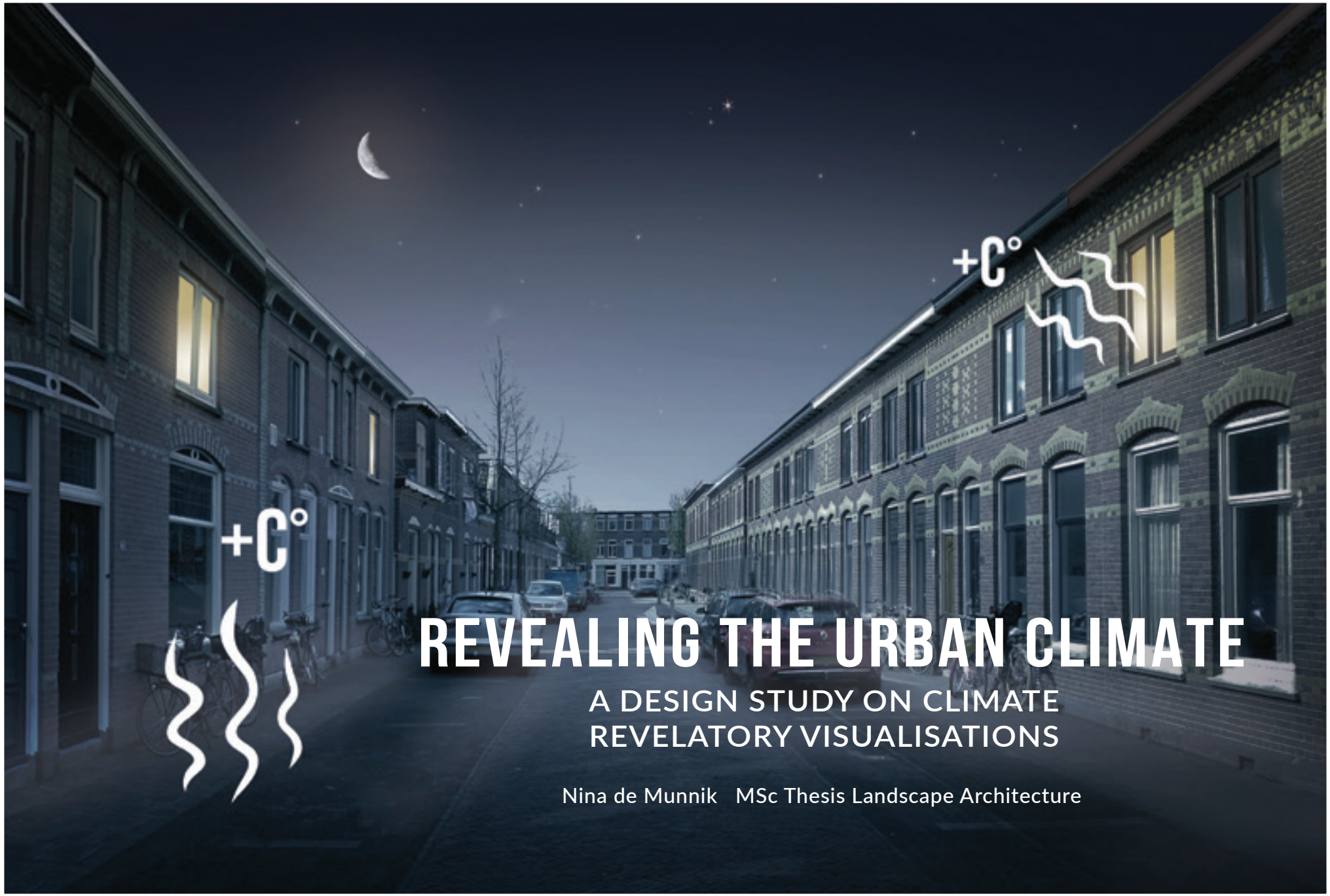

REVEALING THE URBAN CLIMATE

A DESIGN STUDY ON CLIMATE REVELATORY VISUALISATIONS

Nina de Munnik MSc Thesis Landscape Architecture

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ABSTRACT

Climate change intensifies problems in the Dutch urban climate environment, such as more heat waves and intensive rain showers. However, urban climate problems bring about not only a spatial challenge, but also a social challenge of engaging inhabitants with climate adaptation. Inhabitants do not recognize the occurring problems, due to several perceptual barriers (e.g. high complexity of the problem, low visibility, lack of immediacy of the impacts). The newly defined concept 'climate revelatory visualisations' carries the potential to tackle the perceptual barriers of experiencing climate processes. This research examined what type of visualisations can reveal the occurring urban climate problems and their adaptive solutions best, in order to raise urban climate awareness. In a research-through designing process multiple design hypotheses (derived from recommendations in literature) in the visualisations are tested on the criteria engagement, clarity, connectivity and trust. The visualisations are embedded in the context of a dense historic labourer's neighbourhood (Assendorp, Zwolle), since common urban heat problems such as heat stress on hot summer days and water accumulation during peak rainfall occur here. The generated visualisations are assessed on the four criteria by the local community. The quantitative and qualitative test results informed the revisions of the visualisations and provided insights in the effectiveness of the tested design hypotheses.

The research findings show that the climate risks and adaptation measures can be effectively presented in photorealistic and animated imagery, supported by graphic information. The climate revelatory visualisations should contain appealing content in which climate adaptation is positively framed and presented in the personal relevant environment of the target audience. A before/after comparison, in which the solutions are revealed subsequent to the problems provides a positive emphasis on climate adaptation. Visualisations revealing the current situations, and thereby the risks of the climate problems, have a warning function; convincing the audience of the urge for adaptation. While visualisations revealing adaptation measures, have a motivating function by promoting a feasible climate adaptive future of their direct environment. The combination of these ingredients in climate revelatory visualisations can tackle multiple perceptual barriers, and therewith trigger significant steps in the awareness level amongst inhabitants according to Sheppard's Awareness-to-Action framework.

Keywords: awareness, visualisations, urban climate, climate adaptation, climate responsive design, climate revelatory design, landscape architecture, research-through-designing, Assendorp, Zwolle

PREFACE

My ambition as a future landscape architect has always been to contribute to the improvement of public spaces and optimize the related human life. I am convinced that the broad profession of landscape architecture can accomplish many things, among which the biggest challenge of adaptation to climate change. In my master studies, I got acquainted with climate responsive design, which taught me to think more creative about a better future of our cities. Many research and design studies consider the possible adaptation techniques, however, the biggest challenge lies in the human aspect.

Adaptation measures need to be implemented soon in order to cope with climate problems in the near future. I am curious about how design can bring about changes in the functionality of society. I think it is interesting to reflect on the influence of my actions as a designer and researcher on the direction of the long-term achievements of our society. I attempted to make contribute positively, by researching the potential of visualisations in engaging the public with climate adaptation.

Creating visualisations is a skill I always loved practicing in design projects. Furthermore, visualisations are a powerful tool which can be employed to convey a message. Therefore, I researched how visualisations can reveal climate problems and solutions in order to raise climate awareness. I am breaking new ground by examining how visualisations should be designed in order

to evoke behavioural change on urban climate adaptation. Within this thesis process, I was able to explore the possibilities of visualisation techniques and get insight in the power of visualisations.

During the process of this thesis I always had the highest ambition to get the most of my research results. However, this aspiration sometimes resulted in the struggle of wanting too much, while having the ability of only contributing a little. I was able to persist my motivation in this research topic by some great support.

My acknowledgments to the great support of my supervisor Sanda Lenzholzer. Her enthusiasm and extensive knowledge in the field of climate research and design has been very valuable. She asked the necessary questions and guided me with constructive feedback. Every meeting was inspirational, in which she passed on her enthusiasm about the relevance of this research. This has greatly encouraged me to get the most out of this thesis.

The enthusiasm for climate adaptation was also present in Zwolle, where I met inspiring people in the context of the research case Assendorp. Special thanks to Ryan Hoekman who was very generous in connecting me with the local community, which has been very helpful. Among others, she introduced me to Adriaan Mosterman, an inhabitant of Assendorp who initiated the first climate adaptive measures in Assendorp. I am thankful for his hospitality for the use of his living room for the survey meeting. I like to thank all participants of the survey, who made an essential contribution in this research. As well as everyone who took the effort to disperse the link of the questionnaire.

I would also like to extend my thanks to my peer students, who were always ready to give advices and challenge each other with thought-provoking questions. Special thanks to Joa, with whom I went through the thesis process simultaneously. The mutual encouragement, as well as the brainstorming allowed us to move forward. Our conversations contributed in bright insights throughout my research.

I wish to thank my supportive family, friends and roommates. Although, this thesis absorbed the majority of my time you were always patient and comforted me with understanding. Last but not least, I thank my parents for their infinite support and encouragement throughout this thesis and my entire education.

In hindsight, I am very satisfied with my thesis research and its contribution on a scientific and societal level. I hope my thesis research inspires others to research the subject of climate revelatory design as well, since much potential waits to be discovered.

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03 RESULTS AND DISCUSSION

04 GENERAL REFLECTIONS AND CONCLUSION

INTRODUCTION

1.1 PROBLEM INTRODUCTION

"I think people grasp it, but it seems something distant, far off, intangible and almost otherworldly. An individual doesn't feel like they can make an impact."
– Leonardo DiCaprio in Before the Flood (Stevens, F. et al., 2016)

Climate change is known to be a very urgent problem threatening the human living environment. However, it is a problem outside the concerns of our daily lives. A personal experience with the climate issues might raise the feeling of urgency to come into action (Sheppard, 2012; Moser, 2010; Roenhovde Tiller and Schott, 2012; van der Linden, Maibach, & Leiserowitz, 2015). When it comes to offering experiences, landscape architecture can be of value in bringing the urge for adaptation closer to people's experience. Can design shift minds? This thesis researches the potential of landscape visualisations in raising awareness, and as a result, making a step towards climate-resilient environments and communities. It is an exploratory study on how climate can be revealed to laymen, in order to raise awareness about the urban climate among citizens.

Adaptation challenge
Climate change is happening; whether it accelerates further depends on our actions. We need to both mitigate and adapt our environment to minimize the negative impacts. An optimal response to climate change would be anticipatory adaptation complementary to mitigation, since mitigation alone is not sufficient to offset climate change in the Netherlands (De Bruin et al., 2009).

The main consequences of climate change affecting the Netherlands include sea level rise, change of wind patterns, raised temperatures, which causes higher humidity and therewith more extreme rainfall events (KNMI, 2015). In cities, these changes will be tangible at a pedestrian level in the future microclimates (figure 1).

The general changes in the Dutch climate intensify problems in the urban climate. Higher temperatures will occur during the whole year, resulting in more heatwaves in the summer (KNMI, 2015). During these heat waves, many urban areas in the Netherlands suffer from heat stress. The built environment and paved surfaces cause a higher level of radiation, contributing to the 'urban heat island' effect (Klok et al. 2012; Lenzholzer, 2015; Steeneveld et al., 2011). The temperature in cities can be 9˚C higher than its surrounding rural areas at night, because materials of buildings and streets absorbed heat during the day and radiate this at night (Klok et al. 2012). These conditions have influence on people's direct living environment, and can negatively affect people's health and productivity (Lenzholzer, 2015; De Bruin et al., 2009).

The temperature rise causes higher humidity which has another major impact on the urban microclimate; more precipitation and

Figure 1. Illustration of the adaptation & social challenge in accomplishing climate adaptive cities

increase of extreme rain showers (KNMI, 2015). This effect can be very tangible in the cities due to its delayed infiltration reaction, caused by the many paved surfaces (Lenzholzer, 2015; Roggema, 2009). When too much rain falls in a short period, cities suffer from floods. The many paved surfaces make the city improperly prepared for increased precipitation, since this cannot drain nor infiltrate. In recent years, urban floods have already caused many problems in Dutch cities (ANP, 2016).

These problems and their consequences are concentrated on a relatively small surface: the outdoor space in cities. Moreover, the urban population is growing, resulting in more people coming into contact with urban climatic problems. This makes it a challenge for urban designers to come up with sustainable solutions for the public space (Hall & Barrett, 2012). Most cities are not yet designed to alleviate the effects of global warming, while it is known that climate adaptive design can actually achieve this (Lenzholzer, 2015; Vanos et al., 2016). Climate change and urbanization ask for solutions to make the public space in the city sustainable and thermally comfortable.

Still, much effort is needed to make cities in the Netherlands climate adaptive. The many challenges in the city ask for society, inhabitants and municipality officials, to act upon them. There is a need to search for new paths in the creation of resilient communities (Ercoskun, 2013). Planners and designers of future cities need to ensure their plans to be climate adaptive (Lenzholzer, 2015), while individuals can contribute by changing

their lifestyles and adapting their private properties. It is clear that action needs to be undertaken to achieve climate adaptive cities in the near future.

Social challenge

Besides the need for spatial adaptation, a behavioural change is needed (figure 1). Societal factors play an important role in climate adaptation (Adger et al., 2009). Since many surfaces in the city are private properties, all inhabitants' contribution is essential to make the whole city climate-adaptive. To accomplish effective action in climate adaptation, problem awareness and general consensus to act upon them among all citizens is required (Kennis voor Klimaat, 2013; Sheppard, 2012).

However, not everyone is acquainted with the knowledge about climate adaptation, its necessity and how it can be implemented. There are challenges in communicating the need for action, mostly due to perceptual barriers. Lay-men do not see the long-term changes in their environment and often do not have the knowledge about the possibilities to adapt (Moser, 2010; Sheppard, 2012). Roenhovde Tiller and Schott (2012) state that there is a lack of action following upon climate awareness. They call this gap between awareness and action an attitude-behaviour gap, which is caused by several barriers. All these perceptual barriers need to be tackled in order to solve the lack of action and thus taking care of climate change (Sheppard, 2012).

By raising awareness about the topic, understanding will be created and people might come into action (Sheppard, 2012; Ercoskun, 2013). Raising awareness is therefore the first step towards adaptation to urban climate problems.

Opportunity for landscape visualisations

Landscape architectural visualisations can be deployed to communicate the need for action on urban climatic problems. Climate adaptation itself can be used as branding to make people aware of its necessity (Kennis voor Klimaat, 2013). Showing people how adaptation can be done is a chance to overcome perceptual barriers in experiencing the climate. Visualisations can "increase the visibility of climate change features in local landscapes" (Sheppard, 2015), and therewith be of value in awareness raising. In this thesis is researched how landscape visualisations can contribute in raising climate awareness.

1.2 THEORETICAL FRAMEWORK

Urban climate awareness

This research focuses on 'awareness', which can be defined as: knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience (Cambridge online dictionary, 2016). In this research, the concept of awareness is be narrowed down to 'urban climate awareness', which is conceptualized as knowing what happens within the urban climate ánd the willingness to act upon the occurring problems.

Research of Van der Schans (2017) reveals that a low sense of urgency for climate adaptation in the Netherlands exists, what causes a low sense of urban climate awareness. Moser (2010) points out that some people show their willingness to act upon climate problems, however, actions lack. Van der Schans (2017) concludes that the current level of climate awareness can be improved to accomplish more successful climate adaptation.

To overcome the reluctance to act (Van der Schans, 2017), all urban inhabitants should gain insight in the upcoming adaptation necessity and possible solutions in their direct environment. A better-informed community is promised to be more confident and motivated to take the step towards adaptation action and to provide more support on local planning efforts (Sheppard, 2012). Raising awareness about the urban climate among the inhabitants of the Netherlands would therefore help to achieve climate adaptive cities in the near future.

From awareness to action

Sheppard (2012) describes how awareness about climate problems can be constructed. His 'Community Awareness to Action Framework' shows the road towards action in people's behaviour on climate change (figure 2). In this framework, external influences affect individual attitudes and behaviour. Through external influences the level of awareness can shift from 'seeing' or 'hearing' to 'recognizing', to 'caring' and finally into 'action'. Such behavioural changes are desirable, since they can make a difference in making the society more aware.

However, behavioural changes are limited by perceptual barriers. These are described in the framework of Sheppard (figure 2) and in multiple other sources (Nicholson-Cole, 2005; Moser, 2010; Roenhovde Tiller and Schott, 2012; Sheppard, 2012; van der Linden, Maibach & Leiserowitz, 2015).

The causes and impacts of climate change are not visible. There is a lack of immediacy and direct experience of the impacts. The distant impacts are overruled by the more immediate day-to-day concerns, leading to no connection with people's daily life. Schroth, Pond & Sheppard (2015) address this as the temporal dimension. The temporal dimension indicates the fact that long term goals are usually not well aligned with human cognition, since people usually anticipate on 5-15 years into the future. Furthermore, the climate problems have a high complexity and are sometimes uncertain, which can make people feel powerless. People can feel a lack of gratification for the actions that are taken. Besides, there is a lack of responsibility for the problem; people appoint others and other places for causing problems.

Lastly, there is a disbelief about the occurrence of the problem and the belief that the problems occur elsewhere (Sheppard, 2012; Moser, 2010; Roenhovde Tiller and Schott, 2012; van der Linden, Maibach & Leiserowitz, 2015).

These perceptual barriers must be tackled in order to make behavioural change possible. Sheppard (2012) suggests to "make it local, make it visual and make it connected". By doing so, he showed that the message of the urge of mitigation and adaptation will be conveyed. Sheppard (2015) addresses that more needs to be done to bridge the perceptual barriers and reach citizens. He summarizes common recommendations in literature in the following four approaches.

- Experiential learning; to provide a personal experience with emotional meaning in order to connect/engage people with the subject
- Place attachment; to relate to people's direct and meaningful environment by relating to spatial characteristics and social or physical elements of the landscape
- Social or peer pressure; to help establish new social norms and therewith evoke behaviour change
- Visual learning tools; to make climate more concrete for laymen, to increase engagement, enhance learning, tap emotions and evoke behaviour change by the use of visual media

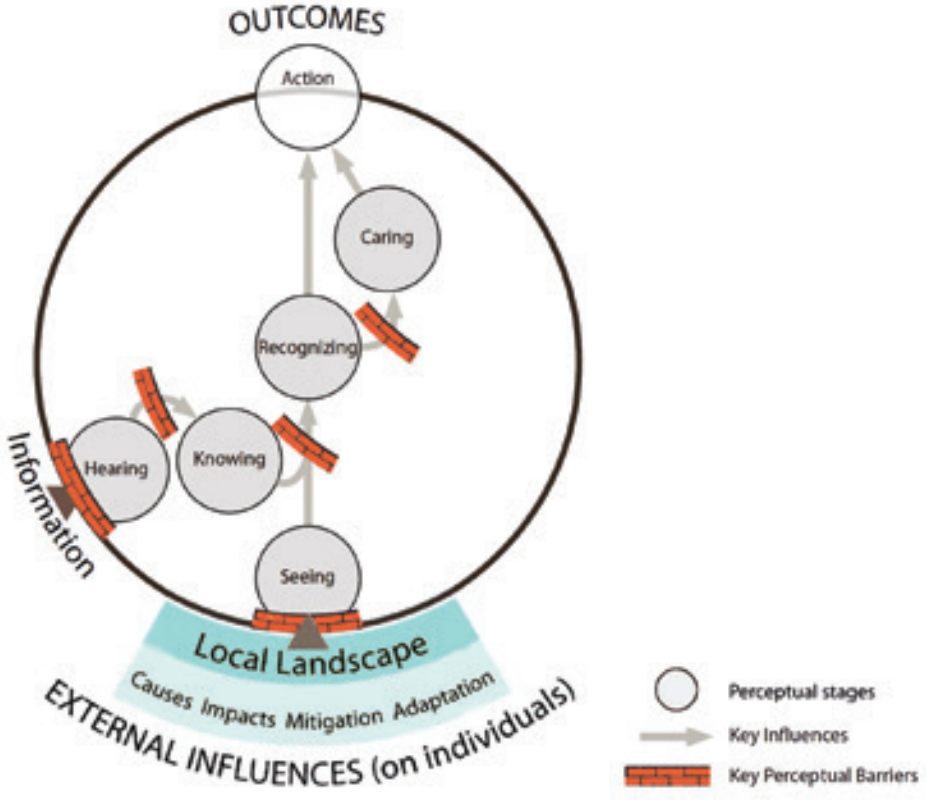


Figure 2. The Community Awareness-to-Action Framework (Sheppard, 2012)

Potential of visual media

As the saying goes, "a picture says more than a thousand words"; visual imagery is a powerful stimulus (Sheppard, 2012). Sheppard (2012) emphasizes the fact that people's perception can effectively be influenced by visual media. Visual media can help to overcome the perceptual barriers and influence people's level of awareness. Visualisations have the power to alter people's interpretations of complex concepts, such as climate problems (Nicholson-Cole, 2005; Bishop & Lange, 2005). They can give people the chance to recognize the impacts of climate in

the city, and therewith make the step from the stage of 'seeing' to 'recognizing' in Sheppard's Awareness-to-Action Framework (2012). Baldwin & Chandler (2010) conclude in their research that visual images have the capacity to communicate and convey multi-layered meanings, and are therewith effective in raising awareness and challenge the intention to act.

The local landscape is the main stage for raising awareness according to the Awareness-to-Action framework. Sheppard (2012) distinguishes four segments of climate change in the landscape: Causes, Impacts, Mitigation and Adaptation (CIMA). Sheppard emphasizes the need to deal with the whole system. Next to making the impacts of climate change known, there is a need to act on the causes and address the 'cure', which concerns mitigation and adaptation. Sheppard (2012) points out that it is very important to tell what can be done about climate change consequences. Moser (2014) confirms the importance of visualising adaptation options, instead of only emphasizing the risks. **Accordingly, it is important to reveal the occurring climatic problems and their solutions in visualisations.**

Climate revelatory design

A chance to take Sheppard's recommendations a step further, is climate-revelatory design. This concept is derived from the established concept eco-revelatory design. Eco-revelatory design can be described as a design strategy in which ecosystems are enhanced by revealing ecological and cultural phenomena, processes and relationships, to engage users (Arısoy, 2013). Through such design people are able to experience the ecological processes in their daily life, feel and learn what these processes do for them and their cities (Koh, 2013). Eco-revelatory design can bring to light processes that usually remain unseen and forgotten (Arısoy, 2013). These processes to be revealed, can be also the climatic processes in the city, such as heat retention or the route of water in the city. Climate revelatory design carries the potential of making the invisible visible or tangible, and by that overcoming the barrier of invisibility and lack of immediacy.

Climate revelatory design can be expressed in the form of **climate revelatory visualisations.** Such visualisations might support the approaches recommended by Sheppard (2015). They might accomplish behavioural change with an increased personal experience, creation of place attachment, establish a new norm and enhance learning about the climate. Nicholson-Cole (2005) points out the significance of visualisations in revealing the climate, since it can "bridge the gap between what may seem an abstract concept and everyday experience, making clearer its local and individual relevance". In that sense, visuals itself can reveal climate processes, which otherwise remain invisible for laymen. Abstract concepts can be shown with visualisations in a way laymen comprehend and connect to their direct environment (Nicholson-Cole, 2005).

Next to revealing the problematic microclimate processes, climate revelatory visualisations carry the potential to reveal adaptation measures. Roggema (2009) states that "design is capable to make abstract numbers and unimaginable sentences visible in what climate change implies for inhabitants and visitors".

He is convinced that design plays a central role in shifting minds (Roggema, 2009). Daan Roosegaarde shares this vision, as he states that “a good design can shift the minds, it can change the feeling of what we think is normal and what is not” (Roet, 2016). Van Dijk (2011) states that the way design is communicated affects people’s frame of reality, and can therewith alter people’s perception of a specific land use. The question is, if design is that powerful that it can shift people towards acting upon climate problems. Design can showcase how climate adaptation and a future world might look like. This can be done in a tangible (implemented) or intangible (visualizations) way (Roggema, 2009). Visualisations can show people future possibilities by provoking their imagination; it is a method for showing the unseen (Lewis, Casello, & Groulx, 2012). Schroth et al. (2015) affirm that landscape visualisations can help people understand alternative future conditions.

In addition, visualisations can function as means to increase public involvement. It is a valuable way to improve communication between planners and designers and the involved user group (Lewis et al., 2012; Schroth, Pond & Sheppard, 2015). As a communication tool, visualisation can have an educating function and contribute to an improvement of awareness about complex environmental changes and therewith may provoke behavioural change (Sheppard, 2005; Lewis et al., 2012). Visualisation techniques can achieve common ground and can result in more ‘bonding’ among participants, which implies more cooperation of participants than usual with local planning activities (Baldwin & Chandler, 2010).

Effective climate revelatory visualisations

The literature describes which ingredients visualisations should include in order to be effective in raising climate awareness. From van der Linden, Maibach, & Leiserowitz (2015) we can learn that public engagement on climate change can be enhanced to overcome perceptual barriers (Sheppard, 2012; Moser, 2010; Roenhovde Tiller and Schott, 2012). Van der Linden, Maibach and Leiserowitz (2015) identified five best practices for policymaking to improve public engagement with climate change. Despite the fact that these do apply for policymaking, they are relevant as guidance for climate revelatory design as well. The main strategies to enhance involvement are:

- *Facilitate more affective and experiential engagement.* Climate problems are now communicated in an abstract and analytical way. The human brain privileges experience over analysis. Information needs to be connected to people’s feelings and experiences.
- *Help promote collective efficacy.* Certain social group norms can be promoted to steer a community to behave accordingly. These norms can embody that it is normal to think about and adapt on the urban climate problems. Behaviour change is more likely to happen when such social norms are promoted within a community. (Baldwin & Chandler, 2010) substantiates that a shared sense of values is required to accomplish collaboration and collective action.
- *Out of sight, out of mind.* Make clear that climate change is a present, local, and personal risk. Highlight the fact

that climate change impacts are already happening. Emphasize local risks and impacts for the specific location.
- *Frame it differently.* Instead of showing what the negative impacts climate change can entail, show the positive benefits and the gains of immediate action. Also Derkzen, van Teeffelen & Verburg (2017) recommend to provide information on the benefits.
- *Appeal on the long term.* People's intrinsic motivation is to care about the well-being of others and the environment. Anticipate on this by motivating with valued long-term environmental goals and outcomes, such as a safe and comfortable living environment.

These general recommendations give insight in what the drive should be behind whatever action will be pursued to improve public engagement. Sheppard brings it a step further by focusing on how these aims can be achieved by visualisations. Sheppard (2005, 2012) shows how people are affected by imagery and how visuals can compel people to change their behaviour. Moreover, the visualisations should reach the emotional side of the viewer, in order to raise enthusiasm and eventually motivate or compel to act. Therefore, Sheppard (2005, 2012) argues that the following aspects are important in the visualisations.

- Realism (photorealistic imagery to make abstract concepts concrete)
- Personal relevant environments (relatable and strong association)
- Immediacy of impacts (show conditions that can occur in the near future)
- Strong affective content (such as people or symbols which evoke stronger and affective responses)
- Demonstrating future consequences of people's actions or inactions
- Immersion in a virtual environment to intensify the experience (e.g. through the use of large images or panoramic displays)
- Dynamic or animated imagery, which are eye-catching (Sheppard, 2012), and can clarify environmental change in the landscape and its future (Bishop & Lange, 2005). Nicholson-Cole (2005) substantiates that animated images are powerful and efficient tools in climate change communication
- Interactivity (e.g. with multi-dimensional landscapes in which users can navigate through time and by theme (Schroth et al., 2015))
- Disclosure of the positive and negative outcomes on the local scale in the future. Provide disclosure on implications of the climate, also non-visible info, for scientific and logical underpinning of the visualisations (Sheppard, 2005)
- Drama (a vivid and compelling presentation with emotional content)

Sheppard (2015) summarizes the recommendations by composing five general guidelines for engaging communities with visualisations in a responsible and effective way. These guidelines can help ensuring the visualisation of its effectiveness in raising awareness about the urban climate.

- Make climate change easily seen and understood **(clarity)**
- Link climate change to people, place and context **(connectivity)**
- Keep the process interesting and inclusive **(engagement)**
- Keep the presentations honest, balanced, and verifiable **(trust)**
- Keep the engagement practical and cost-effective **(feasibility)**

The literature provided an extensive amount of recommended aspects which have to be present in climate revelatory visualisations in order to be effective in raising awareness. These aspects are established in four representing criteria: engagement, clarity, connectivity and trust (figure 3). The visualisations are expected to be most effective in raising awareness if they embody these criteria. The four criteria correspond with Sheppard's general guidelines (2015) and are complemented with recommendations by Sheppard (2005, 2012), Nicholson-Cole (2005), Van der Linden, Maibach and Leiserowitz (2015) and Derkzen, van Teeffelen & Verburg (2017). Sheppard's (2015) fifth guideline 'feasibility' is incorporated in the criterion 'trust'. Feasibility is less prominent in the criteria, since this aspect concerns the adaptation measures, instead of the design of the visualisation.

Engagement	▪ Immediate experience ▪ Interesting and inclusive ▪ Immersion in virtual environment ▪ Dynamic imagery (time/processes/change) ▪ Drama (vivid & compelling presentation)
Clarity	▪ Easily understandable ▪ Disclosure
Connectivity	▪ Strong affective and emotional content ▪ Personal relevant environment (local risk emphasized)
Trust	▪ Realistic (photorealistic & lifelike imagery) ▪ Verifiable (based on scientific info and honest) ▪ Feasible (practical & cost effective)

Figure 3. Criteria for climate revelatory visualisations

1.3 KNOWLEDGE GAP

The literature points out that visualisations are a very powerful tool in engaging communities with the climate around them, and therewith can raise people's awareness level (Nicholson-Cole, 2005; Sheppard, 2012; Roggema, 2009). Scientific knowledge needs to be translated into comprehensible visual imagery to engage users (Sheppard, 2012; Moser, 2014). However, this visual medium is not made use of sufficiently, according to Sheppard (2012, 2015). Sheppard (2012) states that the examples of "systematic attempts with visual media to reveal the face of climate change over time in local communities" are still rare. Landscape architects can play a key role in engaging the public by connecting climate adaptive design with the local landscape and community. Climate revelatory visualisations have the potential to communicate climate problems and solutions, and therewith bridge the gap between scientific knowledge and laymen. Accordingly, this research examines the potential of the newly defined concept climate revelatory visualisations. Sheppard's recommendations of engaging people with the climate's impact (2005, 2012, 2015) will thereby be taken into practice.

Furthermore, visual media should not only reveal the climate's impact, but show what can be done about it as well, in order to motivate people for climate adaptation. It is important to let communities know what the impacts and their solutions for their local environment are. The climatic processes in the city are often subtle changes, which are not recognized by laymen (Sheppard, 2015). However, the causes and mitigation tools are most visible in Western media (Sheppard, 2015). Adaptation options are not well enough presented yet in visualisations. This research fills this gap by generating knowledge on how climate adaptation can be revealed in visualisations.

Perceptual barriers now block people's perception of climate, since the climate processes are not visible in their immediate environment. Climate change is often seen as a distant problem and people therefore feel a lack of responsibility. The impacts need to be shown in a personal relevant environment in order to connect with people's daily life. However, Sheppard's recommendations are now only elaborated in visualisations emphasizing climate change in general. Existing examples of visual media in Sheppard (2012) mostly reveal the climate change impact, by the use of photos of melting glaciers, photo collages with use of simple cutting and pasting, virtual 3D landscapes or geo models.

Therefore, this research addresses climate change in the local environment; the urban climate. Problems in the urban climate, such as heat stress, take place, which can be solved with simple adaptation measures. Currently, most inhabitants in the Netherlands do not have enough knowledge of climate adaptation to come into action. The urban climate needs to be brought to the attention of Dutch citizens in order to evoke behavioural change. By revealing the urban climate problems and solutions on a small scale, the climate is brought into the personal environment. Therefore, this research examines how

the urban climate problems and solutions can be communicated.

The literature provided recommendations of what aspects should be incorporated in climate communication (Schroth et al., 2015; Sheppard, 2005, 2012; Van der Linden, Maibach & Leiserowitz, 2015)). Animated imagery is promoted as powerful tool by Bishop & Lange, 2005; Nicholson-Cole, 2005; Sheppard. 2012), as well as added non-visible information for more disclosure on the climate's effects (Derkzen, van Teeffelen & Verburg, 2017; Sheppard, 2005). These recommendations can be seen as design hypotheses, which presume what kind of style are effective for climate revelatory visualisations. It is not known yet if these assumptions are valid. Accordingly, this research attempts to fill the gap of knowing if dynamic imagery and added information are beneficial for climate revelatory visualisations.

In summary, this research contributes to filling multiple gaps in the scientific field. It is important to explore the potential of revelatory visualisation whereby the urban climate problems and solutions on a local scale can be communicated with inhabitants. Assumptions derived from literature, such as dynamic imagery and added non-visible information can be incorporated in that research in order to find out their effectiveness in engaging people with the climate around them.

3 RESEARCH DESIGN AND METHODS

2.1 RESEARCH OBJECTIVE

The theoretical framework shows that visual media have the power to influence people's perception of climate change impact. Climate revelatory visualisations are a promising tool to reveal invisible aspects of the climate in people's direct environment. They can give people the chance to recognize the impacts of climate in the city, and therewith make the step from the stage of 'seeing' to 'recognizing' in Sheppard's Awareness-to-Action Framework. In that way, people's awareness level can be positively influenced by the displaying and revealing of climatic processes in visualisations. Raising the level of awareness about the urban climate is expected to result in more understanding of the problem, more willingness to adapt and more public support towards local planning efforts. Multiple aspects of the visualisations determine the effectiveness of the visual on the receiver's climate awareness. This research tests the effectiveness of the design hypotheses that animated imagery and a graphic overlay in climate visualisations.

My basic assumption is that visualisations revealing climate problems and solutions and which meet the criteria engagement, clarity, connectivity and trust, can raise people's level of urban climate awareness. This research examines the potential of such climate revelatory visualisations and its impact on urban climate awareness.

2.2 RESEARCH QUESTIONS

The main research question focuses on the relation of climate revelatory visualisations with raising awareness. The two sub research questions aim to answer the main question by asking for a way to visualize on the one hand the occurring urban climate problems (SQ1) and on the other hand the climate adaptive solutions (SQ2).

Main research question

How can visualisations, revealing urban climate problems & solutions, raise awareness about the urban climate among inhabitants of dhl-neighbourhoods?

Sub question 1

How can visualisations reveal occurring urban climate **problems,** considering *engagement*, *clarity*, *connectivity and trust*?

Sub question 2

How can visualisations reveal climate adaptive **solutions**, considering *engagement*, *clarity*, *connectivity and trust*?

2.3 CONTEXT

The urban climate needs to be brought to the attention of urban inhabitants, in order to accomplish more climate adaptation. Revelatory visualisations can convey this message by revealing the climatic problems and solutions. The literature shows that more engagement can be achieved among people by evoking a strong association with their personal living environment (Sheppard, 2005, 2012; Van der Linden, Maibach and Leiserowitz, 2015). This research therefore focuses on a case where urban climatic problems occur and need to be solved by the community. The climate visualisations can then be revealed to its corresponding community in order to evoke behavioural change.

Urban climatic problems such as heat stress and water accumulation occur in urban areas which are densely built, due to their many paved and built up surfaces. The urban typology 'dense historic labourer's neighbourhood' is suitable as research context, since it exists in many cities in the Netherlands. Assendorp, a dense historic labourer's neighbourhood, is taken as subject for the climate revelatory visualisations in this research.

Dense historic labourer's neighbourhood

The urban typology that is taken as context in this research is defined as the 'dense historic labourer's neighbourhood' (dhl-neighbourhood), based on its spatial and historical characteristics. This typology is characterized by middle high closed urban blocks with little greenery (Kleerekoper, 2016; Kluck et al., 2017). The dhl-neighbourhoods are built in most middle and big cities in the

Figure 4. dhl-neighbourhoods in the Netherlands

Netherlands from 1880 to 1910, mainly functioning as residence for the labourers who came work for newly built factories in the cities. These neighbourhoods are therefore being called "arbeiderswijk" (labourer's neighbourhood) in Dutch, although the inhabitants of these neighbourhoods are mostly not from a low social class anymore. The houses are built in high density in order to accommodate as many residents as possible, which has resulted in narrow streets and backyards. The dhl-neighbourhoods can be characterised by their monotonous building style, long rows of houses, no front yards and minimal public greenery. Dhl-neighbourhoods in the Netherlands show many similarities in typology, dimensions, colours, roof shapes, material, demography and location in relation to the city centre. Since this urban

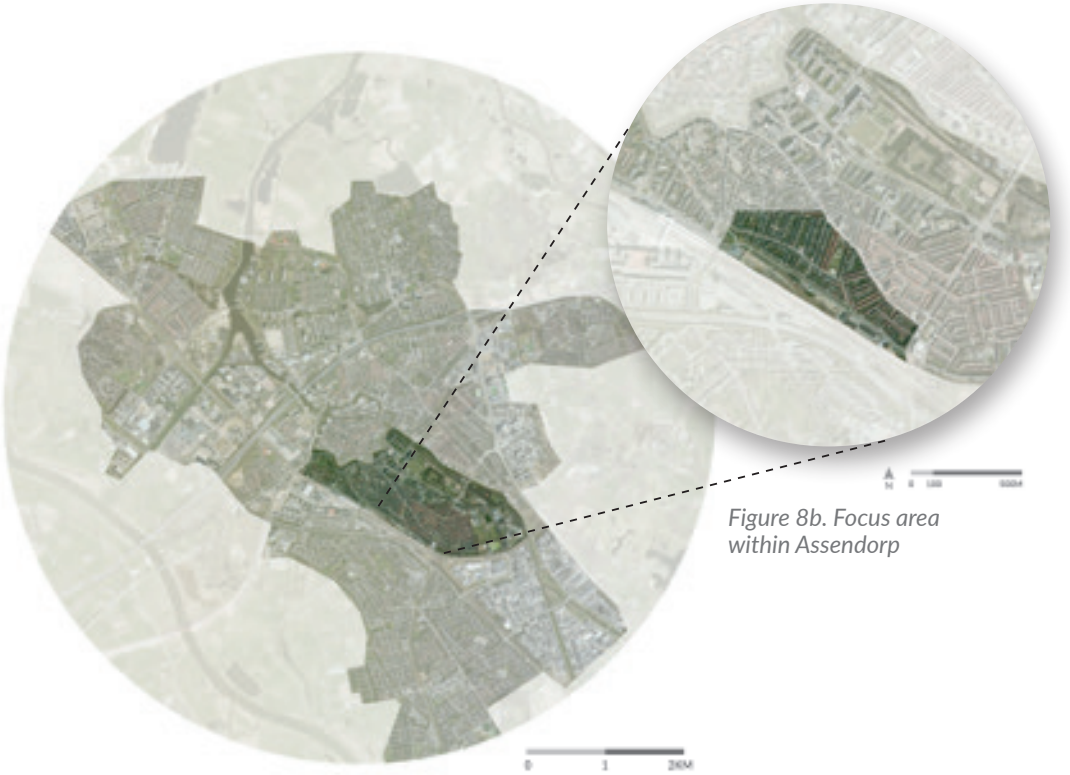


Figure 8b. Focus area within Assendorp

Figure 8a. Location of Assendorp within Zwolle

typology is common throughout the Netherlands, the outcomes of this research are relevant for other similar neighbourhoods. In figure 4 the many dhl-neighbourhoods in the Netherlands are displayed.

This spatial design is very sensitive for heat and water accumulation, due to its narrow streets (with a high height/width ratio), many paved surfaces and little greenery. The challenge is to cope with these urban climatic problems and make these residential areas climate adaptive. Therefore, it is relevant to make the subtle and sometimes 'invisible' climate processes recognizable for the inhabitants of dhl-neighbourhoods.

Assendorp

The neighbourhood Assendorp in Zwolle is a typical example of a dhl-neighbourhood. This location suffers from heat stress during hot days and water accumulation during peak rainfall events, which are described according to figure 9 to 20. However, only minor action is taken to adapt to these climate problems. Therefore, this is an ideal test-case for revealing urban climate problems and solutions. Knowledge of how visualisations can have an influence on awareness, can be applied by testing it onto this case. The generation of knowledge here can afterwards be applied to similar dhl-neighbourhoods as well.

Assendorp is a neighbourhood in the Dutch city Zwolle. The neighbourhood is located on the South-Eastern side of the city centre (figure 8a), and is characterised by early 20th century labourers' houses (figure 5-6-7). The streets are narrow and mainly paved. The community, with various backgrounds and ages, is eager to think about the neighbourhoods' possibilities. Also, the municipality of Zwolle has ambitions to develop this neighbourhood and the whole city into a climate adaptive one. A focus area (figure 8b) within Assendorp is chosen based on the most intense problems as regards the heat and water problems.

Figure 5, 6, 7. Characteristics of Assendorp

Urban climate of Assendorp

The case Assendorp is analysed on its urban climate. This analysis is used to determine the test beds, the specific locations for which the revelatory visualisations are made.

All aspects of the design case (Assendorp) are analysed and documented, which is done by mapping and looking into information provided by the municipality and online sources. The main problems that ask for attention in Assendorp are heat stress in the summer and water accumulation during peak rainfall events.

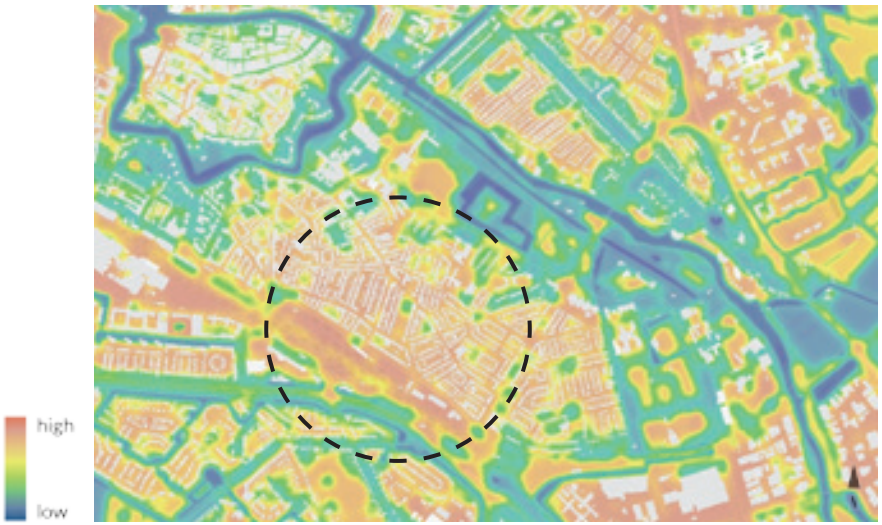


Figure 9. Air temperature map of Zwolle (Tauw, 2013)

Figure 10. Average of greenery per housing block

Heat stress

The air temperature map (figure 9) shows high temperatures in Assendorp, compared to the rest of the city. These high temperatures are caused by the many heat retentive surfaces which are present in the neighbourhood. These temperatures will even intensify due to climate change. The scenarios for temperature rise in the Netherlands predict an increase of 1,3-3,7˚C. (figure 11).

The grey-green percentage map (figure 10) shows the division of paved surfaces versus green surfaces. This analysis is made by mapping the green surfaces from a raw indication of a satellite photo in Adobe Photoshop, of which the percentages could be calculated. This map confirms the high average percentage of paved surface. The average of greenery per housing block is around 15%. This is low according to other researched neighbourhoods with an average of 25% (Zhang, 2017).

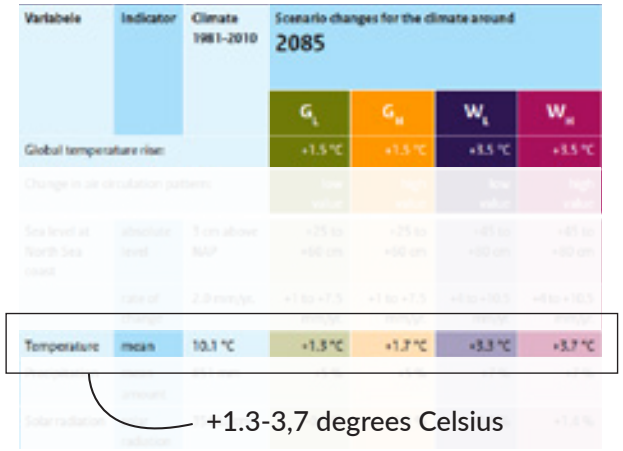


Figure 11. Predicted temperature rise for the Netherlands (KNMI, 2015)

Figure 17. Street orientation towards the sun

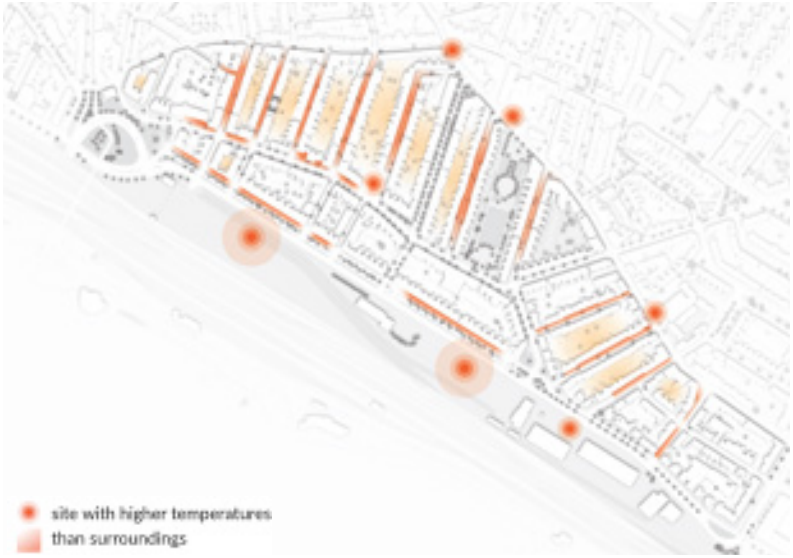


Figure 18. Hotspot map

Figure 12-16. Many paved surfaces in the streets and backyards of Assendorp

The photo inventory of the neighbourhood confirms this situation, they show a 'grey' ambiance of many stones and minor greenery (figure 12-16). In addition, many streets are oriented to the South, mainly SSW-NNE & SW-NE (figure 17). As a result, have many hours of direct sunlight during the summer.

The many heat-retentive surfaces cause much longwave radiation at night. The paved surfaces absorb heat during the day from direct sunlight, and radiate this heat at night (Lenzholzer, 2015). This contributes to the 'urban heat island' effect, which is also present in Assendorp (Tauw, 2013). Moreover, the neighbourhood has a lack of shade which causes extra heat stress during the day.

This information is combined in one map, revealing the potential 'hot' spots in Assendorp (figure 18).

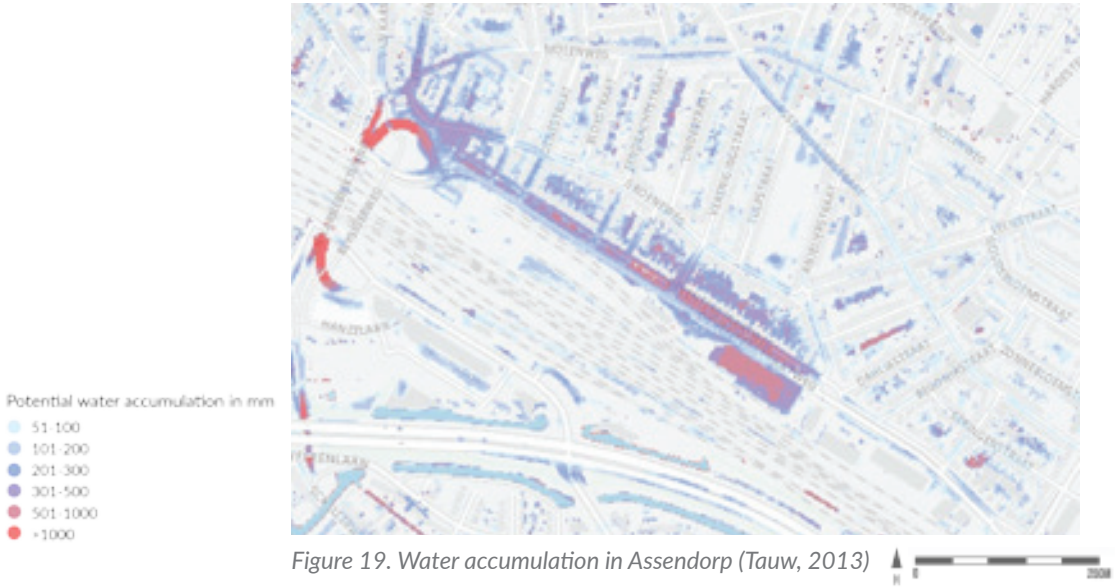


Figure 19. Water accumulation in Assendorp (Tauw, 2013)

Water accumulation

Extreme rainfall for Assendorp means a shower of more than 50mm/day, which now happens on 10 days per year. An extreme shower of, for example, 100mm/day has a repetition time of ±5 years (KNMI, n.d.). The neighbourhood cannot cope with too much rain in a short time, which causes accumulation at the lowest point (figure 19). Moreover, the repetition time of such extreme rain showers will shorten, since the total precipitation in the Netherlands will increase with 5-7 percent, which means an average of 894-911 mm per year (figure 20).

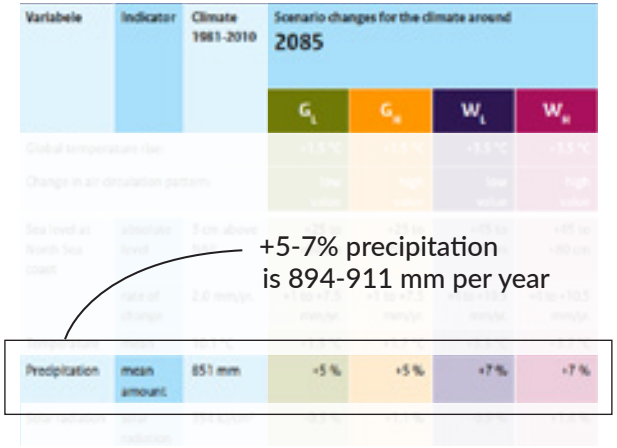


Figure 20. Predicted precipitation increase for the Netherlands (KNMI, 2015)

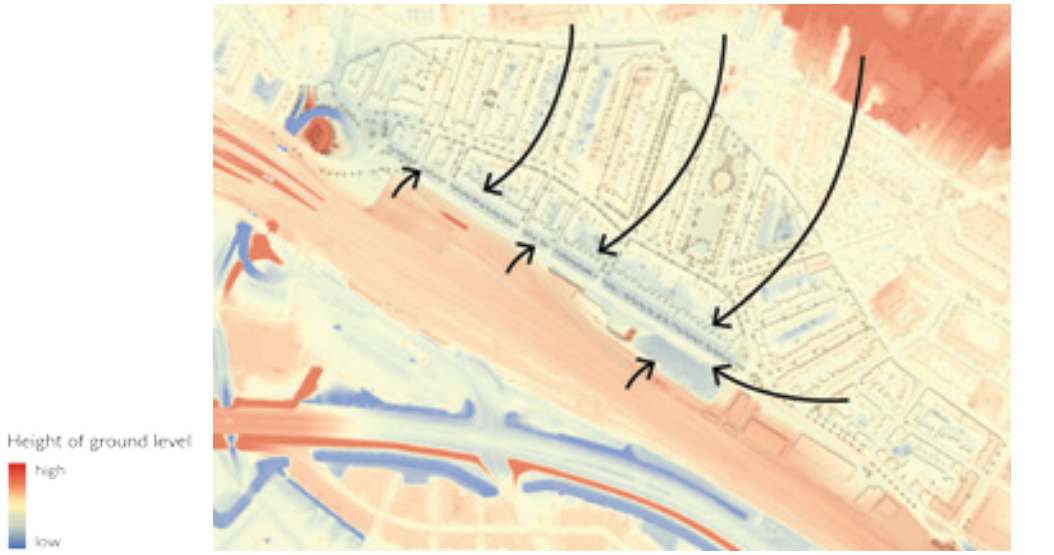


Figure 21. Elevation map revealing the height difference in Assendorp, causing rainwater to drain to the lowest point.

The analysis shows that accumulation is mainly caused by an outdated drainage system. Additionally, a delayed infiltration reaction occurs due to abundant paved and built-up surfaces. Moreover, a sloping of the ground level in the neighbourhood from North to South influences the water drainage. This slope ranges from 2,5m to 0,8m above NAP, which is a 1,2 to 2,2m difference overall (figure 21).

All information is combined in the ‘water problem map’ (figure 22).

Possible solutions

The main spatial configurations that can be adjusted are the many paved surfaces, the lack of greenery, the direct sunlight, high housing density and the many cars in the streets.

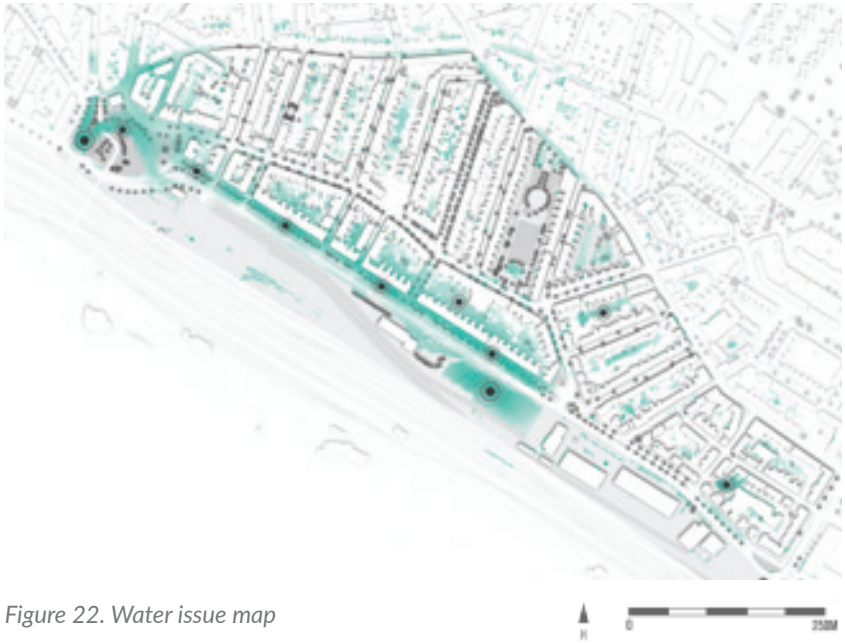


Figure 22. Water issue map

Test bed identification

To be able to apply visualisations on a certain spot in the case, test beds are identified. The test beds represent the most characteristic and problematic spatial configurations of the case. The urban climate analysis carries the knowledge of the most problematic sites in Assendorp. Therefore, the summary maps of heat and water problems are compared. The analysis has resulted in five problematic spatial configurations in the case of Assendorp.

These five test beds consist of four types of streets and one average size backyard. Every test bed has its own characteristics, differentiated based on their orientation, height-width ratio and presence of front yards (specifications of every test beds can be found in appendix I).

The climatic problems of the different street types are very similar. To prevent too much repetition and therewith irrelevance of test beds, only the two most relevant test beds are elaborated into visualisations. The most prominent types are a street with a height/width ratio of 1:1,5 and the backyards (figure 23). These test beds are the most representative for the whole neighbourhood and are the sites where adjustments are most needed.

The chosen street test bed is the most common and average of all, and therefore most representative for Assendorp and other dhl-neighbourhoods. The test bed is similar to streets in Assendorp such as the Lindestraat, Van Ittersumstraat, Tulpstraat,

Figure 23. Location of the chosen test beds in Assendorp

Anjeliersstraat and the Klimopstraat. The orientation of the streets is for roughly 70% SSW-NNE, which is as well common in Assendorp. The other streets have a slightly higher or lower height/width ratio or are only characteristic for Assendorp and not for other dhl-neighbourhoods.

The two chosen test beds are different in many ways, such as spatial configuration, ownership and function. This makes it suitable for the research to reveal different climatic problems and interventions. In this way, I can represent a public and a private area, which makes the visualisations relevant for different target groups, namely inhabitants and municipals. This makes the research also generalizable for other dhl-neighbourhoods in the Netherlands. Moreover, it is intended to be clearer for the survey respondents when they are exposed to two very specific and different sites.

***Street** (figure 24)*

For this test bed the problems and solutions for the public space in the street can be revealed. In that sense, it has a focus on the awareness of its inhabitants, but also municipals who can make plans for its development. In the street, I can show how the urban climate behaves in the city outlines and how adaptation measures can look like when implemented.

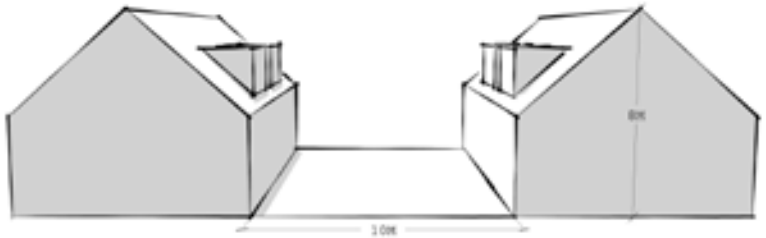


Figure 24. Dimensions of test bed: street

***Backyard** (figure 25)*

This test bed shows private property, and therefore has a main focus on the inhabitants' awareness of interventions in private property. The aim is to convey how they can contribute and make a difference themselves. They should have a stimulating function and encourage citizens to come into action themselves. Therefore, the solutions should be feasible, realistic and low in cost to be of value for the inhabitants.

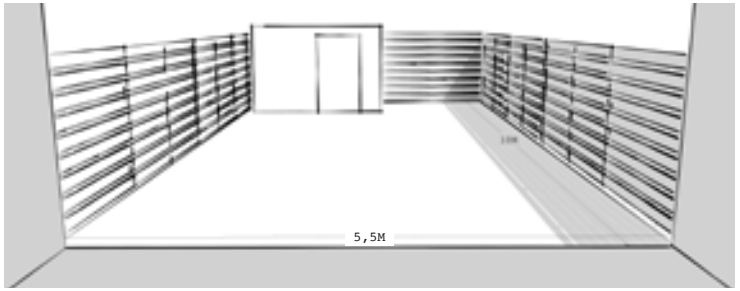


Figure 25. Dimensions of test bed: backyard

2.4 METHODS

This chapter clarifies how the research questions are answered and how the revelatory visualisations came into being.

Knowledge claim

This research is embedded in a pragmatic knowledge. In a pragmatic knowledge claim the emphasis is on the research problem, and all approaches are used to understand the problem (Creswell, 2014). The research problem asks for an integration of knowledge of different aspects, namely a spatial (climate revelatory design) and a social aspect (awareness). Mixed methods are used to be able to answer the research questions. A research-through-designing process is conducted to be able to answer the research questions. This can be seen as fitting to the constructivist knowledge claim, since it suggests new constructs and generate something new (namely climate revelatory visualisations). The visualisations are tested in the community, which fits within the participatory knowledge claim (Lenzholzer, Duchhart, & Koh, 2013). The inquiry of the test in the community resulted in quantitative and qualitative data. The visualisations are evaluated based on this data, in order to verify or falsify certain design hypotheses (e.g. that a graphic overlay is effective). Revisions of the visualisations are made according to this data, which implies that also a post-positivistic knowledge claim is adopted (Creswell, 2014). A combination of these three knowledge claims in one research results in a pragmatic knowledge claim throughout this thesis research.

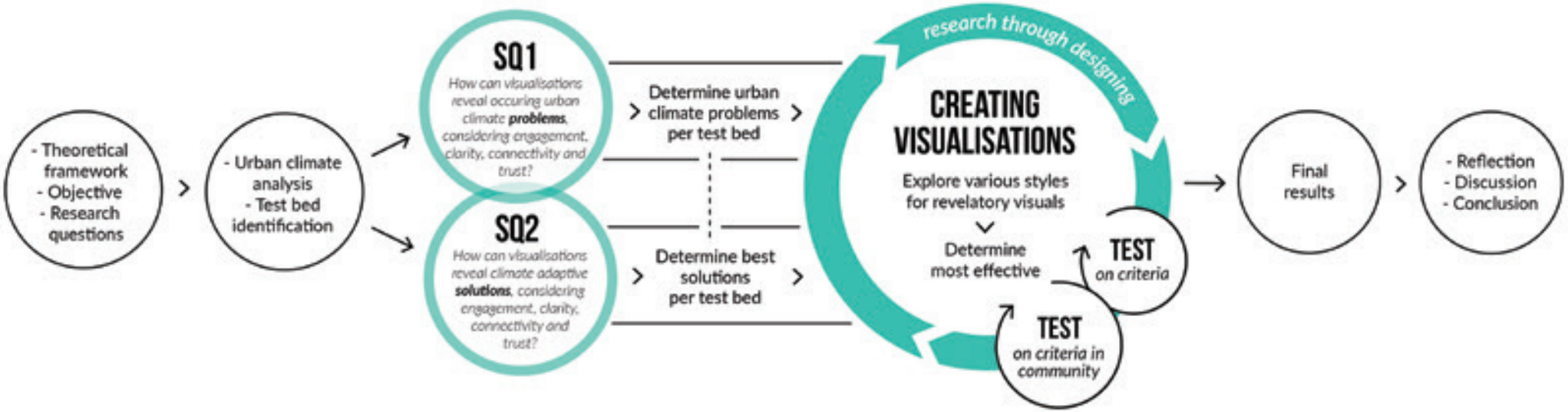


Figure 26. Research process

Research process

The process of finding the answers to the research questions is illustrated in figure 26. The sub research questions ask for visualisations of on the one hand urban climatic problems (SQ1), and on the other hand the climate adaptive solutions (SQ2). The problems and solutions are found in a preliminary literature study and context analysis. Although the content of these visualisations differs, the style of the visualisations is determined through the similar 'research through designing' process.

In this research through designing process, climate revelatory visualisations are generated which incorporate assumed theories based on the literature. The visualisations are tested on the criteria engagement, clarity, connectivity and trust by the means of an inquiry amongst the community of Assendorp. The test results are used to improve the visualisations, which results in the final results. The main research question is answered based on these final results.

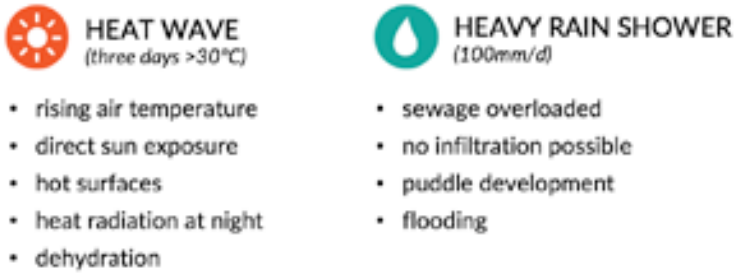


Figure 27. Most extreme urban climate problems in Assendorp

	PROBLEM	CAUSE	WAY TO SHOW
Street	**Water** accumulation	× Old fashioned drainage; sewer system getting overloaded × No infiltration possible	Flood, puddle development, no infiltration, sewage full, udometer fills up
Street	**Heat** retention	× Temperature rises during heat wave × Direct sun exposure × Paved surface absorbs heat and radiates this at night × No greenery for cooling	Hot surfaces, sun exposure, dehydration, heat radiation at night, rising temperatures, comparison rural areas
Backyard	**Water** accumulation	× Withhold of infiltration by 'bad' garden setup × No storage possible	Flood, puddle development, no infiltration, udometer fills up
Backyard	**Heat** retention	× Temperature rises during heat wave × Paved surface absorbs heat and radiates this at night × Lack of greenery × Direct sun exposure	Hot surfaces, sun exposure, heat radiation at night, rising temperatures

Figure 28. Overview of climatic issues in Assendorp, and how these can be revealed

Answering SQ1: determining urban climate problems

Sub question 1 concerns what type of visualisations can reveal the occurring urban climate problems. The occurring problems are derived from the site analysis and are directly translated into the content for the visualisations.

The site analysis displayed what climatic problems occur in the neighbourhood Assendorp. These problems exist mainly of heat stress during hot summer days and water accumulation when extreme rainfall occurs. The climatic impacts that occur in Assendorp are too subtle for inhabitants to recognize, since these are blocked by perceptual barriers (chapter 1.2) Accordingly, the visuals are ought to be most effective when they show the moment of an extreme weather event. At these extreme weather events the climatic problems appear most intense and noticeable. In the case of Assendorp, these events are a day with an extreme amount of precipitation (100mm/day) or a day during a heatwave when the temperatures rise above 30˚C (figure 27).

By showing an extreme weather event, a clear difference can be made between the situation when no adjustments are made and the same situation when the right climate adaptation solutions are implemented. In figure 28 I described which specific problems occur at the two test beds and which effects can be revealed in the visualisations.

Answering SQ2: determining best adaptive solutions

Sub question 2 concerns how visualisations can reveal climate adaptive solutions, which can solve the found climatic problems from SQ1. An inventory of the most suitable solutions was made from the climate adaptation tools known. These solutions are found in literature (books and articles) and on websites (e.g. Lenzholzer, 2015; Kluck et al., 2017; Amsterdam Rainproof, 2017; Atelier Groenblauw, 2016). The collected solutions are sorted on their functionality and effectiveness (the complete chart can be found in the appendix II).

Solving heat problems consists of cooling, provision of shadow and generation of evaporation. For solving water accumulation, providing rainwater infiltration, storage and/or drainage are the most effective. Next to that, it is important that the solutions shown are feasible and low in costs, according to the criteria trust (Sheppard, 2015). Furthermore, an easily understandable communication of the solutions lowers laypeople's threshold to come into action.

After the suitable solutions were collected and ranked, the solutions are matched to the occurring problems per test bed. I looked into what specifically needs to be revealed per test bed and which solution from the list is most suitable for this. The results are described in figure 29. This figure is used to determine what solutions should finally be shown in the visualisations. In the research through designing process later on, is looked at what combination of solutions is most optimal to reveal in the visualisations. This combination is not only based on functionality, but also on its visual appeal, clarity, engagement and connection with the audience.

	VISUAL MUST REVEAL	SUITABLE SOLUTIONS
Street	**Water** can quickly drain	× Infiltration: depave, permeable paving, more infiltration surface, bioswale × Drainage: (open) runnel, bioswale, water playground × Storage: trees, green facade
Street	**Heat:** improved thermal comfort	× Shadow: canopy/louvre/awning, street trees × Cooling: green facades, less heat retentive materials, less cars, 'uchimizu', trees/plants with high evapotranspiration
Backyard	**Water** can gradually and naturally dissolve	× Infiltration: pond, plants, grass, crates, depave, semi paved (gravel, woodchips, shells), permeable paving × Storage: pond, barrel, fence (multifunctional with tap), green roof on shed (sedum) × Drainage: relief, detach pipeline
Backyard	**Heat:** improved thermal comfort	× Shadow: pergola, trees × Cooling: depave, permeable paving, perennial plants with large leaves, trees, green roof on shed (intensive)

Figure 29. Overview of suitable solutions per test bed

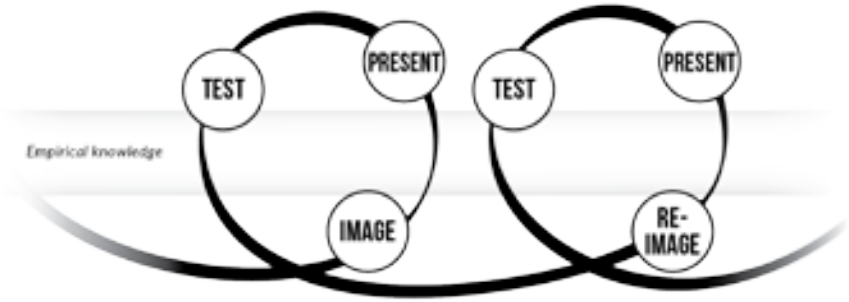


Figure 30. Research through designing model based on Zeisel (1984)

Creating the visualisations

The climate revelatory visualisations were generated through a process of 'research through designing' (RTD). Designing is used as a tool to make problems spatial and visual and to generate solutions (Nijhuis & Bobbink, 2012; Lenzholzer et al, 2013). RTD was the main approach to generate new knowledge, namely: how climate revelatory visualisations can look like in order to contribute to awareness raising.

Research through designing is used to determine the most effective style for the climate revelatory visuals. In this process, multiple alternatives were tried out and reflected upon to come to an optimal final product. In the literature many examples can be found of how visuals can be deployed to achieve certain goals (e.g. Lewis et al., 2012; Mertens, 2010; Pettit, Raymond, Bryan, & Lewis, 2011). These resources were used to inform the trial-and-error process in which diverse forms of visualisations were tried out to determine the most effective one. Continuous reflection supports this process, in which the unconscious use of knowledge becomes explicit (Schön, 1993). The reflection can help improve decisions, evaluate, summarize, brainstorm, refine and help gaining new insights (Gray & Malins, 2004).

A clear explanation of how research through designing was carried out in this phase can be given through the spiral model of Zeisel (1984, figure 30). In this model, the iterative design process is composed of three activities, namely imaging, presenting and testing. The empirical knowledge expands with every next iteration. The RTD process was iterative in which former knowledge informed the latter and continuous reflection enriched the knowledge generation (Nijhuis & Bobbink, 2012).

In this research, these activities involved the following actions:

Image: generate the way of visualising climate problems and solutions (the idea or internal image) by brainstorming about the creation of alternatives in terms of visualisation style, abstraction level, software, illustrations, etc.

Present: create the visual, from sketch to complete digitally rendered image, and thereby making the image ready to externalize and communicate.

Test: test the visual by a continuous evaluation on the pre-defined criteria and test it in the community, to find out what aspects of the visual score best on criteria.

By practising this model, alternative visuals were generated and consecutively tested upon the criteria. The model was run through multiple times. The repeated review of the visuals is critical to achieve an optimal final product. This method created an *iterative improvement* of the design: the revelatory visualisations.

The style of the visualisations

During the RTD process is continuously questioned what type of visualisations are most effective in raising awareness. Multiple design hypotheses, based on literature, are incorporated in the revelatory visualisations in order to verify their effectiveness. How these hypotheses are elaborated in the visualisations is decided throughout the research through designing process.

The visuals have an **eye level perspective**, since this viewpoint close to the ground makes the visualisations more personal. To make the experience of the viewer most inclusive and immersive, a **high level of realism** is opted. Higher levels of realism are desirable, since the image connects more to the viewer's experience of the world (Bishop & Lange, 2005; Nicholson-Cole, 2005; Sheppard, 2012). Accordingly, realistic photo material of the current situation was adjusted to the desired image that reveal the problems or solutions, using Adobe Photoshop.

Although realistic images are recommended, some **drama** is added by slight exaggeration. This attracts people's attention and can motivate them to act (Nicholson-Cole, 2005). The most extreme weather events are displayed to ensure the dramatic effect. These are showed in the most vivid and compelling, but still accurate presentation.

A **'before/after' comparison** is an effective medium in improving clarity, promoted by Sheppard (2005 & 2012) and Bishop & Lange (2005). The visuals display the difference between the current situation, the situation of an extreme weather event and a situation with adaptation measures. The current situation forms the 'base image' for all the other visuals. This base image is created by adjusting a photograph with Photoshop into a simple and basic image, that represents the characteristics of the test bed best (figure 31&32). The lay out of the two base images is kept simple in order to point the viewer's attention to the revealed climate problems and solutions.

To display the dynamic climatic processes best, **animated imagery** is most effective. With animations, the change over time and the changes caused by the weather and climatic processes can be revealed as well. Nicholson-Cole (2005) states that animated images are likely to be powerful and efficient tools in climate change communication. Animations can show the environmental change in the landscape and its future (Bishop & Lange, 2005). The climate processes are not always visible in the still images that are commonly used to communicate design interventions.

Figure 31. Base image for test bed 'Street'

Figure 32. Base image for test bed 'Backyard'

On the contrary, animation allows the viewer to 'time travel' by which the viewer can experience future conditions as though the viewer is actually there (Sheppard, 2012). (Sheppard, 2005) states that "dynamic or animated imagery increases enthusiasm and engagement", which is one of the four important criteria for effective revelatory visualisations. Therefore, this theory is employed by making the visualisations animated. The software programs Adobe Premiere and SketchUp are used to transform the photo based visualisations into animations.

In addition, my presumption is that the visuals cannot speak for themselves. The visuals show many possible solutions displayed in an animated 2D image. The shown solutions mostly perform in a certain time frame and all have a certain impact on the site's climate. Therefore, an explanation is needed for the viewer to be able to understand the effects of the interventions. Derkzen, van Teeffelen and Verburg (2017) promote that it is effective to **"provide information on the benefits".** These benefits can be in terms of how much heat reduction the solutions will cause or how much more rainwater the site can cope with. The functionality of the displayed solutions can thereby become clearer. In case of the problem visuals the effects of the climate are negative and in case of the solution visuals these are positive.

The 'invisible' effects on the urban climate can be amplified with an extra layer of information. Information that otherwise would only been seen separate can therewith be connected (Sheppard, 2012). Sheppard (2005) explains that this 'conceptual or non-visible info' provides more disclosure on the implications of climate change. Next to that, Sheppard (2005) claims that realistic visualisations presented without corresponding scientific explanations, might not be taken seriously. An overlay of information in the visualisations is assumed to score on more clarity (by providing disclosure on the climate's impact) and trust (by providing accurate scientific info). All visualisations are shown in the survey with, and without a graphic overlay to be able to find out the difference in effectiveness.

Information can be added to the visuals in various forms, such as graphic overlays of text, symbols or illustrations, in various layouts;

Use of symbols

Symbolic icons can represent an action, object or concept at a higher level of abstraction (Lidwell, Holden, & Butler, 2003). Symbols are a means of iconic representation, by which complex subjects can be communicated in a simple way. Symbols are effective when the subject can be recognized with ease. The symbols can make the subject more understandable across cultures (Lidwell et al., 2003). In this case explanatory symbols are needed, since scientific knowledge is conveyed to laymen. Symbols are incorporated in the revelatory visualisations to indicate the climate processes, emphasize their effects and illustrate the status quo versus solutions having been applied.

Use of illustrations

Illustrations over the visualisations can emphasize how the

shown climatic processes function and what their effects are for the environment. They can guide the viewer's attention towards the message that needs to be conveyed. Drawn illustrations emphasize the author's personal view (Mertens, 2010), and therewith highlight the message which needs to be conveyed. The positive or negative effects of the processes can be made clear with this graphic overlay.

Use of text

An accompanying title can describe the situation shown (Mertens, 2010). Since the climatic processes can be complex, the explanation in a textual way can clarify the visuals' content. In the visualisations, text explains the processes, additional to the symbols and illustrations.

The assumptions described are incorporated in the visualisations, and tested on the criteria by the means of an inquiry amongst the community. This test contributed to the improvement of the visualisations and provided clarity on the efficacy of the assumed theories.

Number of visualisations

During the RTD process the question arose how many visualisations should be presented to the inhabitants. A limited number of visuals is elaborated, to reduce the amount of information the respondents have to process and to be realistic in the time frame of this research.

The two test beds which showed the most problematic configuration in the context of Assendorp are the street and the backyard. The visuals revealing the problems are separate from the visuals revealing the solutions. The problems and solutions for heat and water are shown separately, since extreme precipitation and a heatwave do not occur on the same day. Furthermore, I made an extra variant of every visual in which the functioning and effects of the problems and solutions are emphasized with a graphic overlay. This results in a division of 8 visualisations per test bed, which makes a total of 16 visuals. The division is as follows:

Street

- water > problem visual x2
- water > solution visual x2
- heat > problem visual x2
- heat > solution visual x2

Backyard

- water > problem visual x2
- water > solution visual x2
- heat > problem visual x2
- heat > solution visual x2

Testing

The visualisations were evaluated on their quality of being climate revelatory by testing. This was done according to the pre-defined criteria engagement, clarity, connectivity and trust, which were composed by recommendations from literature (chapter 2.1 figure 3). The visualisations were continuously checked by the researcher on their fulfilment on the criteria, which corresponds with the spiral model of Zeisel.

Another test is carries out by an inquiry amongst the community of Assendorp. The aim was to find out what kind of visualisation scores best on the same criteria, and therewith is most effective in raising awareness. The community's contribution in comments and tips is helpful in optimizing the revelatory visuals. The test was carried out among inhabitants of the case Assendorp. The inquiry amongst the community of Assendorp was carried out in the form of a **survey**, which consisted of an organized meeting and an online questionnaire.

This survey asked the inhabitants to assess the visualisations shown on the four criteria. Afterwards, the inhabitants are questioned about the visual's impact on their urban climate awareness. The opinion of the community is valuable since they can share their view on their awareness level and the influence of these kind of visualisations on that. This participatory approach provides more insight in people's awareness level and the process itself might as well contribute to more awareness.

The meeting was organised on Thursday evening October 12th, in the living room of one of the inhabitants of Assendorp (figure 33). Unfortunately, only four people showed up to participate. An online questionnaire with a similar set up was distributed to reach more inhabitants. This questionnaire gained more response, namely 49 participants. Hence a total number of 53 people participated in the survey.

During the meeting, the visualisations were presented in a PowerPoint presentation by the researcher herself. The participants filled in a questionnaire during the presentation (see appendix IIIa-b for the presentation file and answer form). The online questionnaire is set up in Google Forms and the link was distributed among inhabitants via mail, the local newspaper and social media (see appendix IIIc for the total questionnaire in Google Forms). The survey was carried out in Dutch, since this is the native language of the participants.

Figure 33. Presentation of visualisations during the organised meeting

The set-up of the survey is as follows:

A) introduction

The participant is provided with background information on the research and the researcher. This gives the participant insight in the research objective and their participation in it. However, not too much information is released to prevent that the participants are influenced before being questioned.

B) social demographic questions

A few social demographic questions are asked, in order to find out how representative this sample of participants is for the population of Assendorp. These questions include age, gender, education level and whether they are residents of Assendorp.

C) test of the visuals

The visuals are judged by the participant one by one. Some context is provided about the occurring weather event (e.g. “this is the situation in the street during a rain shower of 100 mm/day”). The 8 visuals of the street are shown first, followed by the 8 visuals of the backyard. Before both of these groups start, the current situation is showed with the ‘base’ image. Showing the solution visuals right after the problem visuals are revealed emphasizes the positive effect of taking adaptation measures. This approach lies within the theory of Van der Linden, Maibach and Leiserowitz (2015) to frame climate problems differently.

Figure 34. Example of part C of the questionnaire in Google Forms

The visuals shown are assessed by the inhabitants according the four criteria; engagement, clarity, connectivity and trust. The criteria are represented by four corresponding statements. The four statements represent the meaning of the criteria in an indirect way, in comprehensible and common language. After every visual the same set of statements is provided, and the respondent can react to these by level of agreement on a five-point Likert scale, ranging from total disagreement to total agreement. A section of this part of the questionnaire is showed in figure 34.

The statements are the following:

- *De situatie is levendig uitgebeeld (engagement)*
- *Ik begrijp door dit beeld goed... wat de klimaatproblemen in de stad inhouden / hoe de maatregelen werken* (clarity)*
- *Ik kan mij inleven in deze situatie (connectivity)*
- *Dit is een realistische weergave van de (toekomstige) werkelijkheid* (trust)*

Translation in English:

- *The situation is displayed vividly (engagement)*
- *Because of this image, I understand very well what the climate issues in the city are / how the interventions function* (clarity)*
- *I can empathize with this situation (connectivity)*
- *This is a realistic rendering of the (future) reality* (trust)*

* A difference in the verbalization of the statement is made between visuals where issues are revealed and visuals in which solutions are revealed.

D) impact on awareness

After the assessment of the visuals, their impact is questioned in four final statements. These statements ask for the participant's opinion on the impact of the visuals. This section is incorporated in the survey to provide insight in the impact of the visuals on the participant's behaviour and thoughts. In addition, the statements can stir up thoughts about the subject 'urban climate'. This is an advantage, since afterwards is asked for the participant's opinion on the visuals, their impact and this research.

The statements are based on the research of Baldwin & Chandler (2010) in which similar statements are used to measure the impact of a participative project. In this project, a photo method (photovoice) was aimed to capture the groups' values and concerns about climate change and sustainability. The statements are adjusted to be applicable for this research. The answers are registered on a five-point Likert scale, ranging from how 'little' to how 'much' the participants agree with the statement.

The statements are the following:

In hoeverre hebben deze beelden...

- *Mij aan het denken gezet over het klimaat in de stad*
- *Mij gestimuleerd om meer te willen weten over het stadsklimaat*
- *Mijn kennis over klimaatadaptatie verbeterd*
- *Mij aangemoedigd om actie te ondernemen in mijn eigen omgeving*

Translation in English:
In what amount have the visuals...

- *Made me think about the urban climate*
- *Stimulated me to wanting to know more about the urban climate*
- *Improved my knowledge about climate adaptation*
- *Encouraged me to undertake action in my own environment*

E) comments & tips

In the final section, the participants are thanked for their contribution and asked for final comments or tips on how to optimize the visuals. During the meeting, a discussion was provoked, to find out how the participants perceived the visuals. In the questionnaire, room is provided for comments by an open question. The comments provide the researcher with feedback for optimizing the visuals for revelatory purposes. This was the moment when the participants could share their thoughts in their own words about the visuals and the research in general. Besides that, the comments and discussion can give the researcher insight in what is going on in the neighbourhood and how they think about climate adaptation. This can also help in making an indication of the level of awareness of the participant and the neighbourhood. And last but not least, Sheppard (2012) states that “asking for feedback from the audience after the presentation builds goodwill and will help improve similar activities in the future.” This presentation on its own can therefore contribute to more public support as well.

Part A-D of the survey produced quantitative data. This data consists of the social demographic statistics, the ratings of the visuals on the criteria and the rating of the impact of the visuals. To be able to distinguish a difference in effectiveness between the visuals, the results are analysed in various ways in Microsoft Excel. Part E of the survey resulted in qualitative data, which consists of the comments and tips, which are categorized per theme by the researcher. These results are used to improve the revelatory visualisations and get a sense of the awareness level of the community.

RESULTS AND DISCUSSION

3.1 INTERIM VISUALISATIONS

The research through designing process resulted in these interim visualisations. The respondents of the survey assessed these interim visualisations according the criteria: engagement, clarity, connectivity and trust. The survey results are used to improve the visualisations, which resulted in the final visualisations (chapter 3.3).

During the creation process, I made sure that the four criteria were well embodied in these visualisations. The recommendations from literature are elaborated in these visualisations in the form of animations and graphics. Figure 35 and 36 describe how the criteria engagement, clarity, connectivity and trust were presented in the visuals. These two visuals are examples for the issue visuals (figure 35) and the solutions visuals (figure 36).

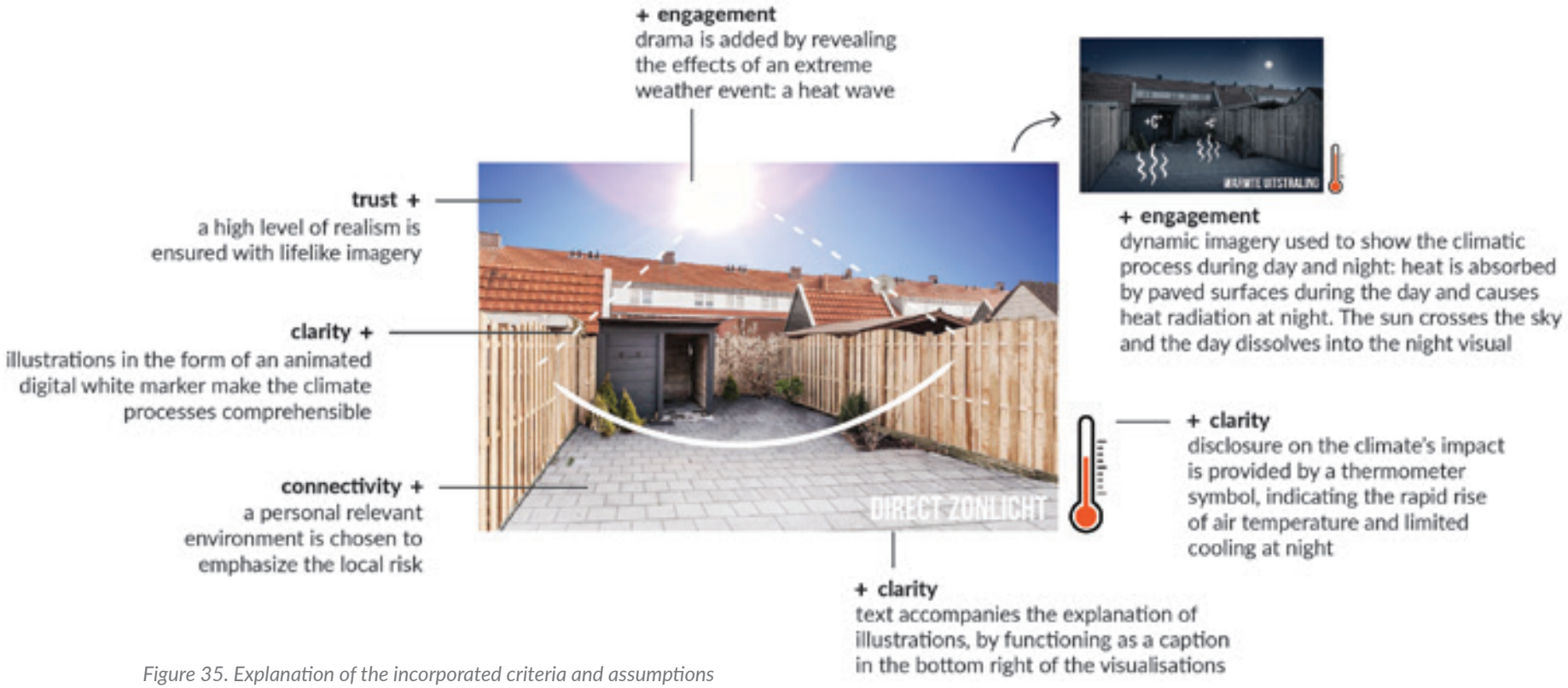


Figure 35. Explanation of the incorporated criteria and assumptions in the problem visuals (example is 'visual 14': http://bit.ly/2kQxCBU)

Note that this is an example and that every visualisation reveals different problems and solutions, which are showed by different animations and graphic explanations. The examples shown in figure 35 and 36 concern the heat problem. The water accumulation problem is revealed in other visuals, in which other features are animated to provide engagement and clarity. The water accumulation is for example made clear by slowly developing puddles by which the backyard or street eventually floods. The 14 other visuals can be found in appendix Va.

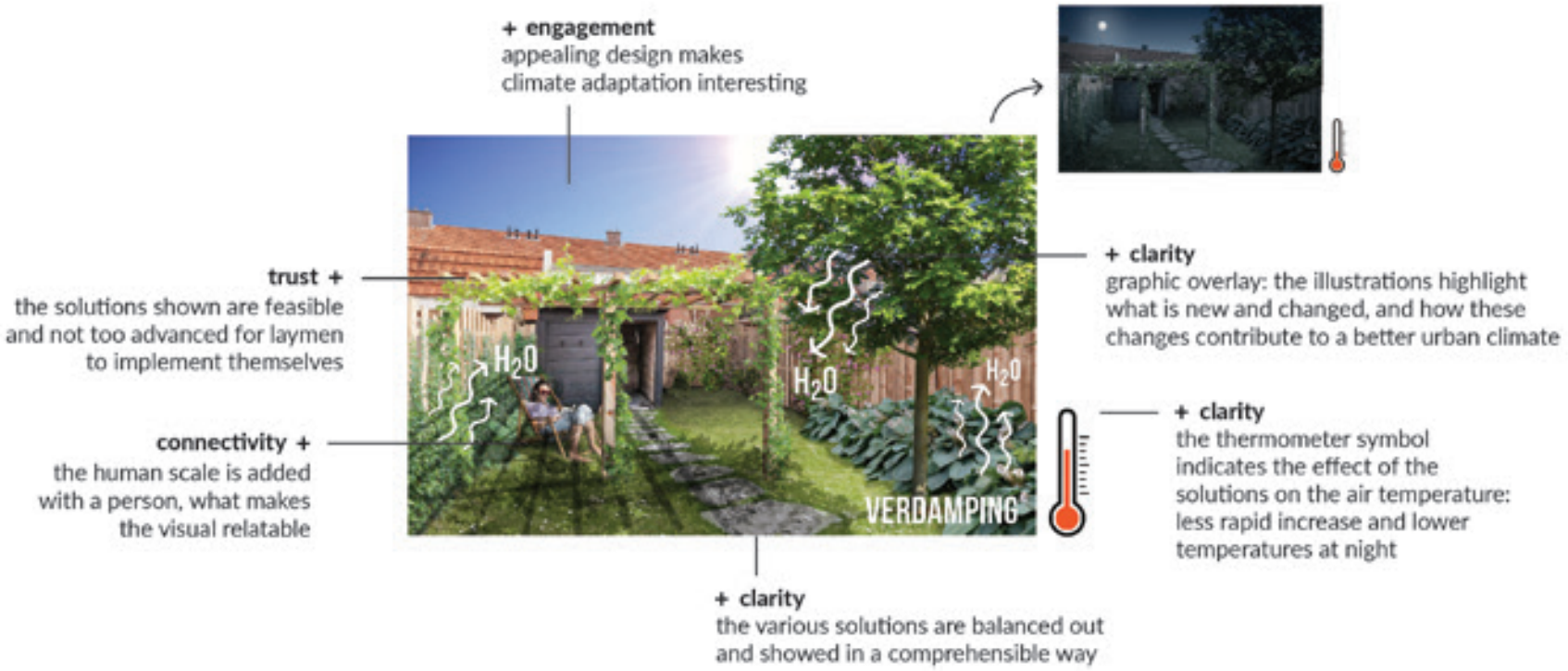


Figure 36. Explanation of the incorporated criteria and assumptions the solution visuals (example is 'visual 16': http://bit.ly/2C2eScq)

3.2 INQUIRY AMONGST THE COMMUNITY

The inhabitants of the case Assendorp are questioned by means of a survey, in which the interim visualisations are assessed on the four criteria: engagement, clarity, connectivity and trust. The test results consist of quantitative and qualitative data, which are documented in appendix IV. The results of this inquiry are analysed and discussed in this chapter.

Sample distribution

The social demographic statistics of the sample is shown in figure 37. These show that the sample consists of a majority of women, primarily middle-aged (35-49 years old) people, as well as a greater-than-average population of higher educated people and the majority lives in Assendorp. The gender and age distribution of the sample correspond well with the statistics of the population of Assendorp. The sample misses the age group of 0-20, since the survey is only carried out among adults.

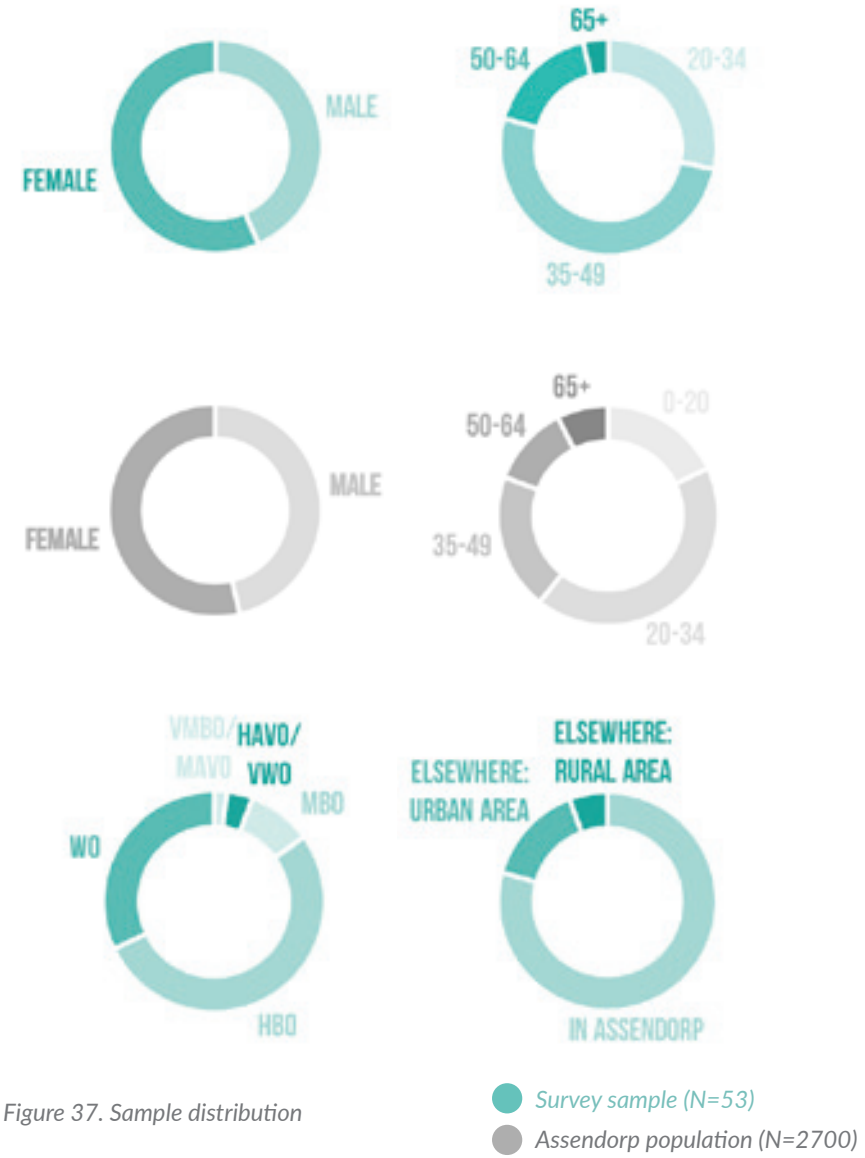


Figure 37. Sample distribution

Evaluation on the criteria

The test results show that the visualisations are rated relatively high on all four criteria, with an average score of 4,1 on a scale of 1 to 5 (figure 39). This implies that the aspired aspects of the criteria are incorporated in the visualisations. The tested design hypotheses based on literature (animated imagery, use of personal environment, high level of realism, permissible drama and added information on the effect) thereby turn out to be effective in combination.

I analysed the test results per visual to become more precise in determining what aspects of the visualisations are effective in raising climate awareness. The results show that visuals 4, 12 and 16 have the highest rating on all four criteria (figure 38). These visualisations are all revealing solutions and contain a graphic overlay. However, the differences between the visual's ratings are relatively small and cannot tell explicitly what makes which visual more effective.

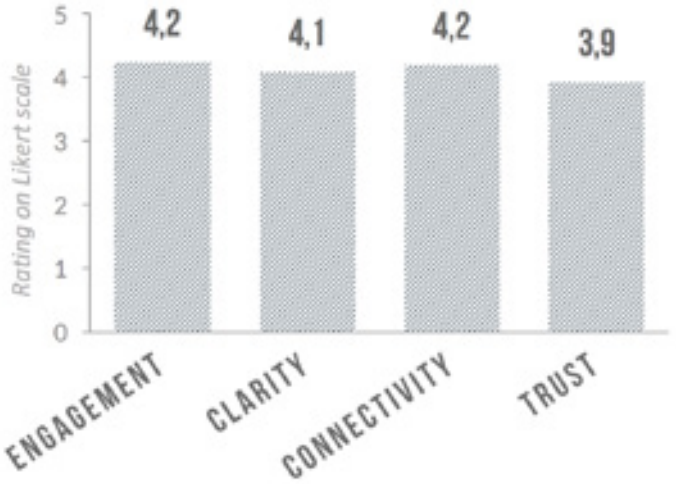


Figure 39. Rating of the visualisations on the four criteria

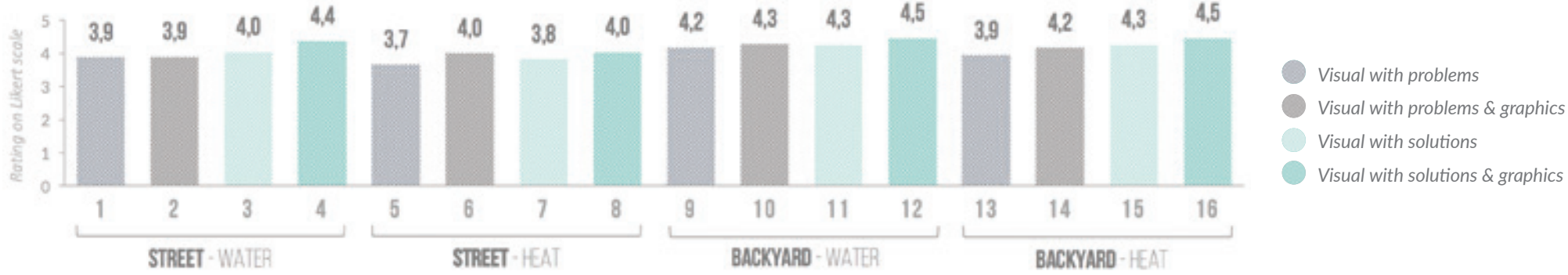


Figure 38. Rating of the visualisations

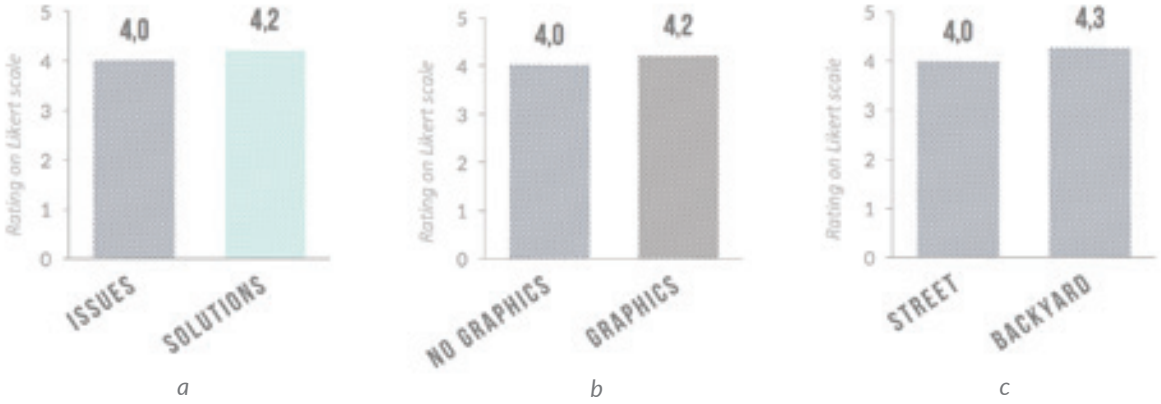


Figure 40. Groups of visualisations compared on their rating on the criteria

The visuals are subdivided in groups to find out what type of visualisation is more effective than others. The visuals can be divided based on content (revealing problems or solutions), on context (street or backyard test bed) and on style (with or without graphics). The test results show that the participants rated the visual with graphics, with solutions, and in a backyard context higher on the criteria (figure 40). This diagnosis is further interpreted in the analysis of the test results per criteria.

Engagement

The test results show that the visuals generally score slightly higher on engagement and connectivity, than on clarity and trust (figure 38). This might have the cause that statements A (representing engagement) and C (representing connectivity) evoke a more behavioural response, which is based on experience and feelings (Sheppard, 2005). Filling in statement B and D requires more thought and understanding, which is a more rational response. This can imply that the visualisations evoke a more behavioural

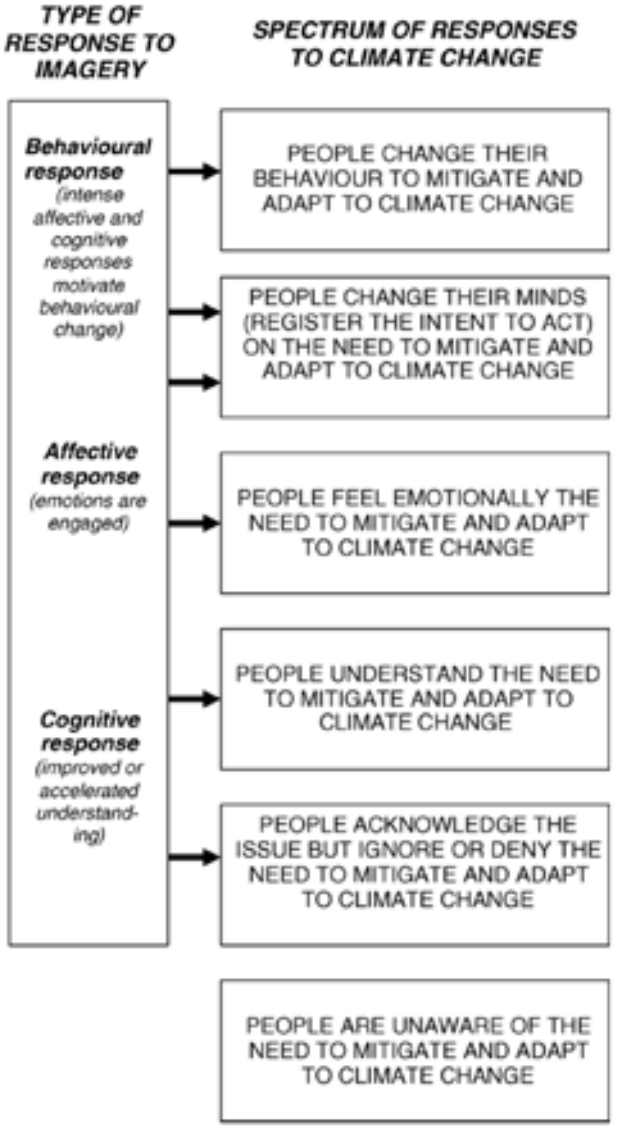


Figure 41. Theoretical spectrum of human responses to visual information on climate change (Sheppard, 2005)

response. According to Sheppard (2005, figure 41) this can be seen as a positive result, since it indicates a behavioural change which implies awareness raising.

The qualitative test results show that the participants reacted positively on the visualisations shown. Many compliments were given in the comments and discussion. According to the participants, the visualisations are vivid and interesting and draw their attention. That the visualisations can be powerful in climate communication is substantiated by the participants. Test results show that these revelations were effective in imagining possible futures:

> *"Nice visualisations. Powerful through simplicity. I have never encountered images like these before, while this crosses my work field" (Participant, male, 34 years old (translated from Dutch))*
> *"I need to imagine it, so this is very helpful" (Participant, male, 45 years old (translated from Dutch))*

Although the difference between a still image and dynamic imagery is not researched, one can assume that the animated features of the visualisations contributed to the positive score of engagement in the visualisations. Showing the dynamics of climate processes was recommended by Bishop & Lange (2005), Nicholson-Cole (2005) and Sheppard (2012). The animated imagery contributed to a more dramatic and compelling presentation of the urban climate, which was even more emphasized by the choice for extreme weather events.

Clarity

The literature stated that it is important to clarify how to adapt to the climate problems in order to motivate people to come into action themselves (Moser, 2014; Sheppard, 2012, 2015). The test results show that the revelation of adaptive solutions was indeed effective, since they were rated higher on the criteria than the problem visuals (figure 40a). The solution visuals provoked positive reactions among respondents of the survey:

> *"Nice to see ideas of what can be done and how this can look like in the street" (Participant, female, 37 years old (translated from Dutch))*

The test results confirm that the visualisations accomplished to make the urban climate comprehensible for layman. The visualisations meet the need of making abstract (scientific) knowledge easy understandable, and therewith tackle the perceptual barrier of complexity and feeling powerless (Sheppard, 2012; Moser, 2010; Roenhovde Tiller and Schott, 2012; van der Linden, Maibach & Leiserowitz, 2015).

The high rating of solution visuals can also be influenced by the set-up of the survey. The visuals are shown in sequence, in which the solutions solve the precedent revealed climate problems. This set up was based on the assumption that a before/after comparison, in which the current situation is followed by the improved situation, provides more clarity (Bishop & Lange, 2005; Sheppard, 2005 & 2012). The emphasis on the positive effects of the transition towards climate adaptation provides disclosure.

The transition of a 'bad' situation with mostly paved surfaces to a new design of a climate adaptive backyard, could have been eye-opening. The fact that the 'after' visual is rated higher supports this theory.

Providing information on the benefits of an adaptive environment was another recommendation from literature for effective climate visualisations (Derkzen, van Teeffelen & Verburg, 2017; Sheppard, 2005). This assumption is incorporated in the visualisations in the form of a graphic overlay. Such an overlay was assumed to provide more disclosure on the positive and negative effects of the climatic processes, and therewith provide more clarity towards the viewer. The test results show that visuals with graphics indeed rated higher than visuals without graphics (figure 40b). When the visuals with and without graphics are compared

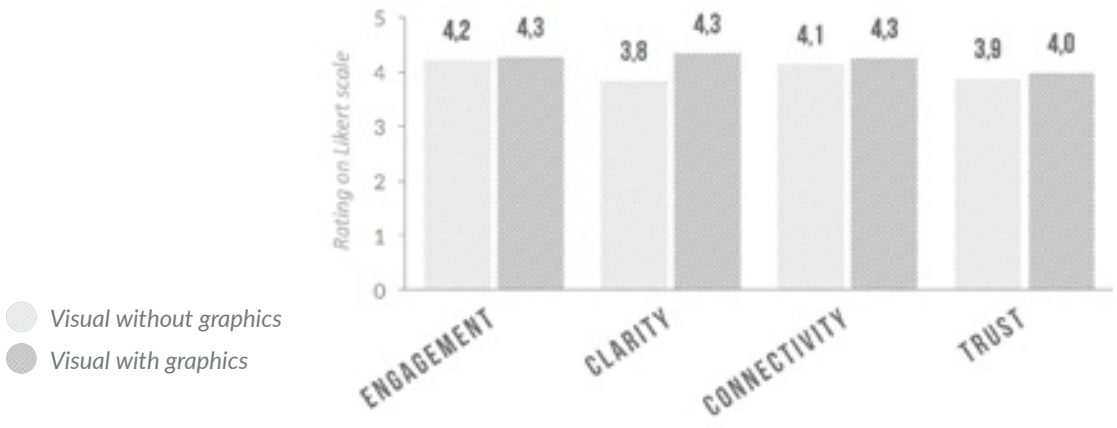


Figure 42. Visuals without and with graphics rating on the four criteria

on their rating on the criteria, one can see that the visuals with graphics score mostly higher on the criterion 'clarity' (figure 42). A respondent substantiated the significance of the graphic overlay:

> *"It is very intuitive and harder to understand without text" (Participant, male, 45 years old (translated from Dutch))*

These test results support the assumption that the provision of extra information on the effects of the climatic processes is important in climate revelatory visualisations.

Connectivity

The test results show that visuals in the backyard context score higher (figure 40c). The respondents might have rated this type of visualisations higher than the street, since they felt more connected to it. The literature stated that the inclusion of a personal environment in the visualisation evokes a strong association with a person's own experiences. (Sheppard, 2005, 2012; van der Linden, Maibach & Leiserowitz, 2015). Inhabitants might have recognized the layout of their own backyard and identified themselves with the context of the visual. The visualisations anticipated on the feeling of responsibility of the audience, which is now one of the perceptual barriers limiting behavioural change (Roenhovde Tiller and Schott, 2012; Sheppard, 2012). The viewer cannot deny that the problems only occur elsewhere.

Trust

As described under 'clarity', visuals with graphic overlay were rated higher on the criteria (figure 42). The information provided

in the graphic overlay also anticipates on the trust of the viewer, since it concerns the verifiability of the information shown. Respondents pointed out that this aspect could be improved:

> *"The images itself were clear. But I missed the movement of the sun's shadow. That would have brought more reality to the animations. Another addition could be more data (for example water litres or degrees Celsius). However, I know this would take more time and energy" (Participant, male, 41 years old (translated from Dutch))*

Also, the level of realism was addressed by the respondents. A high level of realism for visualisations was promoted in literature, because it corresponds more with the viewer's own experience of the environment (Bishop & Lange, 2005; Nicholson-Cole, 2005; Sheppard, 2012). The qualitative test results imply that the realism of the visualisations is appreciated, since many compliments were given. However, also some suggestions for even more realistic imagery were given. The suggestions of the respondents are incorporated in the improvement of the visualisations.

Impact on awareness level

After the assessment of the visuals on the criteria, some questions on the impact of the visuals on the awareness level were asked in the survey. The results on the questions of the final set of statements concerning the impact on awareness, are shown in figure 43. The test results show values above average, varying from 3,6 to 3,9 on a scale of 5, what indicates a positive effect

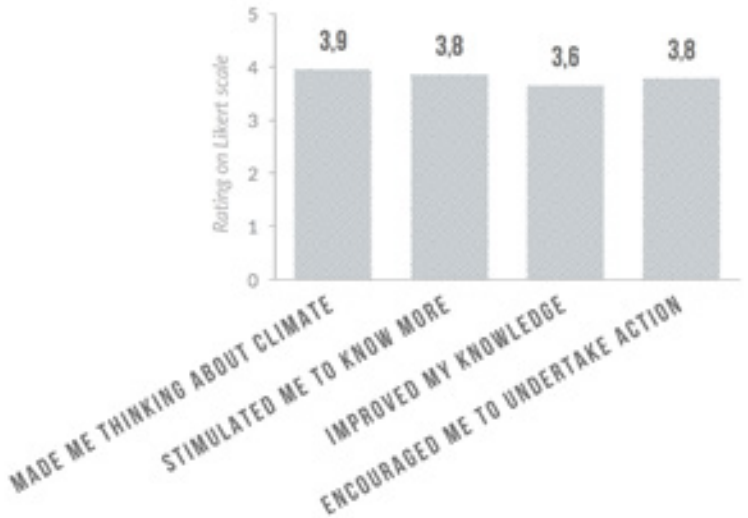


Figure 43. Test results on the statements of the impact of the visualisations on awareness

of the visualisations on the awareness level of the respondents. These positive results imply that the visualisations contributed to more recognition of the urban climate, which is a crucial step forward in the Awareness-to-Action framework by Sheppard (2012, figure 2).

I had a chance to get more insight in the climate awareness level of the community with the use of the qualitative data. These test results gave a sense of the impact of the visuals on the level of awareness of the community. Many respondents were very positive and enthusiastic in their reaction on the visuals and saw the potential of these type of visuals for communication on climate problems. They indicated that these visualisations are helpful in imagining the future of their neighbourhood. Respondents expressed that the visuals showed nice solutions and provided insight in the occurring urban climate problems:

> *"Nice images, they offer a nice idea of the possible scenarios concerning heat stress and flooding." (Participant, female, 47 years old (translated from Dutch))*

However, some respondents were sceptic about the impact of the visualisations on their awareness level. These respondents didn't agree with the solutions shown or made clear that the visuals were not having enough impact on their advanced level of awareness:

> *"I thought the whole thing assumed that inhabitants know nothing, too simplistic" (Participant, female, 57 years old (translated from Dutch))*

> *"I myself am already busy with sustainability and am aware of the urban climate. I hope your ideas in the research and the examples shown will result in practical action" (Participant, female, 34 years old (translated from Dutch))*

The variety in reactions indicates that the awareness level of the inhabitants differed per person. Nicholson-Cole (2005) explains that the public interprets climate related visualisations in different ways. "People's prior perceptions, experiences, attitudes, social background, cultural orientation and behavioural dispositions influence the reactions they will have to images of climate change, the messages they take away and whether they act on the basis of the visual communication they have received" (Myers, 1994 in Nicholson-Cole, 2005). Also in this case, the respondents framed and interpreted the visuals in their own context.

However, people's worldview is continually updated based on observations and experience (Baldwin & Chandler, 2010). The climate revelatory visualisations respond to this resilience and attempt to influence people's worldview about the urban climate by revealing the urge to adapt to the problems. (Baldwin & Chandler, 2010) point out that "understanding underlying values improves the likelihood of reaching a mutually satisfactory outcome in a decision-making process". Therefore, achieving the same level of awareness helps in the process of choosing for climate adaptation as a community. The presentation of climate revelatory visualisations can contribute to a streamlining of everyone's mind-set towards a general consensus of acting on climate problems.

3.3 FINAL VISUALISATIONS

The test results are employed to improve the visualisations once more, to assure the most effective revelatory visualisations. The insights of the test results were useful for the final iteration of improving the visualisations, since many specific comments were given on the effectiveness of the visuals concerning their content and style.

The analysis of the test results showed a slightly lower rating on clarity and trust. The qualitative test results confirm this shortage, since suggestions were made concerning the reality and verifiability of the visualisations and for clarifying some ambiguity. Therefore, more attention will be payed to improve the clarity and trust in the visualisations. The main improvements that are done after the survey was carried out, are:

- improving trust: by adding more data: adding the temperature differences in degrees Celsius and the amount of rainwater in millimetres
- improving clarity: by adding and adjusting illustrations that were unclear
- improving engagement: by adding more reality, such as animated shadows and a colour touch up

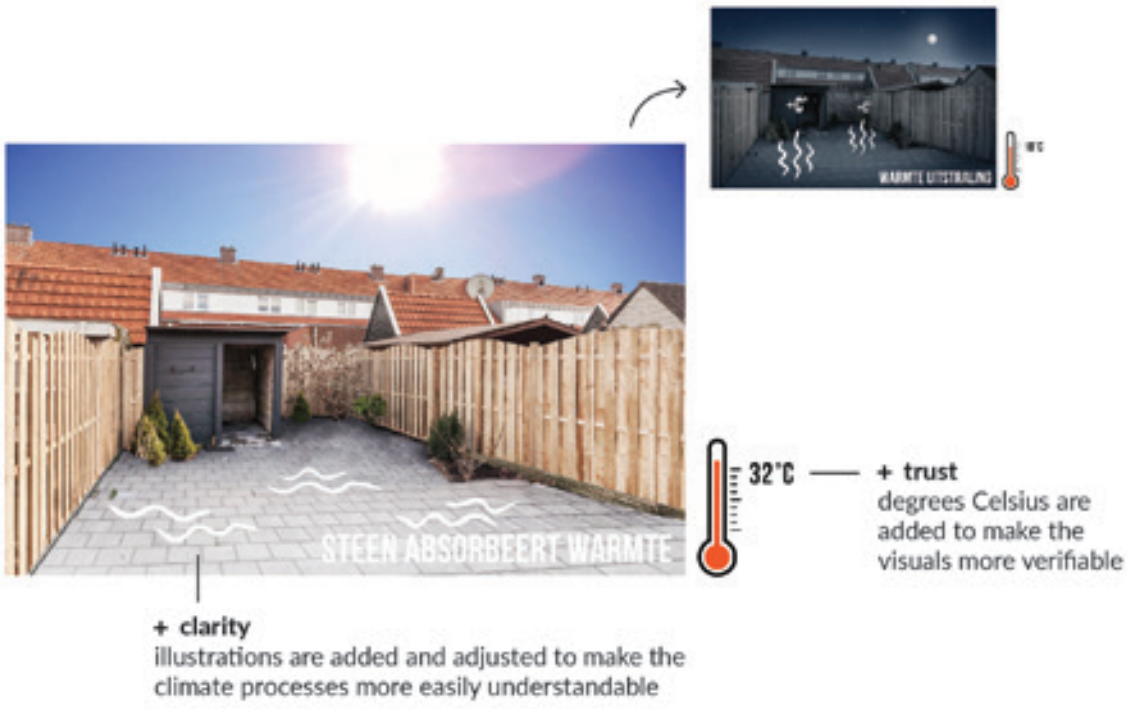


Figure 44. Explanation of the improved aspects in the problem visuals (example is 'visual 14': http://bit.ly/2ByVJey)

The improvements are incorporated in the final visualisations, of which examples are shown in figure 44 and 45. These figures show the specific improvements on the criteria in the same visual that was used for the explanation of the interim visualisations (chapter 3.1). Not all improvements are visible in the example, such as the colour touch up and rainwater level in mm. The other 14 final visualisations are documented in appendix Vb. The essential animated features are accessible via the links in the captions or appendix Vb.

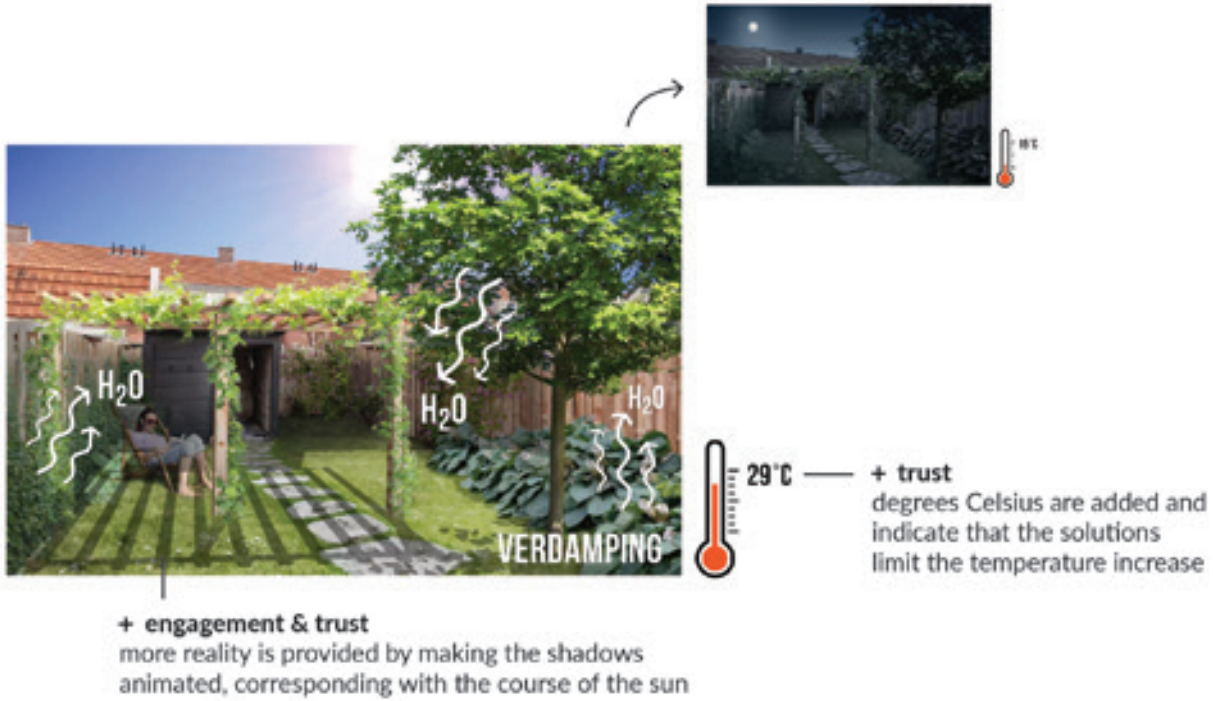


Figure 45. Explanation of the improved aspects in the solution visuals (example is 'visual 16': http://bit.ly/2pvm9MH)

THE MAKING OF

To pass along the generated knowledge, insight will be given on how a climate revelatory visualisation can be made. The climate revelatory visualisations can be applied on other locations as well, anywhere where climate issues need to be solved. This step-by-step guide can be useful for design offices or municipalities, for example in participatory processes.

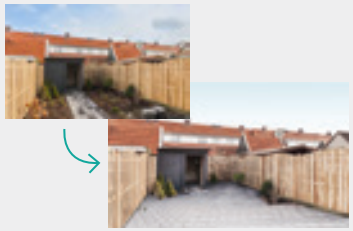
1. **Define the message.**
   What message do you want to convey?
   What is your target audience? How much do they know about the climate (base knowledge level)?

2. **Define the content.**
   What climate issues occur and do you want to show?
   And how do these processes work?
   What design interventions can solve these issues?
   And how can they be displayed best?

3. **Determine the style.**
   What will speak to your public? What will motivate them?

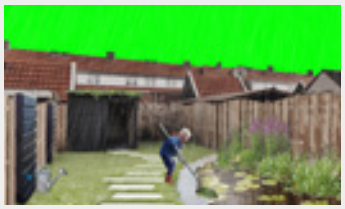
4. **Visualise**
   1. *Choose your base image > a site in the local environment evokes most emotional affection.*
   2. *Visualise the situation during chosen climate/weather event*
   3. *Visualise the situation when design interventions are applied*
   4. *Make the visualisations animated*
   5. *Add extra information for extra clarification if necessary*

ADOBE PHOTOSHOP



1 *Make a photograph or find an appropriate image on internet. Adjust this image to desired and 'simple' base image that represents the situation*

2 *Make the chosen weather event look dramatic, but keep it accurate*



3 *Find suitable images online and adjust into place in Photoshop*

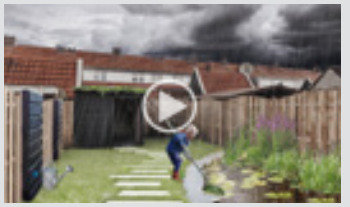
4 ***To animate the sky:** prepare the visual with a green screen*

ADOBE ILLUSTRATOR

5 *Make illustration in Illustrator and save with transparent background as .png*

ADOBE PREMIERE PRO

4 ***To animate puddle development:** let sequence of puddle images merge with the effect 'cross dissolve'*
***A similar approach is needed for a shift of day to night:** let day and night images 'cross dissolve'*



4 ***To animate the sky:** replace green color with 'color key' with online found footage of a moving sky*
A similar approach applies for animating rain & shadows

5 *Add the illustration to the visual and animate it by 'crop, scale and opacity'. Add text with the 'type tool'*

04

GENERAL REFLECTION AND CONCLUSION

4.1 GENERAL REFLECTION

In this chapter is reflected upon the embraced approaches and the outcomes of this research.

Criteria derived from literature (chapter 1.2) were used to represent the effectiveness of the visualisations on the climate awareness level of the community. The final results show that the visualisations, generated in this research, scored well on the criteria. Some improvements were needed in order to achieve more clarity, trust and engagement with the visualisations. It was a challenge to create optimal clarity about the urban climate processes, since abstract scientific info needed to be translated into comprehensible common language. The addition of graphics made this communication process best possible. Moreover, the visualisations with a graphic overlay proved to be clearer than without.

The climate revelatory visualisations have the aim to raise awareness on the urban climate. However, awareness is a complex concept, which is difficult to measure. Therefore, one has to be careful in drawing conclusions on the impact of visualisations on the awareness level. The aim of the research was nevertheless not to determine the level of awareness, but to explore the potential of what kind of revelatory visualisations can influence it. The concept urban climate awareness is expounded in the theoretical framework (chapter 1.2), in which multiple stages of awareness are distinguished by Sheppard. These stages are taken as starting point which the climate revelatory visualisations could influence.

I cannot confirm if the visualisations of this study did shift the awareness level with the methods used in this research. The impact on the awareness level is only measured afterwards. Therefore, a difference in awareness level before and after the visualisations were shown cannot be been determined. The hypothesis, that climate revelatory visualisations which meet the criteria can raise people's level, can therefore never be completely confirmed. To overcome this issue, the awareness level could have been assessed on forehand. This zero measurement could have been compared with the measurement in order to establish a difference in awareness level. However, since measuring awareness is complex, this assessment should be very extensive in order to cover all aspects of people's worldview on the urban climate. Moreover, one can never be certain what influenced the awareness level of a person exactly. Many other aspects influence people's thoughts about the climate, such as prior perceptions, experiences, cultural orientation and background (Nicholson-Cole, 2005).

In addition, the test results indicated that the awareness level of the inhabitants varied per person. The diversity in awareness level among the participants of this study can be caused by the heterogeneous nature of the group. The audience was made up of a range of people who have prior conceptions of climate change, different personal circumstances and social values (Nicholson-

Cole, 2005). A heterogeneous audience ensures heterogeneous interpretations (Nicholson-Cole, 2005). Therefore, we cannot assume that an image conveys the same message to every individual. A different interpretation of the image may as well lead to different actions (Baldwin & Chandler, 2010). One can therefore never be certain if the visualisations evoked behavioural change in acting on climate problems.

The assumption at the start of this research was that the inhabitants weren't aware and were at the start of Sheppard's Awareness-to-Action Framework. This assumption was based on the observation that the neighbourhood wasn't climate adaptive at all. However, this assumption might have been too straight forward, since people's mind-set wasn't assessed beforehand and the awareness level differs per individual.

Since this research was focused on which design hypotheses could work in visualisations, an extensive awareness assessment is not incorporated in this study. Although the impact of the visualisations of this research cannot be established, a positive effect of the visualisations was measured in the survey. We can therefore prospect that climate revelatory visualisations as a tool in the future can contribute to raising climate awareness.

4.2 LIMITATIONS OF THE RESEARCH

In this chapter, the constraints of this research are elaborated and recommendations for future research are highlighted.

Approach

The impact of the visualisations on the awareness level could not be accurately determined in this research, since no before and after measurement was carried out. The difference in awareness level before and after visualisations are shown can be measured in more extensive future research. In addition, a before measurement could have been helpful to get insight in the awareness level of the target audience. Nicholson-Cole (2005) explains that it is "important to consider the characteristics of a target audience and their likely range of interpretations, when considering a visual communication activity." In future research, it is recommended to measure the awareness level in advance. The climate revelatory visualisations can then be adapted to influencing this base level.

Design hypotheses were tested in the visualisations through research through designing. Designing as a form of research proved to be a very useful approach in this study. The iterative improvement of the visualisations made it possible to test alternatives from which lessons could be learned. The quantitative and qualitative input from the survey supported the research through designing process, which was very valuable. It proved to be a very valuable to use mixed methods in order to find answers to the research questions. The input of qualitative data in the inquiry enabled me "to access deeper attitudes, opinions and motivations than would be possible using a purely quantitative approach" (van den Brink et al., 2016). The survey results provided extensive information which informed the improved the creation of the visualisations. The design iterations could have continued endlessly to make the visualisations even better. Due to time constraints, this process was limited to a modest number of visualisations.

The application of animated imagery to the visualisations was one of the tested design hypothesis. Using animations derived from recommendations from literature (Bishop & Lange, 2005; Nicholson-Cole, 2005; Sheppard, 2012). The assumption that animations are effective in climate communication was adopted in this research, by making all visualisations animated. Therefore, I cannot confirm if animations are more effective than still images in revelatory visualisations. In future research, one can compare the impact of still and animated on awareness to be able to confirm this theory accurately.

The criteria engagement, clarity, connectivity and trust, which the revelatory visualisations have to fulfil were yielded from selective literature (chapter 1.2). It is debatable if these criteria cover all requirements of effective climate revelatory visualisations. In order to set up a clear list of comprehensible and feasible criteria for this study, a selection was made in the theoretical framework. In this selection, some recommendations from literature are dismissed or demoted. For instance, the criterion 'interactivity'

is not incorporated in the list. An interactive aspect in which participants can 'learn by doing', is very promising in order to connect laymen with the urban climate. However, time constraints did not allow further examination in this research. Interactivity could be a very interesting aspect of visualisations to examine in future research. Sheppard's (2015) fifth guideline 'feasibility' is demoted, since it concerns the adaptation measures, instead of the design of the visualisation. This aspect is incorporated in the criterion 'trust'.

Visualisations

The climate revelatory visualisations in this study show exemplary solutions to alleviate the occurring climate problems in the test bed cases. The creation of visualisations is influenced by the researcher, since choices had to be made. The credibility of the visualisations need to be kept in mind, since the designer chooses the perspective and the (not) shown aspects (Wergles & Muhar, 2009). The visualisations can consist of a different style and content, while still being effective for climate revelatory purposes.

Other solutions can be effective as well to overcome the problems. For example, a comment in the survey pointed out that more pragmatic solutions might be effective as well, since these can appeal more to the inhabitants. Besides, the visualisations are very context dependent. In a different context, with other occurring problems, other solutions are suitable. Moreover, the visualisations in this research are kept rather 'basic', in order to measure their effectiveness accurately and to be able to reveal the problems and solutions clearly. Other variants and subjects can be explored in future research on climate revelatory design.

Local climatic processes have effects at a bigger scale. For example, the heat radiation of the paved surfaces contributes to the urban heat island on a larger scale. And rainwater drains from the paved backyard to the neighbours, street or sewage. The actions of the individual can have a negative impact on the entire society. Barriers in the perspective of inhabitants such as "my backyard, my bad" or "I don't mind the heat, what's bad about a few degrees more?", have to be tackled by the visualisations. The positive and negative impacts of individual actions on the whole neighbourhood should be addressed in the visualisations. However, the visualisations made in this research have a focus on the source, the impacts of the urban climate are only featured on the scale of the street and backyard. The impacts of the local adaptation measures on the larger scale are not made clear. Making the impacts on a larger scale visible can contribute to more responsibility among inhabitants to change behaviour. In future research, the impacts of local actions on a larger scale could be addressed, in order to create more responsibility for the urban climate problems.

Next to the impact on a larger scale, the communal benefits of adaptation measures can be addressed more in visualisations in future research. Moser (2014) and Van der Linden, Maibach and Leiserowitz (205) recommended to promote collective efficacy, in order to engage people with climate adaptation. In future research, more attention can be payed to revealing the

communal benefits in visualisations, for example in the form of costs advantages.

The creation of climate revelatory visualisations entailed some risks. Since this study focuses on the perception of visualisations on the viewer, one needs to be keep in mind that visualisations are always a simplification and abstraction of reality (Nicholson-Cole,2005). Although the simplification of knowledge is inevitable in the creation of climate revelatory visualisations, this can influence a viewer's experience (Appleton & Lovett, 2003 in Nicholson-Cole, 2005). For instance, visualisations can unintentionally push the wrong message and by that mislead the receiver's opinion about the design (Forester, 1989 in Lewis et al, 2012). Images can trigger emotional responses, which can also include undesirable reactions. For example, the audience can become defensive, the visualisations can provoke 'issue fatigue' or lead to feeling powerless (Nicholson-Cole, 2005). Also, the visualisations could have provoked overly subjective reactions or lead to overkill (Sheppard, 2012). These effects could have occurred among participants of the online questionnaire. However, this could not have been traced nor prevented. In future research, one has to be careful in communicating climate problems with the community by adopting a systematic approach and pay utmost care in order to reduce the risks.

Survey

The survey, used to test the visualisations in the community, can be discussed on its content validity. The content validity indicates if the items measure the content they were intended to measure (Creswell, 2014). Whether or not the statements cover the criteria well enough cannot be verified. The participants can interpret the statements in their own way. The meeting and online questionnaire were intended to measure the same aspects and were set up in a similar way. However, a difference exists between presenting visualisations personally and virtually without a mediator (Sheppard, 2012). If these instruments measure the same thing is an assumption. Besides, the sample does not adequately represent the population of the whole neighbourhood, since the survey sample is small compared to the neighbourhood of Assendorp and most of the participants were higher educated than average for Assendorp. However, the results of the survey are only used within the research itself, to improve the visualisations. The conclusions of this research are drawn upon the final results of the research through designing process, which are the climate revelatory visualisations.

4.3 CONCLUSION

Answers to the research questions

SQ1: How can visualisations of occurring climate problems raise awareness about the urban climate, considering engagement, clarity, connectivity and trust?

This research produced an optimized way to visualise climate problems of Assendorp. The tested design hypotheses generated new insights on what aspects are important in visualisations, which have the function to raise urban climate awareness. The insights are discussed according to the criteria engagement, clarity, connectivity and trust.

Engagement

Climate revelatory visualisations have the function to bring the experience of the impact of climate change closer to people's daily life, in order to raise their awareness level. The visualisation of the most extreme weather events offers the most dramatic and affective content possible. The risks of climate consequences are emphasized as very present and existent in the viewer's direct environment. This approach overcomes the perceptual barrier of a lack in immediacy and direct experience of the climate's impact. The research results showed that the revelation of the risks can be eye-opening for the viewer. The visualisations function as a warning for what can happen to people's direct environment when no adaptation efforts are taken. The presumption is that this warning drives inhabitants to reflect on their actions and thereby provoke care for the future of the environment.

The animated features in the visualisations boosted the experience of the impact of the urban climate. Showing the dynamics of the urban climate with animated footage has a great contribution to more engagement and understanding. It makes the visualisation more vivid, which contributes to a more immediate and inclusive experience of the content shown. Animated imagery has much potential for the landscape architecture field, since the landscape always consists of dynamic processes.

Clarity

The visualisations had the aim to make the complex climate processes more comprehensible for laymen. Animated imagery contributed to clarify the dynamic processes. Moreover, the test results confirmed the clarifying ability of added graphic information. The graphic overlay accomplished to reveal the negative effects of the occurring climate processes, by the use of supportive text, clarifying data and illustrations. In this way, the often 'invisible' negative effects of climatic processes are comprehensible for the audience. The graphic overlay with explanations ensures understanding and verifiability, and therewith tackles the perceptual barrier of complexity.

Connectivity

Climate revelatory visualisations should communicate what can happen to the environment of people's daily life, in order to connect them with the urge of climate adaptation. The research results demonstrated the importance of taking familiar locations of the audience as subject of the visualisations shown to them. The most private environment, the backyard, was rated most effective. The emphasis on the risks in the local environment

in the visualisations responds to the feeling of responsibility of taking adaptations efforts. Accordingly, the viewer cannot deny that the problems only occur elsewhere.

Trust

The climate revelatory visualisations have the function to convince people of the urge of climate adaptation. The content of the visualisations should be accurate and verifiable in order to build trust. The audience of the visualisations should be assured of trustworthy information, in order to tackle the perceptual barrier of disbelief of the occurrence of climate problems. The use of photorealistic and animated imagery contributes to a lifelike experience of the situation shown. Moreover, a graphic overlay contributes to more trust by explaining the inherent scientific knowledge. The importance of trustworthy information was substantiated in the survey, in which the addition of more justifying data to the visualisations was suggested.

SQ2: How can visualisations of climate adaptive solutions raise urban climate awareness, considering engagement, clarity, connectivity and trust?

Next to the problems, the research findings resulted in an optimized way of revealing possible adaptation measures in visualisations. The tests of design hypotheses provided insights on how the message of climate adaptation can be conveyed best to the community.

Engagement

In order to engage people with climate adaptation, the solutions should be made appealing and interesting in climate revelatory visualisations. The visualisations function to appeal people to support climate adaptation. Respondents in the inquiry became enthusiastic about climate adaptation, since they were exposed to - in their words - 'beautiful images'. Animated imagery provided more immersion in the situation, while interesting solutions encouraged people to think about the design of their own street and backyard. The visualisations reveal how adaptation can look like, and therewith translate this 'scientific' knowledge into comprehensible imagery for the local community.

Clarity

Climate revelatory visualisations should illustrate the benefits of climate adaptation, in order to appeal people to undertake action themselves. Emphasizing the positive effects of a transition into a climate adaptive environment is important in the process of raising awareness. The before/after comparison of seeing the current situation, where after the improved situation, provides more clarity. The unknown information of what solutions are suitable for solving which problems can therewith be explained clearly to laymen. The before/after approach is confirmed to be effective in this research, in which solution visuals were rated higher than the problem visuals.

Furthermore, the benefits of an adaptive environment can successfully be revealed with a graphic overlay. This research confirmed the effectiveness of a graphic overlay, since visualisations with graphics were rated higher than without in the survey. Showing the gains of solutions can stimulate people

to undertake behavioural changes, which is equivalent of taking a step further in Sheppard's Awareness-to-Action Framework (figure 2).

Connectivity

Visualisations can anticipate on the feeling of responsibility of inhabitants by revealing solutions in the local environment. Inhabitants might recognize the layout of their own backyard or street, and hence identify themselves with the context of the visual. The transition of a 'bad' situation, with mostly paved surfaces, to a new design of a climate adaptive backyard, can be eye-opening. The visualisations provide the chance for the audience to imagine how the future of their personal environment can look like with adaptation measures. The visualisations draw the attention of the viewer by showing a new design of the viewer's direct and familiar environment. The viewer's imagination can be stimulated with this relatable information, what might provoke more thoughts on the subject and therewith raise urban climate awareness.

Trust

Climate revelatory visualisations should include the presentation of feasible solutions, in order to convince people of the ease of adaptation. The threshold of applying adaptation measures should be kept low to motivate inhabitants to come in action themselves. The motivating function of the solution visuals should result in more support for climate adaptation by the local community.

The realistic sense of the visualisations anticipates on more trust, since it responds to the familiar image of the environment, that the community is familiar with. The new ideas shown in the visualisations influence people's view on how the future can look like. The presentation of these future alternatives can embed the creation of new social values in the community, for example the standardization of having a green backyard. The promotion of new social values contributes to a streamlining of the thoughts of the whole community on climate adaptation.

Main research question: How can visualisations, revealing urban climate problems & solutions, raise awareness about the urban climate among inhabitants of dhl-neighbourhoods?

The answers to SQ1&2 explain what features should be incorporated in climate revelatory visualisations in order to accomplish the criteria, and therewith overcome the existing perceptual barriers which now limit behavioural change. The final visualisations generated in this research demonstrate a successful example of how the urban climate can be conveyed to laymen, in order to get them acquainted with climate adaptation.

This research supports multiple theories derived from literature (chapter 1.2) of what types of visualisation are effective in raising climate awareness, by the tests of multiple design hypotheses. The findings verified that climate revelatory visualisations can best be supported with added graphic information on the consequences of the climate processes. Graphics provide more clarity and trust, which increases the chances for behavioural change amongst the audience. Next to this confirmation, I can conclude that

the combination of photorealistic and animated imagery of the local personal environment is a beneficial foundation for climate revelatory visualisations.

Animated features contribute to engaging inhabitants with the urban climate, by offering a vivid experience of the dynamic climate processes. Also, the revelation of urban climate problems and solutions in a personal environment provokes more connection with the inhabitants. In combination with photorealistic imagery the visualisations respond to the familiar experience of the daily life of the inhabitants. The positive assessment of these design hypotheses in the visualisations indicates the potential of a vital contribution in raising climate awareness.

Furthermore, this research supports the theory that both revealing climate risks, as their solutions, in visualisations contributes to raising awareness on the urban climate. However, these two types of visualisations function in a different way. The problem and solution visuals in this research anticipate on different values, influencing people's motivation for climate adaptation, since they tackle different perceptual barriers in the urban climate experience. The visuals revealing the current situation, including the risks of the urban climate, have a warning function. This type of visualisations provides an explanation of the occurring processes and therewith convince people of the urge for adaptation. While the visuals revealing an alternative future situation, in which adaptation measures are taken, have a more appealing function. These visualisations should promote the adaptation options and their feasibility clearly in order to motivate people to support adaptation efforts. The revelation of adaptation measures in the local environment respond to people's feeling of responsibility and having the power to contribute to a balanced urban climate. Accordingly, the climate risks should be presented with drama and negative consequences, while the climate adaptive design should be framed as a more positive prospect.

The positive effects of climate adaptive design can be even more amplified by presenting the visualisations to the community in a before/after comparison. The sequence of revealing the climate problems first, where after the adaptive design, provides emphasis on the positive effects of climate adaptation.

The test of the climate revelatory in the community indicated a positive impact on the respondent's awareness. In addition, the visualisations already provoked a behavioural response, which implies a potential of change in people's behaviour to adapt to the climate problems. These results give the prospect that the use of these type of climate revelatory visualisations as a tool in the future can raise the awareness level of more urban citizens.

The main ingredients of climate revelatory visualisations as an effective tool in awareness raising can be recommended from the findings of this research. The visualisations should contain appealing content in which climate adaptation is positively framed and presented in the local environment. The risks and solutions of urban climate processes can be effectively presented in photorealistic and animated imagery, supported by graphic information. The visualisations can have a positive impact

on the community by adapting the content on the knowledge of the target audience and presenting the visualisations in a before/after comparison. The combination of these ingredients in climate revelatory visualisations can trigger significant steps amongst inhabitants in Sheppard's Awareness-to-Action framework (figure 2), such as recognition of the climate's impact and provoking enough care to undertake adaptation action. This research therefore provides an effective tool to raise awareness, and therewith contributes to achieving climate adaptive cities in the future.

Significance of this research

The findings of this research are positioned in a broader context, by discussing the scientific and societal relevance.

Scientific relevance

This research is built upon Sheppard's theory of the of several stages of climate awareness represented in the Awareness-to-Action Framework (figure 2), and the fact that perceptual barriers block the ability for shifts in behaviour. The results of this research provide a tool to overcome these perceptual barriers, namely climate revelatory visualisations. Sheppard's theory is further developed by the elaboration of the potential of these climate revelatory visualisations. Moreover, the elaboration of this new concept 'climate revelatory visualisations' extents the knowledge of existing theories such as eco-revelatory design (Arısoy, 2013; Koh, 2013).

The tested hypotheses in the visualisations of this study are built on recommendations made by Sheppard (2005, 2012) and others (chapter 2.4: Bishop & Lange, 2005; Derkzen, van Teeffelen & Verburg, 2017; Nicholson-Cole, 2005). The positive assessment of the visualisations in this study substantiate most of their theories for effective climate revelatory visualisations (see chapter 3.2 and 4.3).

The visualisations created in this research refer to both the climate impacts and the adaptation measures. This is novel as Western media focus mostly on the causes of climate change and mitigation (chapter 1.3). This research fills this gap by focusing on the subtler climatic processes in the local dense urban environment and revealing climate adaptive measures.

Knowledge on the climate revelatory visualisations was generated through the application of a research through designing process with a specific design case and the corresponding community. The research process was informed by quantitative and qualitative tests. Such a systematic approach of deploying visual tools to reveal urban climate problems to a local community, has not been done before (chapter 1.3). The research on this new type of visualisation and communication tool is one of the first steps in climate revelatory research and design.

Societal relevance

In order to engage the public in action on climate adaptation, they have to be informed with the possible solutions (chapter 1.3). This research accomplished to find a way to engage the

community with climate adaptation. data is translated via climate revelatory visualisations and shared in comprehensible language with the community. This design study into climate revelatory visualisations therefore contributes to greater knowledge about engaging the public in climate adaptation. It provides an example of how climate problems and solutions can be revealed and therewith open the eyes of the public.

In the landscape architecture practice, climate revelatory visualisations can be a useful tool when dealing with a location where climatic problems occur, accompanied by a community that needs to be motivated to undertake adaptation measures. Landscape visualisations are currently mostly used as communication tool to make design interventions imaginable. However, when employing visualisations in a climate revelatory manner, more benefits can be gained. Especially in a participatory setting, users can be engaged more in the design process and support, or even initiate, new design interventions. By making the urban climate tangible and fit into the receiver's direct environment, the discussion can be stimulated (Wergles & Muhar, 2009; Gray & Malins, 2004). This approach can be very helpful in a process that involves multiple stakeholders. Realistic visualisations can be helpful in engaging stakeholders in the process (Sheppard, 2005).

Looking at the manner from the inhabitants' perspective, climate revelatory visualisations are very helpful. The research results showed that more visual information on the urban climate around them helps to make this abstract concept more comprehensible. Without knowing anything about the climate's impact on their direct environment, people will never come into action. Laymen could use a clear explanation of the sometimes complex and uncertain problems that the urban climate includes. Climate revelatory visualisations can arouse interest and encourage the public with appealing and most importantly, feasible solutions.

This research is focused on dhl-neighbourhoods, with the research case Assendorp. My visualisations are generable for other dhl-neighbourhoods as well, since the test beds are very common for such a neighbourhood. Therefore, the visualisations from this research can be used to show in other dhl-neighbourhoods to make the urban climate comprehensible. Although the spatial configurations are in line with Assendorp, the context of every dhl-neighbourhood is always different. The recommendation is to use a similar visualisation technique, but applied in the local context.

For the specific case Assendorp, I would like to give some recommendations as Assendorp has many active and concerned inhabitants who have an ambition to make their neighbourhood most liveable. Practical steps in improving the outdoor space are needed, since problems occur (chapter 2.3). The climate revelatory visualisations help inhabitants in imagining their future. It might be helpful to organise participatory meetings in which future plans for climate adaptation are discussed. These meetings can be supported by visualisations to provide clarity and pursue more encouragement to come into action. When more inhabitants are encouraged, more bottom up initiatives might occur. An

example of such an initiative is the Seringenstraat, in which a few inhabitants recently accomplished to implement adaptation measures in the street and backyards in collaboration with the municipality.

In summary, climate revelatory visualisations can be deployed to motivate inhabitants, by make climate problems comprehensible and alternative futures imaginable. Immersive and convincing visualisations contain the power to influence people's behaviour, and therewith steer society in the desired direction of climate adaptation support. The use of animated imagery in climate visualisations carries even more potential than elaborated in this research. Even more inclusive experiences of the urban climate can be offered by means of virtual reality or multi-sensory experiences. These techniques promise to be very powerful tools in raising climate awareness, since they can tackle all perceptual barriers. These techniques can intensify the experience of the climate around them and hence clarify what the immediate individual consequences can be. Also augmented reality can be deployed to connect people's experience of the climate with the direct local environment. Urban climate problems and solutions can be directly revealed in the user's environment in an interactive way (Schroth et al, 2015). It is interesting to research different visualisation techniques which can have a powerful impact on people's awareness level.

The findings of this research give the prospect that the use of these type of climate revelatory visualisations as a tool in the future can raise the awareness level of many more urban citizens. Moreover, many interesting possible elaborations on the concept of climate revelatory visualisations are open for discovery and promise to contribute to more and more urban climate adaptation in the future.

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APPENDICES

I. TEST BED IDENTIFICATION

II. INVENTORY OF SUITABLE SOLUTIONS

III. SURVEY

a. Meeting presentation file
b. Meeting answer form
c. Questionnaire (Google Forms)
d. Article in De Assendorper

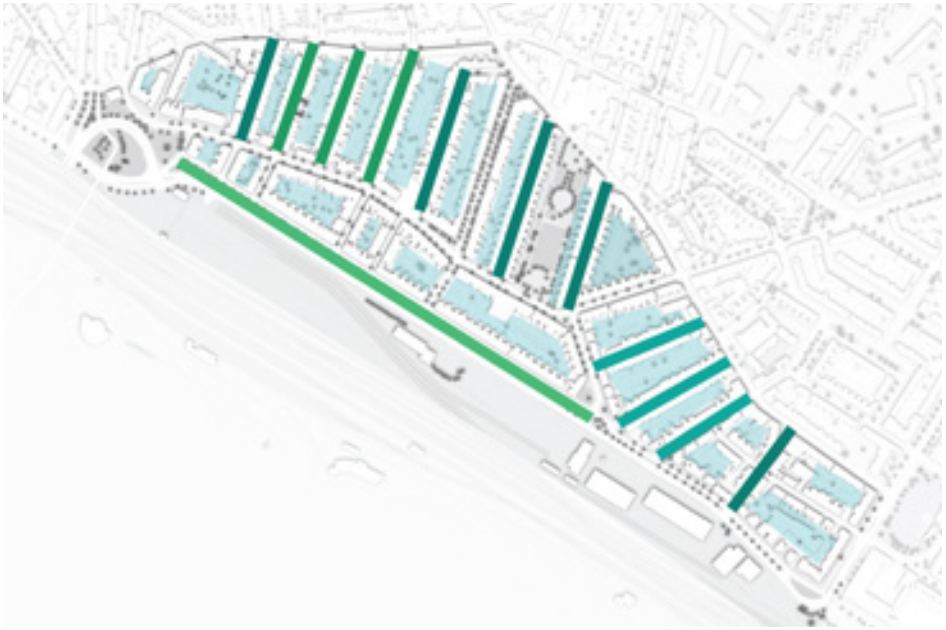
IV. TEST RESULTS

a. Quantitative data
b. Qualitative data

V. VISUALISATIONS

a. Interim visualisations
b. Final visualisations

APPENDIX I. TEST BED IDENTIFICATION



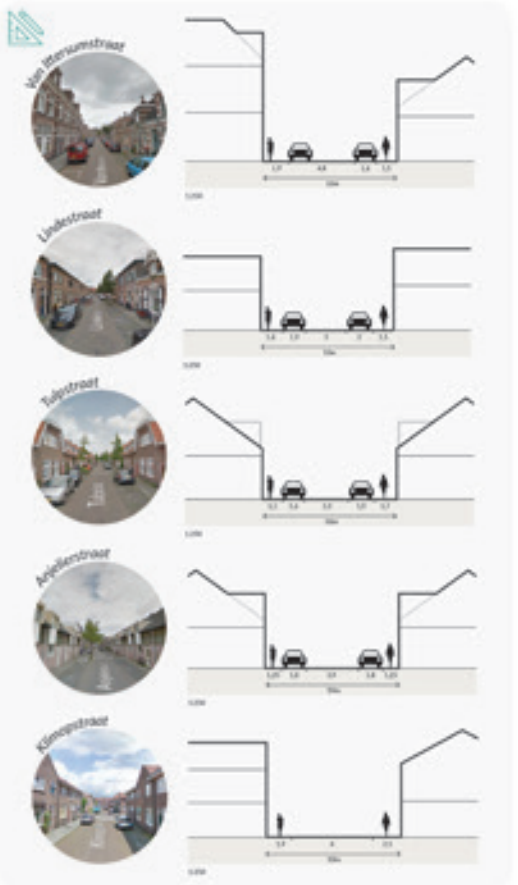
A

10 m
8-10 m
1:1.5
SSW-NNE

heat retentive materials, lack of greenery, direct sun exposure
rainwater drainage via sewer system, little infiltration possible
parking scarcity

shadow course in the morning (8-13h June 21st)

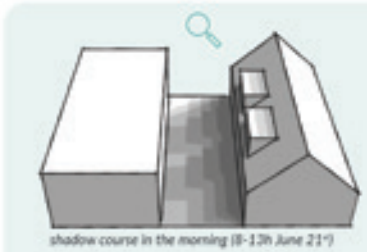
shadow course in the afternoon (14-20h June 21st)



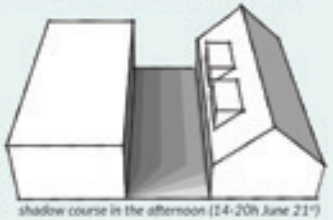
B

7-8 m
7-8 m
1:1
SSW-NNE

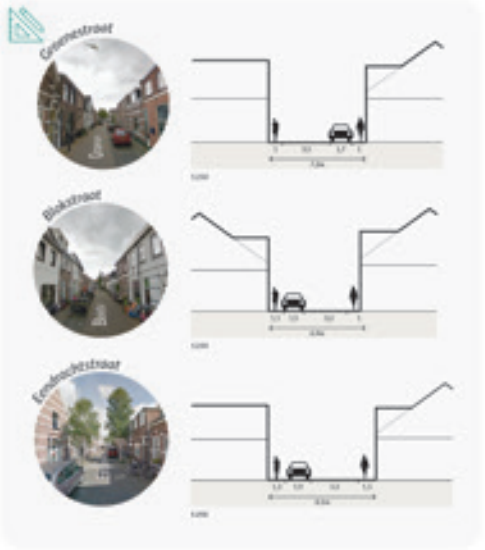
heat retentive materials, lack of greenery, much pavement
rainwater drainage via sewer system, little infiltration possible
parking scarcity



shadow course in the morning (8-13h June 21st)



shadow course in the afternoon (14-20h June 21st)

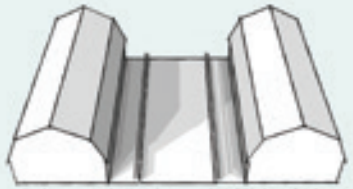


C

12-14 m
7-8 m
1:2
SW-NE

heat retentive materials, much pavement, exposed to sun
rainwater drainage via sewer system, frontyards available for infiltration
parking scarcity

shadow course in the morning (8-13h June 21st)



shadow course in the afternoon (14-20h June 21st)

D

shadow course in the morning (8-13h June 21st)

shadow course in the afternoon (14-20h June 21st)

26+ m
7-9 m
-
NW-SE

much pavement, asphalt, exposed to sun
rainwater drainage via sewer system, rainwater of whole neighbourhood accumulates here
vacant area along the railway

APPENDIX II. INVENTORY OF SUITABLE SOLUTIONS

SOLUTIONS	Effect	TEST BED GARDEN	STREET A	B	C	D
HEAT						
- Shadow possibilities (temporary/flexible?): canopy/louvre/awning	s		x		x	x
- Less heat retentive materials	c	x	x	x	x	x
- Deciduous tree	s, c	x	x	x	x	x
- Needle-leaved tree	s, c					x
- Espalier tree	s, c	x	x	x	x	x
- Green facades	s, c	x	x	x	x	
- Hedges	s, c	x	x	x	x	x
- Perennial plants with large leaves	c, e	x				x
- Hanging garden	s, c	x	x	x	x	x
- Pergola	c	x			x	x
- Mobile green	s, c	x	x	x	x	x
- Green front yards	c,	x			x	
- Climate park	s, c					x
- Colonnades/pavilion/arbours	s, c					x
- Surfacing with high albedo	c	x	x	x	x	x
- Water wall	c					x
- Waterfalls	c					x
- Fountain	c					x
- Water mist installation	c		x	x	x	x
- Sprinkling water ('uchimizu')	c		x	x	x	
- Green roof on shed (intensive)	c	x				
- Depave	c	x	x	x	x	x
- Less cars	?		x	x	x	
WATER						
- Greenery: plants / grass	i	x	x	x	x	x
- Infiltration crates	i	x	x	x	x	x
- Pond	i, r	x				x
- Rainbarrel (with tap)	i, r	x			x	
- Water storage fence (with tap)	r	x				
- Water tower (with tap)	r					x
- Depave: more infiltration surface	r	x	x	x	x	x
- Semi paved: gravel, woodchips, shells	i	x	x	x	x	x
- Permeable paving: waterproof	i	x	x	x	x	x
- Green roof on shed (sedum)	r	x				
- Water playground	r		x		x	x
- Open runnel (shows water direction/story)	d		x	x	x	x
- New canal/ditch	d, r, i					x
- Bioswale /purifying runnel	d, r, i		x	x	x	x
- Relief for water drainage	d	x	x	x	x	x
- Wadi	d, r, i		x		x	x
- Urban infiltration strip	d, r, i		x	x	x	x
- Disconnect drainpipe	d	x	x	x	x	
- Water square	r					x
- Infiltration field	r, i	x				x

APPENDIX III. SURVEY

IIIa Meeting presentation file

PROGRAMMA

- Achtergrond afstudeeronderzoek
- "De straat"
- "De achtertuin"
- Vragen / discussie
- Afsluiting

AFSTUDEERONDERZOEK

- Master Landschapsarchitectuur aan de Wageningen Universiteit
- Klimaatverandering: meer extremen → uitdaging in de stad

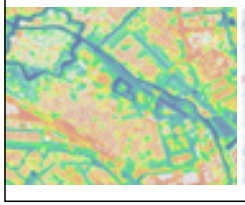
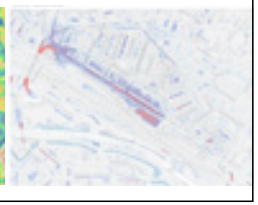

AFSTUDEERONDERZOEK

- Klimaatbewustzijn vergroten
- D.m.v. beelden

Awareness to Action framework (Sheppard, 2012)

ASSENDORP

- Hitte & water problemen aanwezig

TOETSEN VAN BEELDEN

- 8 beelden **straat**
- 8 beelden **achtertuin**
- Per beeld 4 stellingen invullen op invulformulier

5

5

7

8

DE ACHTERTUIN

9

10

11

12

13

14

15

16

DISCUSSIE

- Laatste vragen invullen
- Vragen / mening

IIIb Meeting answer form

KLIMAAT VAN ASSENDORP

INVULFORMULIER

BIJEENKOMST 12 OKTOBER 2017

AFSTUDEERONDERZOEK NINA DE MUNNIK

Geslacht M / V Leeftijd .....

Woont u in de wijk Assendorp in Zwolle?

- ◯ *Ja*
- ◯ *Nee, elders in de stad*
- ◯ *Nee, elders in het buitengebied*

Wat is uw hoogst voltooide opleiding?

- ◯ *Geen opleiding*
- ◯ *Basisonderwijs*
- ◯ *VMBO / MAVO*
- ◯ *HAVO / VWO*
- ◯ *MBO*
- ◯ *HBO*
- ◯ *WO*

2

"De situatie is levendig uitgebeeld" | **"Ik begrijp door dit beeld goed wat de klimaatproblemen in de stad inhouden"**

zeer mee oneens | mee oneens | noch mee oneens, noch mee eens | mee oneens | zeer mee eens

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

3

"Ik kan mij inleven in deze situatie" | **"Dit is een realistische weergave van de werkelijkheid"**

zeer mee oneens | mee oneens | noch mee oneens, noch mee eens | mee oneens | zeer mee eens

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

4

In hoeverre hebben deze beelden...

... mij aan het denken gezet over het klimaat in de stad

Weinig 1 2 3 4 5 *Veel*

... mij gestimuleerd om meer te willen weten over het stadsklimaat

Weinig 1 2 3 4 5 *Veel*

... mijn kennis over klimaatadaptatie verbeterd

Weinig 1 2 3 4 5 *Veel*

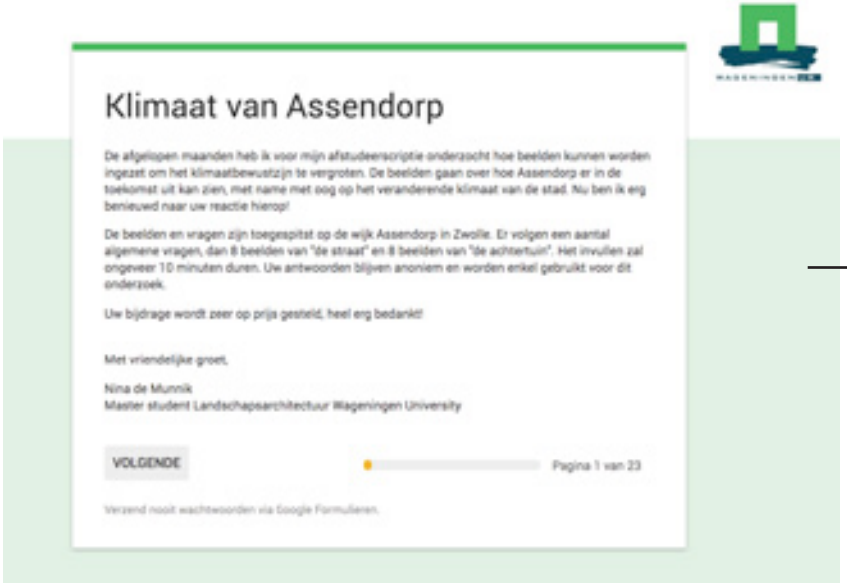
... mij aangemoedigd om actie te ondernemen in mijn eigen omgeving

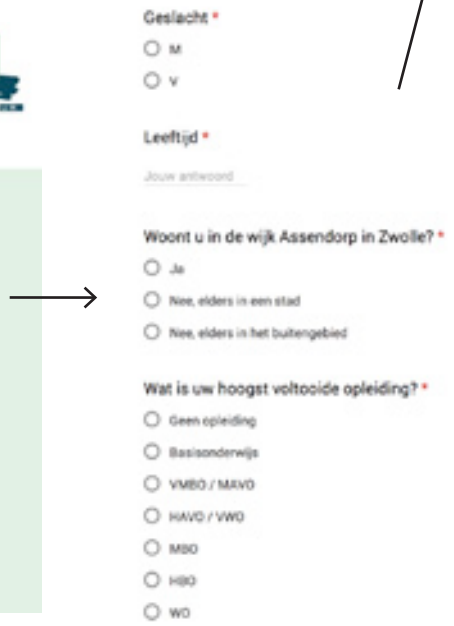
Weinig 1 2 3 4 5 *Veel*

5

IIIc Questionnaire (Google Forms)

https://goo.gl/forms/1t7IwIcJGFEqyuTE3





x 8 Street visuals

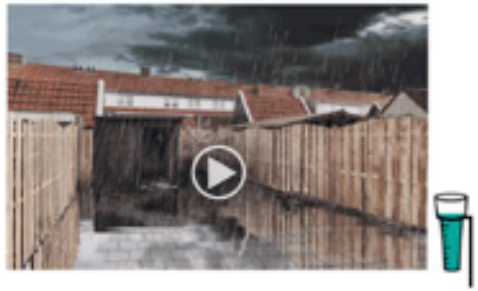
De achtertuin

We zijn op de helft! We gaan door met 8 beelden van een 'gemiddelde' achtertuin. Dit is een tuin op het zuiden.

Huidige situatie

Achtertuin | beeld 1

Bij een hevige regenbui van 100mm/dag kan de achtertuin er zo bij komen te liggen.
Het beeld is een GIF bestand wat automatisch hoort af te spelen. Mocht dat niet goed werken is dit de link naar de beelden op youtube: https://gwo.gl/uXBaHw



"De situatie is levendig uitgebeeld"

	1	2	3	4	5	
Mee oneens	○	○	○	○	○	Mee eens

"Ik begrijp door dit beeld goed wat de klimaatproblemen in de stad inhouden"

	1	2	3	4	5	
Mee oneens	○	○	○	○	○	Mee eens

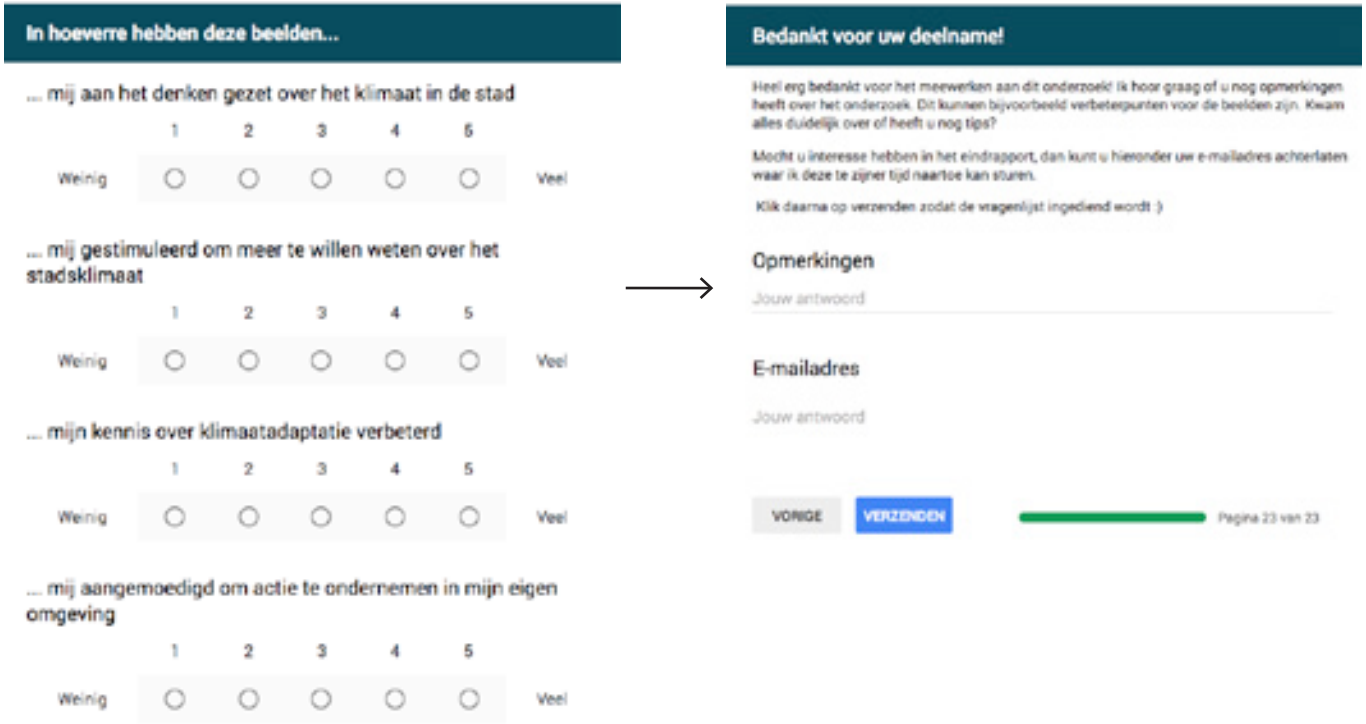
"Ik kan mij inleven in deze situatie"

	1	2	3	4	5	
Mee oneens	○	○	○	○	○	Mee eens

"Dit is een realistische weergave van de werkelijkheid"

	1	2	3	4	5	
Mee oneens	○	○	○	○	○	Mee eens

x 8 Backyard visuals →


In hoeverre hebben deze beelden...
... mij aan het denken gezet over het klimaat in de stad
1 2 3 4 5
Weinig Veel
... mij gestimuleerd om meer te willen weten over het stadsklimaat
1 2 3 4 5
Weinig Veel
... mijn kennis over klimaatadaptatie verbeterd
1 2 3 4 5
Weinig Veel
... mij aangemoedigd om actie te ondernemen in mijn eigen omgeving
1 2 3 4 5
Weinig Veel
Bedankt voor uw deelname!
Heel erg bedankt voor het meewerken aan dit onderzoek! Ik hoor graag of u nog opmerkingen heeft over het onderzoek. Dit kunnen bijvoorbeeld verbeterpunten voor de beelden zijn. Kwam alles duidelijk over of heeft u nog tips?
Mocht u interesse hebben in het eindrapport, dan kunt u hieronder uw e-mailadres achterlaten waar ik deze te zijner tijd naartoe kan sturen.
Klik daarna op verzenden zodat de vragenlijst ingediend wordt :)
Opmerkingen
Jouw antwoord
E-mailadres
Jouw antwoord
VORIGE
VERZENDEN
Pagina 23 van 23

IIId Article in De Assendorper

Hoekman, R. (2017). Is de klimaastverandering ook merkbaar in en rond ons huis?. De Assendorper. Retrieved on 14-12-2017 from https://issuu.com/deassendorper6/docs/assendorper_november2017_web

Student Wageningen Universiteit onderzoekt gevolgen klimaat Assendorp

'Is de klimaatverandering ook merkbaar in en rond ons huis?'

De klimaatverandering is wereldwijd merkbaar. Het lijkt soms ver weg, maar heeft wel degelijk invloed op dichtbij. Om dat beter in kaart te brengen riep Nina de Munnik, studente aan de Wageningen Universiteit, inwoners van Assendorp op mee te denken in haar afstudeeronderzoek over het klimaat in de wijk.

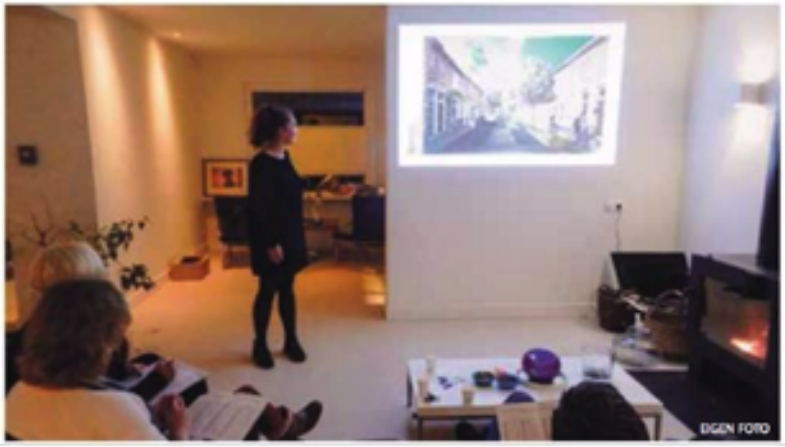
Door: Ryan Hoekman

Nederland krijgt als gevolg van de klimaatverandering te maken met meer extremen in het weer. Zwaardere regenbuien die zich vaker voordoen en meer hittegolven. Dit heeft ook gevolgen voor je eigen omgeving. Zeker in Assendorp, een wijk met veel steen waar, gelukkig, veel te verbeteren valt.

Nina wil met haar scriptie de processen in beeld brengen die de klimaatverandering beïnvloeden. Ze wil daarbij testen of en hoe visualisaties kunnen bijdragen aan een groter klimaatbewustzijn. Ze rondt hiermee haar master Landschapsarchitectuur af aan de Wageningen Universiteit. Donderdag 12 oktober presenteerde ze haar beelden in de huiskamer van Adriaan Mosterman. Die beelden lieten zien hoe belangrijk het is om actie te ondernemen in de wijk. Zo niet, dan komen straten eens in de vijf jaar blank te staan en koelt het na een hittegolf 's nachts niet meer af door het vele steen en het weinige groen. De pasaangelegde geveltuintjes in de Seringenstraat geven het goede voorbeeld: zo krijg je meer groen in de wijk en het ziet er ook nog leuk uit! Niet alleen de problemen, maar ook slimme oplossingen vielen er in Adriaans woonkamer te zien. De bezoekers van de bijeenkomst waren positief verrast over de kleurrijke zonneschermen. Niet alleen vrolijk, maar ook erg verkoelend. Door oplossingen zo te laten zien, werd voor deze bewoners van de wijk het nut van de oplossingen veel duidelijker. 'Het is goed om beelden te zien, dat helpt enorm en is beter voor je bewustwording dan een tekst. Abstracte termen als klimaatverandering en klimaatadaptatie krijgen op die wijze ook praktische inhoud.'

Nina merkte tijdens haar onderzoek dat er onder bewoners van Assendorp een ambitie is om de wijk in alle opzichten te verbeteren. Door visualisaties te tonen kunnen de bewoners de verandering letterlijk voor zich zien. Op deze manier wordt duidelijk hoe de toekomst van Assendorp eruit kan zien.

Ben jij benieuwd naar hoe jouw straat eruit kan gaan zien? En wil je meedenken? Vul dan de online enquête in: https://goo.gl/forms/WRlStLxd9HtzTQHB2.



	RESP.	GENDER	AGE	RESIDENCE	EDUCATION	STREET																											
						1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D	6A	6B	6C	6D	7A	7B	7C	7D	8A	8B	8C	8D
Meeting	1	M	45	Assendorp	HBO	4	2	4	4	4	2	3	4	4	3	3	4	5	4	4	4	4	3	4	4	4	4	4	4	4	3	3	5	4	4	3
	2	M	59	Assendorp	VMBO/MAVO	3	4	5	4	4	5	5	4	4	4	4	5	5	3	5	5	4	4	4	5	4	4	4	5	4	3	4	5	5	3	4	5
	3	V	37	Assendorp	WO	5	5	4	3	4	5	4	3	5	5	5	4	5	5	5	4	5	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
	4	V	65	Stad	HBO	5	5	4	3	5	5	5	5	5	5	5	5	5	5	5	5	4	1	1	1	4	1	1	1	5	5	5	5	5	1	1	1
Enquete	5	V	46	Assendorp	HBO	2	4	4	2	2	4	4	2	3	4	4	4	4	4	4	4	3	4	4	5	3	4	4	5	4	4	4	5	4	4	4	4
	6	V	50	Assendorp	HBO	3	4	4	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	3	3	2	2
	7	V	45	Assendorp	WO	4	5	4	4	4	3	4	4	4	4	4	4	4	4	4	4	5	5		4	4	5	4	4	4	3	3	3	4	3	3	3
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	12	M	66	Assendorp	WO	5	5	5	1	5	5	5	1	5	5	5	5	5	5	5	5	5	5	5	1	5	5	5	1	5	5	5	1	5	5	5	1
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	19	V	36	Assendorp	HBO	5	5	5	4	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	2	2	2	4	3	4	3
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	21	M	40	Assendorp	MBO	5	4	4	4	4	4	4	4	5	4	4	4	5	5	5	5	4	4	4	4	4	5	5	4	4	4	4	4	5	5	4	4
	22	V	29	Assendorp	MBO	5	5	4	3	4	5	4	3	5	5	5	4	5	5	4	5	5	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
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	46	V	56	Assendorp	MBO	2	4	1	1	3	4	1	1	5	5	3	3	5	5	5	5	5	5	1	3	5	5	3	3	5	5	3	3	5	5	4	3
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BACKYARD																													IMPACT AWARENESS			
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IVb Qualitative data

Visualisations content

- ‘Afvoer’ in straat werd niet begrepen: ‘welke ingreep’ is dat?
- Beeld achtertuin + water > water loopt huis in, toevoegen aan beeld voor extreme effect > persoonlijk maken, aangrijpend
- Ik heb nog nooit zo’n volgelopen straat gezien > maar kan wel vaker gaan gebeuren
- Vijver ‘schiet door’, is wel grote stap
- Kan realistischer en pragmatischer
- Zou je niet iets met fijnstof moeten doen?
- Tekst isolatie + maatregel bij elkaar (niet ene links, andere rechts)
- De beelden op zich waren helder. Maar ik miste het meebewegen van de schaduw bij de zon. Dat zou wat meer realiteit aan de animaties hebben meegegeven. Een andere toevoeging zouden meer data kunnen zijn (hoeveel liter water, hoeveel graden Celsius bijvoorbeeld). Maar ik weet dat dat veel meer tijd en energie vergt. Succes!
- Bij de nacht misschien nog iets van uitleg geven over (de afwezigheid van) die rode gloed, want ik snapte eerst niet goed wat dat was.
- Hoi! Mooie beelden, bieden een goed beeld van mogelijke scenarios's wat betreft hittestress en wateroverlast. Een kleine tip: de beelden met het water in de tuin zijn erg donker. Het lijkt een beetje alsof er olie in de tuin loopt. Mogelijk kan je die iets blauwer(wateriger) maken zodat het meer op water lijkt. Verder zou ik zeggen ga zo door, ziet er top uit! Goed onderwerp om onderzoek naar te doen!
- Ik weet niet of het altijd even realistisch is, kunnen groenstroken zo breed zijn in een straat waar geparkeerd wordt? Begrijpt een leek de beelden ook? En tenslotte leek het voor mij alsof de zon zijn invloed heeft op de nacht, terwijl het over de hele periode genomen flink opwarmt en zowel beplanting als schaduw noodzakelijk is. Afbeeldingen zijn wel heel helder gevisualiseerd!

Visualisations style

- Eenvoudig houden
- Bij beeld met tekst ontbreekt rode gloed. Een sluit ander niet uit
- Tekst is erg handig
- Zonder tekst is erg intuïtief en lastiger te begrijpen
- Thermometer op rechts: ‘meelezen’
- Thermometer erg klein, getallen erbij > nu door enkele niet opgevallen
- Hoi, Wat een leuke filmpjes., Mag ik een link/ plaatje of filmpje gebruiken op mijn website? Maartje van den Berg Blossom architecture 0653501260
- Mooie beelden!
- Hartstikke goede visualisaties. Simpel en daardoor zeer krachtig. Ik ben ze niet eerder zo goed tegengekomen terwijl dit raakt(e) aan mijn werkveld. Veel succes met het vervolg!!

Awareness

- Mooie visualisatie, leuke ideeën voor in de straat
- Deze beelden helpen enorm bij bewustwording
- Goed om ideeën te zien, wat je kunt doen
- Levendig uitgebeeld
- Ik moet het ook voor me zien, dus dit helpt ook enorm

- Ik vond het geheel erg uitgaan van bewoners die van niets weten, simplistisch.
- Ter aanvulling: ik weet vanuit mijn werk (waterschap) al veel over dit onderwerp. Het voegt daarom voor mij niets toe. Ik denk dat beelden wateroverlast meer tot de verbeelding spreken dan hitte. Ik voel het wel. Veel mensen zien probleem hittestress irt klimaatverandering niet. Velen geven aan het wel prettig te vinden dat het warmer wordt.. Teksten voegen voor mij niets toe.. vraag of woord ‘infiltratie’ ook door iedereen wordt begrepen. De vraag is hoe mensen hun gedrag wordt beinvloedt. Bewustwording niet altijd nodig en/of genoeg.. tip: arjo travaille gedragsbeinvloeding.. wat beweegt mensen.. Succes met onderzoek "
- ik was me er al van bewust, wij kiezen al voor andere achtertuin en meer groen voor in de straat. Straat is mooi met bomen en andere tegels (waterdoorlatend).
- Ik ben zelf al veel bezig met duurzaamheid en bewust van het klimaat in de stad. Hoop dat je ideeÃ«n uit het onderzoek en de voorbeelden die je laat zien ook daadwerkelijk doorgevoerd gaan worden. Succes ermee!
- Hee Nina wat ontzettend leuk gedaan! Enige wat ik me kan voorstellen is dat een vraag aan het begin om de beginkennis van stadsklimaat te peilen een kleine aanvulling kan zijn, ter vergelijking met wat je aan het einde vraagt. Maar super hip! Ik wil jouw thesis straks wel lezen (of bekijken^^) hoor! Succes met de laatste loodjes!!
- In onze straat (seringenstr) zijn we al aardig op weg maar de beelden laten zien wat vergroening kan doen. Mooi gedaan!
- Wellicht wel heel postief ingevuld, maar aangezien wij actief bezig zijn met vrijwel alle benoemde scenario's zijn we al enorm tot nadenken gezet. Voor ons dit jaar veel nieuwe inzichten in water en hitte!
- Heel mooi in beeld gebracht, vooral ook de graphics verduidelijken veel. Ben benieuwd naar de resultaten van je onderzoek.
- Vaak is er nog geen bewustwording

Aftermath

- Ik denk dat als er meer mee gedaan wordt (klimaat), dat de gemeente gaat ingrijpe
- Zou mooist zijn als het vanuit bewoners zelf komt
- Mensen in Assendorp willen heel graag, maar weten niet hoe ze dat moeten doen
- Misschien ook rond laten sturen via burgerpanel van Gemeente Zwolle
- Deelnemers meeting willen ook online versie verspreiden via straat
- Misschien delen via LinkedIn

Other

- Succes
- Veel succes met je onderzoek!
- 1e keer invullen ging niet helemaal goed. Succes!
- kom op, wordt serieus
- het heeft mijn volle (financiële) effectief én efficiënt aandacht.
- Iets teveel dezelfde vragen
- De vraag is op z’n minst interessant om je af te vragen waarom zo weinig groen en onverhard is in de wijk. Kattenpoep is bijvoorbeeld een veel gehoorde klacht. Onderhoud van tegels is een stuk minder dan van gras/groen.
- Geen

APPENDIX V. THE VISUALISATIONS

Va Interim visualisations (assessed in the survey)
Animations are accessible by clicking on the 'play' button (with internet connection)
or by following the link to the complete YouTube playlist: http://bit.ly/2BmVOoJ

Vb Final visualisations

Animations are accessible by clicking on the ‘play’ button (with internet connection)
or by following the link to the complete YouTube playlist: http://bit.ly/2C5GZ6B