test cases in other climate zones are very relevant to test whether the method is universally applicable. In case of different climate zones the first maximisation and the second optimisation step should be redefined towards the climate challenges the area is facing.

The sub-question answered in this chapter contributes to the research question '*How to integrate microclimate in a planning or design process?*' by proposing a method that guides the design process. The method makes explicit which steps are followed and which are not. Thus, not all designs contain a similar analyses of the heat accumulation in the area, nor do they all contain similar computer simulations that indicate the effectiveness. This is actually a reflection of everyday practice where the means and necessity of both types of analyses will vary per situation. Moreover, an important objective of this research is to increase the attention and action in relation to climate adaptation in daily practice. This is attained by offering a set of measures in the previous chapter, a method to structure the design process in this chapter accompanied by three examples.

§ 9.7 Acknowledgments

I would like to express my gratitude to Jan Spaans from the municipality of Amsterdam Nieuw-West, Niels Al from the municipality of The Hague and Jos Streng and Lissy Nijhuis from the municipality of Rotterdam for their input, questions and reflection on the case studies.

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