HEAT STRESS IN THE CITY

opportunities for integration of UHI mitigation measures within urban policy

LUP 80436 – MSc Thesis Land Use Planning

Anhilde de Jong – 890411 401100

Thesis supervisor: prof. dr. A.J.J. van der Valk

Wageningen University, 10 October 2012

HEAT STRESS IN THE CITY

opportunities for integration of UHI mitigation measures within urban policy

MSc thesis Land Use Planning

LUP-80436

This thesis is written as a final assignment for the master Landscape Architecture and Planning, specialisation Spatial Planning, at Wageningen University.

Wageningen University
Droevendaalsesteeg 3
6708 PB Wageningen
The Netherlands

Supervision:	prof. dr. A.J.J. van der Valk
Examination:	prof. dr. A.J.J. van der Valk
	dr. ir. W.G.M. van der Knaap

Author: Anhilde de Jong
anhilde@gmail.com

ABSTRACT

Continuing climate change has led to an increase in worldwide temperatures and more frequent weather extremes such as heat waves. The heat-absorbing qualities of built-up urban areas makes them especially vulnerable to these high temperatures; this phenomenon is known as the *urban heat island effect (UHI)*. This effect can have several negative impacts on public health and the quality of life in urban areas. Although research into this phenomenon has been conducted internationally for several decades, it is only since the major heat waves of 2003 and 2006, which led to between 1400 and 2200 heat-related deaths, that attention has been paid to this effect in the Netherlands. Still, heat in Dutch cities seems to be mainly considered a problem by scientists. Knowledge on the topic is available; the question is how to turn this knowledge into policy. The present study has identified feasible possibilities to integrate UHI mitigation measures into the urban policy of Dutch municipalities. UHI can be seen as a *wicked problem* – that is, a problem with a lack of consensus on the disputed norms and values, and high uncertainty about available and valid knowledge. Accordingly, the issue calls for a different approach, and therefore a different relationship between scientists and politicians, than the approach that is generally used to solve problems within natural sciences (the search for scientific bases).

Keywords: urban heat island effect, spatial planning, science-policy nexus, agenda change, policy development

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

From the beginning onwards the aim of this study is to contribute to scientific research towards the impacts of heat in the city, and the possible manners to mitigate these effects. With my study I want to contribute to the quality of life within urban areas; contributing to the society. Although it is up to the reader to judge, I belief that I succeeded in my aim to contribute to scientific research and society regarding the topic heat within urban areas. Results of my study are collected in this report. For this I would like to thank the following people.

First of all, my gratitude goes first of all to my supervisor: Arnold van der Valk, for his supervision and eye opening discussions. With his help and understanding he motivation me during my thesis. He was aware of my difficulties and provided me with possible solutions for my struggles.

In addition, I want to thank all the interviewees for their cooperation. Bert van Hove and Gert-Jan Steeneveld for the interviews at the beginning of my research, which provided me with much information on the background of the urban heat island effect. Many thanks for the information, contacts and invitations to meetings that Bert van Hove provided during my research. Susanne Buijs, Lissy Nijhuis en Corjan Gebraad for their information on the current situation, activities, perspectives and developments regarding heat in the municipality of Rotterdam. Anita Kokx and Caroline Uittenbroek for their insightful perspectives on the combining of knowledge and policy in general, and the integration of climate adaptation in urban policy in specific. Florrie de Pater, Peter Bosch and Toon van Harmelen for their detailed information and documents about the research programme "Knowledge for Climate" and research projects within this programme.

It is due to the contribution of these people that you are now able to read this report.

Anhilde de Jong

LIST OF TABLES AND FIGURES

List of figures:

List of tables:

GLOSSARY OF TERMS

advocacy	worldview, focusing on two main points: representation of the needs and interests of marginalised people and social issues within the society, and the development of an action agenda. Argues that research should be integrated in politics
albedo	measure to quantify the reflectance of materials, the percentage of solar energy which is reflected by a surface
antirealism	philosophical movement, the belief that rather than discovered on the basis of empirical data, the truth is constructed and therefore the ultimate truth does not exist
atmospheric urban heat island	urban heat island occurring in the atmosphere of a city, see also '*urban heat island*'
boundary work	work at the intersection of knowledge and practice, see also '*boundary worker*'
boundary worker	policy adviser working at the intersection of science and policy, see also '*policy entrepreneur'*
constructivism	philosophical movement, the belief that people construct their own understanding of reality
decision agenda	the list of subjects within the *governmental agenda* which are up for an active decision, see also '*governmental agenda*'
decisionism	an organisational system which states that policy is a product of decisions made by political bodies
emissivity	ability of a material to radiate absorbed energy
epistemology	the theory of knowledge, focussing on the possibilities and scope of human knowledge
governmental agenda	the list of subjects to which politics is paying attention
heat capacity	ability of a material to store heat

heat wave	period of five days with a daily maximum temperature above 25 degrees Celsius and minimal three days with a daily maximum temperature above 30 degrees Celsius
interweaving	term within spatial planning, the search for agreement on the direction of policy among different stakeholders, with different interests and goals
mainstreaming	the integration of a particular issue into related government policy
mind set	the set of attitude and perspectives on a particular topic
modernism	philosophical movement, assuming that truth is developed through one universal scientific concept
NDVI	measure to indicate the "greenness" of a surface
physiologically equivalent temperature (PET)	measure to express the relation between the actual and experienced temperature
policy entrepreneur	policy advisers willing to invest their resources to promote a position in return for anticipated future gain in the form of material, purposive, or solidary benefits, who keep their proposal ready and wait for a *policy window* to occur, see also '*policy window*'
policy window	an opportunity for policy advisers to push their policy proposals or solutions: an opportunity for agenda change and policy development, see also '*window of opportunity*'
positivism	philosophical movement, the belief that science leads to and holds the truth
post-modernism	philosophical movement, assuming that truth is constructed through different concepts which can change in time and place
science-policy nexus	the relationship between science and policy
semiotic	the science of communication studies through the interpretation of signs and symbols
sky view factor	a measure between zero and one which represents the openness of the sky to transport of radiation
social constructivism	philosophical movement, the belief that reality is a (social) construction and therefore no ultimate truth exists

surface urban heat island	urban heat island occurring at the surfaces of a city and her buildings, see also '*urban heat island*'
synthetic knowledge	the making of normative decisions based on scientific results: the ability to draw links and conclusions
technocracy	an organisational system where policy makers decide and develop policy on the basis of expert advice, mostly from scientists or engineers
triangulation	combining of multiple research materials to confirm the accuracy of the research results
UHI intensity	intensity of the *UHI*, in general referring to the average temperature difference in degrees Celsius, see also '*Urban Heat Island effect (UHI)*'
urban boundary layer heat island (UBL)	*atmospheric urban heat island* occurring in the air-layer starting from the treetops and rooftops until the point whereby the urban landscape no longer influences the atmosphere, see also '*atmospheric urban heat island*'
urban canopy layer heat island (UCL)	*atmospheric urban heat island* occurring in the air-layer where people live, see also '*atmospheric urban heat island*'
urban heat island	retained warm air in urban areas, see also '*Urban Heat Island effect (UHI)*'
Urban Heat Island effect (UHI)	the temperature difference between urban areas and surrounding suburban areas, see also '*urban heat island*'
wicked problem	type of problem, an often ill-defined and inherently complex problem
window of opportunity	originally used in the aerospace to indicate an opportunity for launch, but in this case used as an opportunity for policy advisers to push their policy proposals or solutions: an opportunity for agenda change and policy development, see also '*policy window*'

SUMMARY

The recent heat waves of 2003 and 2006 resulted in 1400 to 2200 heat-related deaths in the Netherlands. Considering the climate change it is expected that the impacts of heat will only increase in the future. Especially cities are vulnerable to heat: the urban structure and building materials, in combination with relatively little unpaved surfaces and vegetation, result in high temperatures in the city. This phenomenon, the difference in temperature between urban and surrounding rural areas, is called the *urban heat island effect* (UHI). Although not always experienced as negative, high temperatures can cause several health problems, such as difficulties with respiration, heat cramps, exhaustion, heat strokes, and may even result in death. Recently, research demonstrated the presence of a UHI intensity in Dutch cities as such that negative impacts may be encountered, and provided possible solutions to reduce these. Knowledge to address UHI seems to be available, but how to ensure that it will be applied in policy?

Objective of the present study is to identify feasible effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities. With the usage of a case-study research these possibilities are investigated for the municipality of Rotterdam. By evaluating the UHI situation in Rotterdam on the basis of scientific theory about the science-policy nexus, insight is gained in the possibilities to enlarge the chance on integration of heat mitigation measures within urban policy.

Heat within cities seems to be a difficult topic for municipalities, and a phenomenon mainly considered a problem by scientists. A lack of urgency and consensus, combined with the current economic circumstances, prove to be the main barriers for the concrete addressing of heat within urban areas. Like most public policy issues, UHI can be seen as a so-called *wicked problem*: a problem with a lack of consensus on the disputed norms and values and the ought-to-be-situation. *Wicked problems* are inherently different from the problems within natural sciences. With regards to *wicked problems*, one should not search for scientific bases for the problem, but for possibilities to improve some characteristics in the society. This requires adjustments in current research methods. It requires the usage of *synthetic knowledge*: the drawing of conclusions based on scientific knowledge. Any attempt to improve the environment, to transform what-is into what-ought-to-be, involves the making of normative decisions; *synthetic knowledge*. The usage of a more synthetic approach has consequences for the cooperation and communication between scientists and policy makers. Instead of ending the cooperation between researchers and policy makers at the completion of analysis, the synthetic approach would suggest that the cooperation goes further into an on-going process of translation; of consideration of the implications of the analysis and of making informed judgments about what-ought-to-be. Finally, since UHI can be seen as a *wicked problem*, a great chance lies in approaching the phenomenon as such that various parties see the added value of it, this is called *interweaving*. This enlarges the chance on *mainstreaming*: the integration of UHI mitigation measures within related, well-established, fields of policy. In this way, heat mitigation measures can be integrated in urban policy and applied in practice without the development of new policy.

SAMENVATTING

De recente hittegolven in 2003 en 2006 eisten in Nederland van 1.400 tot 2.200 mensen het leven. Gezien de klimaatverandering wordt verwacht dat de gevolgen van hitte in de toekomst alleen maar voelbaarder zullen worden. Met name steden zijn kwetsbaar voor hitte: de stedelijke structuur en materiaalkeuze, veelal in combinatie met geringe hoeveelheden groen, leiden tot hoge temperaturen in de stad. Dit fenomeen, het verschil in temperatuur tussen steden en omliggend ruraal gebied, noemt men het stedelijk hitte eiland effect (UHI). Hoewel hoge temperaturen lang niet altijd als onprettig ervaren worden, kan hitte verschillende gezondheidsproblemen met zich meebrengen, zoals moeizame ademhaling, uitputting, beroertes en in het meest extreme geval sterfte. Recent onderzoek heeft aangetoond dat ook in Nederlandse steden hitte op dusdanige schaal voorkomt dat negatieve gevolgen ondervonden kunnen worden, en biedt tevens mogelijke maatregelen om deze gevolgen te verminderen. De kennis lijkt dus aanwezig te zijn, maar hoe valt te waarborgen dat deze daadwerkelijk toegepast wordt in beleid?

Doel van dit onderzoek is het identificeren van mogelijkheden om kennis op het gebied van UHI te integreren in stedelijk beleid van Nederlandse gemeenten. De gemeente Rotterdam fungeert hierbij als centrale case, en representeert daarmee tot op zekere hoogte Nederlandse gemeenten. Door de situatie omtrent hitte in Rotterdam te evalueren aan de hand van wetenschappelijke theorie over het combineren van kennis en beleid, wordt inzicht verkregen in de mogelijkheden om de kans op integratie van maatregelen tegen de negatieve gevolgen van hitte in stedelijk beleid te vergroten.

Hitte in de stad blijkt een lastig hanteerbaar onderwerp voor gemeenten, en lijkt vooralsnog vooral een probleem in de ogen van wetenschappers te zijn. Barrières voor het concreet aanpakken van hitte zijn een gebrek aan urgentie en consensus, in combinatie met de huidige economische omstandigheden. UHI kan daarmee gezien worden als *wicked problem*. W*icked problems* onderscheiden zich op veel aspecten van vraagstukken binnen de natuurwetenschappen, en vergen daarom een andere aanpak. Door dit te onderkennen en hiernaar te handelen wordt de kans op integratie van kennis omtrent UHI in beleid vergroot. In plaats van te zoeken naar wetenschappelijke basis voor het probleem, dient gezocht te worden naar mogelijkheden om bepaalde factoren binnen de maatschappij te verbeteren. Dit vraagt om aanpassingen binnen de huidige manier van onderzoek. Zo vereist het het gebruik van *synthetic knowledge*: het trekken van conclusies op basis van kennis. Elke poging om de omgeving te verbeteren vereist het maken van normatieve beslissingen, om zodoende het gat te dichten tussen de huidige en gewenste situatie. Deze aanpak heeft gevolgen voor de relatie tussen wetenschappers en beleidsmakers. De benadering vraagt om nauwe samenwerking, welke niet eindigt na uitvoering van het onderzoek, maar verwordt tot een continue proces van vertaling van resultaten in consequenties en acties. Tot slot vergt het een andere benadering van UHI. Een grote kans ligt in *doelvervlechting:* mitigatie van UHI op zo'n manier benaderen dat verschillende partijen er toegevoegde waarde in zien. Dit vergroot de kans op *mainstreaming*: integratie van UHI mitigatie in gerelateerde beleidsterreinen. Op deze manier hoeft er geen nieuw beleid ontwikkeld te worden, om UHI mitigatie te integreren in stedelijk beleid en maatregelen in de praktijk te brengen.

1. INTRODUCTION

Even given the current economic and political circumstances, climate change and public health are receiving quite some attention in the Netherlands nowadays. Currently, climate change is a powerful leading force to implement (spatial) adaptation measures at governance level [Kleerekoper et al., 2011]. But how could it be that so little attention is being paid towards a phenomenon directly related to both aspects; the so-called urban heat island effect?

In the last century, 38 heat waves have occurred in Europe, a relatively large amount of them, eleven, occurred after 1990, of which six after 2000 [van Hove et al., 2011]. It is assumed that not only the frequency of these heat waves, but also the strength of them will increase in the future due to global warming, as shown by climate projections for the next 50 years [van Hove et al., 2011] [KNMI, 2011]. Urban areas are especially vulnerable to the consequences of global warming, because of the heat absorbing qualities of built-up areas [Rahola et al., 2009]. Currently, about half of the world's human population lives in urban areas. Due to urban agglomerations and the expected migration from rural to urban areas, it is assumed that the global rate of urbanisation will increase in the near future [Arrau and Peña, 2011]. Expected is that by 2030, more than 60% of the human population will live in urban areas; for Europe it is assumed that as much as 80% of the inhabitants will live in urban areas [van Hove et al., 2011]. Models and scenarios used within spatial planning in the Netherlands all point to a large expansion of urban areas [Heusinkveld et al., 2010]. Because of all the above mentioned developments it is not surprising that more attention is being paid globally to the negative effects of urbanisation and the consequences of global warming on cities [Climate Protection Partnership Division, no date].

1.1. Problem description

Urban areas are more vulnerable to the consequences of global warming than (more) rural areas. This leads to higher temperatures in urban areas than in the rural surroundings. This phenomenon is called the Urban Heat Island effect (UHI) [van Hove et al., 2011]. UHI is defined as "*the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the areas nearby natural landscape*" [Arrau and Peña, 2011]. In general, the average temperature in cities is approximately four degrees higher than the average temperature in the surrounding area [Oke, 2006].

UHI is caused by several aspects. The main cause is the replacement of natural surfaces by built surfaces. Vegetation utilises a large part of the absorbed radiation and releases water vapour which cools the surrounding air. Built surfaces on the other hand, absorb radiation which is released as heat [Rahola et al., 2009] [Climate Protection Partnership Division, no date]. Additionally, due to paved surfaces, there is less evaporation in cities than in more rural and natural areas [Rahola et al., 2009]. Furthermore, extra heat is released by human activities, such as air-conditioning and motorised transport [Rahola et al., 2009].

Due to the formation of urban heat islands, the average temperature in cities increases. These cities climates modify the regional climate conditions, and are thus leading to regional warming [Kleerekoper et al., 2011]. In addition, higher temperatures stimulate the formation of ground-level ozone. In this way UHI not only negatively influences the air quality, but also contributes to climate change [Climate Protection Partnership Division, no date]. Furthermore, as temperatures are rising due to climate change, and weather extremes such as heat waves are occurring more often, the UHI intensity is likely to increase [Rahola et al., 2009] [van Hove et al., 2011].

These projected trends could have serious negative consequences. The formation of urban heat islands combined with the global temperature rise and the expected increase in hot extremes, can lead to major public-health crises in highly urbanised areas due to increasingly uncomfortable and unhealthy heat stresses [Kleerekoper et al., 2011] [van Hove et al., 2011]. The physical well-being of people depends on, among other factors, the meteorological climate, and especially on the urban microclimate. Clearly, high day and night temperatures are likely to contribute to general discomfort, and negatively influence the thermal comfort of humans [Climate Protection Partnership Division, no date]. But besides feelings of discomfort, UHI can also lead to other health problems. Taking into account the climate predictions for the Netherlands, heat stress can be seen as the biggest threat caused by the formation of heat islands [Kleerekoper et al., 2011]. Heat stress can lead to health problems such as respiration difficulties, heat cramps and exhaustion, heat strokes, and may even result in heat-related death [Climate Protection Partnership Division, no date]. In the Netherlands the recent heat waves of 2003 and 2006 resulted in 1400 to 2200 heat-related deaths [Heusinkveld et al., 2010].

Although the expected increase in heat waves and the proven negative impacts of UHI, heat-related problems receive little attention in the Netherlands. Because of the mild maritime climate of the Netherlands and its location next to the sea, heat stress was not considered a problem. This lack of attention also shows in the absence of significant research towards UHI in the Netherlands. This in contrast to several other countries with a climate similar to that of the Netherlands, such as France, Germany and England, where research towards heat within cities is being conducted for a few decades already [Rahola et al., 2009]. In these countries, knowledge on urban climate and UHI is already being applied within urban policy and spatial planning, although still on a small scale only. Despite these developments abroad, research towards UHI in the Netherlands started only recently, after the heat waves of 2003 and 2006. Researchers, commissioned by the overarching project "Knowledge for Climate" ("Kennis voor Klimaat"), have made a first attempt to identify the UHI of cities in the Netherlands. The goal was "to assess whether or not heat stress is currently or likely to become a critical issue" [Heusinkveld et al., 2010] [van Hove et al., 2011]. Results from this research demonstrate the presence of a considerable UHI in the cities. These results stress the need for measures, in order to reduce UHI in Dutch cities, and efficient policy to apply those [Heusinkveld et al., 2010] [van Hove et al., 2011].

1.2. Problem statement and objective

Climate projections predict that weather extremes such as heat waves are likely to occur more frequently in the Netherlands. These heat waves will compound the UHI and heat-related problems in urban areas. In the Netherlands, although research towards this topic has started just recently, results already show that Dutch cities are facing UHI, and it is expected that UHI and therefore heat-related problems will only increase in the Netherlands. Now that recent research has shown that UHI is occurring in Dutch cities as well, it is time to start thinking about adequate measures that can be implemented to counter negative effects caused by UHI [Rahola et al., 2009] [Heusinkveld et al., 2010] [van Hove et al., 2011].

Because urban geometry and urban characteristics of a city influence the UHI intensity, urban design can be used as a way to reduce the negative effects of this phenomenon. Outdoor climate, and especially urban climate, is therefore an important factor for planners to take into account within current spatial planning processes and practices [Kleerekoper et al., 2011]. Improving the outdoor climate and addressing UHI contributes to a better thermal comfort and urban living quality. For spatial planning, the challenge lies in implementing measures to reduce the negative impacts of UHI in areas that are densely populated, both in a short and long term perspective. It is therefore necessary to integrate UHI mitigation with spatial planning and urban policy; knowledge on this topic should be assessed systematically and strategically applied in urban planning processes and policy in order to mitigate the negative effects of UHI [Ren et al., 2012].

This leads to the objective of this study: to identify effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities. The objective will be approached from the perspective of spatial planning. Results of this research can be seen as a first attempt to raise the awareness of heat related issues within Dutch cities and the possibilities to mitigate the negative effects of these phenomena. At governance level, climate adaptation already plays an important role within spatial planning. Better practical transfer of knowledge on UHI might make politicians decide to give higher priority to the mitigation of heat within urban areas [Kleerekoper et., 2011]. Therefore, the present study will identify effective methods to integrate UHI mitigation measures within Dutch urban policy and spatial planning, and provides guidelines about the ways in which knowledge on UHI can be integrated in Dutch policy. All of this in order to mitigate the negative effects of UHI and thus to improve the urban quality of life.

1.3. Research questions

The objective of this study is to identify effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities, from the perspective of spatial planning. From this objective, the following main research question is derived:

“What are effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities?”

In order to answer this question, research towards the following sub research questions is necessary:

- *What is the phenomenon UHI?*
- *What are the causes of UHI?*
- *What are the effects of UHI?*
- *What is the UHI situation in Dutch municipalities?*
- *Which measures and practices are available to mitigate the negative effects of UHI?*
- *What are the current opportunities and limitations for the integration of UHI mitigation measures within Dutch urban policy?*

By answering the sub research questions, the main research question can be answered and therefore the objective of this research can be achieved. In this way, detailed information will be gained about the causes and effects of UHI in general, and the current UHI situation of Dutch municipalities in specific. Besides, feasible measures and best practices to mitigate the negative effects of UHI in the Netherlands will be indicated. Furthermore, current opportunities and limitations for the integration of UHI mitigation measures into practice will be analysed, in order to identify feasible measures and practices to enlarge the chance on integration of UHI mitigation measures within urban (planning) policy of Dutch municipalities.

1.4. Readers guide

The report will start with background information about the phenomenon UHI. Since the objective is to integrate UHI mitigation measures into policy, or in other words the integration of knowledge in policy, theory on the combining of knowledge and policy will be provided in the theoretical framework of this study. But first, the used methods to achieve the objective of this research and the methodological approach for data collection and analysis will be described. In this chapter the usage of case-study research as a strategy for this study is justified.

In the following chapters, the results of the case-study are described, and analysed on the basis of the used theory in the discussion. Finally, the main results, conclusions and consequences of the study are listed in the conclusion.

2. METHODS

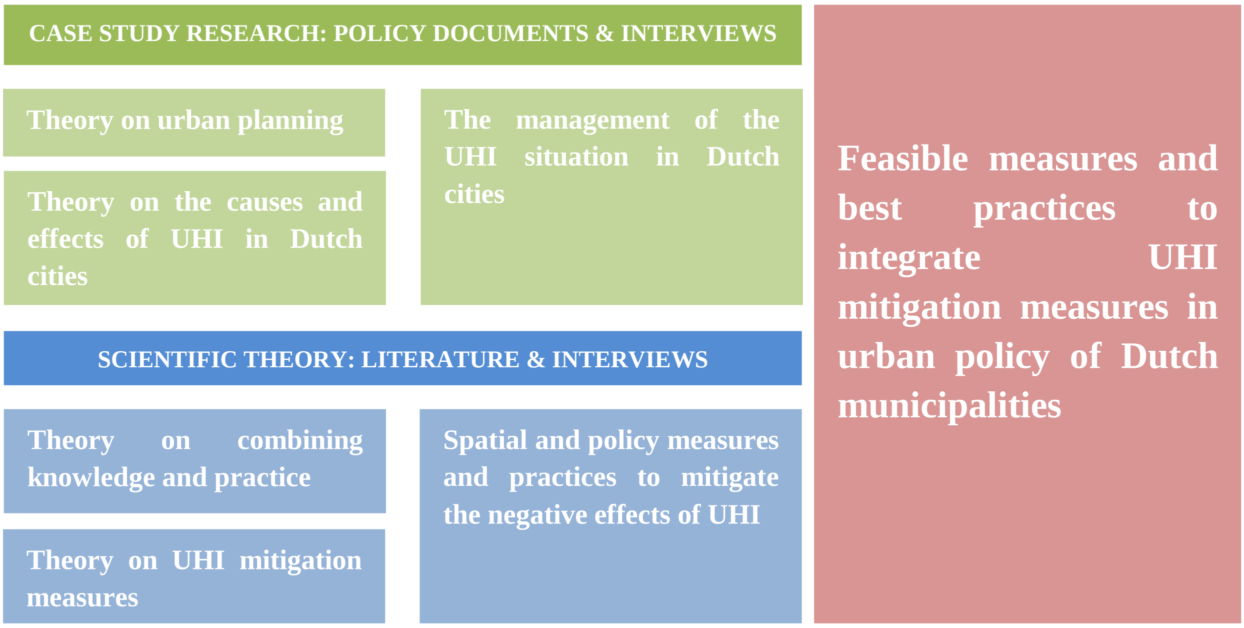
The study can be described as an explorative and pragmatic research, mainly based on qualitative data. Within this research feasible measures and practices to integrate UHI mitigation measures within urban policy of Dutch municipalities will be explored through the usage of a case-study research. By investigating effective methods to apply on the central case, which functions, up to a certain amount, as an example for Dutch municipalities in general, feasible measures to integrate UHI mitigation measures within urban policy of Dutch municipalities can be indicated.

The usage of a case as an example can contribute to construct and cumulate knowledge. Researchers are expected to base their research on the actual situation, context-dependent knowledge [Flyvbjerg, 2006]. Choosing this strategy provides researchers the possibility to thoroughly investigate a practical case. According to Flyvbjerg, this approach is especially useful within social sciences, to which spatial planning belongs, since predictive theories and universals are hard to find within the study of human affairs [Flyvbjerg, 2006]. Although true to a certain extent, as results are rarely fully applicable for other situations, it is possible to draw more general conclusions within social sciences as well. Certain general conclusions can be valid in several similar situations. It is nevertheless necessary to adjust the results to the specific cases and contexts instead of simply applying research results from one case to another. Therefore, one Dutch municipality is chosen as a central case in this research; the municipality of Rotterdam. Rather than a blueprint, the central case should function as an example, and the results of this research as a guideline, for other Dutch municipalities.

2.1. Research framework

In the following scheme (figure 2.1.), the objective, perspective and strategy of this research and the relations between them are visualised in a research framework.

Figure 2.1.: research framework



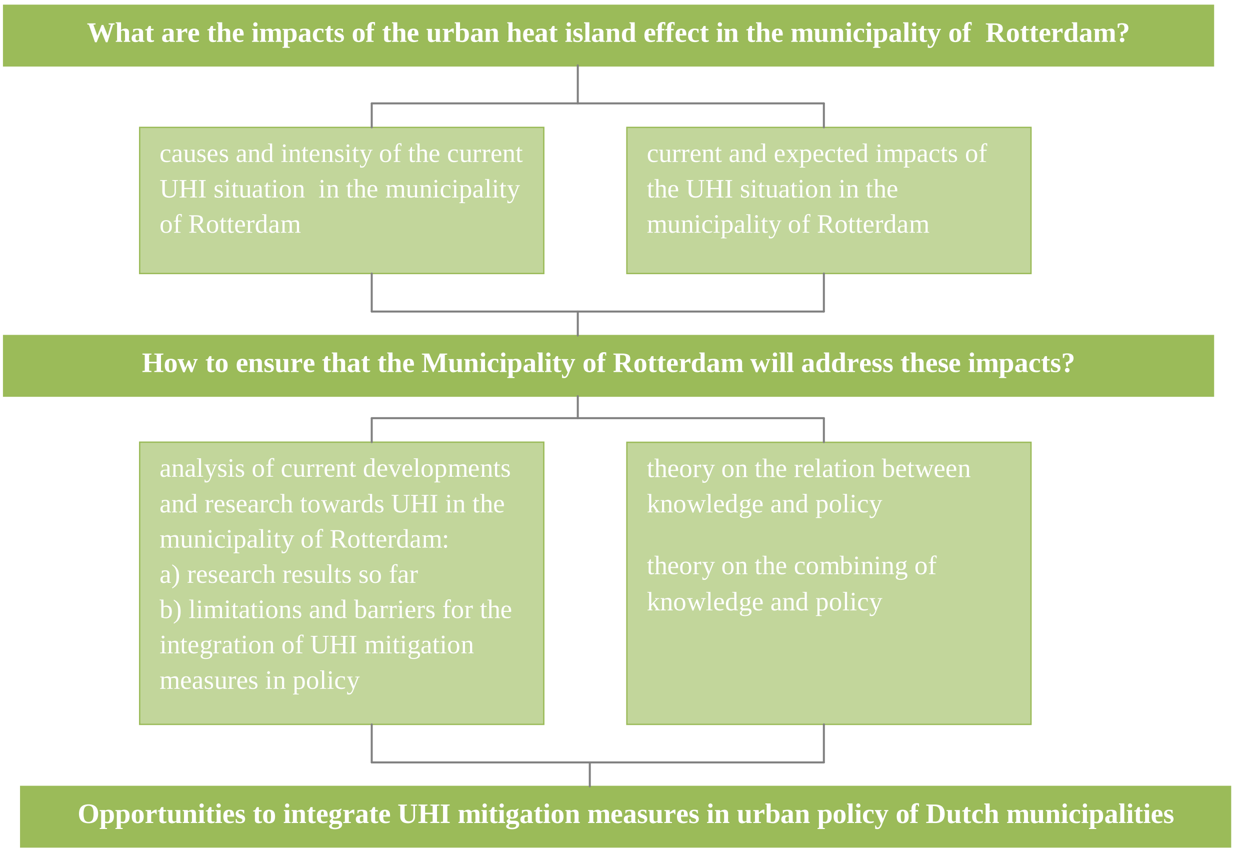
The objective of this research is to identify effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities. These UHI mitigation measures involve spatial ones, but as research towards UHI is still in an early phase these measures will mainly include policy and process practices about the possibilities to integrate UHI mitigation measures within urban policy. The accumulation of feasible measures and practices to integrate UHI mitigation measures within urban policy will occur through literature study and interviews with experts. This will be done on the basis of the following steps as shown in the research framework:

The phenomenon UHI will be approached from the perspective of urban planning. Usage of this perspective implies that there will be searched for practices on the level of urban planning, whereby few or no technical details will be given about the measures. The focus will be on the implementation of measures on a larger scale than the individual implementation of these measures, and on manners to incorporate the UHI mitigation measures into urban planning processes and policy. Therefore, literature is provided about intertwining (scientific) knowledge and policy, to enlarge the chance of actual implementation of (spatial or non-spatial) measures in practice.

In order to investigate which measures are feasible to mitigate UHI, full insight in the UHI situation necessary. To this end, the causes and effects of UHI will be investigated and described to identify which aspects could be addressed in order to eliminate the problem. Thereafter the inventory of possible measures to enlarge the chance on integration of UHI mitigation measures within urban policy will be made, through the usage of literature and interviews, and by studying the central case of Rotterdam: what has been done so far on UHI mitigation? What are the current opportunities and limitations within the processes so far? Rather than a blueprint, the results from the central case can function as guidelines for other municipalities and cities in the Netherlands.

By following these steps, opportunities for integration of UHI mitigation within urban policy will be indicated. In the following scheme, figure 2.2., the above described research steps are visualised.

Figure 2.2.: visualisation of the research steps



2.2. Methods of data collection

The usage of a case-study strategy influences the methods of data collection. The central case of Rotterdam is analysed through the usage of a document and literature study combined with interviewing stakeholders and experts (see the full list of persons interviewed and attended meetings in Appendix "*1. Interviewees & attended meetings*"). The (policy) documents were used to analyse ambitions of the Municipality of Rotterdam regarding climate change and sustainability in general, and heat in specific, as well as the processes and developments regarding these topics so far. The interviews provided a more detailed insight on these topics and processes. The interviewees were selected on the basis of their expertise and relations to the research objective. The interviews were open, in-depth and semi-structured, and on an individual base. During the interviews, guiding questions were used to structure the interview and to ensure that all topics were covered, but leaving much room for the interviewee to come up with other information. This resulted in a rich and detailed collection of data about the UHI situation in Rotterdam, as well as the current opinions and perspectives on this phenomenon and the probable future approach.

Besides the case-study, literature has been consulted about theory on combining knowledge and practice. By testing these theories with the processes in the central case, opportunities and limitations to integrate UHI mitigation measures within urban policy of the Municipality of Rotterdam are identified. In addition, literature is used to gain more insight in the background, and general causes and effects of UHI. Experts were consulted with regards to these topics, through the same form of interviews (semi-structured).

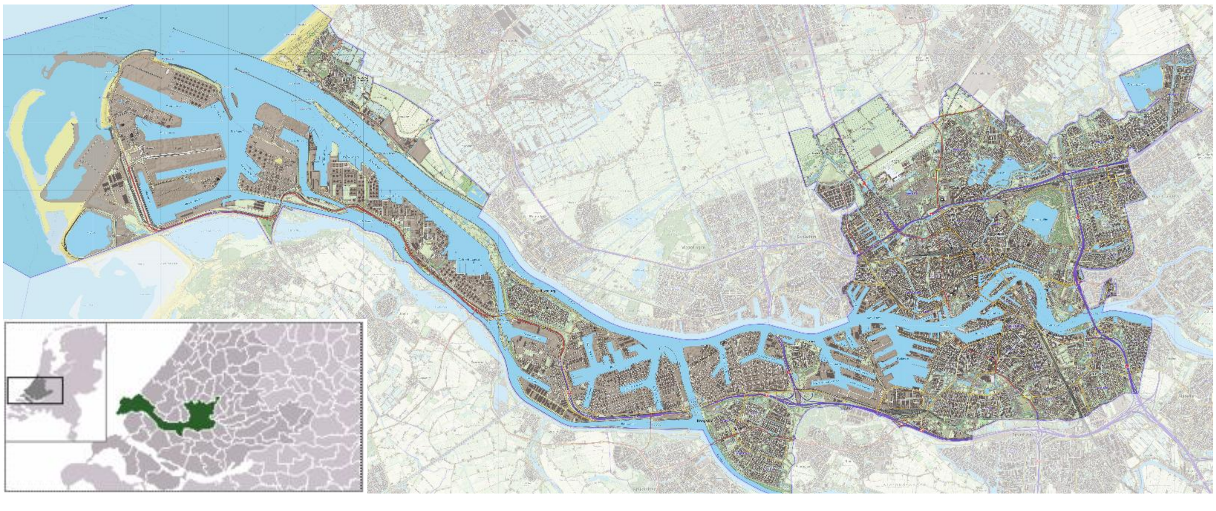
2.3. Validation of the research

As in any research, some ethical issues have to be taken into account during this research. Although ethical considerations should be taken into account in all stages of the research, data collection, analysis and interpretation are the most critical phases which need more ethical concern [Creswell, 2009]. Within this research, both qualitative and quantitative data are collected and interpreted. The main part consists of qualitative data, which makes the ethical consideration even more important. During the research objectivity is attained in several ways. The findings from the case study research (interviews, meetings, policy documents and scientific literature), together with the scientific theory and experts interviews, formed the base for validation. One of the strategies used to increase the validity of the research is *triangulation*. *Triangulation* is the combining of multiple research materials to confirm the accuracy of the research results [Creswell, 2009]. In this case, these materials include the interviews, policy documents and literature. Several techniques were used in order to enlarge the validity of the interviews. Interviewees were selected on the basis of their expertise and relation to the research objective. The interviews are recorded with a voice recorder while notes were taken during the interviews. On the basis of the recordings and the notes taken, interviews were processed by the researcher, afterwards the reports were sent back to the interviewees for a final check and their approval.

2.4. Central case: the municipality of Rotterdam

With regard to UHI in the Netherlands, the Municipality of Rotterdam can be seen as one of the forerunners. The municipality of Rotterdam is a metropolitan municipality in the Dutch province of Zuid-Holland. With 616,260 inhabitants in 2012 [Centraal Bureau voor de Statistiek, 2012] the municipality of Rotterdam is the second largest municipality of the Netherlands. More than one third of the municipal area consists of water, as the River Meuse flows through the city. The Rotterdam Harbour is the largest port- and industrial complex in Europe [Port of Rotterdam, no date]. In figure 2.3. a map of the municipality of Rotterdam is shown, as well as the geographical location of the municipality within the Netherlands.

Figure 2.3.: topographic map image of the municipality of Rotterdam 2010-2011



Source: [Wikipedia, 2012c]

In May 2007, the Municipality of Rotterdam launched the Rotterdam Climate Initiative, as a reaction on the message of Bill Clinton during his visit to the Netherlands in 2006, that the world should take action to combat the emissions of greenhouse gases.

In the Rotterdam Climate Initiative several ambitious goals are stated:

- 50% CO_2-reduction by 2025 compared of 1990
- 100% climate proof in 2025, in combination with:
    - strengthening of the economy of Rotterdam [Rotterdam Climate Initiative, 2009].

With this initiative the Municipality of Rotterdam wants to profile Rotterdam as "climate city" [Rotterdam Climate Initiative, 2009]. The Rotterdam Climate Initiative will be described in more detail in "*6.3. Rotterdam Climate Initiative*". Around the same time, a national research programme (partly founded by the Dutch government) was launched in 2008 by the Wageningen University and Research centre, University Utrecht, Deltares (Dutch knowledge institute for water and subsoil), KNMI (the Royal Dutch Meteorological Institute), TNO (Dutch organisation for applied scientific research) and the VU University Amsterdam: the "Knowledge for Climate" research programme, with the aim to provide public accessible, and from the society operated, scientific knowledge about climate and related subjects such as space, infrastructure and sustainability [Knowledge for Climate, 2012a]. Within this research programme, special attention is being paid towards (problems regarding) heat in cities [Knowledge for Climate, 2012a]. The research programme works with so-called themes and '*hotspots*'. These *hotspots* are formulated as "*real-life laboratories where knowledge is put in practice*. The Rotterdam region is one of the participating *hotspots* within "Knowledge for Climate". With urban investments along the axis of the river and the transformation of old industrial and harbour areas, the Municipality of Rotterdam wants to become more attractive for international businesses and starters, as well as for the current and future inhabitants of Rotterdam. There is heavily invested in the urban development and improvement of the liveability [Knowledge for Climate, 2012b]. Within the "Knowledge for Climate" research programme, research towards heat in the city of Rotterdam has been and is being carried out [Knowledge for Climate, 2012b].

As the above described projects and developments illustrates: the Municipality of Rotterdam pays special attention towards climate(change) and related aspects. Within the "Knowledge for Climate" project research has been done towards the UHI intensity of the city of Rotterdam. Due to this research, detailed information and knowledge about the UHI intensity and situation in the municipality is available. It is because of these developments and available information that the municipality of Rotterdam is chosen as central case within this research.

3. THEORETICAL FRAMEWORK

In this chapter the theoretical framework of this research will be described. First of all the used perspective will be further explained. Afterwards some theory about the application of knowledge into practice will be considered, since the objective of this study is to identify effective methods to integrate UHI mitigation measures within (urban) policy. Furthermore, general theory on the phenomenon UHI will be described.

The objective of this study is to identify effective methods to integrate UHI mitigation measures within urban policy of Dutch municipalities. Important remark here is that this will be done from the perspective of spatial planning, or urban planning as UHI is occurring in urban areas. The phenomenon UHI can be seen as a spatial planning issue, since the urban geometry and urban characteristics of a city influence the UHI intensity. Urban design can therefore be used as a way to reduce the negative effects of this phenomenon. Using an urban planning perspective implies the search for practices on the level of urban planning; involving spatial measures but also policy methods regarding raising the awareness about UHI et cetera; measures to facilitate the implementation process of the spatial measures. Worldwide research towards UHI is being conducted, including the Netherlands since the last recent heat waves of 2003 and 2006 [Rahola et al., 2009] [Heusinkveld et al., 2010] [van Hove et al., 2011], but the question is how all these gathered knowledge can be applied in the society and embedded in spatial policy?

Within this chapter the role of science will be explained, which influences the usage of knowledge. Afterwards, literature on the combination of knowledge and policy; the *science-policy nexus*, will be provided. Besides this theory *on* spatial planning, the final chapter will describe the theory *in* spatial planning regarding climate adaptation in general and the phenomenon UHI in specific.

3.1. The role of science

As society is changing and people are becoming more and more empowered, and knowledge about all kinds of topics is easily accessible for a larger public due to sources such as internet, so is the role of science and scientists [Friedmann, 1987] [Allmendinger, 2009]. From a more *modernistic* view on science, nowadays this perspective is shifting towards a *postmodern* view [Healey, 1997]. According to *modernism* the truth is developed through one universal scientific concept. Science and scientists play an important role as they are considered to be able to provide society with the truth. The belief that science leads to and holds the truth is called *positivism*. The belief that science was essentially concerned with the investigation and discovery of “facts” and “laws”, grounded the conviction that public affairs should be informed by planning [Friedmann, 1987].

By the 1940s the faith in science decreased as it was undermined by sceptical inquiries [Friedmann, 1987]. Over the years the *modernism* type of view on science shifted towards *antirealism* and *post-modernism* [Allmendinger, 2009]. Within *antirealism* it is believed that rather than discovered on the basis of empirical data, the truth is constructed and that therefore ultimate truth does not exist [van Assche, 2004].

Antirealism is associated with *post-modernism*. Hereby, truth is constructed through different concepts which can change in time and place. The belief that science can provide the society with the ultimate truth, *positivism*, no longer holds within this perspective. The belief that reality is a (social) construction and that therefore no ultimate truth exists is called *social constructivism* [Smith, 2006].

3.1.1. The social constructivist worldview

Constructivism is "*the philosophical belief that people construct their own understanding of reality*" [Oxford, 1997]. Constructivists believe that people construct reality based on their experiences and interactions with the environment [Oxford, 1997]. Through usage of these interactions and experiences with the environment individuals construct subjective meanings and their own reality [Smith, 2006] [Creswell, 2009]. In this way reality is not an absolute truth but a construction made by the society which may be subject to change [Smith, 2006].

It will be clear that *social constructivism* leads to an different perspective on science and scientists than the perspective of *positivism*. In this way science is no longer about providing society with the absolute truth, but much more about gathering data and participants perspectives of a situation being studied, whereby researchers acknowledge the fact that their own backgrounds will shape their interpretation of the results [Creswell, 2009]. This does not mean that research results are less relevant or credible, and this world view should thus not be used as an excuse by scientists for not trying to conduct their research in the most objective manner as possible. Rather, it is something to keep in mind, by scientists during the research, as well as by the users of the research results. Still it is assumed that the world can best be known, to the extent it can be known, through a form of emphatic inquiry: science [Friedmann, 1987].

3.1.2. The advocacy worldview

Besides *social constructivism*, another movement which appeared due to feelings of dissatisfaction with the *(post)positivism* perspective is the *advocacy* worldview. According to this worldview, which arose in the 1980s and 1990s, the structural laws and theories of *(post)positivism* do not fit the minorities within society nor issues of social justice [Creswell, 2009]. The key statement of this worldview is that of Davidoff: aim is to build a bridge between planning and the quest of relevance [Faludi, 1996]. Within the *advocacy* worldview it is believed that research should be intertwined with politics and a political agenda in order to be useful for society [Creswell, 2009].

Obviously, these developments within society and the changing role of science, as described in the two worldviews, have large influences on the role of science, and spatial planning within society. From a more *modernism* type of view on science, the perspective on science shifted towards *post-modernism* and *constructivism*. Instead of approaching science as the absolute truth, knowledge is seen as subjective and provisional. These new ideas illegitimate old-fashioned *technocratic* planning, as knowledge is perspectivistic and provisional. The new epistemology turns science, and planning, into a dialogic process between the researchers and actors. This also changed the language of science.

Instead of preachers of the truth, the focus is now on the expressing of subjective realities and the search for meaningful action [Friedmann, 1987]. But as knowledge is rather seen as provisional, instead of ultimate, while at the same time it is still agreed that the world can best be known trough empathic inquiry, how should knowledge than be used in practice?

3.2. The application of knowledge into practice

The role of science and therefore scientists influences the way in which research should be carried out. Spatial planning is a field of study which operates at the intersect of knowledge and action [Campbell, 2012]. Planning attempts to connect scientific and technical knowledge to actions in the public domain [Friedmann, 1987]. The Royal Town Planning Institute describes the essential of spatial planning as "*critical thinking about space and place as the basis for action or intervention*" [Royal Town Planning Institute, 2003], as spatial planning is concerned with intervening and taking action in order to realise a better spatial environment; making decisions and informing actions which are socially rational [Friedmann, 1987]. It is assumed that putting knowledge at the basis of such judgements will result in better outcomes. The idea that scientific knowledge could be applied to society's improvement arose during the eighteenth century, and had several implications for the usage of knowledge. The focus shifted to a consideration of consequences: knowledge can be used to predict the impacts and consequences of certain actions [Friedmann, 1987]. Therefore, the link between knowledge and action (science-policy nexus) plays a central role within the theory and practice of spatial planning [Campbell, 2012]. But how should this link look like: how to turn knowledge about the world into actions to improve the world?

3.2.1. Defining knowledge and its importance

Before one can start investigating the ways in which knowledge can be used within policy, the concept of 'knowledge' in this context has to be defined. Furthermore, the importance of combining knowledge with policy has to be argued. Knowledge is often seen as figures and facts. But somebody who is aware of particular facts does not necessarily has knowledge about the particular subject. Withal, facts can be interpreted in a wrong way. Rather than defining knowledge as just figures and facts, knowledge should be seen as the ability to interpret facts and to give meaning to these facts [Derksen, 2011].

There are several reasons why knowledge is of importance for policy. Knowledge can test the assumptions on which policy is based. Having knowledge about a certain subject or concept makes it possible to estimate the correctness of certain policy theories. Furthermore, in order to be able to develop effective policy the impacts of policy instruments have to be known. Again, this requires knowledge. Logically, the impacts of policy instruments can never be fully known in advance since society is changing and human behaviour is often irrational. But knowledge can provide insights in the consequences and impacts of actions [Friedmann, 1987], and could therefore, up to a certain level, be used to indicate which actions are preferable and which are not. It is recommended to base policy on all the available relevant knowledge, since knowledge can make, among other through impact analysis, an uncertain future less uncertain [Derksen, 2011].

To summarise, knowledge can provide insights in the consequences and impacts of actions (for example policy measures). Since the complexity of the society is increasing and the future is highly uncertain nowadays, promising policy *has* to be based on broad knowledge of society, ecosystems and matter. Although this view is endorsed by the Dutch government, in practice it seems that knowledge and policy do not find each other that easily [Derksen, 2011]. The relation between political judgement and science-based expertise is often seen as a troubled one [Hoppe, 2005]. This is partly caused by the changing perspectives on science. As knowledge is no longer seen as ultimate, the certainties of *positivism* no longer holds [Friedmann, 1987].

3.2.2. Wicked problems

A changing and increasingly complex society has led to other perspectives on science and therefore on spatial planning. As the professors Rittel and Webber described it: "*In the courts, the streets, and the political campaigns, we have been hearing ever-louder public protests against the professions' diagnoses of the clients' problems, against professionally designed governmental programs, against professionally certified standards for the public services.*" [Rittel and Webber, 1973]. Scientists were for a long time seen as professionals solving problems which were definable, understandable and consensual. Perspectives on science have changed however. Growing awareness of the subjectivity of knowledge, nation's pluralism and the differentiation of values and therefore of publics eroded the consensus [Rittel and Webber, 1973], thus leading to more complexity when dealing with problems. Whereas in history professions, including spatial planners, pronounced themselves, full of confidence, ready to tackle anyone's perceived problem and discover its hidden character, it is now realised that one of the biggest problems is that of defining and locating problems [Rittel and Webber, 1973].

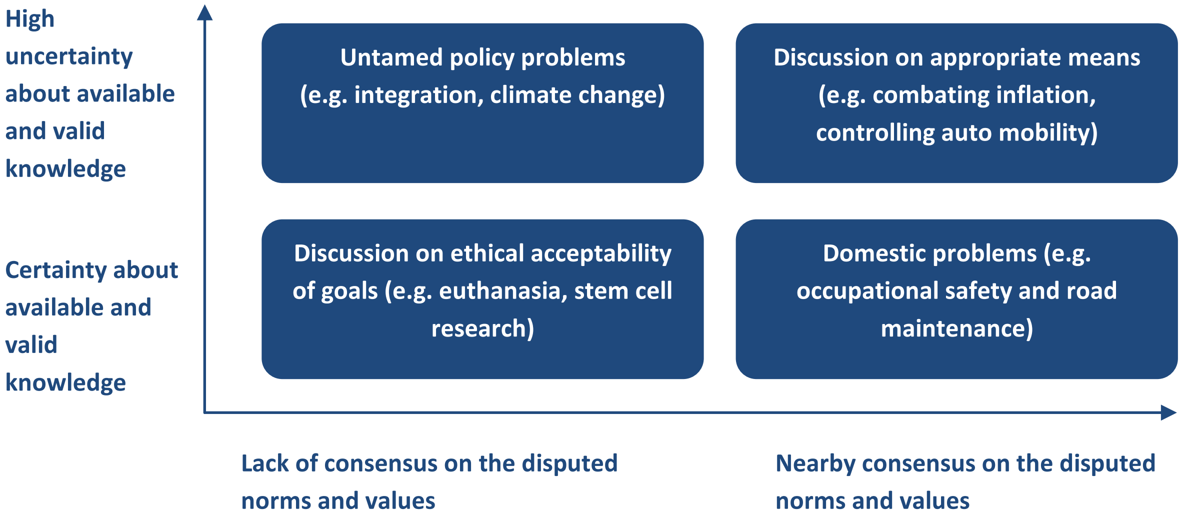
Planning is about narrowing the gap between what-is and what-ought-to-be [Campbell, 2012]. But the indication of actions which might effectively narrow the gap between what-is and what-ought-to-be becomes even more intractable, due to the differentiation in values and publics [Rittel and Webber, 1973]. Or as Rittel and Webber put it: "*As we seek to improve the effectiveness of actions in pursuit of valued outcomes, as system boundaries get stretched, and as we become more sophisticated about the complex workings of open societal systems, it becomes ever more difficult to make the planning idea operational.*" [Rittel and Webber, 1973]. Still, it is assumed that putting knowledge at the basis of such judgements will result in better place-based outcomes [Campbell, 2012].

Although the usage of knowledge within policy is necessary to develop effective policy, the combination of these two elements does not occur that often in planning practices. According to Rittel and Webber one of the reasons lies in the fact that social sciences are mimicking natural sciences [Rittel and Webber, 1973]. According to Rittel and Webber "*the search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems*" [Rittel and Webber, 1973]. Within spatial planning (and other social sciences as well) scientists deal with problems inherently different from the problems within natural sciences.

With regards to these problems, one should not aim to find the truth, but to improve some characteristics in the society [Faludi, 1996]. Problems within natural sciences in general are definable, separable and, mostly, solvable. Problems within social or policy planning (all public policy issues) are often ill-defined and inherently wicked; so-called '*wicked problems*'. These *wicked problems* are difficult to define and locate, and the identification of actions which will narrow the gap between what-is and what-ought-to-be might be even more difficult, due to the different perspectives and values which make the formulation of what-ought-to-be almost impossible [Rittel and Webber, 1973].

The Dutch professor in the field of Policy and Knowledge Hoppe also describes the occurrence of *wicked problems* (named as "*untamed problems*") within policy issues, he distinguishes the following four types of policy problems as shown in figure 3.1..

Figure 3.1.: four types of policy problems



Source: [Hoppe, 2008]

There are several distinguishing properties of planning-type problems (*wicked problems*). First of all there is no definitive formulation of a *wicked problem*. One of the most intractable steps within problem solving is that of defining problems. Whereas in natural sciences this step is relatively easy, defining a *wicked problem* is not. Due to a lack of consensus and differentiation in perspectives and values, *wicked problems* are hard to define: it is hard to define which effects of a phenomenon are negative. This obviously makes the identification of actions to narrow the gap between the current situation and the wished for situation (what-ought-to-be), the search for solutions, far more difficult (and subjective). Therefore, the process of formulating the problem is identical to the process of formulating a solution, because any specification of the problem is in fact a specification of the direction in which the solution can be found [Ritter and Webber, 1973]. The way in which an issue is framed by the (dominant) involved parties can heavily influence the direction in which there will be searched for solutions.

These different perspectives on the problem make it hard to evaluate whether the solutions, the implemented measures, were the right ones. Assessing whether a *wicked problem* is solved is (again due to a lack of consensus on the actual problem definition and therefore the proper solution to it) almost impossible. In addition, spatial interventions in general have a relatively long lifespan and can therefore generate waves of consequences over a long period of time, which are hard or impossible to trace, not to mention evaluate. In that sense solutions to a wicked planning problem can be seen as a 'one-shot operation' because every intervention will have consequences which are often not that easily undone (in fact, every attempt to correct the undesired consequences of a intervention poses another set of *wicked problems*) [Ritter and Webber, 1973].

To summarise: most public policy issues are so-called *wicked problems*; problems with a lack of consensus on the disputed norms and values and the ought-to-be-situation, and high uncertainty about available and valid knowledge. This lack of consensus and uncertainty about the available and valid knowledge makes addressing *wicked problems* very complex. Then how to deal with *wicked problems* within the field of spatial planning?

Unfortunately there is no clear answer to this question. Ritter and Webber distinguish two basic (inadequate) approaches which are currently used to manage *wicked problems*. On the one hand that is the approach in which the decision-making (the formulation of what-ought-to-be) is left to the professional experts and politicians, and on the other hand the approach in which individual choice is involved within decision-making. Ritter and Webber argue that both approaches does fit for 'tame' problems, but not *wicked problems*, due to the above described complex properties of *wicked problems*.

Although Hoppe also does not have the answer, he tries to make combinations between certain types of policy advisers and the four types of policy problems, in such a way that the chance on successfully addressing a problem increases [Hoppe, 2008]. Hoppe investigated the different policy advisers working in the interface of science and policy, and distinguished seven types of '*boundary workers*':

- the '*rational fold-and-arranger'*, who as a prominent member of an advisory board or departmental knowledge officer provides the process of political compromise formation in menial manner with proper arguments from science ('sound science') and professional practice ('best practices') ;
- the *'knowledge broker'*, who as an official or consultant sometimes sees and uses opportunities to create favourable conditions for instrumental policy advice, despite the well-known and unavoidable gap between policy and science;
- the *'policy strategist'*, who wants to function as a think-tank for the government for medium- and long-term policy, and critical look at the key assumptions behind current policy;

- the *'policy analyst'*, who provides policy makers and stakeholders with evidence-based information and models from available and useable sources of knowledge, taking into account rules and relationships in stable policy networks;

- the *'policy advisor'*, who advises his superior(s) with the best available knowledge about the *do's and don'ts*, based on the feasibility and acceptance of policy proposals;

- the '*post-normalist*', who believes that mainly policy issues concerning sustainable development are so fraught with uncertainties and conflicting interests that normal science is not sufficient. He wishes for new rules and relationships between science and policy and calls for an open dialogue between scientists, businessman, other stakeholders and policy makers about the advantages and disadvantages of the full range of possible policy proposals;

- the '*proceduralist*', who as, for example, a secretary of an advisory board, stimulates high quality *boundary work* (work at the interface of knowledge and practice) as an under clear criteria extending debate on all normative and uncertain issues in policy proposals between well-equipped and equal parties [Hoppe, 2008].

From the research of Hoppe it appeared that *policy analysts*, *policy advisors* and *knowledge brokers* are often involved by policy issues within the right side of figure 3.1.: the discussion on means and domestic problems. *Post-normalists* and *proceduralists* are forced to move at the intersection of untamed and domestic problems in their search for open dialogue and debate. Whereas *policy strategists* and *rational fold-and-arrangers* are often working within strategic consultative bodies dealing with untamed problems and discussions on goals. In comparison with advices for the short-term, timing is more important and more complex for policy advisers from these strategic consultancies for the medium- and long-term, due to a smaller and more difficult to determine '*window of opportunity'* [Hoppe, 2008].

To summarise, in order to combine knowledge and policy in a proper way, *boundary workers* are necessary: policy advisers working at the intersect between science and policy. In order to enlarge the chance on combination of knowledge and policy these *boundary workers* should be able to indicate and use so-called *windows of opportunities*. However, there are different types of policy problems, with different types of *windows of opportunities*, thus demanding for different types of *boundary workers* [Hoppe, 2008]. But what exactly is a *window of opportunity*, and how should it be used by *boundary workers* to successfully combine knowledge and policy?

3.2.3. The occurrence of *policy windows*

The term *window of opportunity* is derived from the aerospace; during space shots the *window of opportunity* stands for the opportunity to launch. During this moment, the target planets are in proper position, but they will not stay long. Therefore, the launch has to take place when the *window* is open, if closed again the astronauts have to wait until the *window* reopens [Kingdon, 1984].

This situation can be translated to policy systems in which opportunities occur for participants to push their policy proposals or pet solutions, a so-called *policy window* [Kingdon, 1984]. Similar to the *windows* in aerospace, *policy windows* will only stay open for a short amount of time. If participants, policy advisers and politicians, but also interest groups, scientists, professionals and media, cannot or do not take advantage of such an opportunity, the window closes [Kingdon, 1984]. But how do these *policy windows* occur? When will they open, and when do they close again?

Instead of what long time was thought (or hoped), the process behind agenda setting and policy making is not that of a linear rational approach. If policy makers were operating according to comprehensive rational decision making, clear goals would be formulated beforehand, afterwards feasible alternatives would be systematically compared. Due to several reasons, processes behind agenda setting and policy making do not work in that way. The main reason being that the human ability to process information in that way is insufficient [Kingdon, 1984].

According to Kingdon, who has done a four-year-long study on the process behind agenda setting and policy making, this process can best be described according to the garbage can model, a model developed by Michael Cohen, James March and Johan Olsen [Cohen et al., 1972]. In each organisation there are four, separated, streams within decision making: problems, solutions, participants and choice opportunities. These streams can live a life on their own. As Cohen, March and Olsen describe it, this kind of organisation "*is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work*" [Cohen et al., 1972]. These flows move separated through an organisation, but the moment of coupling can result in changes in agenda or policy [Cohen et al., 1972].

Decision making within governmental organisations occurs in the same manner, there are three families of processes (streams): problem recognition (problems), the formation of policy proposals (policies), and politics (politics) [Kingdon, 1984]. The first stream is that of the problems; various problems can reach the attention of people both in and outside the government. Second is the policy community of specialists (bureaucrats, employees in planning, evaluation and budget offices, interest groups, academics, researchers), concentrating on the formation of policy proposals (solutions in the garbage can model). Participants within this stream come up with problems which are floating around in these policy communities. Through a selection process, based on objective (budget, feasibility) and subjective (acceptability according the norms and values of politics) criteria, a shortlist of proposals is derived from a long list. The third stream, the political stream, consists of several things, such as the national mood, vagaries of public opinion, interest group campaigns, change of administration and the election results. Although in principal all participants within the decision making process are able to involve within each stream, in practice the policy stream (that of solutions) is often dominated by academics and researchers, whereas the political stream is dominated by policy makers and politicians [Kingdon, 1984].

These three streams are operating quite independently of one another throughout the decision making process within governmental organisations. Solutions are developed with or without a certain problem they respond to. The political stream may change drastically, whether or not public problems have changed. But the streams are not absolutely independent. The selection of proposals for example occurs on the basis of criteria which are affected by the norms and values within the political stream. Moreover, since election outcomes are dependent of the public opinion, the political stream can be affected by the public's perception of the problems facing the country (the problem stream). The key to understanding agenda and policy change lies in connecting these streams. Only when a problem is recognised (problem stream), a solution is available (policy stream) and there is a right political climate (political stream) which stimulates action, changes in agenda or policy are possible [Kingdon, 1984]. In practice, such moments are scarce. Coupling of the streams is most likely when a *policy window* is open. It is therefore recommended that policy advisers prepare their proposals, so when an opportunity arises, such as an urgent problem or a change in the political context by which the probability of implementation of their proposal increases, their solutions are ready and they are able to use the opportunity: the *policy window* [Kingdon, 1984].

Although a *policy window* sometimes opens quite predictable, for instance by a scheduled renewal of a program, it is often hard to tell when a policy window will open and when it will close again. Basically, a *policy window* opens due to a change in the political stream (for example a new administration or a shift in the national mood) or a new problem which captures the attention of governmental officials. Once a window is open, it is difficult to estimate how long the situation will last since windows can close very suddenly and for several reasons. First of all participants can have the feeling (whether or not this is correct) that the issue is addressed. On the other hand, a window can close because the participants failed to take action, or by the fact that the event that led to the opening of the window has passed, or the fact that there were no feasible solutions for the particular problem during the time the policy window was open [Kingdon, 1984]. This once again stresses the need for policy advisers to prepare their proposals in order to be able to push them through when a *policy window* is open.

It are these policy advisers, or so-called *policy entrepreneurs* who are able to couple the streams: the policy stream to the problem or political stream. These *policy entrepreneurs*, which Kingdon describes as "*advocates who are willing to invest their resources – time, energy, reputation, money – to promote a position in return for anticipated future gain in the form of material, purposive, or solidary benefits* [Kingdon, 1984]", can be seen as the same policy advisers Hoppe is referring to with *boundary workers* [Hoppe, 2008]. *Boundary workers* are, as described, policy advisers working at the intersect of science and policy and waiting for a window of opportunity in order to enlarge the chance on a combination of knowledge and policy, or in other words: coupling of the policy and/or problem stream with the political stream when a *policy window* opens.

Different types of policy issues ask for different types of *policy entrepreneurs* or *boundary workers*. In the case of *wicked problems*, *rational fold-and-arrangers* and *policy strategists* are helpful to provide the decision making process with arguments from science and professional practice, and to take a critical look at the key assumptions behind current policy [Hoppe, 2008]. Also Kingdon gives a small description of the necessary qualities of a *policy entrepreneur*: expertise and an ability to speak for others, political connections or negotiating skills, and persistence [Kingdon, 1984]. When successfully coupled, solutions (knowledge) are joined to problems and both of them to favourable political forces (policy), but the next question is how to ensure that the knowledge is combined with policy in an effective way?

3.2.4. Science-policy nexus: the relation between knowledge and policy

In order to recommend a certain combination of knowledge and policy, it is necessary to describe a desired relation between scientists and policy makers. According to Derksen, roughly two types of relations between scientists and policy makers can be identified [Derksen, 2011]. These are the technocratic conception and the *decisionism* conception of the relationship between knowledge and policy [Derksen, 2011].

Technocracy is an organisational system where policy makers decide and develop policy on the basis of expert advice, mostly from scientists or engineers. Within this approach scientists can be seen as the dominating party, whereas politicians and civil servants are dependent on the ways in which scientific procedures, techniques and thinking affect them [Hoppe, 2005]. The policy is thus drawn up after extensive technical, economic and social analyses on which decisions are made [de Vries, 1995]. According to this approach the tasks of the policy makers and the scientists can and should be separated from each other during the development of policy, to ensure the objectivity and integrity of the scientists and therefore the research results. Policy makers provide scientists with a problem formulated as a research question. Scientists do their part of the work: they investigate the research question and deliver the answers to the policy makers. It is the task of the policy makers to value this knowledge and to draw decisions from it. In this way, the role of the scientists is merely informative. Decisions and normative judgements are taken by the policy maker [de Vries, 1995].

This approach seems logical and workable, but the reality is more complex. As policy makers often struggle to develop adequate research questions for scientists to investigate, this leads to vague questions, leaving much freedom for the scientists to choose their own perspective. Increasing the chance on mismatches between the research results and the needed information for the policy makers, and therefore unusable information for the development of policy [de Vries, 1995] [Derksen, 2011].

There is one more problem with the technocratic relation between policy makers and scientists: the communication between them. According to the *technocracy* approach the tasks of the policy makers and the scientists should be separated [de Vries, 1995], but such a minimum amount of communication only works in an ideal situation: an excellent formulated research question, clear tasks of the scientists and policy makers and no changes during the process [Derksen, 2011].

The opposite of *technocracy* is *decisionism* – a doctrine which states that policy is a product of decisions made by political bodies [Derksen, 2011]. Within this approach policy makers predominate. Since the authority who makes the decisions is more important than the content, policy makers are allowed to influence the research of the scientists; the political desires and values steer the functioning of science and technology in society [Hoppe, 2005] [Derksen, 2011]. It is the task of science and technology to provide instrumental knowledge, whereas politic decides on the use or non-use [Hoppe, 2005]. In practice this large influence of politics and full independency of science does not only negatively influence the quality of research, but also the quality of formulated policy [Derksen, 2011].

Described approaches in practice often not result in the desired results. Not only because of an improper combination of the fields of science and policy, but also by a false separation between them [Derksen, 2011]. The often sharp distinction between science and politics leads back to the 18th century Enlightenment. Science and politics were considered to be two incompatible ways of life. Notwithstanding, the realisation has grown that both can profit from each other under the right circumstances, as they both serve the same societal functions: social cooperation and collective action by creation of consensus and a fight against chaos [Hoppe, 2005]. The question remains: what are the right circumstances?

3.2.5. Combining knowledge and policy

The previous discussed general approaches (clichés) about the relation between science and policy (*technocracy* and *decisionism*) prove to be incorrect in practice. Politicians tend to believe that they are 'on top' and science available on demand, 'on tap'. On the other hand, scientists are often proud to tell that they, 'power-free smart ones', are able to tell politicians the truth: 'speaking truth to power'. None of these assumptions turned out to be true; the relationship between principals (politicians) and scientific knowledge providers or advisers is much more complicated and varied [Hoppe, 2008].

Several scientists have published their ideas about the difficulties and opportunities with the combination of knowledge and practice [Kingdon, 1984] [Hoppe, 2005] [Derksen, 2011] [Campbell, 2012]. In his book Derksen, a professor who has been operating at the frontier of science and policy for years, describes his experiences [Derksen, 2011]. According to Derksen there are several reasons for the poor combination between knowledge and policy. On the one hand scientists are afraid to lose their independency and integrity as they work with policymakers. Meanwhile, policymakers struggle to develop proper knowledge questions due to lack of experience and moreover: time. Therefore, too much research carried out by the governments research institutes serves no policy purpose and too much policy is developed at a too great distance of knowledge [Derksen, 2011]. But how can the transmission of knowledge into policy be improved?

There is one main lesson to be learned from the usage of the technocratic and the *decisionism* approach: in order to achieve added value nobody should dominate in the interaction between knowledge and policy [Derksen, 2011].

In fact, there should be two ‘bosses’: scientists in the domain of knowledge and policy makers in the domain of policy. Both domains should be governed by its own rules and scientists should justify themselves within the field of science, policy makers within the field of politics [Derksen, 2011]. Although the fact that Derksen recommends two ‘bosses’, he also stresses the need of communication between scientists and policy makers. The challenge regarding this subject is to find a suitable balance between cooperation and independency. If the scientists and the research are heavily influenced by the policy makers this does harm to the objectivity and quality of the research and in this way the quality of the policy. On the other hand, if scientists tend to recommended certain decisions in their research this also harms the effectiveness of the policy, as scientifically never can be proved what should be done [de Vries, 1995] [Derksen, 2011].

In other words: rather than interfering with each other, they must be concerned about each other. Scientists and policy makers should cooperate with a clear division of responsibilities [Derksen, 2011]. This division of tasks is not a foregone conclusion; it is a matter of *boundary work*. Strict boundaries between the work field of scientists and policy makers are difficult to draw. It is a myth that politicians are only concerned with values and interests, and that scientists only deal with (causal) relations. What actually happens, is that both parties from both sides of the boundary are continually negotiating with each other about how to draw the boundary for each individual case [Hoppe, 2008]. This on-going discussion about the division of tasks and responsibilities Hoppe calls *boundary work* [Hoppe, 2008]. *Boundary work* is the on-going process of drawing and protecting boundaries in order to guarantee the quality of the work [Hoppe, 2008]. Instead of focussing on differences between science and policy, one should focus on re-integration, cooperation and meaningful communication, or in the words of Hoppe: well-organised *boundary work* between science and politics (see chapters “*3.2.2. Wicked problems*” and “*3.2.3. The occurrence of policy windows*”) [Hoppe, 2005].

3.2.6. Translation of knowledge in actions

The combination between knowledge and science is often hard to make. On the one hand this is due to more practical reasons such as a, by many causes, often difficult or inaccurate collaboration between scientists and policy makers. The biggest dilemma here is finding the right balance between cooperation and independence. Solutions for this dilemma can be found in the drawing of boundaries between the tasks and responsibilities of scientists and policy makers, for each specific case. Thus it is possible that the final step, linking actions to the available knowledge, is carried out by both scientists and politicians. But how to execute this step, especially when dealing with *wicked problems*, in the first place?

Spatial planning is concerned with intervening and taking action in order to realise a better spatial environment [Campbell, 2012]. It is assumed that putting knowledge at the basis of such judgements will result in better outcomes [Derksen, 2011] [Campbell, 2012]. So in this way it is up to spatial planners to translate available knowledge (including gathered perspectives and desires of relevant stakeholders) into actions to improve the current situation; transforming what-is into what-ought-to-be.

In practice however, any attempt to involve more normative concerns within spatial planning (or science in general) can count on critique such as naïveté or exclusionary or imposing sentiments [Campbell, 2012]. Although critique is important in challenging current practices, it nowadays seem to lead to a fear to act. Since the new epistemology negated the certainties of *positivism*, the reluctance to normative concerns increased. Due to this fear to act knowledge generation becomes a goal on its own, leading to more and more produced knowledge and ever less aspirations or intents to actual contribute to the creation of an improved environment [Campbell, 2012].

In current planning theory and processes analytical knowledge seems to predominate, which leads to a decrease in the *synthetic knowledge* and capabilities; the ability to draw links, to reason and to come to conclusions about what is ought to be done. Analysis may produce knowledge, but to become meaningful and to have an impact on the spatial environment, it needs synthesis: relations have to be made and conclusion have to be drawn. Or as Friedmann puts it: "*We cannot wish not to know, and we cannot escape the need to act.*" [Friedmann, 1996]. Indeed, synthesis brings greater dangers and risks since the chance on taking the wrong actions increases (relative to taking no actions), but synthesis is necessary to translate knowledge (what-is) into actions to improve the environment (what-ought-to-be) [Campbell, 2012].

3.3. General opportunities and constraints for integration of climate adaptation measures in (urban) policy processes

Despite the described general obstacles within the decision making process regarding the integration of knowledge, there are some more specific (content related) obstacles for the integration of climate adaptation measures into policy processes. As UHI adaptation can be seen as a form of climate adaptation, since the phenomenon is closely related to climate change, these general obstacles for the integration of climate adaptation in policy processes will be described in this chapter.

3.3.1. Limits and barriers

Most studies on the integration of climate adaptation in policy processes indicate that there are both limits and barriers to this adaptation. These limits are on the one hand posed by the magnitude and rate of climate change, but these limits can also relate to financial, technological, institutional, cultural and cognitive barriers [Adger et al., 2007].

The actual implementation of climate adaptation measures faces various financial barriers. Estimates from the World Bank indicate that the total costs of 'climate proofing' development will be somewhere between the US$10 billion and US$40 billion per year (not taking into account the financial benefits from this development) [World Bank, 2006]. The scale of the necessary financial investments represents a major threshold for actual implementation of climate adaptation measures. A lack of (financial) resources may withhold people from taking action with regard to climate change.

Technical development can serve as a means of climate adaptation, but also as potential limit, as existing or new technology is likely to be unequal distributed among countries, groups or individuals. Besides, even if technology is available it is not always applied, due to uncertainties about climate change or economic and cultural (ethical concerns) constraints [Adger et al., 2007].

Social and cultural barriers are related to the different perspectives groups and individuals can have on climate change. Individuals might have different risk tolerances or different preferences regarding adaptation measures. Diverse understanding and prioritisations of climate change can limit the implementation of measures. A lack of urgency results in the fact that only few actions are undertaken by governments and individuals to adapt to climate change [Adger et al., 2007] [Uittenbroek, 2012].

Other barriers for climate adaptation could be the in general short-term scope of policymakers (whereas climate adaption demands for a more long-term approach) and the competing of problems [Gupta et al., 2010]. The number of subjects to which politics can pay attention is not infinite. Politicians can only pay attention to a certain amount of subjects, the list of these subjects is named the *governmental agenda*, whereas the list of subjects within this agenda which are up for an active decision is called the *decision agenda*. So only subjects on the *governmental agenda* are receiving political attention and only the subjects on the *decision agenda* are up for active decision making and therefore policy formulation [Kingdon, 1984]. This leads to, in a sense, competition between issues in order to be placed on the agenda.

It is due to these barriers and a lack of urgency that, although the knowledge, technology and even possible solutions might be available, little is being done, even within developed countries, in the field of climate adaptation [Adger et al., 2007].

The same barriers derived from research conducted by Gupta et al. [Gupta et al., 2010] on the adaptive capacity of Dutch institutions regarding climate change. From a questionnaire among 890 experts in the water, spatial planning and energy sectors (response of 30%), the following ten biggest barriers in the development of adaptation policies derived:

1. “short-term thinking and attitudes of policymakers related to the long-term scope of the problem
2. a conflict of interests of policy makers
3. unclear social costs and benefits of different measures
4. lack of resources
5. lack of climate awareness
6. competing short-term problems
7. no long-term caretaker of the climate risk

8. dependence on other actors
9. the reactive approach of policymakers
10. low interest in long term impacts [Gupta et al., 2010]”

Again, the most important barriers for the development of adaptation policies given by the experts relate to a lack of urgency, a lack of insight in the costs and benefits of climate adaptation, and the short-term scope of policy makers.

3.3.2. Possibilities and opportunities

Despite the above described limitations and barriers, climate adaptation measures are implemented in various countries. These adaptation measures are carried out by a range of public and private actors through investments in research, technology, behavioural change, and policies. Furthermore, the possible future impacts of climate change are explicitly considered within several climate adaptation measures and projects [Adger, et al., 2007]. Still this occurs on a limited basis only. Obviously, the opportunities to implement adaptation measures lie in overcoming the previous mentioned barriers for climate adaptation. Next to others, especially a better insight in the actual costs and benefits of implementation of particular measures is likely to reduce the current reluctance regarding the transition to a more structural approach and large scale execution of climate adaptation [Adger et al., 2007].

The measures which are currently implemented are rarely carried out in response to climate change alone. Most of the actions undertaken are responding to current extreme events such as cyclones and droughts, and embedded in broader initiatives such as water management and disaster management planning, called ‘*mainstreaming*’. The term *mainstreaming* refers to the integration of climate change adaptation into related government policy [Agrawala, 2005]. So instead of developing a whole new policy on climate change, the topic climate change could be integrated into current related policies, for example within water management [Agrawala, 2005] [Uittenbroek, 2012]. The concept of *mainstreamin*g as such is new, however, the idea resembles the so-called ‘facet and sector-thinking’, in which certain issues are approached through, one or more, facets (facets of policy, for example spatial policy, economic policy, etcetera) or sectors (policy sectors, such as agriculture, education, etcetera) within governments [Tunnissen, 2009].

Especially due to the uncertainty on precise future impacts of climate change, and the lack of insight in (economic and non-economic) cost-benefit analysis of climate adaptation measures, *mainstreaming* can be seen as a chance to address climate change either way. The idea is that by *mainstreaming* of climate adaptation, climate adaptation will become part of well-established programmes and policies and in that way structural and on a larger scale addressed [Adger et al., 2007].

3.4. Theory on the phenomenon UHI

Now that the theory on spatial planning is described, theory within spatial planning regarding the phenomenon UHI will be described. Although shortly explained in chapter "*1. Introduction*", this chapter will start with a brief history of research on UHI, and the defining of the UHI phenomenon. Followed by the causes and effects of this phenomenon.

3.4.1. History on research towards UHI

In 1830 the urban heat island effect was observed for the first time; in London as well as other European cities. Soon after this, UHI was observed in big cities in the USA, such as New York and Chicago [Yamamoto, 2006]. But it is only until recently that attention is being paid towards UHI and the (negative) impacts of this phenomenon on urban dwellers and the city surroundings. Countries worldwide are studying urban meteorology for over three decades now and as the global temperature is rising and urbanisation increases, the awareness on urban heat islands grows. Under researchers, as well as governments, acknowledgement of the negative effects of urban heat islands and the need for policy to mitigate UHI rises [Yamamoto, 2006] [Heusinkveld et al., 2010] [van Hove et al., 2011]. In England and Germany for example, countries with a climate similar to the Netherlands, various research is conducted on UHI [Rahola et al., 2009]. Especially in Hamburg, Stuttgart, Freiburg and London, attention is being paid towards the urban heat island intensity of cities [Yamamoto, 2006] [Heusinkveld et al., 2010].

Until recently none or little attention was being paid towards the UHI of Dutch cities, or heat-related problems and urban meteorology in general. The heat waves in the summer of 2003 and 2006 can be seen as the start of research on UHI in the Netherlands [van Hove, 2012].

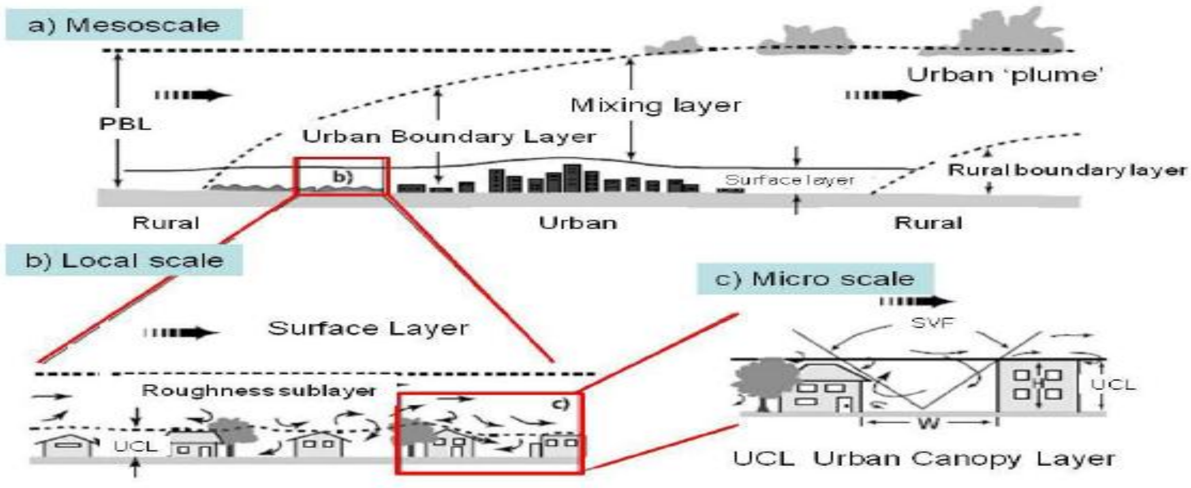
3.4.2. Defining the UHI phenomenon

UHI describes the phenomenon that urban air temperatures are higher than air temperatures of surrounding suburbs and rural environment [Kleerekoper et al., 2011]. UHI can therefore be defined as "*the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area's nearby natural landscape*" [Arrau and Peña, 2011]. Nevertheless, different stakeholders can have different perceptions of the phenomenon UHI and therefore different definitions of it (see chapter "*3.1.1. The social constructivist worldview*").

The difference in temperature between a city and her surroundings is not equal among cities. In fact, each city will face UHI on a different scale and intensity, as a result of differences in meteorological, locational and urban characteristics [Kleerekoper et al., 2011]. The term *UHI intensity* is used to indicate the strength of UHI per city [van Hove et al., 2011]. There are two forms of urban heat islands: surface and atmospheric urban heat islands. As the name suggests, a *surface urban heat island* occurs at the surfaces of a city and her buildings, whereas an *atmospheric urban heat island* arises in the atmosphere of a city. Surface heat islands are strongest during the day, especially when the sun is shining.

Since urban structures have a slow release of heat, the presence of atmospheric heat islands strengthens during the day. Finally, an atmospheric heat island can be further defined in *urban canopy layer heat islands* (UCL) and *urban boundary layer heat islands* (UBL). They differ in location: UCL in the air-layer where people live, and UBL in the air-layer above; starting from the treetops and rooftops until the point whereby the urban landscape no longer influences the atmosphere [van Hove et al., 2011]. The locations of the described types of *atmospheric urban heat islands* are visualised in figure 3.2..

Figure 3.2.: Spatial distinction of the atmospheric urban heat islands



Source: [van Hove et al., 2011]

In figure 3.2. three scales are distinguished on which atmospheric processes in urban areas are taking place. The processes in each scale influence each other, as well as the processes on the other scales. Although the figure contains more elements, the most important in this context is the illustration of the UCL and UBL. Mostly, when research is being done on UHI, it are UCLs which are observed and investigated and referred to in research and discussions [van Hove et al., 2011].

There are different manners to quantify the UHI of cities. Mostly measurements are made on the air layer from ground level to two meter above the ground. But there are several ways to interpret the results of these measurements. One way to quantify the UHI intensity is through usage of the difference between the minimum temperature in the city and the surrounding rural area per day. Though it is also possible to use the maximum difference between the temperature in the city and the rural area per day. Another way is quantifying the intensity by making use of the difference in the 'cooling rate' of a city and rural areas: the difference in the speed with which the temperature decreases. Although all these methods will result in the existence of urban heat islands, the intensity of these islands can vary by method [Steeneveld, 2012].

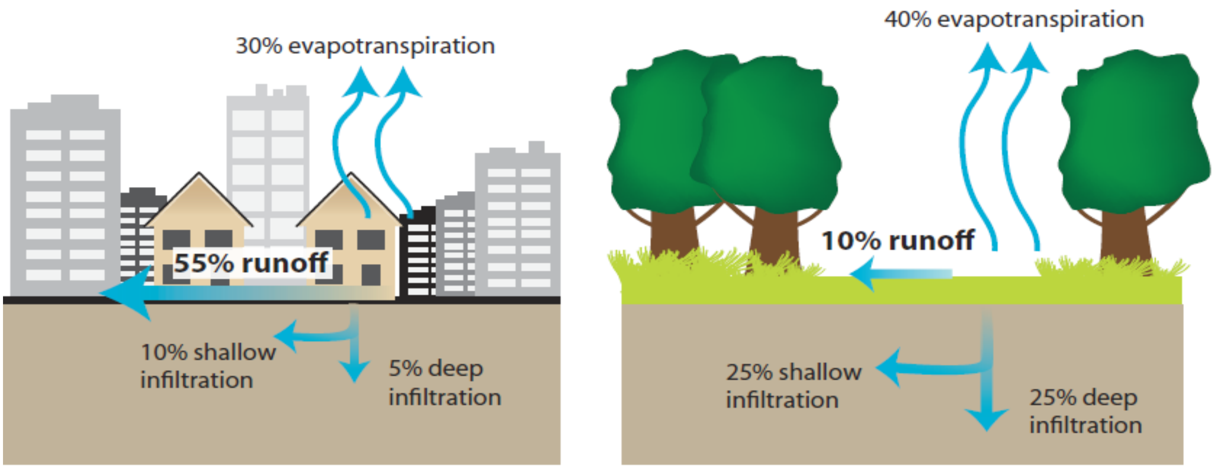
3.4.3. The causes of UHI

The difference between the temperatures in cities and rural areas is caused by several aspects. These causes can be categorised in the following five main causes of the urban heat island effect [Climate Protection Partnership Division, no date]:

- Reduced vegetation in urban areas

In rural areas the landscape is often dominated by vegetation and open land. Vegetation helps cooling the surface temperature in several ways. First of all, trees and vegetation provide shade. Secondly, they reduce air temperatures through evapotranspiration [van Hove et al., 2011] [Climate Protection Partnership Division, no date]. Evapotranspiration is the process in which water is released in the air by plants, which cools the surrounding air. In urban areas natural surfaces are often replaced by built surfaces. Highly developed urban areas consist of 75% to 100% impervious surfaces [Climate Protection Partnership Division, no date]. This replacement of natural surfaces by built surfaces results in less shade and moisture and therefore to decreased evapotranspiration and increased surface and air temperatures [Rahola et al., 2009] [Climate Protection Partnership Division, no date]. The following figure 3.3. shows the difference in usage of precipitation in urban and rural areas.

Figure 3.3.: evapotranspiration and infiltration in an urban and rural area



Source: [Climate Protection Partnership Division, no date]

- Characteristics of urban materials

The used construction materials and surfaces of buildings can highly influence the UHI intensity of cities, as the radiative and thermal properties of these urban materials determine the reflection, emission and absorbing of incoming energy from the sun. In general, built surfaces have a lower *albedo* than natural surfaces. *Albedo* is a measure to quantify the reflectance of materials; the percentage of solar energy which is reflected by a surface. As a result of the relatively low *albedo* of built surfaces, more energy from the sun is absorbed and less energy is reflected in urban areas. Many building materials, for example steel and stone, have higher *heat capacities* than rural materials. The *heat capacity* of a material is the ability of a material to store heat. Due to the higher heat capacities of building materials, more energy from the sun is stored within urban infrastructures. This absorbed energy will be released in the form of heat, this causes increased surface temperatures and the formation of urban heat islands [van Hove et al., 2011] [Climate Protection Partnership Division, no date].

- Urban geometry

Another factor which influences the development of UHI is the urban geometry: the urban structure of a city. This factor refers to the dimensions and spacing of buildings. The city structure can influence the UHI intensity in several ways: through influences on the wind flow, energy absorption and the ability to emit radiation back to space [Climate Protection Partnership Division, no date]. Due to densely packed buildings, surfaces and materials are unable to release their heat, leading to the storage of heat within urban structures [Yamamoto, 2006]. A measure to quantify the effect of the obstruction of sun energy by buildings and other objects is the '*sky view factor'*. The *sky view factor* is a measure between zero and one which represents the openness of the sky to transport of radiation [van Hove et al., 2011]. For example, an open parking lot has a large *sky view factor* value, closer to one. A street in the city centre has a *sky view factor* closer to zero due to the tall buildings which are obstructing the transportation of radiation [van Hove et al., 2011] [Climate Protection Partnership Division, no date]. An overall low *sky view factor* will therefore increase the UHI intensity of a city [van Hove et al., 2011].

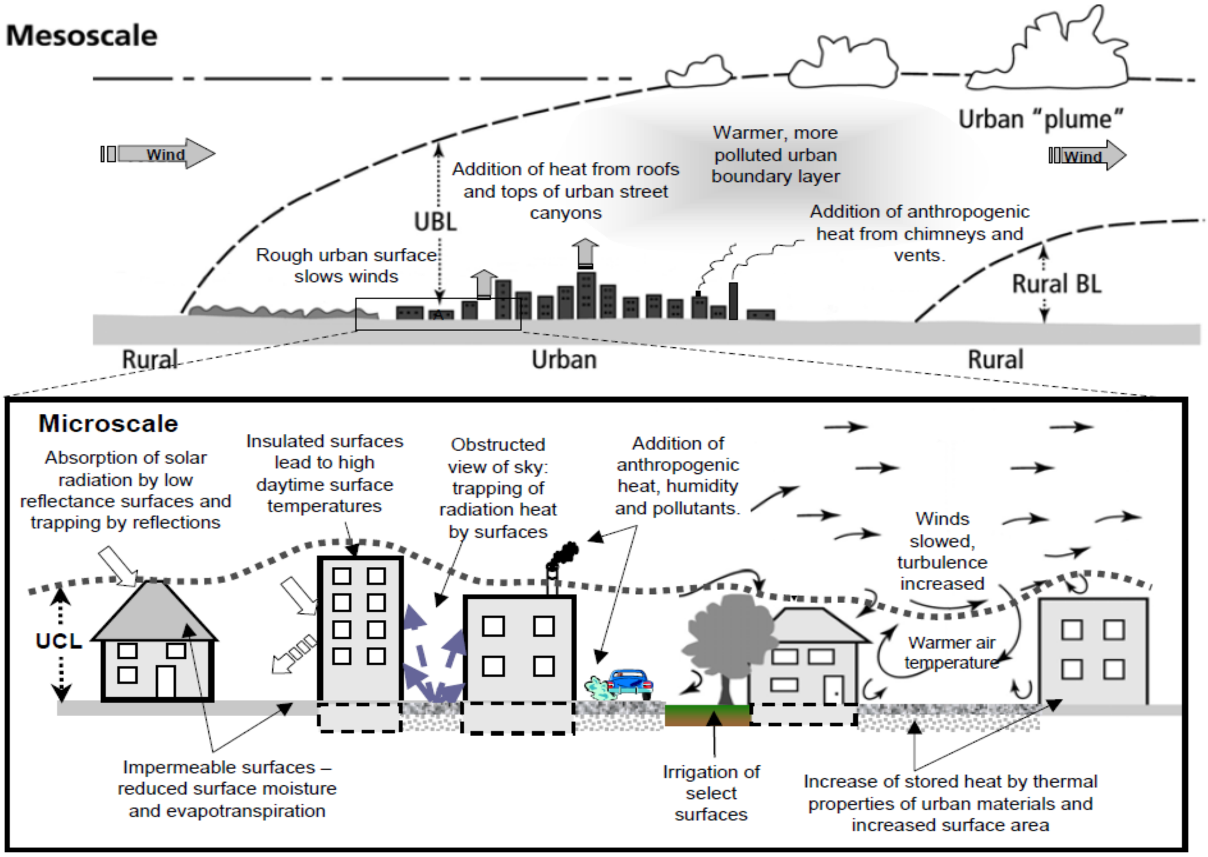
Urban geometry not only influences the transportation of radiation, but also the transportation of wind. Due to the large amount of buildings and obstructions within urban areas, the wind speed and transportation of wind are reduced. Besides the fact that this enlarges air pollution, this also decreases the transport of heat. In addition, air pollution in the urban atmosphere absorbs long wave radiation and emits it back to the urban environment [Kleerekoper et al., 2011].

- Anthropogenic heat

In urban areas 'extra' heat is released from human energy consumption. For example from human activities such as heating, air-conditioning, motorised transport and industries [Rahola et al., 2009] [Kleerekoper et al., 2011]. Clearly, anthropogenic heat contributes to atmospheric urban heat islands as 'extra' heat is released within cities [Climate Protection Partnership Division, no date].

In the following scheme, figure 3.4., the described effects which are causing the formation of heat islands within urban areas are visualised.

Figure 3.4.: the causes of the urban heat island effect



Source: [Voogt, no date]

- Additional factors

Next to the above described factors the weather conditions and the geographic location also determine the UHI in cities. There are two main weather conditions which affect the development of heat islands: wind and cloud cover. Periods of calm winds and clear skies contribute to the formation of UHI in two ways: under these circumstances the amount of solar energy reaching urban surfaces maximises and due to the low wind speed the transport of radiation back to the sky decreases. The geographic location of a city determines the UHI intensity as it determines the climate and topography. Large water bodies and moderate temperatures can for example suppress UHI [Climate Protection Partnership Division, no date].

The phenomenon UHI is indirectly related to climate change. When temperatures are rising due to climate change and weather extremes such as heat waves and droughts will occur more often, the UHI intensity of cities is expected to increase [Rahola et al., 2009] [van Hove et al., 2011]. The International Panel on Climate Change predicts a global surface warming for this century of between 1.1 and 6.4 degrees Celsius and an increase in weather extremes [IPCC, 2007]. The KNMI made predictions for the climate in the Netherlands, in which it is expected that the amount of warm (>20 degrees Celsius) , summer (>25 degrees Celsius) and tropical (>30 degrees Celsius) days and warm nights will increase [Knowledge for Climate, 2011].

Global climate change might strengthen the UHI intensity of cities as natural cooling of cities will become more difficult due to the higher temperatures and the expected increase in sunshine hours in the summer [Rahola et al., 2009]. Nonetheless, little research has been done on the precise impacts of climate change on the UHI intensity in cities [van Hove et al., 2011]. The relation between UHI and climate change is reciprocal; due to the formation of heat islands, the average temperature in cities is increasing, thus leading to regional warming [Heusinkveld et al., 2010] [Arrau and Peña, 2011]. In addition, higher temperatures stimulate the formation of ground-level ozone [Kleerekoper et al., 2011].

3.4.4. The effects of UHI

Research has shown that the annual average air temperature in cities with one million or more inhabitants can be up to three degrees Celsius higher than the annual average air temperature of its surroundings, with maximum differences in temperature of twelve degrees Celsius [Climate Protection Partnership Division, no date]. In fact, UHI can occur in any man-made area; large cities as well as small villages or even districts and neighbourhoods [van Hove, 2012] [Steeneveld, 2012]. But, is this a problem?

Each individual will perceive UHI in a different way. It is therefore impossible to simply submit that UHI should be considered a problem for the society. Fact is that the formation of urban heat islands within urban areas has several impacts on the city, the city dwellers and the surroundings [van Hove et al., 2011] [Climate Protection Partnership Division, no date].

- Energy consumption

UHI influences the energy consumption within cities. Due to the higher temperatures in the summer, the need for cooling increases. Research has shown that the urban electric demand increases with 1.5% to 2% per 0.6 degrees Celsius increase in summertime temperatures [Climate Protection Partnership Division, no date]. Although less common in the Netherlands, the air-conditioning market is growing fast in the Netherlands and is expected to do so in the near future [Rahola et al., 2009]. For the United States is calculated that the implementation of UHI mitigation measures can potentially reduce the energy use with 20%, thus saving over ten billion dollar per year in energy use and improving the air quality in urban areas [Akbari et al., 2001].

During winter UHI might have a positive effect on the energy demand. Due to warmer temperatures within cities, the demand for heating might reduce. In addition, UHI can help melt snow and ice on roads, and in this way not only reduce the usage of road salt, but also improve the traffic safety [Climate Protection Partnership Division, no date]. But too little research has been done on the possible (positive) effects of UHI in the winter to appoint positive effects [Steeneveld, 2012].

- Air quality

An increase of energy demand generally leads to higher levels of air pollution and the emission of greenhouse gasses [Akbari, 2005]. When electricity is produced trough usage of fossil fuel, pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, mercury and particulate matter are emitted [Climate Protection Partnership Division, no date]. These pollutants negatively influence human health and the air quality. [Climate Protection Partnership Division, no date]. In addition, higher temperatures stimulate the formation of ozone on the ground level, thus directly influencing the air quality [Climate Protection Partnership Division, no date]. It is because of this formation of ozone that heat waves and hot periods often occur in combination with summer smog (ozone at the street level). As wind speed is generally low during hot periods, smog and other air pollutants are not dispersed, leading to high levels of air pollution in urban areas. Research has shown that air pollution effects are responsible for 30% to 40% of the increased deaths during heat waves [Rahola et al., 2009] [Fischer et al., 2004].

- Water quality

Besides the possible influence on air quality, UHI can also influence the water quality. Mainly in the form of thermal pollution. As figure 3.3. already indicated, the runoff of precipitation is much higher in urban areas than in rural areas: 55% runoff, respectively, 10% runoff. When built surfaces such as pavements and rooftops reach temperatures of 27 to 50 degrees Celsius higher than air temperatures, they transfer this heat to water. Study showed that during summer days the runoff from cities was about 11 to 17 degrees Celsius warmer than the runoff from a rural area nearby [Roa-Espinosa et al., 2003]. This warm water generally streams into the sewage system and will be released into surface water such as rivers and lakes. Due to this incoming warm water, the temperature of the surface water will increase [Climate Protection Partnership Division, no date]. This process is recognised as one of the biggest threats to cold-water streams, since excessive heated wastewater can significantly and permanently harm the receiving surface waters [Roa-Espinoa et al., 2003]. The large-scale inflow of heated runoff water into surface water negatively effects the metabolism and reproduction of many aquatic organisms and will therefore lead to habitat degradation and losses in biodiversity [Roa-Espinoa et al., 2003] [Climate Protection Partnership Division, no date].

- Organic life

Warmer temperatures can lengthen the plant-growing season and can therefore positively influence yields from (urban) agriculture [Climate Protection Partnership Division, no date]. Increasing temperatures can also lead to shifts in the occurrence of organism. Species which are unable to adapt could migrate to other places, while species that thrive better on these warmer conditions might flourish in cities. Higher temperatures lead to more bacterial life, thus increasing chances on food infections as salmonella and legionella infections. Although these problems not occur in the Netherlands nowadays, several researchers expect that this might happen in the future [Rahola et al., 2009].

- Human health

Above described effects of UHI indirectly influence human health. Air-pollution, for example, can cause several health problems. But high temperatures can also directly influence human health.

The physical well-being of people depends on, among other factors, the meteorological climate, and especially on the urban microclimate. The human body gains heat through absorption of radiation from the sun and sky, directly and by reflection, but also through direct contact with objects warmer than the body, such as street surfaces [Kleerekoper et al., 2011]. There are several mechanisms with which the body can secure a proper balance between heat gains and losses, these mechanisms together form the thermoregulatory system. Extreme temperatures can disturb this system, with thermal discomfort or even health problems as result [Kleerekoper et al., 2011]. Thermal comfort expresses the satisfaction with the chill temperature of the surrounding environment [Rahola et al., 2009]. Clearly, high day and night temperatures are likely to contribute to general discomfort and negatively influence the thermal comfort of humans [Climate Protection Partnership Division, no date].

Besides feelings of discomfort, UHI can also lead to other health problems. Taking into account the climate predictions for the Netherlands, heat stress can be seen as the biggest threat [Kleerekoper et al., 2011]. The optimal outdoor temperature in the Netherlands is 16.5 degrees Celsius. Although there is no set temperature at which heat stress starts, because its dependency on multiple factors, 25 degrees Celsius is seen as the general starting point [Rahola et al., 2009]. A period of five days with a maximum temperature above 25 degrees Celsius and minimal three days with a maximum temperature above 30 degrees Celsius is called a *heat wave* in the Netherlands [KNMI, 2012]. Heat stress can lead to health problems such as difficulties with respiration, heat cramps and exhaustion, heat strokes and heat-related death [Climate Protection Partnership Division, no date]. Formation of urban heat islands combined with the global temperature rise and the expected increase in hot extremes and heat waves, can lead to major public-health crises in highly urbanised areas due to the increased uncomfortable and unhealthy heat stresses [Kleerekoper et al., 2011] [van Hove et al., 2011]. UHI can in this way aggravate the impact of heat waves. Especially elderly people, children and people with existing health conditions are vulnerable to these impacts [Climate Protection Partnership Division, no date].

Mortality rates, for example, are known to increase due to hot weather, especially among the above described vulnerable people [van Hove et al., 2011]. The Centers for Disease Control and Prevention estimated that in the period from 1979 to 2003 about 8000 deaths in the United States where caused by excessive heat exposure. This is more than the number of mortalities resulting from lightning, tornadoes, floods, earthquakes and hurricanes together during this period [The Centers for Disease Control and Prevention, 2009]. The recent heat waves of 2003 and 2006 caused a high mortality rate in the Netherlands as well, with an excess of between 1400 and 2200 heat-related deaths [Heusinkveld et al., 2010].

Heat is however not the only factor which can negatively influence the outdoor urban climate and can therefore lead to health problems, moisture and wind for example also play an important role. Nevertheless, UHI does negatively influence human health in the above described ways [Rahola et al., 2009].

To recapitulate, the urban heat island effect refers to the in general higher temperatures in urban areas than in surrounding rural areas, due to the heat absorbing qualities of built-up area. This phenomenon can have several negative impacts on public health and the living quality. Taking into account the climate predictions for the Netherlands, heat stress can be seen as the biggest threat. Heat stress can lead to health problems such as difficulties with respiration, heat cramps and exhaustion, heat strokes and even heat-related death.

Climate projections predict that weather extremes, including heat waves, are likely to occur more frequent in the Netherlands. These heat waves will compound the UHI and heat-related problems in urban areas. Next to the rising temperatures, urbanisation is also expected to increase. Used models and scenarios within spatial planning all point to a large expansion of urban areas [Heusinkveld et al., 2010]. Although research on UHI in the Netherlands has just started recently, it is expected that UHI and therefore heat-related problems will only increase in Dutch cities [Heusinkveld et al., 2010] [van Hove et al., 2011]. Facing these projections and global warming, outdoor climatic environment becomes an important factor to consider within spatial planning [Ren et al., 2012]. Although the precise effects of these projections remain unclear, Dutch cities are already facing UHI and the related impacts (whether they are positive or negative) nowadays [Kleerekoper et al., 2011]. Because urban geometry and urban characteristics of a city influence the UHI intensity, urban design can be used as a way to reduce the negative effects of this phenomenon. Outdoor climate, and especially urban climate, is therefore an important factor for planners to take into account within current spatial planning processes and practices. Improving the outdoor climate and addressing UHI contributes to a better thermal comfort and urban living quality. It is therefore necessary to intertwine UHI mitigation within spatial planning; knowledge on this topic should be assessed systematically and strategically applied in planning process and practice in order to mitigate the negative effects of UHI [Ren et al., 2012]. This leads back to the objective of this study: identify effective methods to integrate UHI mitigation measures in urban policy of Dutch municipalities.

4. HEAT IN ROTTERDAM: CAUSES & INTENSITY

Within this research, the UHI situation and the developments regarding this topic in Rotterdam will be analysed. Questions to answer are: what is the UHI situation in Rotterdam? What are the causes and effects of the formation of urban heat islands in the city of Rotterdam? Are these effects considered to be negative and are there measures taken to reduce or mitigate these effects? First question is: at which scale does UHI occur in the city of Rotterdam? Within this chapter the current UHI situation in Rotterdam will be described, regarding the intensity of the phenomenon in this municipality.

4.1. The UHI intensity in Rotterdam

Although UHI was not expected to be a problem for the Netherlands, due to the mild temperate maritime climate and the location next to the sea, research has shown that UHI occurs in Dutch cities [Heusinkveld et al., 2010] [van Hove et al., 2011]. Also the city of Rotterdam is facing UHI, with maximal temperature differences of the same order of magnitude as the reported values from other European cities [van Hove et al., 2011]. The UHI intensity of Rotterdam is further investigated within the project “Knowledge for Climate”, as Rotterdam is one of the ‘*hotspots*’ within this project. In the report “Heat stress in Rotterdam” the results of several studies on UHI are combined [Knowledge for Climate, 2011].

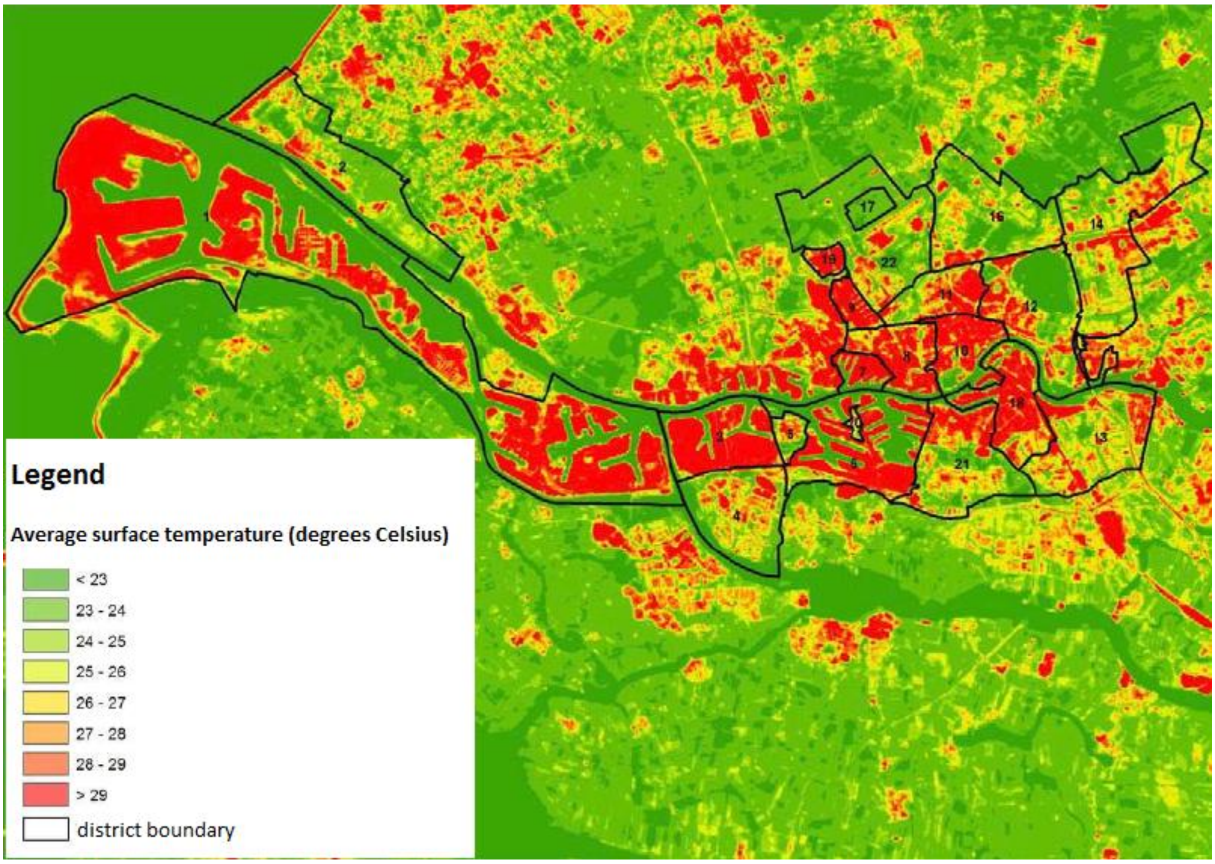
Figure 4.1.: subdivision of the municipality of Rotterdam in districts and green areas which determine the surface temperature of the surrounding countryside

1 Botlek/Europoort/Maasvlakte	9 Spaanse Polder	17 Business park Schieveen
2 Hoek van Holland	10 Stadscentrum (city centre)	18 Feijenoord
3 Vondelingenplaat	11 Noord	19 Business park Rotterdam NW
4 Hoogvliet	12 Kralingen-Crooswijk	20 Heijplaat
5 Pernis	13 IJsselmonde	21 Charlois
6 Eem-Waalhaven	14 Prins Alexander	22 Overschie
7 Nieuw Mathenesse	15 Rivium	
8 Delfshaven	16 Hillegersberg/Schiebroek	

Source: [Klok et al., 2010]

By making use of several research methods, scientists have investigated the current UHI intensity of Rotterdam. Within this research project the municipality of Rotterdam is divided in districts as seen in figure 4.1.. Besides the districts, several green areas were indicated as well, which are influencing the average (during a day) surface temperature of the surrounding rural areas. In figure 4.2. the results of this research are visualised in the form of the average surface temperatures during the day (between sunrise and sunset) in the city of Rotterdam. The colour green stands for temperatures below 22 degrees Celsius, whereas increasing temperatures are visualised with more reddish colours, with a maximum of above 29 degrees Celsius (red).

Figure 4.2.: average surface temperature during the day in Rotterdam

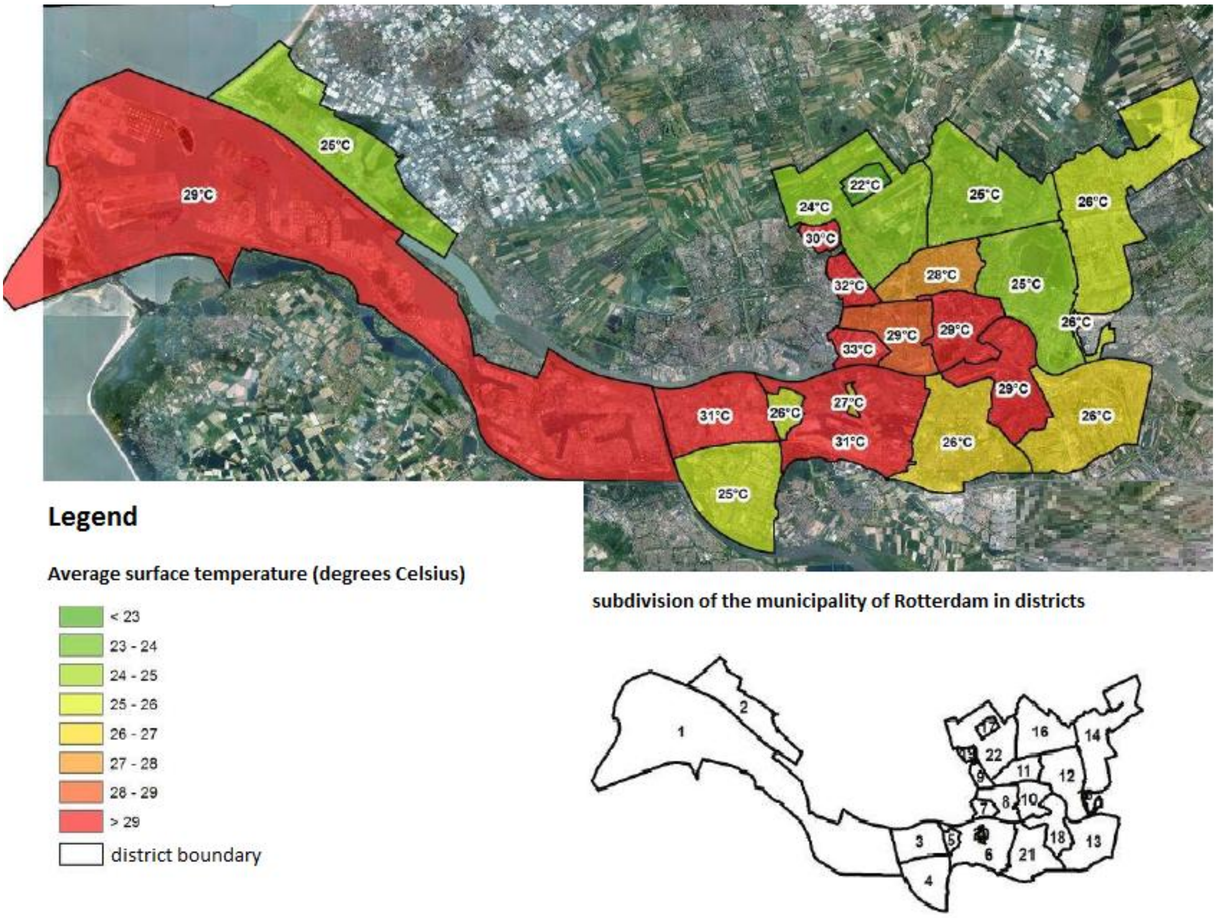


Source: [Klok et al., 2010]

Within the above figure the distinction between urban areas and rural areas is obvious. The highest temperatures occur in industrial areas and in high dense areas of Rotterdam, such as the city centre. Water surfaces, grasslands and arable areas are the coolest areas. To illustrate the contrast between these areas: the average temperature of water bodies is about 20 degrees Celsius, whereas the warmest dark roofs have an average surface temperature of 38 degrees Celsius [Klok et al., 2010].

In figure 4.3. the average daytime surface temperature of each distinguished district is calculated and visualised. The warmest neighbourhoods are Botlek/Europoort/Maasvlakte, Vondelingenplaat, Eem-Waalhaven, Nieuw Mathenesse, Spaanse Polder, Stadscentrum (city centre), Feijenoord and Business park Rotterdam NW.

Figure 4.3.: average surface temperature during the day of the 22 districts in Rotterdam



Source: [Klok et al., 2010]

These average temperatures are compared with the average daytime surface temperature of surrounding rural areas, to indicate the surface urban heat island intensity for each district during daytime. Results of this comparison (the daytime surface urban heat island effect) are shown in table 4.1..

Table 4.1.: average daytime surface temperature and urban heat island intensity per district

District	Average daytime surface temperature	Daytime surface urban heat island intensity (°C)
Nieuw Mathenesse	32.9	9.9
Spaanse Polder	32.1	9.1
Vondelingenplaat	31.1	8.1
Eem-Waalhaven	30.6	7.6
Business park Rotterdam	29.7	6.6
Botlek/Europoort/Maasvlakte	29.4	6.3
Feijenoord	29.3	6.2
Stadscentrum (city centre)	29.2	6.2
Delfshaven	29.0	5.9
Noord	27.7	4.6
Heijplaat	26.5	3.5
IJsselmonde	26.5	3.4
Charlois	26.1	3.1
Rivium	26.0	2.9
Pernis	25.6	2.5
Prins Alexander	25.6	2.5
Hoogvliet	25.5	2.4
Kralingen-Crooswijk	25.0	1.9
Hoek van Holland	24.7	1.7
Hillegersberg/Schiebroek	24.7	1.6
Overschie	24.1	1.1
Business park Schieveen	22.4	-0.6

Source: [Klok et al., 2010]

The districts Nieuw Mathenesse, Spaanse Polder and Vondelingenplaat are the warmest districts with a more than eight degrees Celsius temperature difference with the surrounding rural areas; a daytime surface urban heat island intensity of eight and above. Coolest districts are Businesspark Schieveen, Overschie, Hillegersberg/Schiebroek, Hoek van Holland and Kralingen-Crooswijk. In these districts the average temperature is less than two degrees higher as the average temperature of the rural areas.

Above facts and figures refer to the daytime surface temperature(difference). Research has demonstrated that areas with a high UHI intensity during daytime not necessarily have this same high UHI intensity during night [Klok et al., 2010]. With the usage of thermal infrared images the surface temperature of the districts has been investigated during the heat wave of 2006, at day and night time. The results of this research showed differences in warmest districts during day and night time. During the night the districts Heijplaat, Vondelingenplaat, Pernis and Eem-Waalhaven, mainly industrial and harbour areas, are relatively warm compared to the surrounding rural areas [Klok et al., 2010]. This difference in UHI intensity during the day and night is probably caused by the heat release of built surfaces (absorbed radiation is mainly released during the evening and night).

Furthermore, these districts contain a relatively large amount of water. During the start of a heat wave, water temperature is lower than the temperature of built surfaces, but as the heat wave continuous, the temperature of water bodies will only increase. Due to the fact that water cools less quickly than built surfaces, the existence of water bodies can have a heating effect during the night and longer periods of extreme heat [Klok et al., 2010] [van Hove et al., 2011].

Results from the study of Heusinkveld et al. indicate an maximum UHI intensity in the municipality Rotterdam of more than seven degrees; during the evening and night temperature differences of more than seven degrees Celsius with the surrounding rural areas are easily reached in the city of Rotterdam [Heusinkveld et al., 2011]. The average temperature difference in the municipality of Rotterdam, compared to the surrounding rural areas, is found to be 2.8 degrees Celsius [Steeneveld, 2012b]. But which factors are causing these kind of temperature differences in Rotterdam?

4.2. The causes of UHI in Rotterdam

There are many different aspects which are influencing the formation of heat islands in cities, as described in chapter "*3.4.3. The causes of UHI*". The interaction of these factors, on different temporal and spatial scales, determines the UHI intensity in a particular city [van Hove et al., 2011]. Within these factors, a distinction can be made between controllable and uncontrollable (natural) factors. Uncontrollable factors are for example the climate zone and the topography of a city. Controllable factors can be further categorised into temporary effects, permanent effects, and cyclic effects. Temporary effects are for example weather conditions, such as wind speed and cloud cover. Permanent effects are aspects which can be controlled, but have a more permanent character: for example green areas, building materials and the urban structure of a city. Cyclic effects are recurring elements such as anthropogenic heat sources and solar radiation which are influencing the formation of urban heat islands [van Hove et al., 2011].

Within the programme "Knowledge for Climate" the causes of UHI in the city of Rotterdam are (and will be further) investigated for the municipality of Rotterdam within different research projects. Within these research projects the spatial variation in the average surface temperature in Rotterdam is related to field features that characterise the urban area, such as the amount of vegetation, water and built surfaces (controllable, but permanent factors).

Characteristics which were taken into account within these projects are: *albedo*, *emissivity* (the ability of a material to radiate absorbed energy), *sky view factor*, percentage built area, percentage paved surface, public green, total amount of green, water, building heights, population density and '*NDVI*'. '*NDVI*', or vegetation index, is a measure to indicate the "greenness" of the surface. Bare surfaces have a value about 0.1, whereas vegetation rich surfaces can reach values of 0.9. The aspect *NDVI* is closely related to the *emissivity* and *albedo* of an area [Klok et al., 2010].

In the following table, table 4.2., the average values and the range of values of heat factors are listed for the neighbourhoods in the municipality of Rotterdam, as well as the found correlations: the degree of correlation (consistency) between two aspects. A Pearson correlation of -1 stands for a perfect negative linear relationship, whereas +1 stands for a perfect positive relationship. The closer to zero, the weaker the correlation between the elements.

Table 4.2.: average values and range of values of heat factors for the neighbourhoods of Rotterdam

	Heat factor	Range of values	Average value	Pearson correlation
Direct factors	Albedo	0.06 - 0.16	0.10	-0.64
	Emissivity	0.92 - 1.00	0.97	-0.90
	Sky view factor	0.52 - 1.00	0.77	-0.61
indirect factors	built-up area (%)	0 - 39	15	0.54
	paved surfaces (%)	0 - 96	60	0.62
	public green (%)	0 - 42	11	-0.52
	total green (%)	2 - 66	24	-0.83
	building height (m)	3 - 38	10	0.52
	water (%)	0 - 63	14	0.13
	population density (ha-1)	0 - 256	67	0.36
	NDVI	-0.07 - 0.78	0.39	-0.81

Source: [Klok et al., 2010]

Strong relations with the spatial variation in surface temperature are found for the direct factors: the average *albedo*, *emissivity*, and *sky view factor* of a neighbourhood. These three aspects have a negative correlation with the surface temperature; reduction of the *sky view factor* or *albedo* and *emissivity* of used materials and surfaces will lead to an increase of the surface temperature. Small changes in these aspects, in particular *albedo* and *emissivity*, can cause relatively large differences in the surface temperature. For example, an increase of the *albedo* or *emissivity* of materials with 0.01, has an average lowering effect on the surface temperature of 0.8, respectively 1.7 degrees Celsius [Klok et al., 2010].

Also the aspects percentage built area, percentage unpaved surfaces, percentage public green, total amount of green, the average building heights and *NDVI* demonstrate a significant correlation with the spatial variation in the average surface temperatures. Because of the fact that an increase of the amount of green usually leads to a decrease of the amount of paved surfaces, an increase of 10% green (replacing paved surfaces) in the municipality of Rotterdam can lead to surface temperature reduction of one degree Celsius [Klok et al., 2010]. No significant correlations were found for the existence of water in the neighbourhoods and the population density, with the spatial variation in the surface temperatures [Klok et al., 2010].

With the usage of these found relations, the relative warm surface temperatures of the districts Nieuw Mathenesse, Spaanse Polder and Vondelingenplaat can be explained by relatively low amounts of green in these areas and high percentages of built surfaces. The districts Nieuw Mathenesse and Vondelingenplaat belong to the least green neighbourhoods with percentages of total green of respectively 7% and 8%. The amount of total green in the district Spaanse Polder is with 14% also quite low. This district has notable high percentages built-up area (26%) and paved surface (76%) as well [Klok et al., 2010]. This relation is further enhanced by the fact that lower percentages of built surface and higher amounts of total green are found in the relatively cool districts. The coolest districts Businesspark Schieveen, Overschie, Hillegersberg/Schiebroek, Hoek van Holland and Kralingen-Crooswijk have an average percentage of built area of 8% and an average amount of total green of 43% [Klok et al.,2010].

The contribution of anthropogenic sources to the formation of urban heat islands is limited in Rotterdam [Klok et al., 2010]. Nonetheless, heat released by industries and businesses could negatively affect the productivity of employees. In addition, heat generated inside houses often remains in these rooms and can accumulate over the days, thus resulting in uncomfortable indoor conditions during warm periods [Klok et al., 2010].

To summarise, most important factors determining the UHI intensity in Rotterdam are the *albedo* and *emissivity* of used materials, and the *sky view factor* (controllable permanent direct factors). Especially small changes in the *albedo* and *emissivity* of materials can directly lead to a decrease in the surface temperature [Klok et al., 2010]. Area characteristics which play an important role in the formation of urban heat islands are the percentage built area, percentage unpaved surfaces, percentage public green, total amount of green and the average building heights. An increase of the total amount of green in a neighbourhood with 10%, for example, can decrease the average surface temperature of a neighbourhood with 1.3 degrees Celsius [Klok et al., 2010]. The structure and design of the city is thus influencing the process of warming and cooling of the city of Rotterdam [Knowledge for Climate, 2011].

5. HEAT IN ROTTERDAM: WHY BOTHER?

The average difference between temperatures in the city of Rotterdam and surrounding rural areas is 2.8 degrees Celsius, with easily reached maximum differences of more than seven degrees. But why should we, or in this case the Municipality and inhabitants of Rotterdam, care about these differences in temperature? To answer this question, the effects of the UHI intensity of Rotterdam will be described in this chapter.

5.1. Current effects of the UHI intensity in Rotterdam

Advisor Climate adaptation and Sustainability within the Engineering consultancy for Urban Development Nijhuis declared that the amount of heat-related complaints received by the GGD of Rotterdam (Municipal Health Service Rotterdam) increases during hot periods [Nijhuis, 2012]. During the summer of 2006 the GGD received 600 of such complaints in only two weeks' time [Knowledge for Climate, 2011]. Besides these heat diseases, heat can in the worst case result in death. Based on measurements over the period 1979-2007, an increase of 12% in deaths is calculated for the Netherlands during heat waves, equating to 40 heat-related deaths per day [Knowledge for Climate, 2011]. Passing on these figures to the situation in Rotterdam, 36 heat-related deaths per year are expected (1.5 heat-related deaths per summer day (maximum temperature of above 25 degrees Celsius) [Daanen et al., 2010]. Based on the mortality figures of Rotterdam, the heat wave of 2006 actually caused 20 additional deaths, each week [Knowledge for Climate, 2011].

Heat can also result in general feelings of discomfort, reduced productivity and sleep disturbance. Research within the municipality of Rotterdam showed that temperature affects the various aspects of sleep. On average, people sleep more restless and the total sleep time decreases [Knowledge for Climate, 2011]. Furthermore, high temperatures negatively influence the productivity of people [Knowledge for Climate, 2011]. In addition, heat has an adverse impact on the air quality, as higher temperatures stimulate the formation of smog and ozone [Climate Protection Partnership Division, no date] [Climate Proof Cities, 2011]. Expected is that the combination of high temperatures and air pollution will have bigger consequences for human health, as these two factors separately [Knowledge for Climate, 2011]. To make things worse, the municipality of Rotterdam is already facing a poorer health situation in comparison to the average Dutch public health situation. Inhabitants of the municipality have a significant disadvantage in life expectancy (from 1.3 to 1.6 years) in comparison to the Dutch average. Approximately 10% to 12% of this gap is caused by the poor air quality in the municipality of Rotterdam [Programma Duurzaam, 2012].

But one of the most direct and probably most common impact of UHI and the related high temperatures within cities is a general feeling of discomfort. The municipality of Rotterdam is facing an average UHI intensity of 2.8 degrees Celsius, with maximum differences in temperature of more than 7 degrees [Knowledge for Climate, 2011]. But just like in the winter, when the chill temperature can be much lower than the actual outside temperature due to strong wind, chill temperatures during warm days can be significant higher than the real temperature. It is the experienced temperature which can lead to discomfort or heat stress [Knowledge for Climate, 2011].

A manner to express the chill temperature is the *physiologically equivalent temperature*: PET. Differences in PET between cities and rural areas can easily reach maximums of 15 degrees Celsius [Climate Proof Cities, 2011]. In the following table 5.1., the relation between the chill temperature (PET), the human sensation and thermal stress level is indicated (based on a 35-years old healthy person).

Table 5.1.: comparison between PET, human thermal sensation and thermal stress level

PET (°C)	Human sensation	Thermal stress level
4	very cold	extreme cold stress
8	cold	strong cold stress
13	cool	moderate cold stress
18	slightly cool	slight cold stress
23	comfortable	no thermal stress
26	slightly warm	slight heat stress
29	warm	moderate heat stress
35	hot	strong heat stress
37	very hot	extreme heat stress

Source: [Matzarakis et al., 1999]

Chill temperatures between 18 and 23 degrees Celsius are experienced as the most comfortable. PETs above 26 degrees Celsius are experienced as warm or extreme hot, and can lead to slight or extreme heat stress [Matzarakis et al., 1999] [Heusinkveld et al., 2011].

Maximum PET values per day are calculated in Rotterdam over the period of April to October 2010, these values are compared with the found maximum values in the reference area; the surrounding rural area. In table 5.2. the results of these measurements are listed. For each city district the amount of hours with slight to extreme heat stress in the area, due to high PET values, is indicated.

Table 5.2.: hours of slight to extreme heat stress in the city of Rotterdam and the reference area, 15 April – 31 September 2010

PET (°C)	Thermal stress level	Centre	East	South	Reference
23 - 29	slight heat stress	302	197	224	63
29 - 35	moderate heat stress	79	62	67	11
35 - 41	strong heat stress	16	12	12	0
> 41	extreme heat stress	0	0	0	0

Source: [Knowledge for Climate, 2011]

Although it is not stated how many hours the measurement period covers (probably approximately 4000 hours), the table shows a clear difference in the amount of hours with slight, moderate or strong heat stress between the reference area and the urban districts in the city of Rotterdam.

400 Hours of slight to strong heat stress were measured in the centre of Rotterdam, of which 16 hours of strong heat stress. Also in the urban districts East and South, there were 271, respectively, 303 hours of slight to strong heat stress [Knowledge for Climate, 2011]. In figure 5.1. the results of the measured PET values and radiation exposure on August the sixth of 2009 are illustrated for a small piece of a road [van Hove et al., 2011].

Figure 5.1.: PET (colours) and radiation exposure (circles) afternoon, August 6, 2009

Source: [Heusinkveld et al., 2011]

Figure 5.1. shows that although differences in temperature may be small, especially on the scale of a street, the range in PET values can be quite large. This is mainly due to the large influence of solar radiation on the chill temperature during daytime. The contrast between the north sunny side and the south side covered with trees and shade is perfectly clear. On the south side measured PET values and radiation exposure are relatively low. The north side of the street lies completely in the sun, which is reflected in the measured PET values and radiation exposure on this side of the street [Heusinkveld et al., 2011].

The above described results indicate that especially in densely built areas in Rotterdam the experienced thermal comfort can already cause problems, such as thermal discomfort and heat stress. [Knowledge for Climate, 2011] [Climate Proof Cities, 2011].

5.2. Future UHI situation in Rotterdam

Although relatively little research has been conducted on the impacts of climate change on the UHI intensity in cities [van Hove et al., 2011], the UHI intensity is expected to increase when temperatures are rising and weather extremes such as heat waves and droughts are occurring more often [Rahola et al., 2009]. In fact, recent model studies showed an intensification of the average nocturnal heat intensity as a result of global warming [van Hove et al., 2011]. The International Panel on Climate Change predicts a global surface warming of between 1.1 and 6.4 degrees Celsius for this century [IPCC, 2007]. Moreover, climate change projections for Europe suggest that heat waves will occur more frequently [van Hove et al., 2011].

These predictions also relate to the Netherlands. Climate scenarios from the KNMI show an increase in the amount of warm days in the Netherlands, as well as the average temperature during these warm days (table 5.3.) [Knowledge for Climate, 2011].

Table 5.3.: overview of the expected warm, summer and tropical days in the Netherlands according to climate scenarios from the KNMI (approached on 26 February 2010)

		2020	**2050**
Number of warm days	(max > 20 °C)	87 - 103	96 - 126
Number of summer days	(max > 25 °C)	28 – 36	31 – 50
Number of tropical days	(max > 30 °C)	5 - 9	7 – 15

Source: [Daanen et al., 2010]

Although table 5.3. refers to the average amount of warm, summer and tropical days in the Netherlands, it is expected that the above figures also relate to the city of Rotterdam. Obviously, these higher temperatures could lead to general feelings of discomfort and heat stress. Furthermore, these high temperatures stimulate the formation of urban heat islands, since natural cooling of cities becomes more difficult due to higher temperatures and increased sunshine hours, and thus the chance on heat stress and heat related problems [Knowledge for Climate, 2011] [van Hove et al., 2011]. As mentioned, a summer day in Rotterdam currently causes at average 1.5 heat-related deaths [Daanen et al., 2010]. Based on the most extreme climate scenarios (highest values in table 5.3.) this amount could increase with 50% by 2020 and is expected to double by the end of 2050 [Daanen et al., 2010].

Besides climate change, urbanisation is an important factor determining the UHI intensity of a city. Built surfaces and dense building, whether or not in combination with little or no vegetation, are leading to formation of heat islands within these kind of (urban) areas. In this way, urbanisation will only increase the occurrence of UHI and therefore the occurrence of heat related problems. Currently, around half of the world's human population lives in urban areas, expected is that by 2030 more than 80% of the European inhabitants will live in urban areas [van Hove et al., 2011]. The same is expected for the Netherlands; the majority of the population lives in urban environments and used models and scenarios within spatial planning all point to a large expansion of urban areas [Heusinkveld et al., 2010]. According to the research of van Hove et al., this will undoubtedly further increase the magnitude of the UHI intensity [van Hove et al., 2011].

These forecasted developments show that the UHI intensity in the municipality of Rotterdam is likely to increase if no measures are taken [van Hove et al., 2011] [Knowledge for Climate, 2011]. These developments are, without interfering, thus leading to an increase of thermal discomfort and heat related problems in the municipality of Rotterdam and especially in the vulnerable areas with high dense buildings and little amounts of green [Knowledge for Climate, 2011].

6. HEAT IN ROTTERDAM: ACTIVITIES & DEVELOPMENTS

Above described effects of UHI are well-known by the Municipality of Rotterdam. But how to ensure that this phenomenon will be addressed in policy? In fact, the Municipality indeed considers UHI an issue which deserves attention. Several developments regarding this topic are taking place within the municipality of Rotterdam. Nonetheless, UHI still seems to be primarily a problem of scientists, and the transmission of knowledge into practice is often hard to make. But before going into detail on this aspect of combining knowledge and policy, the previous and current developments within the municipality of Rotterdam regarding UHI will be analysed.

The Municipality of Rotterdam describes herself as one of the forerunners within the field of sustainability and climate change [Rotterdam Climate Initiative, 2009] [Programma Duurzaam, 2012]. Indeed, a lot of activities within the field of climate change and sustainability are going on within the municipality of Rotterdam. With several programmes and activities the Municipality is addressing sustainability and climate change in various ways. Most of them are related to UHI and heat related problems. Within this chapter, these projects will be briefly described, as well as the progress made so far regarding heat related problems. Afterwards, in chapter 8, a start will be made with the analysis of these processes: how is the phenomenon UHI pre-sorted within the municipality of Rotterdam? What are current opportunities and barriers in these processes?

6.1. Timeline: heat in Rotterdam

In the following figure 6.1., the various programmes and activities regarding the UHI situation in Rotterdam are presented in the form of a timeline.

Figure 6.1.: developments and activities regarding UHI in Rotterdam in chronological order

	1830	*first observations of UHI in large cities in the U.S.A.*
	summer 2003	*major heat wave in Europe*
start "Climate changes Spatial Planning"	**2004**	
	summer 2006	*major heat wave in Europe, about 1000 deaths in the Netherlands*
the International Advisory Board places the economic opportunities for clean energy and reduction of CO_2 on the agenda	**November 2006**	
	December 2006	*Former President Bill Clinton visits the Netherlands. His message: the climate changes and the world must take action to counter the emission of greenhouse gases*
start Rotterdam Climate Initiative	**May 2007**	
	2007	*start Office for Climate*
international conference on UHI: "Hot places, cool spaces"	**October 2007**	
	November 2007	*the International Advisory Board advises to profile Rotterdam as a leading water knowledge and climate Municipality*
start "Knowledge for Climate"	**September 2008**	
start Rotterdam Climate Proof	**2008**	
participation of the Municipality of Rotterdam to "Knowledge for Climate"	**2008 / 2009**	
	2009	*start research "Heat stress in Rotterdam"*
	2010	*start Office for Sustainability and Climate change*
	June 2011	*final report "Heat stress in Rotterdam"*
	December 2011	*official end of "Climate changes Spatial Planning"*
end of Office for Sustainability and Climate Change	**2013**	
	December 2014	*end of "Knowledge for Climate"*

6.2. Heat waves brought to the attention

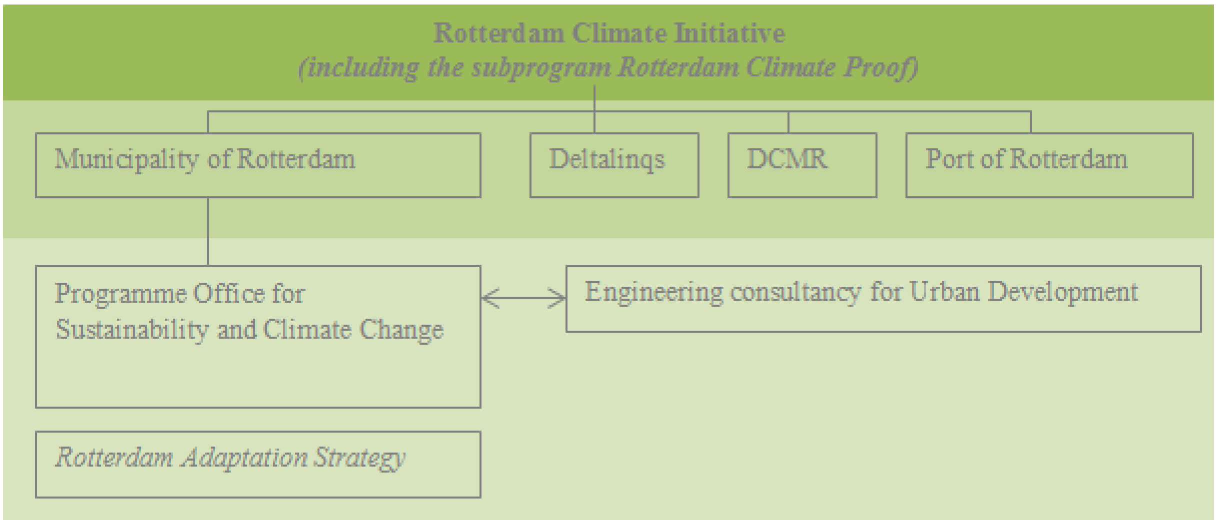
The phenomenon of heat in cities receives very little attention in the Netherlands, especially in comparison with other countries with a similar climate, such as France, Germany and England, where heat is a much more acknowledged problem [Rahola et al., 2009]. It is due to the recent large scale heat waves of 2003 and 2006 that the possible negative effects of heat on human health have come to the attention in the Netherlands. These heat waves, which caused an excess of 1400 to 2200 heat-related deaths in the Netherlands alone [Heusinkveld et al., 2010], received media attention in the Netherlands. Approximately at the same time, the, by the Dutch government financed, Climate changes Spatial Planning (CcSP) ("Klimaat voor Ruimte" in Dutch) research programme started, in 2004, as a reaction on the growing awareness on climate change and the related impacts on the spatial organisation of the Netherlands [Knowledge for Climate, 2012c]. One of these related impacts is heat, therefore on the 25th of October 2007 the CcSP organised an international conference on UHI; "Hot places, cool spaces". Aim of the conference was to "*gain insight in what research and policies on the issue of heat in urban areas are undertaken in some other countries*" [CcSP, 2007]. During this meeting CcSP planned further detailed research on heat related problems in urban areas [CcSP, 2007]. It was already known at that moment that especially urban areas are vulnerable to heat: the so-called urban heat island effect, which was already observed for the first time in 1830 in large cities in the U.S.A. [Yamamoto, 2006]. Part of this planned research was the research conducted by Rahola, van Oppen and Mulder; "Heat in the city", a very first "*inventory of knowledge and knowledge deficiencies regarding heat stress in Dutch cities and options for its mitigation*" [Rahola et al., 2009]. Although on a small scale only and primarily by researchers and experts, these heat waves and the founding of CcSP can be seen as the starting point at which UHI and heat related problems were brought into focus in the Netherlands.

6.3. Rotterdam Climate Initiative

At the same time, several developments took place regarding climate change in the municipality of Rotterdam. In November 2006 the International Advisory Board, an advisory body of the Rotterdam Board of Mayor and Aldermen, placed the economic opportunities of clean energy and CO_2 reduction on the agenda [Rotterdam Climate Initiative, 2009]. A month later, former President Bill Clinton visited Rotterdam to promote his message in the Netherlands: climate is changing and it is time for the world to take action to counter the emission of greenhouse gases [Rotterdam Climate Initiative, 2009]. The Municipality of Rotterdam accepts the challenge and joins forces with the Port of Rotterdam, employers' organisation Deltalinqs, and DCMR Environmental Protection Agency Rijnmond, in the Rotterdam Climate Initiative, launched in May 2007 [Rotterdam Climate Initiative, 2009]. Originally the Rotterdam Climate Initiative was founded with a CO_2 reduction target, 50% CO_2 reduction by 2025 compared of 1990, as a response on the call of Bill Clinton [Rotterdam Climate Initiative, 2009].

The Rotterdam Climate Initiative should be seen as the partnership between the public and private parties the City of Rotterdam, Port of Rotterdam, Deltalinqs and DCMR, and the umbrella name for the entire climate programme within the Municipality of Rotterdam. Within this partnership, each party addresses climate change and sustainability in her own field of responsibility [Rotterdam Climate Initiative, 2009] [Gebraad, 2012]. The following figure, figure 6.2., provides an overview of the Rotterdam Climate Initiative and the parties and departments involved from the Municipality of Rotterdam. Within the Municipality of Rotterdam an office is created which is concerned with the activities from the Municipality of Rotterdam regarding the Rotterdam Climate Initiative; the Office for Sustainability and Climate Change. This office consults the engineering consultancy of the Municipality of Rotterdam, Engineering consultancy for Urban Development, during the various conducted activities for the Rotterdam Climate Initiative in the field of urban development. One of the end products of the Office for Sustainability and Climate Change is the Rotterdam Adaptation Strategy, which should be completed in 2013. In the subsequent (sub)chapters, these sections will be further described.

Figure 6.2.: overview of participating parties and departments within the Rotterdam Climate Initiative



6.3.1. Rotterdam Climate Proof

Rotterdam Climate Initiative originally focused on climate mitigation (CO_2 reduction), but soon after the start of this initiative, it was devised that climate adaptation is of same importance as climate mitigation and that these two aspects are not that easily separated. In October 2007 the International Advisory Board advised the Rotterdam administration to profile Rotterdam as a leading water knowledge and climate city. Besides adaptation to the consequences of climate change is essential to Rotterdam, developing Rotterdam into a water knowledge and climate city will offer economic opportunities [Rotterdam Climate Initiative, 2010]. Or as the Municipality puts it: "*The City has a significant role to play in solving global climate change related issues, which will constitute a new driver of the Rotterdam economy.*" [Rotterdam Climate Initiative, 2010].

On the 5th of February 2008 the advice of the International Advisory Board was adopted entirely into the programme: Rotterdam Climate Proof; a sub programme of Rotterdam Climate Initiative focussing on climate adaptation. The objective of this programme is a fully climate proof Rotterdam by 2025, in combination with strengthening of the economy of Rotterdam [Rotterdam Climate Initiative, 2009] [Rotterdam Climate Initiative, 2010]. Idea is to realise this ambition on the basis of three guiding principles:

- "*Rotterdam will develop into and present itself on a national and international level as a leading centre for water knowledge and climate change expertise.*
- *Investments in climate solutions will enhance the attractiveness of the city and port for residents, companies, and knowledge institutes.*
- *Innovations and knowledge are developed, implemented, and marketed as an export product* [Rotterdam Climate Initiative, 2010]*."*

Besides climate proofing Rotterdam for the sake of climate only, climate change is seen as a chance, as a new driver for the economy: to profile the municipality of Rotterdam, and to export knowledge and innovations [Rotterdam Climate Initiative, 2010] [Nijhuis, 2012]. To illustrate, the brochure "Rotterdam Climate Proof" starts with the sentence "*Making the city even more attractive and economically prosperous.*", somewhat later followed by the paragraph:

"*In order to confront the challenge of climate change as an opportunity rather than a threat, the City of Rotterdam has set up the Rotterdam Climate Proof programme. Rotterdam Climate Proof will make Rotterdam climate change resilient by 2025. Permanent protection and accessibility of the Rotterdam region are key elements. The central focus of the programme is to create extra opportunities to make Rotterdam a more attractive city in which to live, work, relax – and invest.* [Rotterdam Climate Initiative, 2010]."

6.4. Office for Sustainability and Climate Change

The activities of the Municipality of Rotterdam within the Rotterdam Climate Initiative are coordinated and facilitated by the Office for Sustainability and Climate Change (successor of the Office for Climate) [Gebraad, 2012]. Office for Sustainability and Climate Change conducts numerous activities in the various fields of sustainability, for example sustainable mobility, sustainable building, and sustainability in research and education. Originally, the Office for Sustainability and Climate Change would have ended in 2014, however, due to budget cuts this is brought forward to 2013. Results of the Office should therefore be finished a year earlier than planned [Gebraad, 2012]. One of the deliverables is the Rotterdam Adaptation Strategy (RAS) [Municipality of Rotterdam, no date].

6.4.1. Rotterdam Adaptation Strategy

The Rotterdam Adaptation Strategy (RAS) is one of the products of Rotterdam Climate Proof, the sub programme within Rotterdam Climate Initiative. In 2009 a start was made with the development of the RAS, which should be ready by the end of 2013 [Gebraad, 2012]. The RAS should be seen as a strategy to make the municipality of Rotterdam 100% climate proof by 2025. In other words, aim of the RAS is to describe and further specify the possible measures to apply in order to make the municipality climate proof [Municipality of Rotterdam, no date] [Rotterdam Climate Initiative, 2010].

The RAS consists of five main themes: Flood management, Accessibility, Adaptive building, the Urban water system and the Urban climate, each with an own target [Rotterdam Climate Initiative, 2010]. In this target is stated what ‘climate proof’ means regarding the specific theme [Nijhuis, 2012] [Gebraad, 2012]. Theme Urban climate is mainly focusing on UHI and heat related problems, nevertheless, a clear target or even problem is missing for this theme [Nijhuis, 2012] [Gebraad, 2012].

6.4.2. Heat within the Rotterdam Adaptation Strategy

Although the term ‘urban climate’ in principle is a very broad one, the theme Urban climate is actually almost entirely focused on heat. When asking for the cause of this narrow look at urban climate, there seems to be little reasoning behind it. Senior advisor Rotterdam Climate Proof and employee at the Office for Sustainability and Climate Change Gebraad admits that urban climate is more than just heat, but answers the question with the fact that for example wind, although this (and other aspects related to urban climate) may have been a white spot, was not primarily seen as a potential problem within the municipality. Question remains why heat is?

When the programme Rotterdam Climate Proof started, little was known about the possible impact of climate change on the municipality of Rotterdam. According to Gebraad, very general and basic questions were addressed within the municipal council during this phase. The first step was an inventory of the effects of climate change: which aspects are affected by it [Gebraad, 2012]? One of these aspects is heat. None or hardly any knowledge on heat within Rotterdam was available, but from the several research projects carried out within CcSP it was known that urban areas are especially vulnerable to heat, due to UHI, and thus to the various impacts of heat. With Rotterdam being the to-one largest city of the Netherlands [Municipality of Rotterdam, no date], the Municipality of Rotterdam decided to submit several research questions within “Knowledge for Climate” towards heat, leading to a very first exploratory study (consisting of several sub studies) to heat in the Municipality; “Heat stress in Rotterdam” [Knowledge for Climate, 2011] [Gebraad, 2012]. Prior to this study, the Municipality of Rotterdam assumed that Rotterdam would not be prone to UHI, because the River Meuse flows through the city centre of Rotterdam [Nijhuis, 2012] [Rotterdam Climate Proof, no date]. The first question was whether UHI was occurring in the municipality of Rotterdam at all, and if yes, to which extent [Buijs, 2012] [Nijhuis, 2012] [Gebraad, 2012]?

“Heat stress in Rotterdam” clearly showed a heat island effect in the municipality of Rotterdam [Knowledge for Climate, 2011]. Furthermore, the report on “Heat stress in Rotterdam” provides recommendations for possible feasible measures to mitigate or reduce the UHI effect and therefore heat stress in the city [Knowledge for Climate, 2011]. These recommendations are covered in chapter “*6.5.1. Heat within “Knowledge for Climate”*” of this report.

Results from the study “Heat stress in Rotterdam” (as well as results of planned studies towards UHI in Rotterdam) will be included in the RAS, as scientific foundation for the recommended actions and measures in the strategy towards a 100% climate proof Rotterdam [Nijhuis, 2012] [Buijs, 2012] [Gebraad, 2012]. One the one hand, there are the scientific reports from “Knowledge for Climate”, and on the other hand there is the RAS: a less detailed and more integrated story about the expected impacts of climate change on the municipality of Rotterdam and the ways in which the municipality can adapt to this in a beneficial way; an integrated policy framework about climate adaptation measures. “Between” the RAS and the scientific reports, background reports will be developed for each theme within the RAS, wherein a translation between the scientific results and the RAS, the policy document, will be made [Gebraad, 2012].

6.5. Knowledge for Climate

Meanwhile, developments regarding climate change took place on national level. As a reaction on the growing awareness on climate change and the impacts this could have on the spatial organisation of the Netherlands, the programme “Climate changes Spatial Planning” (CcSP) was founded in 2004. Aim of this programme was to equip both the Dutch government and the private sectors with operational knowledge about the relationship between climate change, climate variability and land use. The underlying social purpose of the programme was the promotion of ‘climate proof’ land use. In September 2008 the programme “Knowledge for Climate” started, which can be seen as the successor of “CcSP” [van Hove, 2012] [Knowledge for Climate, 2012c]. Initiators Wageningen University and Research centre, University Utrecht, Deltares (Dutch knowledge institute for water and subsoil), KNMI, TNO (Dutch organisation for applied scientific research) and the VU University Amsterdam founded “Knowledge for Climate” with the aim to provide public accessible and from the society operated scientific knowledge about climate and related subjects such as space, infrastructure and sustainability [Knowledge for Climate, 2012a].

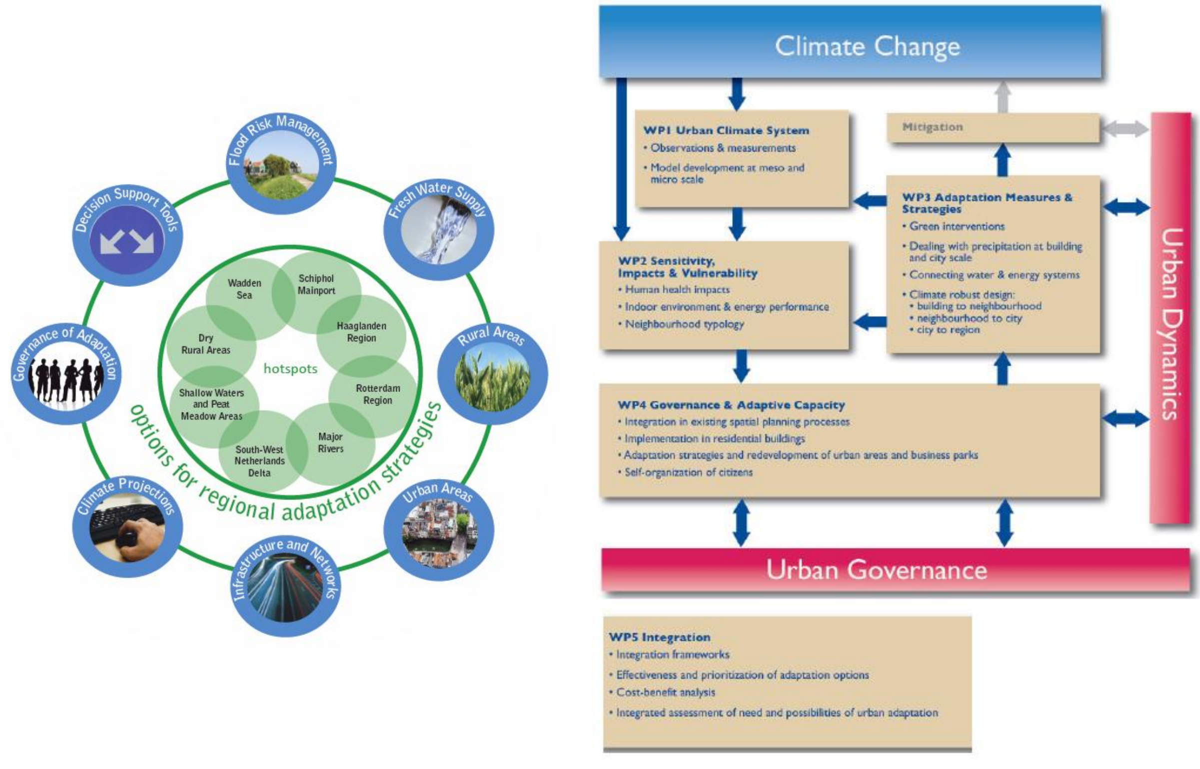
The establishment of “Knowledge for Climate” reasonably coincided with the start of Rotterdam Climate Proof. The goals of the both projects are quite comparable as well: providing knowledge on climate change and related subjects. Therefore, the Municipality of Rotterdam decided to participate in “Knowledge for Climate”. The Municipality of Rotterdam considered the participation a chance to combine her own ambition as well as available time and budget with those of “Knowledge for Climate” [Nijhuis, 2012].

“Knowledge for Climate” is a large and for an outsider complex programme. The research programme is partly (50%) financed by the Dutch government, which has 50 million budget planned for the entire programme. This money is derived from the natural gas revenues, which are used for large infrastructure projects, but also for large knowledge projects to stimulate the economy in the long term development.

“Knowledge for Climate” is one of those projects. One fourth is financed by the participating institutions and the last quarter is financed by the various stakeholders involved in the research programme (through the so-called *hotspots*) [van Hove, 2012] [Bosch, 2012]. The research programme lasts from 1 September 2008 until 31 December 2014 and is divided into three phases: from 2008 to 2010, 2010 to 2012 and from 2012 until 2014. The first tranche was that of an exploration round about the occurrence of phenomena related to climate change, based on the wishes of the stakeholders (*hotspots*). In the second tranche possible measures to address the in the first tranche analysed phenomena will be investigated. Original aim of the third tranche is a translation of the results from the second tranche into a climate adaptation strategy [Bosch, 2012].

The research programme consists of several themes and *hotspots* (formulated as “*real-life laboratories where knowledge is put in practice. Whereby teams of government, business and science are working together.*”), of which Region Rotterdam is one [Knowledge for Climate, 2012b]). One of the themes is “Climate Proof Cities”, aiming at “*strengthening the adaptive capacity and reducing the vulnerability of the urban system against climate change and to develop strategies and policy instruments for adapting our cities and buildings*” [Knowledge for Climate, 2012b]. Within this theme, research on the urban heat island effect and heat related problems is conducted [Knowledge for Climate, 2012b]. The research programme works with so-called work packages, which are involved in each *hotspot* [Knowledge for Climate, no date]. An overview of the structure of “Knowledge for Climate” is given in figure 6.3..

Figure 6.3.: structure of “Knowledge for Climate and the work packages within “Climate Proof Cities”



Source: [Knowledge for Climate, 2012b], [Bosch, 2011]

6.5.1. Heat within “Knowledge for Climate”

Aim of the “Knowledge for Climate” research programme is to provide public accessible and from the society operated scientific knowledge about climate and related subjects such as space, infrastructure and sustainability [Knowledge for Climate, 2012 a]. One of the to climate change related aspects is heat. This subject is being addressed within the theme “Climate Proof Cities”. As direct reasons for the inclusion of heat, Bosch, secretary of the “Climate Proof Cities” consortium, mentions the on-going climate change and the KNMI scenarios which all point to increasing temperatures, resulting in the question: what should (and can) we do with these predictions [Bosch, 2012]?

The list of possible measures to address UHI and heat stress in urban areas is almost endless, but can be summarised with the following scheme in table 6.1.:

Table 6.1.: adaptation measures for heat stress

	Dwelling / Building	**Street / District**	**City**
Proactive measures	insulation cooling sunshades thermal chimneys orientation of buildings green roofs (vegetation on roofs) green walls (vegetation on walls) reflective roof material medical insurance increase in albedo by material choice	water bodies vegetation reflective pavement optimal shading optimal wind flow by orientation and profile of streets relocation of vulnerable people monitoring and inspection warning systems and emergency plans	research on the occurrence of heat stress anticipate on potential increases in premature mortality and hospitalisations
Reactive measures	cooling (air conditioning)	watering of streets and roofs	information campaigns moving to cooler areas health care

Source: [Runhaar et al., 2011]

Above measures are measures to apply in general. The provided measures within the study “Heat stress in Rotterdam” are specifically formulated for Rotterdam [van Harmelen et al., 2011]. The entire list of these measures is not included in the present study; only the so-called ‘*no regret*’ measures will be mentioned. From the long-list of possible measures to address UHI, a short-list is derived trough the usage of certain criteria which lead to so-called ‘*no regret’* measures. The study emphasises that these criteria for ‘*no regret*’ measures should be established by the Municipality, based on preferences and targets of the Municipality of Rotterdam, and that different criteria will lead to different ‘*no regret*’ measures.

Within the study criteria are developed from the perspective of urban heat. Measures with a cooling effect during summer and no or little cooling effect in winter, and no or hardly any negative side-effects (on liveability, energy use and climate change, etcetera), are seen as '*no regret*' measures and are therefore recommended to apply in the municipality of Rotterdam [van Harmelen et al., 2011]. These measures are:

- *Indoor measures against heat stress*: because of uncertainties regarding the relationship between (measures against) UHI and the experienced heat stress, it is recommended from the viewpoint of efficacy to start with measures indoors which are directly directed against heat stress. First step is for example the usage of communicative measures: information brochures on UHI and heat related problems, and the stimulation of behavioural measures such as the usage of local refrigerants, search for cool places and modifying of clothing [van Harmelen et al., 2011].

- *Measures at building level*: heat stress can be addressed through measures at building level such as insulation, blinds (permanent at the south facade, automatic at the east and west facades), passive cooling and energy savings on appliances and lights. Viewed purely from the heat problem, active cooling is also a good solution. This is in contradiction with the Rotterdam Climate Initiative target of 50% CO_2 reduction by 2025, although applying active cooling on each household within the municipality will lead to an increase in CO_2 emission of only 1% of the total CO_2 emission of the municipality [van Harmelen et al., 2011].

- *Measures at street level*: measures which lower the city temperature during the summer but not in the winter (or even warm the temperature in the winter) and can be relatively easily undone (within five years) are the realisation of fountains and small scale green, temporary street shading and spraying of roofs, facades and streets [van Harmelen et al., 2011].

The by the Rotterdam Region submitted research questions regarding UHI resulted in the explorative study: "Heat stress in Rotterdam" [Knowledge for Climate, 2011] [Nijhuis, 2012][Gebraad, 2012]. As it seems, the study "Heat stress in Rotterdam" not only provided the Municipality of Rotterdam with an insight in the causes, current and expected future effects of UHI, but also with possible measures to apply in order to reduce these effects. Problem solved: measures are available, it just a matter of execution. This might seem logical, practice however is more complex.

7. HEAT IN ROTTERDAM: FUTURE PLANS

With regards to UHI and heat related problems, several activities and developments are carried out and going on in the municipality of Rotterdam. A first exploratory research, "Heat stress in Rotterdam", indicated a UHI intensity of 2.8 degrees in the municipality, and also provided some recommendations for possible measures to apply in order to reduce this intensity and thus the heat related problems. Quite some information to address the UHI situation in Rotterdam seems to be available. In practice however, the issue of UHI is more complex to address and no clear policy goal or strategy is set yet. How to proceed? What are the further plans of the Municipality of Rotterdam regarding this subject?

7.1. Reactions on "Heat stress in Rotterdam"

The several sub studies within the exploratory research "Heat stress in Rotterdam" were initially carried out to answer the basic question from the Municipality of Rotterdam: does UHI occur in Rotterdam? [Knowledge for Climate, 2011] [Gebraad, 2012]. Results of this study clearly showed a heat island effect in Rotterdam, and also indicated several possible measures to apply in the municipality to reduce the negative effects of heat. Knowing this, the second question arises: whether or not to take action? Answering this question became even more complex due to the achieved attention in the media. Several articles were published in national newspapers calling the research a waste of time and money [Steeneveld, 2012] [Buijs, 2012] [Gebraad, 2012]. One example (in Dutch) of these manifestations of criticism is included in the following figure 7.1. (more of these published articles are included in Appendix 2.: "*Heat in the Dutch media").*

Figure 7.1.: "Criticism on research towards 'heat stress' in city", article on "Heat stress in Rotterdam" in Dutch national newspaper: Algemeen Dagblad, 10 August 2011

STAD & REGIO | AD 3

'Tonnen naar kulstudie'

Kritiek op onderzoek naar 'hittestress' in stad

ROTTERDAM • Onnodige paniekzaaierij met lachwekkende conclusies, waar onderzoekers goed aan verdienen. Zo omschrijven critici het onlangs verschenen rapport 'Hittestress in Rotterdam', dat in totaal zes ton kost.

ANTTI LIUKKU

Al geruime tijd doen wetenschappers in Rotterdam onderzoek naar 'stedelijke hitte-eilanden'; het fenomeen dat het in de stad een paar graden warmer is dan daarbuiten. Meest in het oogspringend waren de klimaatbakfietsen vol meetapparatuur, waarmee Wageningse onderzoekers in de zomer van 2009 door de stad fietsten.

Zes ton kost de studie die onderdeel is van het Rotterdamse klimaatprogramma, meldt de gemeente. De helft wordt betaald door het rijk. De andere helft komt voor rekening van de gemeente, de GGD Rijnmond en enkele waterschappen. Het zestig pagina's tellende rapport *Hittestress in Rotterdam* is vorige maand uitgekomen.

De belangrijkste conclusie is dat in Rotterdam het temperatuurverschil met een plek buiten de stad kan oplopen tot acht graden. Vooral in de avond van een hete, windstille dag en in industriële gebieden, zoals de Heijplaat en Pernis.

Een van de aanbevelingen is om in de stad meer water en groen aan te leggen, omdat het zorgt voor schaduw en een prettig briesje. Verder wordt mensen geadviseerd om luchtige kleding te dragen en 's avonds het raam open te doen. Want 'hittekrampen, hitte-uitputting en hitteberoertes' zijn een reëel gevaar, zeker als de opwarming van de aarde zich voortzet.

„Lachwekkend, dit soort aanbevelingen..." schampert de Rotterdamse wetenschapsjournalist Simon Rozendaal. „Uit onderzoek is allang duidelijk dat de stad minder snel afkoelt. Het is ook logisch: steen en beton nemen overdag hitte op, en geven de warmte 's nachts af. Maar dan gaan mensen niet dood van de hitte, hoor." Volgens Rozendaal worden tonnen uitgegeven aan een kulrapport. „Kijk, onderzoekers hebben ook een hypotheek en last van lekkende dakgoten. Als je iets schrijft over klimaatsverandering is de kans op subsidie een stuk groter."

De epidemioloog Luc Bonneux draait het zelfs om: „Opwarming is juist goed voor de gezondheid. Tijdens een koudegolf sterven er drie tot vier keer zoveel mensen. Maar dat is iets wat altijd onder tafel wordt geschoven," aldus Bonneux. „Rotterdam te warm? Hou toch op met deze paniekzaaierij."

De studie is nog niet klaar. Onlangs is aan de Berkelselaan een 'temperatuurkabel' van drie kilometer aangelegd, om te meten wat daar de warmste en koudste plekken zijn.

De gemeente hecht waarde aan de resultaten. „Het helpt ons om het verblijfsklimaat in de stad te verbeteren," licht een voorlichter toe.

De 'klimaatbakfiets' reed in 2009 door de stad.

Source: [Liukku, 2011a]

In this article the investigation on heat stress in Rotterdam is undermined: the phenomenon that temperatures in urban areas are in general higher than in rural areas is an already long time known, and obvious, fact. According to this article, the phenomenon should not be seen as a problem since mortality rates are three to four times as large during low temperatures in winter. To top it off, the article starts with the massive quote: “Tons towards nonsense study”, referring to the total costs of six tons of the project [Liukku, 2011a]. The research not only received criticism in the form of articles in the media; written questions about the study were submitted to the Municipal council, among others from the political party Leefbaar Rotterdam (literally translated: Liveable Rotterdam) [Buijs, 2012] [Gebraad, 2012]. Derived from the several interviews with employees within the Municipality of Rotterdam and Engineering consultancy for Urban Development, these expressions of criticism has led to a greater awareness of the lack of consensus about the urgency of the issue among employees within these organisations; heat in the city can not be considered an unilateral problem, and should moreover been seen in perspective to other issues and problems in the city [Buijs, 2012].

7.2. Plans of the Municipality of Rotterdam

Despite the study “Heat stress in Rotterdam”, no clear answer is formulated on the question whether or not heat should be considered a problem; it seems that the Municipality of Rotterdam hesitates to answer this question, due to its complexity and the different perspectives involved. Nevertheless, several follow-up studies are carried out and planned, including an investigation on the specific effects of individual measures and combinations of them, and the costs and benefits of these measures. Furthermore, a case area is indicated, the district Bergpolder Zuid in Rotterdam North, in which targeted research is conducted on precipitation and heat [Buijs, 2012] [Gebraad, 2012]. According to the several interviewed employees from the Municipality of Rotterdam and Engineering consultancy for Urban Development, this kind of knowledge is necessary in order to conclude if UHI should be seen as a problem demanding for a direct approach [Nijhuis, 2012] [Buijs, 2012] [Gebraad, 2012]. The Municipality would like to see some kind of quantification of the vulnerability to heat, such that areas and districts can be indicated in which heat is perceived as a problem and the implementation of actions (physical or communicative) is most desirable [Buijs, 2012]. However, the Municipality of Rotterdam has not submitted any heat related questions for the third and final tranche of the “Knowledge for Climate” research programme [Gebraad, 2012]. Although the interviewed senior advisor at Rotterdam Climate Proof, did not know the precise reasons behind this decision, he assumes this is due to the on-going doubt whether heat should be seen as a problem [Gebraad, 2012].

Although quite some information is available about the UHI situation in Rotterdam, still a lot of knowledge and especially consensus is missing. The Municipality of Rotterdam is still doubting about whether or not the issue should be approached as a problem necessary to address. Meanwhile, several research projects are being conducted regarding heat in the city. Logically, further developments regarding the UHI situation in Rotterdam are depending on the still to come results of these projects, however, the contours of the probable policy on heat are becoming visible.

Results of the research projects will be included in the RAS. In the RAS it is tried to describe and develop concrete (preferably quantitative and measurable) ambitions and goals for each theme, and preferred measures to get there. Instead of a new, binding policy document, the RAS should be seen as a policy framework integrating the different aspects of climate adaptation and providing guidelines: in certain areas certain measures are recommended in view of climate adaptation [Gebraad, 2012]. Nonetheless, the Municipality of Rotterdam is still struggling with the policies to implement regarding heat [Buijs, 2012]. This is due to several reasons: the received criticism in the media and uncertainty about the scale of the 'problem': how many people experience inconvenience due to heat, how will this develop in the future and what should be seen as acceptable (how many people should experience heat-related problems to consider heat in the city as a problem) [Buijs, 2012]? With these questions still unanswered, it is hard to even formulate the problem, not to mention to develop concrete goals, actions plans or measures for it.

Therefore, to use the words of senior advisor Gebraad at the Office for Sustainability and Climate, the ambitions and goals for the theme Urban climate will most likely be less "SMART"[1] than these of the other themes [Gebraad, 2012]. With regard to the theme Urban climate it will probably come done to a description of the current and future developments and an identification of vulnerable areas (densely built urban areas), where possible a preferred set of actions can be indicated.

The issue heat receives attention from the Municipality of Rotterdam (due to the 100% climate proof objective) as such that attempts are made to implement '*no regret*' measures through coupling with other policy fields. Heat is, on project basis, used as an additional argument for the implementation of certain measures. For example, the Municipality of Rotterdam is currently investing in the realisation of high quality and attractive living environments, in order to attract and retain more higher educated inhabitants. Such an attractive living environment also includes a certain thermal comfort and in general a relatively green environment. In this way heat can be included in these city-wide goals, in the sense of achieving and maintaining a pleasant city climate; thermal comfort [Nijhuis, 2012] [Buijs, 2012]. In fact, the mitigation of heat is being used as an additional argument within the 'green roofs programme' of the Municipality, whereby the Municipality subsidises the construction of green roofs: constructing roofs as such that vegetation can be planted and cultivated on top of it (mainly for the purpose of water retention and attractiveness) [Gebraad, 2012] [Rotterdam Climate Initiative, 2012]. In addition, the Municipality of Rotterdam uses information and communication measures to reduce the negative effects of heat (for example through information leaflets about heat via the GGD, but also through intern workshops) and takes heat into account in agreements with private parties [Buijs, 2012]. But mandating of certain measures within the physical environment, purely from the perspective of heat, seems to be, at least for the time being, a bridge to far.

[1] "SMART" is a popular term used to concretise and quantify objectives. The letters of SMART stand for Specific, Measureable, Acceptable, Realistic and Time-bound. When there is spoken of a "SMART objective" this means the objective is specific, measurable, acceptable, realistic and has a certain time limit [Roozenburg and Eelkes, 1998].

7.3. Plans of the "Knowledge for Climate" research programme

On the "Knowledge for Climate" website it is explicitly mentioned that the aim of the research programme is to provide from society operated and for the society useful knowledge about climate (change) in order to climate proof the Netherlands [Knowledge for Climate, 2012a]. A proper translation of scientific results into policy, into practice, forms thus an important part of the research programme [Bosch, 2012]. This is reflected in the structure of the programme (the usage of *hotspots*) and the various meetings between the researchers and actors from the *hotspots* [Bosch, 2012]. With regards to the *hotspot* Rotterdam Region, the researchers and the board of "Knowledge for Climate" hope that results of studies will be included in the RAS, despite the conflicting deadlines (the RAS should be completed by the end of 2013, whereas the research programme continues until the end of 2014) [Bosch, 2012] [Buijs, 2012]. Since the researchers from the "Climate Proof Cities" consortium seem to be convinced about the need to mitigate the negative effects of UHI, they further hope that the results of the studies within the second tranche of the programme (the studies on the precise impacts, costs and benefits of individual measures as well as combinations of them) will used as such that measures will be actually implemented in practice. Originally, the third tranche of the research programme was entirely focused on this translation between results and practice [Bosch, 2012]. But given the signals (and type of research questions) which are now being received from the *hotspots*, the third tranche is slightly adapted and room will be given for further research and follow-up studies. This doubt is not only caused by the given economic circumstances, but also by the very fact that actors were involved in the research as such that a third and final tranche entirely focused on translating the results into policy might seem less necessary [Bosch, 2012].

The probability that the Municipality will start introducing physical measures in urban areas is, as described in the previous chapter "*7.2. Plans of the Municipality of Rotterdam*", as yet, small. Even though the Municipality of Rotterdam recognises the fact that high temperatures can lead to negative effects on human health. Thus the Municipality of Rotterdam is willing to implement '*no regret*' measures to improve the city climate when they are beneficial for other policy goals as well, and uses improving of the city climate and thus the prevention of heat related problems as an additional argument for the implementation of other measures within other policy fields.

Although the Municipality of Rotterdam intends to address UHI (being it in the form of achieving and maintaining a pleasant city climate), it remains yet to primarily communicative measures and a 'soft' approach to bring the issue heat under the attention and to stimulate the implementation of '*no regret*' measures (this could be measures to improve the urban climate which are also beneficial for other policy fields, but seem to be mostly measures initially planned for other purposes but also beneficial for the urban climate) on project basis. The question is, would it have been possible to take the doubt away for the Municipality of Rotterdam and could in that way a more concrete approach be achieved? If yes, why has this not occurred yet, and more importantly, how can this still be ensured?

8. INTEGRATION OF UHI MITIGATION IN URBAN POLICY

Despite the conducted studies, programmes and activities, no clear strategy or policy on heat is developed yet. The Municipality of Rotterdam still struggles to formulate concrete goals and ambitions (or even an precise problem description). Nevertheless, as a start is made with the formulation of the RAS the contours of the probable policy on heat are becoming visible, even though it remains a relatively abstract strategy. Mandating of measures within the physical environment purely from the perspective of heat seems to be a bridge to far due to doubts and uncertainties. What is causing this doubt? Why is UHI so complex to address for the Municipality of Rotterdam? Would it have been possible to remove this doubt (and complexity) and could this have resulted in a more concrete approach? In this chapter the previous described processes regarding UHI will be analysed: which barriers have blocked the concrete integration of UHI mitigation measures in urban policy?

8.1. Discussion: analysis of the processes

Although a more abstract approach instead of a more concrete approach does not necessarily should be seen as less effective or an inferior outcome, it seems that the probably selected strategy – a relatively abstract and 'soft' strategy, is affected by doubts and uncertainties. A better translation between knowledge and practice could have possibly abate these uncertainties and doubts, and could therefore have resulted in a more concrete policy on UHI. But how could this (if possible) be achieved?

8.1.1. Policy windows

In the theoretical framework of this report one famous and often used theory on agenda and policy change is described: the theory of *policy windows* from Kingdon [Kingdon, 1984] (see chapter "*3.2.3. The occurrence of policy windows*"). During the occurrence of such *policy windows* (*windows of opportunities* [Hoppe, 2008]) opportunities occur for participants to push their policy proposals or pet solutions [Kingdon, 1984]. Basically, a *policy window* opens due to a change in the political stream or due to a new problem which captures the attention of governmental officials. Once a window is open, it is hard to predict how long the situation will last [Kingdon, 1984]. This stresses the need for policy advisers to prepare their proposals in order to be able to take advantage of a *policy window*. It are these policy advisers – advisers working at the interface between science and policy, or so-called *policy entrepreneurs* who are able to couple the streams: the policy stream to the problem or political stream [Kingdon, 1984] [Hoppe, 2008].

Different types of policy issues demand for different types of *policy entrepreneurs* [Hoppe, 2008]. *Wicked problems*, to which UHI belongs (see chapters "*3.2.2. Wicked problems*" and "*8.1.4. Consensus and urgency*"), ask for *rational fold-and-arrangers* and *policy strategists*: able to provide the decision making process with arguments from science and professional practice, and critically questioning the key assumptions behind current policy [Hoppe, 2008].

Within the Municipality of Rotterdam especially the *rational fold-and-arranger* entrepreneurs seem to be present: prominent members of an advisory board or departmental office, willing to invest their resources to promote a certain issue. Through various activities employees (*policy entrepreneurs*) from the Engineering consultancy for Urban Development and the Office for Sustainability and Climate try to create attention, urgency and consensus on the subject heat. But even among these entrepreneurs the enthusiasm and determination about UHI seems to decline due to received (negative) attention in the media and current external circumstances, which hamper the occurrence of an open *policy window*. These side factors which impede an opportunity to couple the streams, will be described in the following subchapters.

8.1.2. Perspectives on UHI

The Rotterdam Climate Proof programme was not only launched for the sake of climate, but especially by the economic opportunities of climate adaptation, on which the Municipality of Rotterdam was noticed by the International Advisory Board [Rotterdam Climate Initiative, 2009]. Thus, marketing of innovations and knowledge, and the creation of an attractive environment for inhabitants, tourists and companies, are important outcomes for the Municipality of Rotterdam [Rotterdam Climate Initiative, 2010].

During the same time the "Knowledge for Climate" research programme started, with a comparable goal: providing the society with usable knowledge on climate change and related subjects [Knowledge for Climate, 2012a]. To combine ambitions, time and budget with those of "Knowledge for Climate" the Municipality of Rotterdam decided to participate in this project as a *hotspot* [Nijhuis, 2012] [Buijs, 2012]. The Engineering consultancy for Urban Development submitted several basic questions towards UHI within "Knowledge for Climate", leading to the very first exploratory study: "Heat stress in Rotterdam" [Knowledge for Climate, 2011] [Nijhuis, 2012] [Gebraad, 2012].

Aim of this research was to investigate whether or not UHI occurs in the municipality of Rotterdam. Results of the study can be summarised as follows: the municipality of Rotterdam has an average UHI intensity of 2.8 degrees, with maximum differences in temperature of more than seven degrees, which can lead to heat stress, feelings of discomfort or even death. Considering climate change, it is expected that this intensity will increase in the future [Knowledge for Climate, 2011]. In addition, possible measures against heat stress and related problems were provided, see chapter "*6.5.1. Heat within "Knowledge for Climate*" from this report. The report explicitly emphasises the urgency to improve the thermal comfort in the city [Knowledge for Climate, 2011].

But despite this report the Municipality of Rotterdam could not answer the question whether or not UHI should be seen as a problem [Nijhuis, 2012] [Buijs, 2012]. This seems to have several reasons. Prior to the study the Municipality of Rotterdam expected that Rotterdam would not be prone to UHI since the River Meuse flows through the city centre [Rotterdam Climate Proof, no date], when it turned out that UHI is actually occurring in the municipality this might have been slightly overwhelming and disappointing for the Municipality of Rotterdam. But the chosen approach path seems to be particularly responsible.

Within the "Knowledge for Climate" programme heat and heat related problems are approached from the perspective of UHI [Knowledge for Climate, 2011]. The UHI intensity only refers to the difference in temperature between an urban area and the surroundings [van Hove et al., 2011] [Steeneveld, 2012]. The UHI intensity silent as to the height of the temperature in the city, let alone to the possible effects such a temperature might have. The decision whether or not heat should be seen as a problem based on the UHI intensity might therefore be hard to make.

Besides the fact that the UHI intensity does not refer to the actual temperature and related consequences in a city, this perspective might be even more problematic because of the fact that the research showed a maximum UHI intensity during night: between sunset and sunrise. A period in which few people can be found in the public space. By presenting and framing the issue heat in this way, the line of thought that there seems to be hardly a problem because most people are sleeping during these hours, is easily made. According to the same interviewee approaching the issue heat from the perspective of thermal comfort might have been a better flight path [Nijhuis, 2012]. When looking at heat from the perspective of thermal comfort, it is not of importance whether or not it is cooler or warmer in the surrounding areas, instead it is about the relation between the actual temperature and the experienced temperature: the *physiologically equivalent temperature* or PET. High PET values can lead to heat stress and thus to heat related health problems (see chapter "*5.1. Current effects of the UHI intensity in Rotterdam*") [Matzarakis et al., 1999] [Heusinkveld et al., 2011]. Accordingly, the added value of an attractive urban climate, a pleasant temperature in the city and thus a welcoming environment to linger, is probably more easily recognised by politicians, as well as inhabitants. Instead of emphasising the fact that cities are warmer than rural areas (UHI perspective), on could better emphasise the fact that temperatures in cities are as such that negative impacts may be experienced. Based on interviews, meetings and documents published by Rotterdam Climate Proof, it seems that the Municipality of Rotterdam tends to frame heat from the perspective of thermal comfort.

Approaching heat from the perspective of thermal comfort better connects with the ambitions of the Municipality of Rotterdam to use climate change as an opportunity to strengthen the economy and the living environment in the municipality [Rotterdam Climate Initiative, 2009] [Rotterdam Climate Initiative, 2010]. Improvement of thermal comfort in the living environment can be relatively easy related to the realisation of a more attractive, high quality living environment (one of the ambitions of the Municipality of Rotterdam) [Buijs, 2012]. This is also mentioned during a discussion with policy makers on the results of "Heat stress in Rotterdam". Main advice of the policy makers was to focus on the opportunities of UHI: focus as a city on increasing the welfare of those who live, work and recreate in the municipality. Use a pleasant thermal comfort to "brand" the city [Engineering consultancy for Urban Development, 2010]. Approaching heat from the perspective of thermal comfort might have been a better flight path in order to in the first place decide whether or not heat should be considered a problem for the Municipality of Rotterdam, and if yes, to address the issue.

8.1.3. Responsibilities of science and policy

It seems that the Municipality of Rotterdam hesitates to draw conclusions based on the various studies conducted so far. In fact, it even seems that the Municipality of Rotterdam hoped (or expected) for more guidance from the researchers of "Knowledge for Climate" within the decision making process. The researchers however, are reluctant to make such normative choices or recommendations. These attitudes hark back to the earlier described relationship between policy and science.

Although one of the aims of the "Knowledge for Climate" research programme is to provide from society operated and for society useable knowledge, and the communication and cooperation between scientists and politicians therefore forms an important part of the programme [Knowledge for Climate, 2012a] [Bosch, 2012], it seems that a common pitfall within the *technocracy* approach has occurred. Within this approach the tasks of the policy makers and the scientists are separated as such that policy makers provide scientists with a research question, which the scientists will answer through investigations. It is the task of the policy makers to value the knowledge and to draw decisions from it [de Vries, 1995]. In theory, this approach seems logical and workable, the reality is more complex. Since policy makers often struggle to develop proper research questions (which can be answered by researchers, but withal cover the actual issue), policy makers tend to ask, subjective, recommendations from scientists. But scientifically it can never be proved which decisions policy makers should make; science can describe the what-is situation, but not the what-ought-to-be situation [de Vries, 1995] [Derksen, 2011].

As emphasised in the theory on combining knowledge and practice, a clear and proper distinction between the tasks and responsibilities of scientists and politicians is often hard to make [Hoppe, 2008] [Derksen, 2011]. Derksen and Hoppe both emphasise the fact that added value can be achieved when scientists and politicians work together on an equal base [Hoppe, 2008] [Derksen, 2011]. The challenge is to find a proper balance between cooperation and independency, this requires on-going interaction by *boundary work* – simultaneously defining and coordinating science and policy [Hoppe, 2008] [Derksen, 2011].

The communication between the researchers and the actors from the Rotterdam Region could have been better during the execution of the actual research. Communication during the execution of the research might have decreased the chance on mismatches between provided and wanted knowledge, and thus might have provided the policy makers with more sufficient knowledge to draw conclusions from; to decide whether or not heat forms a problem for the municipality.

Although scientifically never can be proved what should be done, normative decisions have to be made in order to actually change a situation. As planning is about intervening and taking action to realise better place-based outcomes than the outcomes which would be achieved otherwise [Royal Town Planning Institute, 2003], planning is about narrowing the gap between what-is and what-ought-to-be [Campbell, 2012]. Analysis may produce knowledge, but to become meaningful it needs synthesis; relations have to be made and conclusion have to be drawn.

In practice any attempt to apply this more synthetic approach (drawing relations and conclusions) in spatial planning, or science in general, can count on critique [Campbell, 2012]. It seems that this has led to a fear to act among planners and scientists, and in the case of Rotterdam even among politicians. Due to this fear, knowledge generation becomes a goal on its own, leading to more produced knowledge and less intents to contribute to the creation of an improved environment [Campbell, 2012]; exactly the opposite of the ambitions of the "Knowledge for Climate" research programme to provide the society with useable knowledge [Knowledge for Climate, 2012a]. Indeed, synthesis brings greater dangers and risks since the chance on taking the wrong actions increases (relative to taking no actions), but synthesis is necessary to translate knowledge (what-is) into actions to improve the environment (what-ought-to-be) [Campbell, 2012]. This, a proper translation of knowledge into action, stresses the need for cooperation and communication between researchers and policy makers [Hoppe, 2008] [Derksen, 2011] [Campbell, 2012]. Instead of ending the cooperation between researchers and policy makers at the completion of analysis, the synthetic approach would suggest that the cooperation goes further into an on-going process of translation: of consideration of the implications of the analysis and of making informed judgements about what-ought-to-be [Campbell, 2012]. In that sense, the researchers could have given more advice and guidance. On the same hand, it is unnecessary that the policy makers from the Municipality of Rotterdam hesitates to draw conclusions: any attempt to improve the environment involves the making of normative decisions.

8.1.4. Consensus and urgency

A lack urgency among society and a lack of consensus about the negative effects of heat seem to be the main causes for the reluctance to draw conclusions [Nijhuis, 2012] [Buijs, 2012] [Gebraad, 2012]. Most public policy issues are so-called *wicked problems* – problems with a lack of consensus on the disputed norms and values and the ought-to-be-situation, and high uncertainty about available and valid knowledge [Rittel and Webber, 1973] [Hoppe, 2008]. Based on the by Rittel and Webber described characteristics of a *wicked problem* [Rittel and Webber, 1973], the phenomenon of UHI can be considered a *wicked problem*. Hoppe already mentioned climate change as an example of a *wicked problem* [Hoppe, 2008], and UHI is closely related to this topic. Although knowledge about UHI is available, the Municipality of Rotterdam is uncertain how to use this knowledge in practice, among others, due the lack of consensus on this topic. This lack of consensus and uncertainty about the available and valid knowledge makes addressing *wicked problems*, and in this case UHI, very complex.

The possible negative impacts of heat are unknown by most people, not to mention the phenomenon UHI [Nijhuis, 2012] [Buijs, 2012] [Gebraad, 2012]. As these impacts are hard to measure, no consensus is reached on the severity of them [Nijhuis, 2012] [Uittenbroek, 2012]. These different perspectives on heat and related effects are emphasised by the various articles published in the media (see chapter "*7.1. Reactions on "Heat stress in Rotterdam*", and appendix "*2. Heat in the Dutch media*") [Steeneveld, 2012] [Buijs, 2012]. According to some, the conducted studies on UHI in the municipality of Rotterdam are a waste of time and money, since the Municipality is facing other more important issues to tackle [Liukku, 2011] [Steeneveld, 2012] [Buijs, 2012] [Gebraad, 2012].

Instead of focusing on similarities and relations between different issues, the Municipality prioritises UHI in perspective of other issues in the municipality. Employees within the Engineering consultancy for Urban Development and the Office for Sustainability and Climate Change mentioned that this prioritising might suppress heat from the political agenda. This state of affairs corresponds with the in theory described phenomenon competing of problems. The number of subjects to which politics can pay attention is not infinite (due to reasons as human capacity, amount of time, and budget etcetera), leading to competition between issues in order to be placed on the agenda. This competing of problems further decreases the chance on concrete policy on heat [Kingdon, 1984] [Gupta et al., 2010], especially since heat is a *wicked problem* competing with other issues on which consensus and a sense of urgency might been achieved.

For climate change in general and UHI in specific applies that a sense of urgency among governments and individuals is lacking. Partly this is stimulated by the current political context and economic circumstances, but this is also due to the in general relatively short-term perspective of aldermen, who are working with terms of four years. This short-term scope of policymakers is hampering the implementation of climate adaptation measures, since climate adaptation demands for a more long-term approach [Gupta et al., 2010]. In order to enlarge the chance on actual usage of research results, it is furthermore important that both scientists and policy makers are convinced of the relevance of the research [Derksen, 2011].

It is difficult to enlarge the sense of urgency among parties. Often a *policy window* opens due to an extreme event, for example a disaster, which increases the sense of urgency and consensus [Kingdon, 1984]. When this opportunity is used, such an event can lead to agenda and policy change [Kingdon, 1984] [Kokx, 2012]. With regard to UHI such a situation occurred by 2006. As a reaction on the large scale heat waves in 2003 and 2006, which received media attention in the Netherlands, the research programme "Climate changes Spatial Planning" organised an international conference on UHI and started to conduct several studies on this phenomenon [CcSP, 2007]. Though, as happens so often with these kind of extreme events, the peak of attention is temporarily [Kingdon, 1984] [Kokx, 2012], and the sense of urgency seems to be already waning. Due to this lack of urgency and consensus it is unclear which actions should be linked to the available knowledge; it is unclear in which direction solutions should be searched and which actual problem these solutions must solve, and finally to which (what-ought-to-be) situation these solutions should transform the current situation. It is, among others, due to this lack of urgency and consensus that, although the knowledge, technology and even possible solutions might be available, the Municipality of Rotterdam is still doubting about whether or not considering UHI as a problem to formulate policy on.

But how is it that in countries such as Germany and France, heat is found to be an important topic as such that active policy is formulated? One example of combining climatological knowledge with urban planning is given by the Municipality of Stuttgart, Germany. Researchers in the Department of Urban Climate of Stuttgart developed a Climate Atlas with climatic information and guidelines for the design and restructuring of the city [Kleerekoper et al., 2011] [Ren et al., 2012].

Worldwide first attempts are made to decrease the gap between urban climate research and urban planning through the usage of a so-called Urban Climatic Map System (UCMS). Within UCMS scientific climatic knowledge is translated into guidelines and planning recommendations. Nowadays, cities in more than 15 countries have developed their own Urban Climatic Maps [Ren et al., 2012]. In the Netherlands, first studies on UCMS just started in the municipality of Arnhem, were research is carried out to help the Municipality of Arnhem to incorporate climate effects in planning processes [Ren et al., 2012]. Although UCMS can be very helpful to narrow the gap between urban planners and urban climatic information, it is a noncommittal tool whereby the question remains to which extent Municipalities and urban planners will actual use the tool and implement certain advised measures. In Germany, leading country in the field of urban climate, the willingness to invest in urban climate seems to be larger than in the Netherlands, where Municipalities are struggling with and doubting about policy on UHI [Rahola et al., 2009] [Ren et al., 2012]. According to one of the interviewed researchers within the "Knowledge for Climate" Governance theme, the difference in attention given to issues such as urban climate among countries is caused by, among other, different perspectives and mentalities regarding sustainability and climate change. It is difficult to increase the willingness and conviction among individuals and governments to invest in climate adaptation measures as long as the sense of urgency is lacking. Rather than a strict policy, a change in the *mind set* (perspectives) of individuals, project developers, urban planners and municipalities is necessary. Influencing and stimulating this change in *mind set* might be a chance to enlarge the sense of urgency and consensus and thus the willingness to invest in urban climate. A good example of this is given by Al Gore and his famous film "An Inconvenient Truth", released in 2006, about the consequences of climate change [Al Gore, no date]. Aim was to raise awareness on climate change trough the usage of strong messages and doom scenario's about the impact of global warming. It succeeded, the film resulted in temporary worldwide debate and (political) attention towards climate change.

8.1.5. Mainstreaming

M*ainstreaming* of UHI seems to be a potential successful approach to address heat in urban areas. *Mainstreaming* refers to the integration of a certain issue into related government policy [Agrawala, 2005]. Instead of developing new policy, political decisions on the topic can be accommodated within existing fields of policy. The possibility to integrate UHI into current policies, instead of the development of new policy, might reduce the threshold to start active policy on UHI mitigation [Uittenbroek, 2012].

There are two main reasons why *mainstreaming* could be a successful approach to address heat in the city. First of all current climate within Municipalities is not ideal to develop new policies; due to the current economic circumstances and the austerity pressure within Municipalities the willingness (as well as resources) to develop new policy is low. Presenting UHI and heat related problems as an entire new field of policy might therefore not be the most successful approach during these days. Approaching UHI as a to sustainability and urban living quality related subject which could be included in current policy on these subjects (*mainstreaming*), is supposed to be more successful.

Secondly, *mainstreaming* can enlarge the sense of urgency and consensus on the topic among different stakeholders. By approaching UHI in a more broader perspective there can be searched for *interweaving*. *Interweaving* (“doelvervlechting” in Dutch) is a term within spatial planning which stands for the search for agreement on the direction of policy among the different stakeholders, each with their own interests and goals. Folding UHI mitigation in such a way that various parties see the added value of it, enlarges the chance on concrete policy and the implementation of measures. UHI can for example be approached in a more broader perspective by relating the topic to human health, or (since one of the possible solutions to reduce UHI is the implementation of greenery) to an attractive living environment and social cohesion [Kokx, 2012]. Trough *interweaving* UHI with these policy fields, UHI can be integrated within these established policies.

According to the interviewed researchers within the Governance theme of “Knowledge for Climate”, *mainstreaming* of UHI still occurs on small scale only, as policy makers not always see the possible relations with other fields of policy. Climate adaptation is nowadays still seen as an issue for the environmental department to deal with, while there are many more connections to make. By making these connections, the chance on implementation of measures increases, not only because of an increased consensus and sense of urgency on the topic, but also because the linkage of resources such as time and budget [Kokx, 2012]. A good example would be the including of heat within so-called EIAs: Environmental Impacts Assessments. In the Netherlands, such an assessment is obligated for decisions of the government on initiatives of private individuals. An EIA investigates the impacts of certain projects on the environment [Rijksoverheid, 2012]. Through integration of the topic heat or urban climate, projects are reviewed for possible harmful consequences on this aspect.

Currently opportunities are missed as UHI is primarily approached from the perspective of climate adaptation and is considered to be a problem for the environmental department only. A chance to develop more concrete policy on UHI is the stimulation of a more integrated approach towards the phenomenon within the Municipality of Rotterdam, and the drawing of relations with other fields of policy. The researchers of the “Knowledge for Climate” research programme could (and should) had contributed to this through the way in which they presented the topic and the research results. For example by analysing and focusing on beneficial relations between UHI and other fields of policy. With regards to *mainstreaming* approaching heat from the perspective of thermal comfort might have resulted in better outcomes. Approaching heat related problems from the perspective of thermal comfort leaves more room for relations with other fields of policy (attractive living and working environment) and enlarges the chance on intertwining heat in other city-broad goals of the Municipality, thus on the actual formulation, development and implementation of measures to reduce the negative impacts of heat.

8.1.6. Cooperation between science and policy

During the process and cooperation between researchers from the “Knowledge for Climate” programme and stakeholders from the *hotspot* Rotterdam Region, the in theory described common frictions between politicians and scientists seem to actually have occurred. Such as friction regarding time limits, presentation of the results and scientific quality. The political demands for research results differ from the scientific demands, or as one of the interviewees from the Engineering consultancy for Urban Development puts it: “*We do not need 100% scientifically-approved results, 80% will do. Ultimately, running a city comes down to making decisions under uncertainty.*”.

One other example is the fact that actors from the Municipality of Rotterdam indicated that besides focusing on the negative effects of UHI (the amount of additional deaths, heat stress, etcetera) it is recommended to focus on the opportunities (pleasant thermal comfort, and thus an attractive environment for tourism, living and working). According to the policy makers from the Municipality of Rotterdam, focussing on the opportunities will probably ease the communication and combination with other policy fields [Engineering consultancy for Urban Development, 2010]. It would have been wise if the researchers responded to this call and approached heat as such that the change on usage of the research results would have been increased, for example by a shift in focus on the opportunities heat mitigation could offer.

Within the “Knowledge for Climate” research programme communication and cooperation between scientists and policy makers plays an important role [Knowledge for Climate, 2012a]. In practice however, adequate cooperation between the two seem to be rather difficult. One of the most striking aspects is the thinking in terms of ‘us’ and ‘them’ under scientists as well as policy makers. Both parties seem to consider themselves as separated and even entirely different from each other, as politics and science are considered two incompatible ways of life [Hoppe, 2005]. But in fact, despite their different operational codes, scientists and politicians are eventually serving the same societal functions: creation of consensus and the fight against chaos [Hoppe, 2005]. Instead of focusing on the differences between science and politics, one should pay attention to the similarities and integration of science and policy [Hoppe, 2005]. Translated to the situation in Rotterdam, some practical examples to possible improve the cooperation between scientists and politicians would in the first place be ending the thinking in terms of ‘us’ and ‘them’ and the related distanced and suspicious attitude towards each, as well as better communication during the actual execution of studies and the translation of research data into research results and conclusions. For example in the form of more substantive meetings, with scientists from “Knowledge for Climate” and officials from the *hotspot* Rotterdam Region, during the process of data collection and processing. Important remark hereby is that the scientists should actually consider the feedback from the officials and vice versa.

Although above standing might be considered as minor aspects within the entire processes and research on the UHI situation in the municipality of Rotterdam, even a slight improvement in communication could have resulted in (even) less frictions and miscommunication between the researchers and the policy makers and could therefore enlarged the chance on proper application of knowledge into practice.

8.2. Conclusion

Despite various studies on the so called urban heat island effect (UHI) conducted abroad, and the recently started research in Dutch municipalities, heat within cities in the Netherlands still seems to be a phenomenon mainly considered a problem by scientists alone. Although topics such as climate change and public health both receive quite some attention nowadays, it is only until recently that attention is being paid in the Netherlands towards a phenomenon directly related to both topics; the urban heat island effect.

The urban heat island effect refers to the fact that temperatures within urban areas are in general higher than the temperatures in surrounding, more rural, areas. This difference in temperature is primarily caused by the structure of a city. Which commonly has good qualities for heat retention due to the high and dense building and the materials used within urban areas: a relative large amount of paved surfaces and materials with a low albedo, and on the same hand relative less unpaved surfaces and vegetation, thus leading to the absorption of radiation which is being released as heat during the evening. As a result, cities are more vulnerable to heat, and temperatures within cities can rise quickly. Which in turn can easily result in differences in temperature between urban and surrounding rural areas of more than 10 degrees Celsius. These high temperatures can have a negative impact on the human health and living quality in urban areas. Logically, high temperatures during day and night contribute to discomfort in general, and thermal discomfort in specific. But besides general feelings of discomfort, heat can also cause physical symptoms. Considering the Dutch geographic situation and the climatological predictions for the Netherlands, the biggest threat of heat in cities lies in the occurrence of heat stress. Exposure to heat stress, which occurs under high temperatures when the bodily mechanisms to regulate the body temperature are disturbed, can cause various health problems, such as difficulty with respiration, heat cramps and heat exhaustion, heat strokes, and even death. Although not everyone is equally sensitive to heat stress (especially elderly appear to be vulnerable), there seems to be a connection between the outside temperature and the amount of heat-related complaints received by the GGD, moreover, the recent heat waves of 2003 and 2006 resulted in 1400 to 2200 heat-related deaths in the Netherlands. Considering the climate change and the on-going urbanisation, it is expected that the (negative) effects of heat within cities will only increase.

It is only until these two recent heat waves that the first studies on heat in Dutch cities are being conducted. One of the forerunners regarding this aspect is the Municipality of Rotterdam. Through participation in the Dutch research programme “Knowledge for Climate”, several studies on heat in the city of Rotterdam are conducted. This research showed that the municipality of Rotterdam is facing such a UHI intensity that negative impacts might occur. This research recommended several ‘*no regret*’ measures (relatively easy to apply (and to undo), and none or few negative side-effects), such as communicational measures on the negative impacts of heat and the stimulation of behavioural measures as humidification of air indoors, use of local refrigerants and searching for cool places. As well as measures at building or street level: insulation and blinds, and the implementation of vegetation and small scale green and fountains. These are all scientifically proven feasible measures to apply within cities in order to reduce the negative effects of UHI.

The Municipality of Rotterdam wants to use the outcome of the studies within the “Knowledge for Climate” programme as input for the Rotterdam Adaptation Strategy; a policy framework in which the strategy to make the municipality of Rotterdam 100% climate proof by the end of 2025 is described. This strategy consists of five, climate change related, themes, of which heat (or urban climate) is one. The RAS tries to describe and develop factual (preferably quantitative and measurable) ambitions and goals for each theme, and preferred measures to get there. But the Municipality of Rotterdam seems to struggle with the policy regarding heat, thus heat as a theme will probably remain rather abstract: coming down to a description of current and future developments and an identification of vulnerable areas (densely built urban areas). Moreover, first attempts are made to combine *‘no regret’* measures with other fields of policy. On project basis, heat mitigation is used as an additional argument for the implementation of measures initially meant for other purposes. Mandating particular measures within the physical environment, purely from the perspective of heat, seems to be, at least for the time being, a bridge too far. The question is why heat appears to be such a difficult issue to address, and more importantly, in what way heat can be translated in a manageable subject for Dutch municipalities? Or in other words: what are the opportunities to integrate UHI mitigation measures into urban policy?

The integration of UHI mitigation measures implies a change in agenda setting and policy making. As described in the theory and confirmed by the case study in Rotterdam, there are many (extern) factors which can influence the process of policy change and development. The chance on actual agenda and policy change is highest during the occurrence of a *policy window*: right circumstances in the problem, policy and political stream. With regards to heat in the city, this is currently not the case. A lack of urgency and consensus, in combination with the current economic circumstances, seem to be the main barriers to effectively address the possible problem of heat within urban areas. Due to this lack of urgency and consensus on the phenomenon, defining the problem in the first place is difficult: what are the precise negative effects which should be reduced? This uncertainty about the what-ought-to-be situation complicates the translation of knowledge into actual actions. Meanwhile, current economic circumstances (belonging to the political stream) are hampering the development of policy on heat even more, through the austerity pressures Dutch Municipalities are facing nowadays. The current economic and political circumstances increase the competition between issues and thus decrease the chance on the placement of heat within cities at the *governmental* and *decision agenda*.

Despite these barriers, there are also opportunities to integrate measures against UHI within urban policy. In the first place by reducing the above mentioned barriers where possible. Like most public policy issues, UHI can be seen as a so-called *wicked problem* – an ill-defined and difficult to locate problem, with a lack of consensus on the disputed norms and values and the what-ought-to-be-situation. For such confronting problems of social policy, the search for scientific bases is often bound to fail as these *wicked problems* are inherently different from the problems within natural sciences. In order to reduce above mentioned barriers, the addressing of *wicked problems* demands a different approach than the general used approach to solve problems within natural sciences.

First of all, the lack of consensus on the what-ought-to-be situation stresses the need for *synthetic knowledge* even more. Regarding heat within cities, the what-is situation is known, doubt exists on the what-ought-to-be situation and in addition: the way to get there. This emphasises the need for *synthetic knowledge* and capabilities; the ability to draw links, to reason and to come to conclusions about what is ought to be done, on the basis of (scientific) knowledge. Analysis may produce knowledge, but to become meaningful and to have an impact on the spatial environment, it needs synthesis: relations have to be made and conclusions have to be drawn. As stated in the theory, scientists, for example spatial planners, (but also policy makers), seem to hesitate to make such decisions and to draw such conclusions. This attitude has to change. Policy makers should have the nerve to draw conclusions based on knowledge, while on the same hand scientists should provide them with advice and guidance. Any attempt to actually contribute to the society and to improve the environment, to transform what-is into what-ought-to-be, involves the making of normative decisions: *synthetic knowledge*.

Secondly, the usage of a more synthetic approach has consequences for the cooperation and communication between scientists and policy makers. Due to the importance of the translation of knowledge into actions, to narrow the gap between what-is and what-is-ought-to-be, the need for a proper engagement where policy makers and researchers are actively working together in formulating the nature of the problem and thus the form of research, increases. Rather than focusing on the differences between scientists and policy makers, the focus should be on re-integration, cooperation and meaningful communication: well-organised *boundary work* between science and politics. Plus instead of being the completion of analysis the end of the cooperation between researchers and policy makers, the synthetic approach would suggest that the cooperation goes further into an on-going process of translation: of consideration of the implications of the analysis and the making of informed judgments about what-ought-to-be.

Given the current austerity pressure among municipalities, and hence the reluctance to develop new policies, the biggest chance lies in the *mainstreaming* of the topic; in the search for relations and combinations with other fields of policy. This requires a different perspective on the topic. *Mainstreaming* of heat asks for a more integrated approach, as combinations and relations have to be made between different fields of policy. Instead of looking to the phenomenon from one perspective, the multiple interpretations of this phenomenon should be taken into account in order to enlarge the chance on combination with other fields of policy and consensus building. This does not imply that all departments should work together and divisions in tasks and responsibilities should be demolished. The issue of heat in urban areas can be addressed within several departments without losing sight of the connections and relations. These opportunities for coupling are not always seen or used, while certainly in the field of heat several connections to combine the goals, measures, budgets and time of different fields of policies are possible to make. For example with the creation of an attractive living and working environment, stimulation of tourism, through realisation of an pleasant city climate and the implementation of greenery and parks. The prevention of heat should not be seen as an entire new subject, but should rather be approached as sub-subject which can be integrated in current well-established policies.

This demands for a change in the *mind set* of municipalities; to approach UHI as a subject related to other fields of policy instead of a new subject. Scientists working on this topic should take this into account during their research, in order to approach the topic and to present the results as such that the chance on *mainstreaming* of the topic increases, for example by indicating possible connections with other fields of policy.

Regarding *mainstreaming*, approaching heat from the perspective of urban climate or urban living quality might have enhanced the chance of the actual use of research results in policy. Approaching heat from these perspectives increases the chance on connections with other fields of policy, as links with for example public health, social cohesion, attractive living and working environment and tourism are (more) easily made. Approaching heat from the perspective of (a pleasant) urban climate, instead of from the perspective of UHI, might further increase the consensus and sense of urgency regarding the topic, as the advantages of a pleasant urban climate, and the disadvantages of an unpleasant urban climate (too hot, sweaty weather, not welcoming to activities), are better understandable.

Obviously, research on heat within urban areas has just recently started in the Netherlands. Although possible mitigation measures are available, further research should in the first place be beneficial to gain broader knowledge on the subject, thus improving the ability to make normative decisions about what-ought-to-be. Considering the current economic circumstances, detailed cost-benefit analyses of potential measures are likely to increase the chance on actual implementation of heat mitigation measures within urban areas.

These are possibilities to enlarge the chance on integration of heat mitigation measures within urban policy. During future research it is important to take the above mentioned recommendations and opportunities into account to enlarge the chance on integration of knowledge and therefore heat mitigation measures in the urban policy of Dutch municipalities. However, processes behind agenda setting and policy development are influenced by many more (extern) side factors. As for example economic and political circumstances are currently hampering the integration of heat mitigation measures. This stresses the need of *policy entrepreneurs* within municipalities; policy advisers willing to invest their resources to promote a certain issue and who keep their proposals ready in order to push them through when a *policy window* occurs. It are these *policy entrepreneurs*, working at the intersection of knowledge and practice, who are able to combine knowledge and policy and to couple the streams: the policy stream to the problem or political stream, thus ensuring agenda and policy change.

9. DISCUSSION ON METHODS

Within this chapter used methods during the execution of the research are discussed and reflected on. During the present study the phenomenon UHI is approached from the perspective of urban planning. This perspective heavily influenced the research design, as the main focus is on the application of knowledge into (spatial) policy.

A case study is used to investigate possible opportunities for the integration of UHI mitigation within urban policy, allowing in-depth analysis of one specific case. Rather than general information on UHI and urban policies, case specific data is gathered through the usage of interviews and meetings. During the research, ten experts have been interviewed, ranging from researchers from the Wageningen University and Research centre within the field of meteorology, researchers from the University of Utrecht within the field of governance and urban planning, and employees of the Engineering consultancy for Urban Development and the Office for Sustainability and Climate Change in Rotterdam (see Appendix "1. Interviewees & attended meetings"). In addition, two meetings from the "Knowledge for Climate" research programme, regarding heat in urban areas, were attended, as well as two PhD colloquiums regarding this subject. These interviews and meetings resulted in detailed and case specific data on the UHI situation in Rotterdam. In an ideal situation, more interviews would have been conducted.

The interviews were organised in a semi-structured way. This format was used to in the first place ensure that all the necessary topics were addressed, and secondly to obtain a certain amount of flexibility and room for the interviewees to discuss other issues. This was especially of added value since the study can be seen as an explorative study. For the same reason, the coding technique has not been applied during processing of the interviews. The chance on mismatches between the researchers interpretation and the actual intentions of the interviewees is tried to kept at minimum through recording of the interviews, almost literally transcribing the interviews and sending these reports to the interviewees for feedback and approval. Despite this effort it still may be that the researcher's perspective influenced the way in which information from the interviews is used and provided.

REFERENCES

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., and Takahashi, K., (2007), "Assessment of adaptation practices, options, constraints and capacity", *in*: Parry, M.L., Canziani, O.F., Palutikok, J.P., Hanson, C.E., van der Linden, P.J., *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press, pp. 717-743

Agrawala, S., (2005), "*Bridge Over Troubled Waters: Linking Climate Change and Development*", Paris: Organisation for Economic Co-operation and Development (OECD), pp. 23-43

Akbari, H., Pomerantz, M., and Taha, H., (2001), "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas", *Solar Energy*, vol. 70 (3), pp. 295-310

Akbari, H., (2005), "Energy saving potentials and air quality benefits of urban heat island mitigation", *Heat Island Group, Lawrence Berkeley National Laboratory*

Allmendinger, P., (2009), "*Planning Theory*", second edition, United Kingdom: Palgrave MacMillan

Arrau, C.P., and Peña, M.A., (2011), "Urban Heat Islands", available at www.urbanheatislands.com, (accessed: 7 March 2012)

van Assche, K., (2004), "Signs in Time – An interpretive account of urban planning and design, the people and their histories", *Wageningen University*, doctoral thesis

Beunen, R., and Hagens, J.E., (2009), "The Use of the Concept of Ecological Networks in Nature Conservation Policies and Planning Practices.", London: *Routledge, Landscape Research*, vol. 34 (5), pp. 563 – 580,

Bosch, P., (2011), "Climate Proof Cities: an integrated research framework", *Knowledge for Climate*

Campbell, H., (2012), "Planning to Change the World: Between Knowledge and Action Lies Synthesis", *Sage, Journal of Planning Education and Research*, vol. 32 (2), pp. 135 – 146

Centraal Bureau voor de Statistiek, (2012), "*Statline – Bevolking; geslacht, leeftijd, burgerlijke staat en regio, 1 januari*", available at http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=03759NED&D1=0&D2=0&D3=683&D4=l&VW=T, (accessed: 27 August 2012)

Climate changes Spatial Planning (CcSP), (2007), "Hot places – cool spaces", symposium 25 October 2007, Amsterdam

Climate Proof Cities, (2011), "Kennismontage Hitte", Knowledge for Climate, *Climate Proof Cities consortium, May 2011*

Climate Protection Partnership Division, (no date), "*Reducing urban heat islands: compendium of strategies – urban heat island basics (draft)"*, United States of America: Climate Protection Partnership Division

Cohen, M., March, J., and Olsen, J., (1972), "A Garbage Can Model of Organizational Choice", *Administrative Science Quarterly* vol. 17, pp. 1 – 25

Creswell, J.W., (2009), "*Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*", United States of America: Sage Publications

Daanen, H.A.M., Simons, M., and Janssen, S.A., (2010) "De invloed van hitte op de gezondheid, toegespitst op de stad Rotterdam", *Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek (TNO),* September 2010

Derksen, W., (2011), "*Kennis en beleid verbinden*", Den Haag: Boom Lemma Uitgevers

Engineering consultancy for Urban Development, (2010), "Bespreking resultaten hittestress", Rotterdam, 7 December 2010, *Municipality of Rotterdam,* Rotterdam

Faludi, A., (1996), "Rationality, Critical Rationalism, and Planning Doctrine", *in*: Mandelbaum, S.J., Mazza, L., and Burchell, R.W., "*Explorations in Planning Theory*", New Brunswick: Center for Urban Policy, pp. 65 - 82

Fischer, P.H., Brunekreef, B., and Lebret, E., (2004), "Air pollution related deaths during the 2003 heat wave in the Netherlands", *Atmospheric Environment*, vol. 38 (8), pp. 1083-1085

Flyvbjerg, B. (2006), "Five misunderstandings about case-study research", *Qualitative Inquiry* , 2006 12: 219

FNV Bondgenoten, (2012), "*Werken in de Hitte*", available at http://www.fnvbondgenoten.nl/werk_en_inkomen/dossiers/Veilig_en_gezond_werken/werken_in_de_hitte_/, (accessed: 25 May 2012)

Friedmann, J., (1987), "*Planning in the Public Domain – From Knowledge to Action*", New Jersey: Princeton University Press

Friedmann, J., (1996), "Two Centuries of Planning Theory: An Overview", *in*: Mandelbaum, S.J., Mazza, L., and Burchell, R.W., "*Explorations in Planning Theory*", New Brunswick: Center for Urban Policy, pp. 10 - 30

Gore, A., (no date), "*Al Gore*", available at http://www.algore.com/, (accessed: 3 October 2012)

Gupta, J., Termeer, K., Bergsma, E., Biesbroek, R., van den Brink, M., Jong, P., Klostermann, J., Meijerink, S., and Nooteboom, S., (2010), “How Dutch Institutions Enhance the Adaptive Capacity of Society”, *IVM Institute for Environmental Studies,* vol. W-10/19

van Harmelen, T., ten Broeke, H., Klok, L, and Janssen, S., (2011), “Maatregelen tegen het hitte-eilandeffect en hittestress in Rotterdam”, *TNO,* 31 January 2011

Healey, P., (1997), “*Collaborative Planning – Shaping places in fragmented societies*”, Canada: UBC Press

Heusinkveld, B.G., van Hove, L.W.A., Jacobs, C.M.J., Steeneveld, G.J., Elbers, J.A., Moors, E.J., and Holtslag, A.A.M, (2010), “Use of a mobile platform for assessing urban heat stress in Rotterdam”, *Proceedings of the 7th Conference on Biometeorology*

Heusinkveld, B.G., van Hove, L.W.A., and Jacobs, C.M.J., (2011), “Ruimtelijke analyse van het stadsklimaat in Rotterdam*”, Knowledge for Climate and Wageningen University and Research centre*, 27 February 2011

Hoppe, R., (2005), “Rethinking the science-policy nexus: from knowledge utilization and science technology studies to types of boundary arrangements”, *Poiesis Prax,* vol. 3, pp. 199 – 215

Hoppe, R., (2008), “Na ‘doorwerking’ naar ‘grenzenwerk’ – Een nieuwe agenda voor onderzoek naar de verhouding tussen beleid en wetenschap”, *Bestuurskunde,* vol. 2 (2008)

van Hove, L.W.A., Steeneveld, G.J., Jacobs, C.M.J., Heusinkveld, B.G., Elbers, J.A., Moors, E.J., and Holtslag, A.A.M, (2011), “Exploring the Urban Heat Island Intensity of Dutch cities”, *Wageningen University and Alterra*

Huisman, C., (2011), “Help! Wat is het heet in de stad!”, *De Volkskrant*, 12 July 2011

IPCC, (2007), “*Publications and data*”, available at http://www.ipcc.ch/index.htm, (accessed: 7 March 2012)

Kingdon, J.W., (1984), “Agendas, alternatives, and public policies”, *Ron Newcomer & Associates*, America

Kleerekoper, L., van Esch, M., and Salcedo, T.B., (2011), “How to make a city climate-proof, addressing the urban heat island effect”, *Resources, Conservation and Recycling*

Klok, L., ten Broeke, H., van Harmelen, T., Verhagen, H., Kok, H., and Zwart, S., (2010), “Ruimtelijke verdeling en mogelijke oorzaken van het hitte-eiland effect”, *TNO*, 7 July 2010

KNMI, (2011), “*Klimaatscenarios*”, available at www.knmi.nl, (accessed: 8 March 2012)

KNMI, (2012), “*Hittegolven sinds 1901*”, available at http://www.knmi.nl/klimatologie/lijsten/hittegolven.html, (accessed: 16 April 2012)

Knowledge for Climate, (2011), “Hittestress in Rotterdam”, *Gemeentewerken Rotterdam,* 30 juni 2011

Knowledge for Climate, (2012a), “*Organisatie, taken en verantwoordelijkheden van organisatieonderdelen*”, available at http://kennisvoorklimaat.klimaatonderzoeknederland.nl/organisatie, (accessed: 27 March 2012)

Knowledge for Climate, (2012b), “*Hotspots en thema’s*”, available at http://kennisvoorklimaat.klimaatonderzoeknederland.nl/onderzoekprogramma/hotspots-en-themas, (accessed: 27 March 2012)

Knowledge for Climate, (2012c), “*Nationale klimaatonderzoeksprogramma’s – Klimaat voor Ruimte*”, available at http://www.klimaatonderzoeknederland.nl/klimaatvoorruimte, (accessed: 9 July 2012)

Knowledge for Climate, (no date), “Climate Proof Cities”, *Knowledge for Climate*

Liukku, A., (2011a), “Kritiek op onderzoek naar ‘hittestress’ in stad”, *het Algemeen Dagblad*, Wednesday 10 August, pp. 3

Liukku, A., (2011b), “Klimaatonderzoeker pareert kritiek op “hittestress” en fietst vrolijk door”, *het Algemeen Dagblad,* Tuesday 16 August

Matzarakis, A., Mayer, H., and Iziomon, M.G., (1999), “Applications of a universal thermal index: physiological equivalent temperature”, *Int J Biometeorol,* vol. 43, pp. 76 – 84

Municipality of Rotterdam, (no date), “*De Rotterdamse aanpak voor duurzaamheid*”, Rotterdam: Municipality of Rotterdam

Oke, T.R., (2006), “Towards better scientific communication in urban climate”, *Theor. Appl. Climatol*, vol. 84, pp. 179-190.

Oxford, R. (1997), "Constructivism: Shape-Shifting, Substance, and Teacher Education Applications.", *Peabody Journal of Education*, vol. 72 (1), pp. 35-66

Port of Rotterdam, no date, “*Port in general*”, available at http://www.portofrotterdam.com/EN/Pages/default.aspx, (accessed: 27 July 2012)

Progamma Duurzaam, (2012), “Investeren in duurzame groei”, *Gemeente Rotterdam – Programma Duurzaam*

Rahola, B.S., van Oppen, P., and Mulder, K., (2009), "Heat in the city - An inventory of knowledge and knowledge deficiencies regarding heat stress in Dutch cities and options for its mitigation", *Klimaat voor Ruimte*

Ren, C., Spith, T., Lenzholzerc, S., Yimd,H.L.S., Heusinkveld, B., van Hove, B., Chena, L., Kupsif, S., Burghardf, R., and Katschnerf, L., (2012), "Urban Climate Map System for Dutch spatial planning", *Applied earth observation and geoinformation, volume 14, February 2012*

Rijksoverheid, (2012), "*Milieueffectrapportage*", available at http://www.rijksoverheid.nl/onderwerpen/milieubeleid/milieueffectrapportage, (accessed: 30 August 2012)

Rittel, H.W.J., and Webber, M.M., (1973), "Dilemmas in a General Theory of Planning", *Policy Sciences* vol. 4, pp. 155 – 169, Amsterdam

Roa-Espinosa, A., Wilson, T.B., Norman, J.M., and Johnson, K., (2005), "Predicting the impact of urban development on stream temperature using a Thermal Urban Runoff Model (TURM)", *National Conference on Urban Stormwater: Enhancing Programs at the Local Level*, February 17-20, Chicago, avaiable at http://www.epa.gov/nps/natlstormwater03/31Roa.pdf, (accessed: 11 April 2012)

Roozenburg, N., and Eekels, J., (1998), "*Productontwerpen, structuur en methoden*", Utrecht: Uitgeverij Lemma

Rotterdam Climate Initiative, (2009), "Het nieuwe Rotterdam", *Programmabureau Rotterdam Climate Initiative*, juni 2009

Rotterdam Climate Initative, (2010), "Rotterdam Climate Proof – adaptation programme 2010", report prepared by Molenaar, A., van Barneveld, N., Goedbloed, D., Jacobs, J., de Jager, W., de Koeijer, D., Kuitert, M., van Nimwegen, M., Pol, P., Streng, J., van Veelen, P., and Wirschell, N., *Rotterdam Climate Inititiave*, Rotterdam

Rotterdam Climate Initiative, (2012), "*Groene daken in Rotterdam*", available at http://www.rotterdamclimateinitiative.nl/nl/100_klimaatbestendig/projecten/groene_daken_in_rotterdam?portfolio_id=23, (accessed: 23 July 2012)

Rotterdam Climate Proof, (no date), "Rotterdam's climate adaptation – research summaries 2010", report prepared by Molenaar, A., van Barneveld, N., de Boer, F., Goedbloed, D., Kuitert, M., Mayenburg, D., Nijhuis, L., Rijcken, T., van Veelen, P., and Wirschell, N., *Rotterdam Climate Proof*, Rotterdam

Royal Town Planning Institute, (2003), "*RTPI Education Commission Report*", London: Royal Town Planning Institute

Rozendaal, S., (2011), "Pas op: 'Hittestress!'", *Elsevier*, 27 Augustus 2011

Runhaar, H., Mees, H., Wardekker, A., van der Sluijs, J., and Driessen, P., (2011), “Omgaan met hittestress en wateroverlast in de stad”, *Vereniging van Milieuprofessionals,* Milieu Dossier, vol. 2

Smith, B.H., (2006), “*Scandalous Knowledge – Science, truth and the human*”, Durham N.C.: Duke University Press

Steeneveld, G.J., (2012b), “Groene stad is minder heet”, *Wageningen World,* vol. 1

The Centers for Disease Control and Prevention, (2009), “*Extreme Heat: A Prevention Guide to Promote Your Personal Health and Safety*”, available at http://www.bt.cdc.gov/disasters/extremeheat/heat_guide.asp, (accessed: 12 April 2012)

Tunnissen, M.J., (2009), “*Een juridisch bestuurlijke inleiding in de ruimtelijke ordening – Het bestemmingsplan*”, Alphen aan den Rijn: Kluwer

Voogt, J., (no date), “*How researchers measure urban heat islands*”, Department of Geography, Canada: University of Western Ontario

de Vries, G., (1995), “*De ontwikkeling van wetenschap – een inleiding in de wetenschapsfilosofie*”, third edition, Groningen: Noordhoff Uitgevers B.V.

Wikipedia – The Free Encyclopedia, (2012c), “*Rotterdam (gemeente)*”, available at http://nl.wikipedia.org/wiki/Rotterdam_(gemeente)#Politiek, (accessed: 27 July 2012)

World Bank, (2006), “*Clean Energy and Development: Towards an Investment Framework*”, Washington: District of Columbia

Yamamoto, Y., (2006), “Measures to mitigate urban heat islands”, *Quarterly Review,* vol. 18

APPENDIX 1. INTERVIEWEES & ATTENDED MEETINGS

Interviewees

P. Bosch	"Knowledge for Climate" research programme *secretary "Climate Proof Cities" consortium*	on 8 May 2012
S. Buijs	Engineering consultancy for Urban Development *Advisor Environment and Sustainability*	on 30 May 2012
CJ. Gebraad	Municipality of Rotterdam *Office for Sustainability and Climate Change*	on 11 July 2012
T. van Harmelen	TNO - *researcher within the research* *"Measures against UHI and heatstress in Rotterdam"*	on 8 May 2012
L.W.A. van Hove	Wageningen University and Research centre *Earth system science group*	on 23 March 2012
J.M.C. Kokx	University of Utrecht (*geosciences*) *researcher "Knowledge for Climate", Governance*	on 22 May 2012
E.W.J.T. Nijhuis	Engineering consultancy for Urban Development *project leader "Heat stress in Rotterdam" and RAS*	on 7 May 2012
F. de Pater (*e- mail contact only)*	"Knowledge for Climate" research programme *Knowledge Transfer*	received on 11 April 2012
G.J. Steeneveld	Wageningen University and Research centre *Meteorology and Air Quality Section*	on 26 March 2012
C.J. Uittenbroek	University of Utrecht (*geosciences*) *PhD "Climate Proof Cities" consortium*	on 31 May 2012

Note: For access to interview recordings and reports, please contact the author at *anhilde@gmail.com*

Attended meetings

“Knowledge for Climate”	“Climate Proof Cities” meeting: case Bergpolder Zuid - Rotterdam	on 19 April 2012
“Knowledge for Climate”	consortium meeting “Climate Proof Cities”	on 26 April 2012
S. Grimmond *King’s College London*	PhD colloquium: “Cities and Vegetation: impact on heat, water, and carbon exchanges”	on 20 June 2012
L. Klok *TNO*	PhD colloquium: “Analyses of urban heat islands in the Netherlands; creating liveable and sustainable cities”	on 26 June 2012

APPENDIX 2. HEAT IN THE DUTCH MEDIA

Article 1 “Criticism on research towards ‘heat stress’ in City”

STAD & REGIO

AD 3

‘Tonnen naar kulstudie’

Kritiek op onderzoek naar ‘hittestress’ in stad

ROTTERDAM • Onnodige paniekzaaierij met lachwekkende conclusies, waar onderzoekers goed aan verdienen. Zo omschrijven critici het onlangs verschenen rapport ‘Hittestress in Rotterdam’, dat in totaal zes ton kost.

ANTTI LIUKKU

Al geruime tijd doen wetenschappers in Rotterdam onderzoek naar ‘stedelijke hitte-eilanden’; het fenomeen dat het in de stad een paar graden warmer is dan daarbuiten. Meest in het oogspringend waren de klimaatbakfietsen vol meetapparatuur, waarmee Wageningse onderzoekers in de zomer van 2009 door de stad fietsten.

Zes ton kost de studie die onderdeel is van het Rotterdamse klimaatprogramma, meldt de gemeente. De helft wordt betaald door het rijk. De andere helft komt voor rekening van de gemeente, de GGD Rijnmond en enkele waterschappen. Het zestig pagina’s tellende rapport *Hittestress in Rotterdam* is vorige maand uitgekomen.

De belangrijkste conclusie is dat in Rotterdam het temperatuurverschil met een plek buiten de stad kan oplopen tot acht graden. Vooral in de avond van een hete, windstille dag en in industriële gebieden, zoals de Heijplaat en Pernis.

Een van de aanbevelingen is om in de stad meer water en groen aan te leggen, omdat het zorgt voor schaduw en een prettig briesje. Verder wordt mensen geadviseerd om luchtige kleding te dragen en ’s avonds het raam open te doen. Want ‘hittekrampen, hitte-uitputting en hitteberoertes’ zijn een reëel gevaar, zeker als de opwarming van de aarde zich voortzet.

De ‘klimaatbakfiets’ reed in 2009 door de stad.

„Lachwekkend, dit soort aanbevelingen...” schampert de Rotterdamse wetenschapsjournalist Simon Rozendaal. „Uit onderzoek is allang duidelijk dat de stad minder snel afkoelt. Het is ook logisch: steen en beton nemen overdag hitte op, en geven de warmte ’s nachts af. Maar dan gaan mensen niet dood van de hitte, hoor.” Volgens Rozendaal worden tonnen uitgegeven aan een kulrapport. „Kijk, onderzoekers hebben ook een hypotheek en last van lekkende dakgoten. Als je iets schrijft over klimaatsverandering is de kans op subsidie een stuk groter.”

De epidemioloog Luc Bonneux draait het zelfs om: „Opwarming is juist goed voor de gezondheid. Tijdens een koudegolf sterven er drie tot vier keer zoveel mensen. Maar dat is iets wat altijd onder tafel wordt geschoven,” aldus Bonneux. „Rotterdam te warm? Hou toch op met deze paniekzaaierij.”

De studie is nog niet klaar. Onlangs is aan de Berkelselaan een ‘temperatuurkabel’ van drie kilometer aangelegd, om te meten wat daar de warmste en koudste plekken zijn.

De gemeente hecht waarde aan de resultaten. „Het helpt ons om het verblijfsklimaat in de stad te verbeteren,” licht een voorlichter toe.

Source: [Liukku, 2011a]

Article 2 "Climate researcher parried criticism of "heat stress" and rides happily through"

Klimaatonderzoeker pareert kritiek op 'hittestress' en fietst vrolijk door

ANTTI LIUKKU

ROTTERDAM • Wetenschappers blijken tot op het bot verdeeld over de vraag wat nu dodelijker is: hitte of kou. „Wat sommigen ook zeggen: het sterftecijfer gaat per graad Celcius met factor twee omhoog. Dat is belangrijk te weten, zeker omdat het in een stad als Rotterdam warmer is dan in de omgeving," aldus de Wageningse klimaatdeskundige Bert Heusinkveld.

Hij verdedigt zich tegen de kritiek op zijn onlangs gepresenteerde studie *Hittestress in Rotterdam*, die in totaal zes ton kostte en heeft geleid tot vragen van Leefbaar Rotterdam.

Bert Heusinkveld gaat door op zijn klimaatbakfiets. FOTO ANP

Volgens critici is het een 'kulonderzoek' omdat het helemaal niet erg is als het in de stad een paar graden warmer is. Kou zou veel dodelijker zijn. Kul, zegt Heusinkveld op zijn beurt.

Daarnaast zou het rapport vol staan met onzinnige aanbevelingen, zoals: loop in de schaduw en trek luchtige kleding aan. „Die adviezen lijken misschien een open deur, maar uit onderzoek blijkt dat met name ouderen niet goed omgaan met hitte. Daar kunnen we wat aan doen."

Heusinkveld kwam in de zomer van 2009 in het nieuws omdat hij met een zelfgemaakte 'klimaatbakfiets' (die 'slechts' 8000 euro kostte) door Rotterdam reed om precies – straat per straat – de temperatuur en luchtvochtigheid te meten.

De kritiek van Leefbaar doet hij af als 'populistisch'. „Dit is zeker geen linkse hobby," zegt hij. Sterker, hij gaat door met een nieuw onderzoek. Namelijk naar de invloed van parken op de temperatuur in de stad. „We weten dat parken voor verkoeling zorgen, maar het is onduidelijk tot hoe ver deze verkoeling strekt. En: moet je bomen juist verspreiden, of bij elkaar zetten? Ook een zeer interessante vraag."

Source: [Liukku, 2011b]

Article 3 "Watch out: 'Heat stress!'"

HITTE

Pas op: 'Hittestress!'

In Rotterdam is 'wetenschappelijk' onderzocht of er hitteberoertes kunnen ontstaan in de stad. Het advies aan de burgerij: doe luchtige kleding aan

Simon Rozendaal

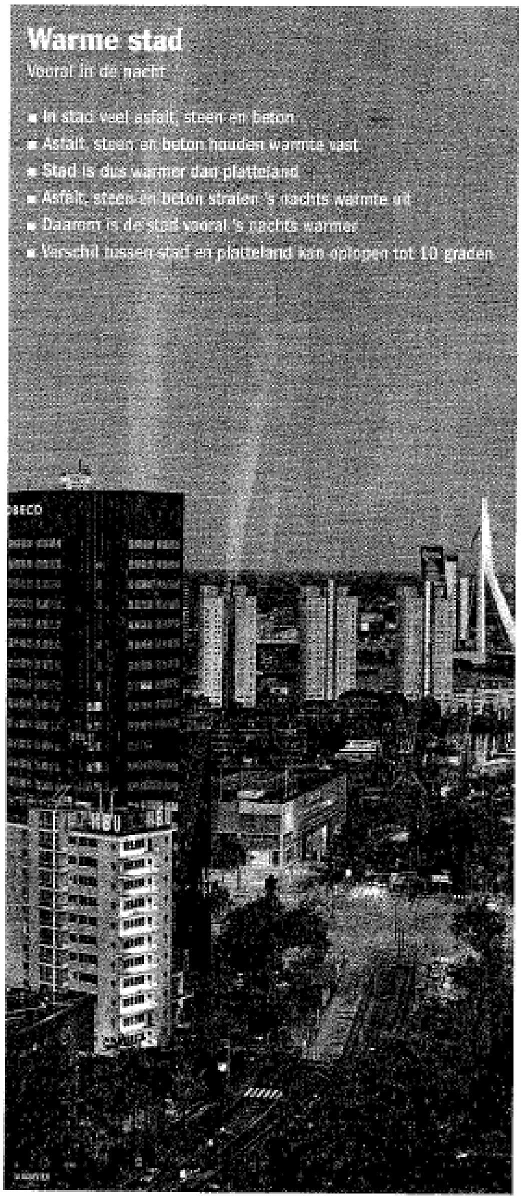
Alsof het Opperwezen over superieure ironie beschikt, werd enkele weken geleden in Rotterdam een rapport over 'hittestress' gepresenteerd. Tijdens een dramatisch slechte, maar tevens ouderwets Hollandse zomer kwam de tweede stad van Nederland met een waarschuwing voor hitteberoertes (jawel, u leest het goed: hitteberoertes) tijdens de zomers die volgens de theorie van het versterkte broeikaseffect namelijk steeds heter en droger zouden moeten worden.

Voor 600.000 euro mochten onderzoekers en studenten van de Wageningen Universiteit met bakfietsen vol *fancy* apparaten die, ontdaan van alle technische hyperbolen, in feite gewone thermometers waren, de stad doorkruisen. Ze kwamen in hun rapport *Hittestress in Rotterdam* tot de conclusie dat het in de stad warmer is dan op het platteland.

Dat is een open deur van jewelste. Het is al vele decennia bekend.

In de klimatologie heet dit het *urban heat island effect*. De metropool zindert als een warm eiland te midden van een koele, groene oceaan. De verklaring hiervoor is simpel: in een stad is veel asfalt, baksteen en beton, en dat houdt nu eenmaal warmte vast.

Er zijn de afgelopen tientallen jaren werkelijk tientallen onderzoeken geweest die dit effect ondubbelzinnig in kaart hebben gebracht. De bekendste (waar het Intergovernmental Panel on Climate Change – het IPCC, het klimaatpanel van de Verenigde Naties – zich op baseert) zijn in China gedaan, maar zelfs in Nederland was Rotterdam spuit elf, want al eerder zijn vergelijkbare onderzoeken in Arnhem en Amersfoort verricht.



Het onderzoek dat in Rotterdam is uitgevoerd, was totaal overbodig. In eerste instantie leek één conclusie nog een tikje opmerkelijk: dat de warmteverschillen tussen stad en platteland in het geval van Rotterdam opmerkelijk bleken, tot aan 8 graden! Uit de documentatie blijkt echter dat zelfs dit gegeven allesbehalve uniek was: in Amersfoort is zelfs een verschil van 10 graden gemeten.

Bij dit alles dient de lezer – voor zover hij of zij inmiddels nog niet gealarmeerd genoeg zou zijn – zich ook nog eens te realiseren dat het *urban heat island effect* in het brandpunt van het wetenschappelijke klimaatdiscours staat.

Het is geen slimme of originele gedachte van het Rotterdam Climate Initiative (een Rotterdamse ambtelijke werkgroep die het project heeft bedacht), of van de Wageningen Universiteit (die het plan heeft uitgevoerd) om te kijken of het in de stad warmer is dan op het platteland. Dit is namelijk de kern van de discussie of de wereldwijde temperatuurmetingen wel kloppen, een discussie die al een jaar of twintig woedt.

Thermometers over de hele wereld geven aan dat de temperatuur gedurende de afgelopen honderd jaar met ongeveer 1 graad Celsius is gestegen. Dit wordt aangeduid met de inmiddels bekende term *global warming*.

Het debat gaat onder meer over de vraag in hoeverre de temperatuurmetingen van de KNMI's van deze wereld kloppen, gegeven het feit dat er in de buurt van de thermometers (zoals in De Bilt, waar het KNMI is gevestigd) steeds meer asfalt, baksteen en beton is gekomen. Met andere woorden, het *urban heat island effect* is om het op zijn Rotterdams te zeggen zo oud als de weg naar Kralingen.

Waarom moest die weg opnieuw worden bewandeld? Waarom nagaan of de zwaartekracht ook in Rotterdam geldt?

Temeer omdat een volgende conclusie ook allesbehalve verrassend is. De opwarming van de stad, zo heeft de Wagenings-Rotterdamse studie ontdekt, manifestoert zich vooral 's nachts.

Als de zon brandt, is het overal heet – in de stad 1 tot 2 graden extra – maar de kneep zit hem in de nacht. Dan is het op het platteland veel koeler, terwijl stenen en betonnen gebouwen plus het asfalt de hitte die ze overdag hebben opgevangen, weer uitstralen. Dan kan het midden in de stad wel 8 graden warmer zijn.

De studie kostte 6 ton, waarvan de helft door het Rijk werd betaald en de rest door de gemeente, de GGD en enkele waterschappen. Het doel was om na te gaan of er door de opwarming van de aarde wellicht 'hittestress' in Rotterdam zou kunnen ontstaan.

Kou erger

Meer sterfte

- Hete zomers: benauwdheid en hartaanvallen
- Koude winters: drie keer zoveel sterfte
- Opwarming aarde: goed voor gezondheid

Welnu, de conclusie was dat dit een serieus gevaar was. Door de opwarming van de aarde als gevolg van het verbranden van olie, gas en steenkool ontstaan er mogelijk 'hittekrampen', 'hitteuitputting' en 'hitteberoertes'. Het rapport adviseerde om in de stad meer water en groen aan te leggen (schaduw en een koel briesje) en kwam als klap op de vuurpijl met de aanbeveling aan de burgerij van Rotterdam om 's avonds het raam open te doen en overdag luchtige kleding te dragen.

In het *Algemeen Dagblad*, dat de geldverspilling de afgelopen week aan de kaak stelde, sprak hoogleraar epidemiologie Luc Bonneux van de Erasmus Universiteit Rotterdam over 'paniekzaaierij'.

Hij wees erop dat warmte voor de gezondheid beter is dan kou. 'Opwarming is juist goed voor de gezondheid. Tijdens een koudegolf sterven er drie tot vier keer zoveel mensen. Maar dat is iets wat altijd onder tafel wordt geschoven.' ■

SPIRITUEEL

Pauselijke megafoon

Studie van Robert Hughes over Rome is onevenwichtig, maar de kunstcriticus schrijft mooi over de relatie tussen cultuur en godsdienst

Toen Karel van het Reve zijn *Geschiedenis van de Russische literatuur* had gepubliceerd, loofde hij 25 gulden (ruim 11 euro) uit voor elke correctie van onjuistheden in zijn ambitieuze overzichtswerk. Dat kostte de bekende slavist nogal wat geld, want ijverige studenten wisten een flink aantal onnauwkeurigheden op te sporen. Van het Reve nam, zoals hij zelf toegaf, niet altijd de moeite elk feitje uitgebreid te checken.

Robert Hughes is ook zo'n erudiete, knap formulerende auteur voor wie leesbaarheid zwaarder telt dan nauwkeurigheid. De Australische kunstcriticus houdt van grootse perspectieven en meeslepende vertellingen, waarmee hij niet alleen kijkers van zijn kunstprogramma *The Shock of the New* imponeerde, maar ook lezers van boeken als *The Fatal Shore* en *Barcelona*.

Zijn nieuwste boek, dat deze week in Nederlandse vertaling verschijnt bij Balans, handelt over de geschiedenis van Rome. De *volledige* geschiedenis, dat wil zeggen: van Romulus tot Silvio Berlusconi. Een complex onderwerp, dat de schrijver noodzaakt met grote stappen door de historie heen te banjeren, waarbij hij weleens een steekje laat vallen.

Cornarokapel van Bernini

Bij de verschijning van de Engelstalige versie ervan hebben classici in kritische besprekingen laten zien hoe vaak Hughes in de fout is gegaan. Latijnse citaten verhaspeld, namen van keizers door elkaar gehaald, gebeurtenissen verkeerd gedateerd: het is maar goed dat Hughes, anders dan Van het Reve, geen beloning heeft uitgeloofd voor het vinden van onjuistheden in zijn geschiedeniswerk, want dit was voor hem een kostbare affaire geworden.

Ook lezers zonder grote kennis van de Romeinse geschiedenis zal opvallen dat *De zeven levens van Rome* niet in alle opzichten geslaagd is. Het begint met een soort liefdesverklaring aan de Eeuwige Stad, waarvan de schoonheid haar gelijke nauwelijks kent: 'Niets overstijgt het genot van de eerste onderdompeling in Rome op een mooie voorjaarsochtend.' Maar dan volgt een overdonderende hoeveelheid feiten, afgesloten met een uitgebreide beschouwing over het futurisme, die weinig verband toont met het onderwerp van het boek, en met een klaagzang over het moderne massatoerisme.

Maar soms stuit de vermoeide, verwarde lezer ineens op prachtige stukken. Zoals over Rome aan het eind van de achttiende eeuw, toen welgestelde jongemannen praktisch verplicht waren de stad te bezoeken in het kader van de 'grand tour'. Ze moesten wel erg sterk in de schoenen staan, of erg homoseksueel zijn, wilden ze niet in het bed van een Italiaanse vrouw belanden. Rome was in die tijd niet alleen een groot openluchtmuseum, maar ook een groot openluchtbordeel, waarbij meisjes zich buiten onder de *fornices* (bogen) aanboden. Het woord *fornicare* (ontucht plegen) is aan deze praktijk te danken.

Mooi schrijft Hughes ook over de relatie tussen cultuur en godsdienst, die op weinig plekken in de wereld zulke bijzondere artistieke vruchten heeft afgeworpen. De sympathie van de auteur ligt duidelijk bij de kunstenaars. Met nauwelijks verholen afkeer verhaalt hij over de politiek van het Vaticaan, waarbij hij gretig aandacht besteedt aan pauselijke zwakheden. Maar de kerkvorsten gaven ook opdrachten voor het maken van magnifieke kunst.

In de zeventiende eeuw, toen de roomsen te maken hadden met de opmars van de protestanten, reageerde de kerk, in de woorden van Hughes, 'met een briljante vaardigheid en energie'. Ze zette de beeldende kunsten volop in om de eigen positie te verdedigen. De kunstenaar die de artistieke Contrareformatie de meeste allure gaf, was een diepgelovige architect en beeldhouwer die met genoegen fungeerde als de 'marmeren megafoon van de pauselijke orthodoxie': Gian Lorenzo Bernini (1598-1680).

Zijn leven lang wijdde Bernini zich aan de kunst. Toen hij de tachtig al was gepasseerd, kon hij nog rustig zeven, acht uur aan één stuk een marmerblok bewerken. Onder vier pausen diende hij. Voor paus Urbanus VIII werkte hij bijna twintig jaar aan een grafmonument.

Maar indrukwekkender is de Cornarokapel in de Santa Maria della Vittoria, met daarin het beeld van de Extase van Teresa van Avila. En natuurlijk het door Bernini ontworpen Sint-Pietersplein. Het zijn voorbeelden van religieus bezielde kunst die de door Robert Hughes zo verafschuwde toeristen in grote aantallen naar Rome blijft lokken.

Gerry van der List

Source: [Rozendaal, 2011]

Article 4 "Help! It is hot in the city!"

Help! Wat is het heet in de stad!

CHARLOTTE HUISMAN − 12/07/11, 00:00

Het verschil tussen de temperatuur in de stad en in de groenere gebieden erbuiten wordt steeds groter. Oorzaak: veel steden worden steeds dichter bebouwd. In Rotterdam bedraagt het maximale temperatuurverschil tussen stadswijken en een groene plek buiten de stad 8 graden Celsius, vooral in de avond van een hete, windstille dag.

ROTTERDAM/SOESTERBERG - Dit blijkt uit het onderzoek 'Hittestress in Rotterdam' van de gemeente Rotterdam dat deze maand wordt gepubliceerd.

Nederlandse steden, de rijksoverheid en universiteiten onderzoeken het fenomeen dat 'stedelijk hitte-eiland' wordt genoemd, en hoe zij kunnen voorkomen dat het in de zomer in de steden te heet wordt. De noodzaak van dit onderzoek werd extra duidelijk na de hittegolven in 2003 en 2006, toen bleek dat er onder ouderen boven de 75 jaar aanzienlijk meer sterfgevallen zijn als de temperatuur stijgt. Daarnaast willen steden niet dat hun milieuambities teniet worden gedaan doordat de inwoners massaal airco's aanschaffen vanwege de gestegen temperaturen.

Volgens voorspellingen van het KNMI zullen er in Nederland waarschijnlijk vaker hittegolven voorkomen. Ook zijn veel steden bezig met 'binnenstedelijk' bouwen, wat het warmteverschil met de weilanden buiten de stad verder vergroot.

Het is heter in de stad doordat er veel asfalt ligt dat meer zonnestraling absorbeert, zoals ook donkere gebouwen doen. Dichte bebouwing staat bovendien een verkoelend windje in de weg. Ook verkeer leidt tot hogere temperaturen. Voor groen is in steden die dichter bebouwd zijn minder ruimte, terwijl juist parken een verkoelend effect hebben. Een boom is te vergelijken met tien airco's. De vrees is dat het door de klimaatverandering te warm zou kunnen worden in de Nederlandse steden, die niet op hitte zijn gebouwd.

Minder goed slapen

Natuurlijk zijn er mensen die de warmte een zegen vinden. 'Niet iedereen heeft last van de hitte. Jongeren gaan er bijvoorbeeld meer op uit', zegt klimaatonderzoeker Sonja Döpp van onderzoeksinstituut TNO. 'Maar veel mensen slapen minder goed als de warmte in de stad blijft hangen en sommige mensen krijgen gezondheidsproblemen.'

Hein Daanen van TNO, gespecialiseerd in de gevolgen van temperatuur op het menselijk lichaam: 'Vooral ouderen hebben er last van. Uit een recente studie uit Berlijn blijkt dat bij hitte meer mensen sterven in dan buiten de stad.' Döpp: 'De vraag waar het om draait is: wat kun je als stad het beste doen om het er in de zomer zo koel mogelijk te houden?'

Het eerste grote Nederlandse onderzoek naar hitte in de stad, in samenwerking met onder meer de kennisinstituten TNO en Deltares en de universiteit van Wageningen, begon in 2009 in Rotterdam en zal deze maand zijn afgerond. Er werden meetstations geplaatst en een bakfiets met meetapparatuur van de universiteit van Wageningen reed rond in de stad. Het centrum en de Kop van Zuid, met veel hoogbouw dicht op elkaar, bleken het warmst.

Rotterdams projectleider Lissy Nijhuis van het project Hittestress: 'We dachten vooraf: misschien valt het wel mee in Rotterdam omdat er veel water is dat verkoelend werkt. Maar Rotterdam blijkt met zijn dichte bebouwing en veel asfalt wel degelijk een hitte-eiland te zijn. Binnenstedelijk bouwen is de trend, maar daardoor wordt het wel ontzettend warm. Dan kun je bijvoorbeeld maatregelen treffen door bijvoorbeeld meer groen te planten en groene daken en groene gevels aan te leggen,

of de stoepen te bekleden met materiaal met een lichtere kleur, dat minder warmte absorbeert. Asfalt is het ergst, gele klinkers zijn veel koeler. '

Voor een vervolgonderzoek zijn nu meetkabels opgehangen tussen de lantaarnpalen en bomen aan de Berkelselaan in Rotterdam-Noord. Daarmee wordt gemeten hoezeer de temperatuur verschilt op verschillende plekken in een straat: onder een boom, vlak langs een gevel, in de zon en in de schaduw. Nijhuis: 'We willen bijvoorbeeld weten met welke soort groen het verblijf in een straat zo aangenaam mogelijk wordt.'

Sommige bewoners die weten waarvoor de losjes opgehangen draden in hun straat dienen, zeggen benieuwd te zijn naar de uitkomsten. Maar een moeder met een kind die er in het parkje wandelt, begrijpt niet helemaal wat het probleem is van een warme stad. 'Als het heet is, is het heet', verklaart ze.

In de provincie Utrecht gaat de Natuur en Milieufederatie Utrecht (NMU) met andere organisaties deze zomer de hitte in de stad onderzoeken. Tweehonderd bewoners uit Utrecht, Amersfoort, Veenendaal en Nieuwegein krijgen een thermometer opgestuurd, waarmee ze tijdens een hittegolfmetingen kunnen doen. De Universiteit van Wageningen voert in de stad Utrecht metingen uit met een bakfiets.

De onderzoekers zijn zich ervan bewust dat in tijden van bezuinigingen maatregelen tegen hitte niet erg hoog op de politieke agenda staan. Maar door bijvoorbeeld vooraf te praten met architecten over materiaalgebruik en door maatregelen aan te bevelen zoals de aanplant van meer groen en door groene daken kan er volgens hen - zonder veel extra geld - wel degelijk iets worden ondernomen tegen de hitte in de stad.

Door asfalt en de dichte bebouwing kan het in de stad wel 8 graden warmer worden dan in de weilanden erbuiten. Er komen meer hittegolven. Worden onze steden te warm?

'Als de dood voor tocht'

Het onderzoek naar hitte in de steden in Nederland kreeg prioriteit na de hittegolf van 2003, toen bleek dat meer ouderen stierven tijdens een hete periode. Bij temperaturen boven de 30 graden Celsius sterven 12 procent meer mensen, wat neerkomt op dagelijks veertig extra sterfgevallen. Het betreft vooral ouderen boven de 75 jaar. Gebleken is dat ouderen zich minder snel kunnen aanpassen aan wisselende temperaturen, maar volgens professor Hein Daanen van TNO speelt ook gedrag een rol. 'Veel ouderen zijn als de dood voor tocht en zetten in de koelte van de ochtend niet even een raam open. Ook kunnen ze zich soms te warm kleden.' Verder zouden ouderen soms te weinig drinken. Daanen deed vorig jaar onderzoek in Tilburg, waaruit bleek dat ouderen meer last hadden van hitte dan van verkeerslawaai. Hij gaat nu onderzoeken hoe ouderen zich beter kunnen wapenen tegen de hitte.

Source: [Huisman, 2011]