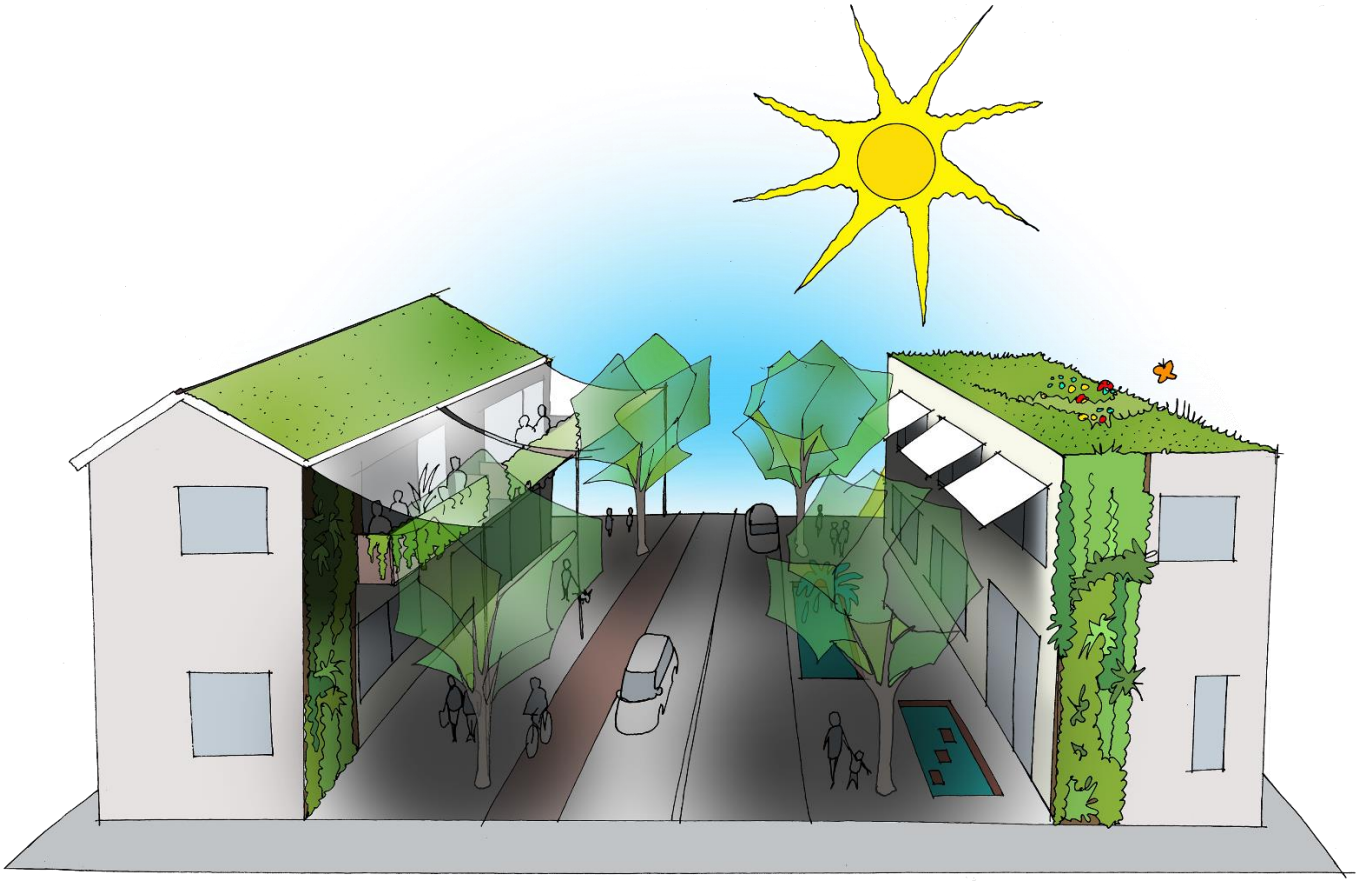
Universiteit Utrecht

Master Thesis

The Transformational Process of Addressing Heat Stress in Social Housing



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Preface

Dear reader,

Before your lies my master thesis “The Transformational Process of Addressing Heat Stress in Social Housing”, which I have been working on for the past 5 months. Throughout my studies I have worked on many different research reports, almost always in collaboration with fellow students. Therefore, in the weeks leading up to the master thesis period, I was definitely intimidated by the perspective of conducting and writing a research project on my own. However, in retrospect this was unnecessary. Mainly because even though the master thesis is a personal research project, it has been established through the help, support and guidance of multiple people I would like to thank.

First, I would like to thank my supervisor, Niki Frantzeskaki for the knowledge and enthusiasm she provided throughout the entire master period. Through her help I have learned many new things, ranging from how to conduct research to even the most practical aspects such as the importance of saving work to the cloud.

Second, I would like to thank Claudia Reuter and Freya Macke for the opportunity to combine writing my thesis with doing an internship. I really enjoyed doing an internship at Arcadis and I am thankful for the guidance and expertise they provided me with. Furthermore, I would like to thank my fellow intern, Jelske Koopstra for the collaboration throughout the internship.

Third, I would like to thank my fellow students for feedback they provided. In particular, I would like to thank Fabian Dorreboom, Jill van Velden, Larissa van Waardenberg and Thijs Meeusen for their companionship every Monday during the meetings on campus where we worked on our theses. Struggling together on the master thesis was definitely a fun experience.

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Last but not least, I would like to thank my dad, my mother and my sister for all their love and support through all these months. I am very grateful for their support that allowed me to complete this thesis.

Furthermore, thanks for taking the time to read this thesis. I hope you enjoy reading it.

David Kooistra

Zeist, August 5, 2022

Summary

As a consequence of climate change, heat waves are expected to occur more frequently, increase in duration and be more severe in the coming decades. High temperatures lead to higher incidences of heat stress among humans which can have multiple adverse health effects. Especially urban residents are at risk for heat stress which can be attributed to higher temperatures associated with the urban heat island effect. Since humans spend most of their time indoors, climate adaptation of private spaces to prevent indoor heat gain is crucial to provide people with a comfortable and healthy home temperature. As existing urban areas are not built with the ideas of climate adaptation in mind, an urban transformation is needed to bring about these changes.

When it comes to climate adaptation of private space, housing associations represent an important group of actors as they own a large proportion of private space in the Dutch urban context. Other involved actors include the tenants of the housing associations and the municipality. Due to the involvement of different actors in urban transformations – each with their own responsibilities, resources and visions on what measures should be taken – these transformations are often characterized by complexity. Furthermore, complexity arises due to variations in local urban context such as the built form. Consequently, there is no 'one size fits all' solution and the transformation is dependent on a good transformational process among stakeholders.

Therefore, the urban transformative capacity framework, as formulated by Wolfram (2016), was used to analyze whether the transformative capacities are present among stakeholders in this transition. Three pre-war neighborhoods in the municipality of Rotterdam were selected as a case study for this purpose. Data has been gathered by means of interviews with the municipality of Rotterdam, housing associations and tenant associations.

Results suggest that large scale implementation of heat resistant measures will not be possible in the near future among every housing association due to a lack of resources. This necessitates sharing of resources among involved stakeholders, an efficient and cost-effective way of choosing measures and prioritization of where to spend the limited available resources. To bridge the gap until structural measures are taken, temporary measures could present a relatively affordable solution. Furthermore, a heat plan for all housing associations – that is made and distributed in collaboration with each of the stakeholders – could provide tenants with knowledge of the behavioral measures they themselves can take to keep their dwelling cool.

Additionally, more research is needed to investigate which buildings are most susceptible for heat gain, which measures are most effective for a certain building and when sufficient measures are taken. This could help to prioritize what buildings to address first in addition to other factors such as presence of risk groups for heat stress. Furthermore, a clear target for when a dwelling is sufficiently heat resistant is currently lacking and a standardized national approach could help with this

Another aspect that could improve the transformative nature of this transition is a comprehensive approach in which public and private stakeholders keep interactions between public and private space in mind. The temperature in private space is also dependent on characteristics of public space and vice versa. Therefore, collaboration between the municipalities and housing associations could lead to implementation of measures that would benefit both. An example of this are trees in public space providing shade for the dwellings of housing association. This way the limited available urban space could be fully utilized to become climate adaptive and costs would be shared among stakeholders.

Abstract

Contemporary areas worldwide increasingly face the impacts of climate change. One of these impacts is a higher temperature for which cities are especially vulnerable due to the urban heat island effect. Climate adaptation can reduce the negative impact of heat stress on cities. This requires climate adaptation of both public and private space. In Dutch cities, housing associations are important actors in this respect as they own a large proportion of private space. The current study therefore looks at the process behind retrofitting their housing stock. Complexity is often an unavoidable aspect of such transitions. Therefore, the urban transformative capacity framework, as formulated by Wolfram (2016), was used to analyze whether the transformative capacities are present among stakeholders in this transition. Three pre-war neighborhoods in the municipality of Rotterdam were selected as a case study for this purpose. Data has been gathered by means of interviews with the municipality of Rotterdam, housing associations and tenant associations. Results suggest that large scale implementation of heat resistant measures will not be possible due to lack of resources among most housing associations. This necessitates sharing of resources among involved stakeholders, an efficient and cost-effective way of choosing measures and prioritization of where to spend the limited available resources. Furthermore, a clear target for when a dwelling is sufficiently heat resistant is lacking. Another aspect that could improve the transformative nature of this transition is a comprehensive approach in which public and private stakeholders keep interactions between public and private space in mind. This way the limited available urban space could be fully utilized to become climate adaptive.

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1. Introduction

Responding to the effects of climate change is often discussed in terms of two established concepts: 'climate mitigation' and 'climate adaptation'. Climate mitigation and climate adaptation are two related but distinct concepts with the former referring to reducing the effects of climate change and the latter referring to reducing the impacts of climate change as well as vulnerability to the effects of climate change (Swart & Raes, 2007). However, both concepts were historically not always seen as equally established within both science and practice. Two decades ago, climate adaption was a highly debated subject as climate mitigation efforts were seen as a sufficient way to curb climate change (Kongsager, 2018). Investing in climate adaptation was seen as giving up on mitigation efforts prematurely and removing valuable funding from the latter (Pielke et al., 2007). Furthermore, climate adaptation was seen as having only local benefits whereas climate mitigation efforts would have benefits at a global scale level (Ayers & Dodman, 2010; Pielke et al., 2007). However, from 2001 and on, reports made by the Intergovernmental Panel on Climate Change (IPCC) indicated that mitigation efforts would not be enough to prevent the effects of climate change causing the IPCC to call for more attention towards adaptation measures as a way to deal with these effects (IPCC, 2001; IPCC, 2007; IPCC, 2022). Ultimately, the inability of mitigation to curb climate change, together with the impacts of climate change becoming reality, gradually led to climate adaptation being seen as equal and complementary to climate mitigation (Ayers & Dodman, 2010; Swart & Raes, 2007).

1.1. Climate adaptation

Nowadays, climate adaptation is probably more relevant than ever as areas worldwide increasingly suffer from the impacts of climate change (IPCC, 2021). While the exact effects are dependent on the specific local context, in general they include rising sea levels, extreme weather events, including a rise of global temperatures and more periods of droughts alternated by periods of heavy precipitation (IPCC, 2021). Furthermore, in all scenarios it is expected that climate change will continue in the coming years and consequently the effects of climate change will increase as well. Even if emissions are heavily reduced starting today, a certain degree of climate change has been "locked-in" and its effects will thus irreversibly continue (IPCC, 2022). This can be explained by the relatively long period in which carbon dioxide stays in the atmosphere after emission and also by heat that has already been trapped in the ocean which takes a long time to readjust to lower temperatures (KNMI, 2021; Wigley, 2005). Due to these factors, a certain degree of continuing climate change and its effects are unavoidable. As a consequence of the expected impact of climate change, climate adaptation is now an important part of the policy agenda at many different scale levels (Bulkeley, 2010).

This can be illustrated in the context of the Netherlands where different levels of Dutch government, including the state, provinces, municipalities and regional water authorities, aim to adapt to the effects of climate change with the national program 'Delta Plan on Spatial Adaptation' (Deltaplan Ruimtelijke Adaptatie). Together, they have the ambition to make the Netherlands climate adaptive by 2050 (Rijksoverheid, 2021). Climate adaptation is especially of importance in the Netherlands due to two main vulnerabilities. The first vulnerability is due to the Netherlands' low elevation level relative to sea level which increases the chance of floods (PBL, 2011; Runhaar et al., 2012). This vulnerability is further exacerbated by the fact that a large proportion of Dutch cities are located near riverbanks, a delta close to the sea or a combination of the two (PBL, 2011). The second

vulnerability is related to the vulnerability of urban areas when it comes to the effects of climate change. Factors such as high urbanization levels and the fact that the Netherlands is densely populated result in a landscape that consists for a considerable proportion of urban areas (PBL, 2011).

1.2. Climate adaptation in cities

Cities are especially vulnerable when it comes to climate change for numerous reasons. As a consequence of the prevalence of artificial structures such as concrete in cities, periods of heavy rainfall can lead to water drainage problems and subsequent floodings, while periods of droughts can lead to a lack of available water due to the low retention rates of artificial structures (Balaban, 2012). Another reason for the vulnerability of cities when it comes to the effects of climate change is related to increased heat stress in urban areas compared to surrounding rural areas which is often referred to as the urban heat island effect (Balaban, 2012; Kleerekoper et al., 2012). Furthermore, cities serve important societal functions as they are places where political institutions, economical assets, cultural assets, infrastructures and the homes and workplaces of people are located (UN-Habitat, 2018). Cities house more than half the world population which is predicted to increase to 68% in the year 2050 (United Nations, 2018). Climate adaptation is therefore not only important to keep cities livable for the existing and growing number of residents, but also to protect their important societal functions from the effects of climate change (UN-Habitat, 2018).

In the context of increasing urbanization around the world, it is important that the concept of climate adaptation is incorporated in new urban development plans as it presents an opportunity to take climate adaptation into account in every aspect of the plan. This likely leads to more adaptive neighborhoods and an easier process than retrofitting in the future (NKWK KBS, 2020; UN-Habitat, 2018). With this in mind, contemporary building plans in the Netherlands such as brownfield developments often take the need for climate adaptation into account to develop a neighborhood that is climate adaptive from the get-go (NKWK KBS, 2020). However, a different approach is needed for existing neighborhoods as they are in most cases not built with the idea of climate adaptation in mind (NKWK KBS, 2020).

1.3. Retrofitting existing neighborhoods

The process of retrofitting existing neighborhoods presents a challenge due to the existence of the many users and owners of space in these neighborhoods. In existing neighborhoods, stakeholders comprise civil society, public parties and private parties whose goals, interests, values, perceptions and power differ (Trell & van Geet, 2019). Therefore, stakeholder engagement is a crucial aspect in these projects. In existing neighborhoods a distinction can be made between public space and private space. Whether a space is public or private determines which stakeholders are involved, their rights and their formal responsibilities (NKWK KBS, 2020). When it comes to public space, municipalities are often responsible for climate adaptation of these spaces, whereas the responsibility of adapting private spaces is a lot more fragmented over different owners ranging from individual homeowners, the social housing sector, the private housing sector and other companies (Uittenbroek et al., 2019).

Due to the involvement of private space, the owners of these private spaces are often the ones responsible for climate adaptation. The importance of adaptation of private spaces is also reflected in the division of private and public spaces in urban areas. It is estimated that 60% of urban areas in the Netherlands comprise of private space whereas the remaining 40% consists of public space

(NKWK, KBS, 2020). Consequently, making cities climate adaptive will not be possible in just public space (NKWK, KBS, 2020). Therefore, when a local government seeks to make its entire city to become more climate adaptive, stakeholder engagement with private owners is imperative. Furthermore, stakeholder engagement could benefit the transition as a way to sway owners of private spaces to collaborate in this transition (NKWK, KBS, 2020). Examples of private owners that are involved include, but are not limited to, housing associations, investors and citizen house-owners.

Furthermore, complexity arises due to the convergence of many fields involved in climate adaptation, such as spatial planning, public health, housing, environmental policy, water management, infrastructure and many more. Therefore, one of the current successful ways of implementing adaptation principles into existing neighborhoods that has been identified so far involves 'mainstreaming' which makes climate adaptation an integral part of already existing policy domains (Albers et al., 2015; Uittenbroek et al., 2012). However, as mainstreaming involves integration of climate adaptation in municipal policy fields which mainly focus on public spaces, it remains unclear in the literature whether this will also benefit private spaces (Boezeman & de Vries, 2019).

1.4. Heat stress

In general, in both research and practice, there is especially a focus on making public spaces climate adaptive, especially when it comes to the water related impacts of climate change (Hegger et al., 2017). However, there is less attention for climate adaptation of private spaces. Even though climate adaptation of public spaces can deliver important benefits for the users of public spaces, it should be noted that people spend most of their time indoors in their private spaces (Brasche & Bischof, 2005; Khajehzadeh & Vale, 2016). One of the most widely experienced effects of climate change indoors are high temperatures (Franck et al., 2013). Spending a prolonged period of time in high temperatures can have adverse effects on health and wellbeing (Kovats & Hajat, 2008). These effects are the result of the human body not being able to get rid of excess heat which is referred to as heat stress. Climate adaptation in terms of addressing indoor heat stress is especially important for certain groups who are at risk for heat stress to begin with – like the elderly, young children or people with health issues – who might not be able to transport themselves from their warm home to a cooler place (Holmes et al., 2015).

Furthermore, especially people in urban areas are at risk of heat stress due to the aforementioned urban heat island effect. The urban heat island effect and its associated higher air temperature can also contribute to higher indoor temperatures (Franck et al., 2013). However, certain characteristics of private spaces can also influence the temperature outside (Kleerekoper et al., 2012). This interdependency emphasizes the need to address both public and private space when tackling urban heat stress.

1.5. Involved actors

In order for cities to become climate adaptive against heat stress, existing urban areas will need to be retrofitted across the different urban actors. However, as indicated by the numerous complexities that define such an urban transformation, this often requires a multi-sectoral, multi-scalar and multi-actor process. Therefore, in order to achieve a sustainable outcome such as the goal of climate adaptation, structural changes – across sectors, scales and actors – are necessary in an urban system to bring about a sustainable outcome. Urban transformations therefore involve not only the change in outcome of an urban system, but also the process (Wolfram et al., 2016).

When it comes to transformation of private space, housing associations in particular present an interesting group of owners that face a significant task. This is especially the case in the Netherlands, as housing association own 29% of the total Dutch housing stock (CBS, 2021). Furthermore, they are obliged to certain legal duties concerning the quality of the housing stock. Both of these factors make them crucial but relatively approachable stakeholders when it comes to making existing neighborhoods climate adaptive as a single housing association often owns a large amount of dwellings (Roders et al., 2013). Due to the knowledge gaps that exist concerning the urban transformation to climate adaptive private spaces, the question remains whether involved stakeholders such as housing associations can shape this transition successfully; or in other words, whether these stakeholders possess the capacity to make this transition happen.

When it comes to most climate adaptation challenges, there is involvement of a broad range of actors, involving civil society, public parties and private parties (Mees et al., 2012). This is also the case regarding the mitigation of heat stress in the social housing stock. The main actors involved here are the housing associations themselves, the tenants living in social housing and the municipality. Among stakeholders the need for climate adaptation is generally accepted, however it often remains unclear what the responsibilities are of different stakeholders (Mees et al., 2012). Furthermore, the process is complicated due to the variety of stakeholders involved who may each have their own interests, perceptions, values, resources, wants and needs (Trell & van Geet, 2019). To transform the social housing stock to be more climate adaptive, multi-actor engagement is needed due to the interdependency of these actors when it comes to policies and legislation, sharing of resources and responsibilities to make a transformation happen. Furthermore, it is important to create a shared vision of a desirable transformational pathway among the involved actors (Wolfram et al., 2016).

1.5.1. Residents

Citizens can have an important contribution to the process and the outcomes of making existing neighborhoods more adaptive as their local expertise can contribute to better climate adaptive solutions (Uittenbroek et al., 2019). Because residents are often the ones experiencing heat stress in their dwellings, it is important to involve them in the process to get an indication of their wants and needs. Even between relatively similar neighborhoods when it comes to urban form, the wants and needs of citizens might differ, for example when it comes to whether solutions with the greatest impact are valued or whether solutions that are multifunctional are more desired (Derkzen et al., 2017). Furthermore, involvement of residents has the potential to raise awareness for the need of cities to become adaptive, increase support for plans and can also legitimize the measures taken (Runhaar, 2009). Derkzen et al. (2017) note that there is currently not always awareness among residents about potential measures against heat stress even when they do experience it.

1.5.2. Local governments

While there are often no clear responsibilities when it comes to climate adaptation of private spaces, Mees et al. (2012) describe that it is in many cases a government party that takes the lead, for example by creating an adaptation strategy to provide a clear path towards climate adaptative neighborhoods. Additional strategies include implementation of policies, provision of subsidies to facilitate adaptations and by facilitation of collaboration among actors. Furthermore, local governments are often responsible for organizing public participation which is especially important considering that climate adaptation also involves measures taken in residents' living spaces (Hegger et al., 2017). Furthermore, by involving the public and private parties, responsibilities can be shared

and the resources present in society can be used to the fullest extent (Hegger et al., 2017; Tompkins & Eakin, 2012).

1.5.3. Housing associations

Housing associations are semi-private organizations in the Netherlands (Roders et al., 2013). Since they own a large proportion of the Dutch housing stock in cities, they are key stakeholders in the transformation to climate adaptive private spaces. This is especially true when it comes to measures such as implementing green roofs, green facades or green gardens that could mitigate heat stress in a dwelling as well as in public space . While in 2013 it was reported that awareness levels were low among Dutch housing associations, this may have changed since then (Roders et al., 2013). According to housing associations, they increasingly receive reports from tenants with complaints about heat stress and have explicitly formulated a desire to adapt their housing stock to the changing climate (Boerbooms & Verhaeghe, 2020). Furthermore, Roders et al. (2013) reported that financing was seen as an issue when it comes to climate adaptation. Government subsidies could provide a solution for this and has already been applied in some contexts. Another potential barrier that has been identified is the complexity that is involved in climate adaptation as housing associations may lack knowledge on what measures to apply in certain contexts (Roders et al., 2013). This again highlights the need of collaboration among stakeholders to deal with this complexity.

1.6. Research questions

Knowledge about how the process of making private properties adaptive can be configured, how stakeholder involvement can occur and what barriers and opportunities are, can contribute to a just transition to climate adaptive neighborhoods by 2050 as described in the Delta Plan of Spatial Adaptation Rijksoverheid, 2021). Making existing neighborhoods climate adaptive can have many societal benefits, however, climate adaptation is in many cases mostly reviewed on their potential costs and limited financial benefits. Meanwhile, socio-economic benefits are often forgotten, such as health, livability, prevention of climate related damages and spatial quality (Uittenbroek et al., 2019). Attaining these societal benefits is in many cases dependent on a good governance process as well as stakeholder involvement. Therefore, the current study could mainly broaden existing knowledge, mainly concerning climate adaptation of public spaces, by adding knowledge about primarily the process behind climate adaptation towards heat resistant private spaces.

The aim of the current thesis is therefore to answer the following main research question: *How can heat stress in existing dwellings owned by housing associations be mitigated?*

The main research question will be answered with the help of the following sub-questions:

- How is the transition towards heat mitigative social housing currently governed?
- What are the visions of stakeholders when it comes to retrofitting both private and public space to be heat mitigative?
- What are barriers when it comes to mitigation of heat stress in social housing?

The first sub-question will mainly look at governance aspects such as the governance modes used, collaboration and sharing of resources among stakeholders and participation of tenants. The second sub-question will look at whether there is a vision present among stakeholders, how this vision originated and how this vision is further developed. One particular aspect of this is whether housing associations and the municipality use their respective spaces to deliver cooling benefits to each

other. The last sub-question will focus on barriers that obstruct mitigation of heat stress in social housing.

By answering these questions, the aim of the current study is to close the existing knowledge gap concerning knowledge about making private spaces climate adaptive. This could lead to new scientific insights on sustainability transitions and on stakeholder involvement especially in the field of climate adaptation. This is still an uncommon theme in the literature on urban transformation compared to that of climate mitigation.

In practice, these insights could inform policy-makers which could lead to a better process and consequently, also better outcomes. The outcomes are of societal importance due to the expected impacts of climate change and the negative effects of associated higher temperatures. Furthermore, adaptation against heat stress in private space is of importance due to its role in society as being a prominent place of residence. Furthermore, the process is of importance due to the need of involved actors to collaboratively deal with complexities associated with urban transformations. The current research will therefore investigate whether the capacities to make this urban transformation happen are present and which might be lacking. The theoretical framework will further elaborate on this by providing an overview of what outcomes may look like and what the transformational process could contribute to attain sustainable climate adaptive outcomes.

2. Theoretical framework

In the context of climate change, heat stress is one of the most widely experienced effects. To curb its effects in dwellings, adaptive measures will be necessary to preserve a comfortable home temperature. This first necessitates an understanding of what heat stress is, how it arises and what its effects are. However, heat stress inside dwellings is a complex issue involving many different factors at multiple interrelated scale levels. Therefore, it is important to investigate for each scale level what factors may cause heat stress and how these factors can be mitigated. First, the city and neighborhood level will be discussed through the urban heat island effect. Thereafter, by zooming in to the level of the building and the level of the resident, factors on a smaller scale level contributing to heat stress inside dwellings will be discussed. Ultimately, these factors should provide possibilities for transformations of existing neighborhoods to mitigate heat stress. However, actual implementation of transformations is dependent on capacities among actors involved at all of the aforementioned scale levels. On the basis of the urban transformative capacity framework as formulated by Wolfram (2016), the capacities that can contribute to a successful transformation will be discussed.

2.1. Climate adaptation against heat stress

Worldwide the effects of climate change are increasingly being experienced. The consequences are especially being felt in cities as they house more than half of the world population and because they are prone to the effects of climate change due to the prevalence of densely built artificial structures and lack of natural vegetation in many urban contexts (Derkzen et al., 2017; United Nations, 2018). As a consequence, there is a strong call for climate adaptation of urban areas to avert safety risks and disasters, and to preserve the livability and health of urban dwellers (IPCC, 2022; UN-Habitat, 2018). The measures taken to do this are thus part of the concept of climate adaptation, which can be further conceptualized as follows: “Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.” (United Nations, 2021). As mean global temperatures are expected to rise and heat waves are expected to occur more frequently and in longer durations, a key area of focus of climate adaptation is therefore on moderating the negative effects of higher temperatures such as those associated with heat stress (Franck et al., 2013).

2.1.1. Heat stress

Higher temperatures pose a threat to public health and to society in general as heat stress is expected to occur more frequently. Heat stress can be defined as a condition where the body cannot get rid of excess heat as a result of high temperatures outside the body (Kovats & Hajat, 2008). On an individual level, heat stress mainly leads to thermal discomfort but it can also have more serious physical and mental health consequences. Heat stress has been associated with worsened mental health outcomes (Obradovich et al., 2018), higher incidences of heat cramps, heat exhaustion, heat stroke and increased mortality (Kovats & Hajat, 2008). When it comes to broader societal effects, heat stress is associated with a higher energy demand and consequently more emission of greenhouse gasses due to increased need for active cooling (Mohajerani et al., 2017). Furthermore, heat stress may lead to labor productivity loss, resulting in economic losses (Zander et al., 2015).

Even though there are many effects of heat stress, in the context of this study, heat stress will refer to a spectrum ranging from subjective thermal discomfort in humans due to high temperatures to heat-related morbidity and mortality.

Beside the effects of heat stress on people, it should also be noted that some populations are more vulnerable to or disproportionally affected by heat stress. Especially elderly people, young people, people with pre-existing physical and mental health issues and people using certain types of medication affecting thermoregulation are all at increased risk for heat stress (Holmes et al., 2015; IPCC, 2022; Lundgren Kownacki et al., 2019). Additionally, people who experience mobility issues might be unable to transport themselves to cool places (Holmes et al., 2015). Furthermore, lower income populations have been shown to have a higher likelihood of experiencing heat stress in many urban contexts worldwide (Arifwidodo & Chandrasiri, 2020; Fan & Sengupta, 2021; Hsu et al., 2021). This can be attributed to factors such as less urban greenery in their vicinity, neighborhoods with a higher density and less financial means to prevent or reduce heat stress (Fan & Sengupta, 2021). However, the relationship between lower income and heat stress is less clear in that of the European urban context (Kovats & Hajat, 2008; Lundgren Kownacki et al., 2019). Furthermore, studies indicate that cities in general face higher incidences of heat stress which can be attributed to the urban heat island effect (Fischer et al., 2012).

2.2. Urban heat island effect: the neighborhood level

Specific characteristics of the built urban form and its land use interact with natural factors to create a specific climate in an urban area. This climate is referred to as an urban microclimate (Dimoudi et al., 2013). One of the most notable types of urban microclimates is that of the urban heat island effect. The urban heat island effect (UHI) refers to a phenomenon that describes how urban areas often have a higher temperature than surrounding rural areas (Wong & Yu, 2005).

The urban heat island effect is caused by three main factors: urban form, land use and natural factors that together can result in more heat stress compared to surrounding rural areas. As these characteristics can influence the temperature in an urban micro climate, they can therefore explain differences in heat stress between cities and within cities such as between different neighborhoods. Natural factors include factors such as the season, the air temperature, humidity, wind speed, wind direction, solar radiation and so on (Dimoudi et al., 2013; Sharmin et al., 2017). These natural factors are often deemed more or less uncontrollable. This is in contrast to urban form and land use factors, therefore making it more interesting to look at these latter two in the context of adaptation as they present an opportunity to curb the urban heat island effect (Vujovic et al., 2021). Therefore, the urban form factors and land use factors and how they both interact with natural factors will be highlighted in more detail.

When it comes to urban form, the orientation and spacing between buildings can obstruct wind flow which can cause heat to linger (Bhargrava et al., 2017). Furthermore, heat can remain in an urban area due to large buildings that trap heat waves and prevent reflection of heat waves to space. Due to the thermal properties of prevalent artificial materials in urban areas, heat is absorbed and can consequently be emitted to the air (Bhargrava et al., 2017; Kleerekoper et al., 2012). A much related land use factor is the fact that urban areas often lack natural vegetation. Therefore, the cooling effects of evapotranspiration do not occur and there is less shading due to a lack of trees (Bhargrava et al., 2017; Kleerekoper et al., 2012). Finally, anthropogenic heat production is another land use factor that contributes to the urban heat island through for example car use (Bhargrava et al., 2017; Kleerekoper et al., 2012). All of these factors will be explained in more detail in Box 1 below.

Box 1: UHI-effect in-depth

First, urban geometry is an important factor to take into account. It refers to spacing between buildings and the dimensions of buildings (Bhargrava et al., 2017). Areas with a high density of buildings that have been built against the wind direction obstruct wind flow which in turn leads to less heat transportation and consequently an elevation of urban temperatures. In contrast, urban areas with the opposite characteristics can enhance wind flow and thus lower the urban temperature. Furthermore, the urban heat island effect can be exacerbated in an area where the heat that is reflected by a relatively small building is trapped due to the reflection of larger surrounding buildings which prevents the heat from being reflected into space.

A second but much related factor is that of the properties of urban materials (Bhargrava et al., 2017). While urban geometry determines to what extent heat radiation from the sun reaches urban areas and to what extent heat either becomes trapped or is radiated back into space, the properties of urban materials determine the proportion of heat that is actually absorbed or reflected given that it comes into contact with heat radiation (Kleerekoper et al., 2012). The concept of albedo describes the ratio between the reflected solar energy to the incident solar energy. A low albedo value (i.e. low reflection and high incidence) means that a certain material absorbs more heat as opposed to reflecting it which consequently can contribute to heat stress (Nuruzzaman, 2015). Albedo is correlated with the color of the material. Darker colored materials absorb solar energy instead of reflecting it and therefore, in contrast to light colored materials, they contribute to urban heat stress (Bhargrava et al., 2017). Further properties of materials include heat capacity and thermal emittance. Heat capacity refers to the ability of a material to absorb heat and thereby contributing to heat stress. Thermal emittance refers to the ability of a material to emit infrared radiation and thereby keeping itself and the urban area it is in cooler (Bhargrava et al., 2017). Generally, artificial urban construction materials can store more heat than natural materials and as a consequence of this contribute to the urban heat island effect.

The third factor is the specific land-use pattern within an urban area. Natural vegetation such as trees, bushes, grass and other plants do not only store less heat, but also minimize the urban heat island effect in numerous other ways. Due to evapotranspiration, which occurs in natural vegetation, water gets evaporated into the atmosphere which has a cooling effect on the surrounding area (Kleerekoper et al., 2012). A lack of natural vegetation will have the opposite effect which is further exacerbated by the low availability of water due to the high run-off rate and low infiltration rate as is associated with impervious artificial surfaces (Bhargarava et al., 2017). Furthermore, natural vegetation such as trees can prevent heat stress by providing cooler areas of shade. As has been illustrated, natural vegetation can provide many cooling benefits but especially in urban areas natural vegetation is often scarce which can consequently exacerbate heat stress.

Fourth and last are human related factors. One of these is the release of anthropogenic heat in urban areas due to human activities such as transportation based on combustion, industrial processes and both heating and cooling buildings (Kleerekoper et al., 2012). Many of these processes also lead to air pollution and emission of greenhouse gasses, both of which contribute to heat being trapped in urban areas (Santamouris, 2007). This is especially the case when it comes to cooling of urban buildings in the summer. Due to the urban heat island effect, urban areas often consume more energy to keep building cool which results in an increase in greenhouse gas emissions and pollutants (Santamouris, 2007). This exemplifies how climate adaptation and climate mitigation are interrelated as adaptation measures could reduce the need for active urban cooling which consequently could reduce emission of greenhouse gasses, the latter being an integral part of mitigation.

2.2.1. Adaptation against Urban Heat Islands

The described factors that contribute to the urban heat island effect offer several ways in which potential heat stress can be mitigated and therefore, climate adaptation can be applied to urban areas. The first way is by increasing natural vegetation in urban areas. Vegetation can be applied to an urban area in multiple forms such as parks, trees, shrubs, green gardens and green roofs or facades (Lenzholzer et al., 2020). Vegetation can lower the temperature by evapotranspiration and especially trees can increase provision of areas shaded from sunlight. Furthermore, vegetation often has low albedo properties which prevents heat absorption (Kleerekoper et al., 2012). The second way in which heat stress can be reduced is by providing water in urban areas which has a cooling effect mainly due to heat absorption and consequently evaporation (Kleerekoper et al., 2012). However, research shows that the efficacy of urban water bodies is dependent on factors such as proper ventilation due to wind and shading as a lack of these factors leads to a limited cooling effect during the day and also potentially a warming effect at night as water can act as a heat sink (Cortesão et al., 2018; Gunawardena et al., 2017). A third way is by changing urban form characteristics (Lenzholzer et al., 2020). As heat radiation can be trapped between buildings, one way to prevent heat radiation from being trapped to begin with is by creating areas of shade provided by large buildings. However, this might also obstruct the cooling effect of wind flow, trap still existing heat and lead to a significant reduction of the temperature during winter months (Kleerekoper et al., 2012). Therefore, shade provision is preferable by certain trees for example as they let through sunlight in the winter, while the leaves in the summer can block sunlight (Kleerekoper et al., 2012). The fourth way of reducing heat stress is by using different materials of urban surfaces, including roads, pavements, buildings and so on. When these surfaces have favorable thermal and radiative properties, urban temperatures can be reduced (Lenzholzer et al., 2020). The fifth way is by reducing anthropogenic heat production by reducing the use of active cooling and heating, car-use and industrial processes that involve heat production in urban areas (Lenzholzer et al., 2020).

Even though an urban microclimate mainly refers to the temperature in outside public space, this temperature is not separate from temperature in private space and vice versa (De Vries et al., 2021). As has been highlighted, private space can heat up public space through anthropogenic heat production by for example air conditioning. Private space can mainly be heated up by public space through ventilation of warm air. The following paragraphs will explain this and other factors contributing to heat gain on the level of the building in more detail.

2.3. Indoor heat gain: the building level

While the temperature outside of a building is one of the ways in which buildings heat up, heat gain inside buildings is also dependent on multiple other processes. Multiple studies indicate that similar outdoor temperatures can result in different indoor temperatures (Franck et al., 2013; Tamerius et al., 2013). This can be attributed to building-related properties and behavioral factors (Franck et al., 2013). These properties and factors can therefore either reinforce or hamper heat gaining processes.

The first process through which heat gain in buildings occurs is through infiltration of heat (He, 2019; Kleerekoper et al., 2012). This way, warm air caused by the urban heat island effect can infiltrate a building, thereby contributing to heat gain (De Vries et al., 2021). A second process which leads to heat gain is thermal conduction which describes the process of heat being transmitted from warmed up surfaces like roofs or walls to the inside of a building (He, 2019). The properties of a material determine how much heat is absorbed and is consequently transmitted to the inside of a building. The third process is through radiation of sunlight through windows for example (He, 2019). Larger windows, orientated to the sun will therefore lead to higher temperatures (Nuiten & Leenarts, 2018). Generally, this process contributes the most to heat gain (Lundgren Kownacki et al., 2019). The fourth process is through anthropogenic heat production (He, 2019). Some electronic devices, cooking or even people themselves generate heat that warms up the inside of a building (Lundgren Kownacki et al., 2019). Together these processes determine how vulnerable a building is to heat gain.

2.3.1. Adaptation against indoor heat gain

These processes offer several opportunities to reduce vulnerability to heat gain. However, in the context of climate change, there is especially a need for passive climate change adaptation measures (Porritt et al., 2012). Many of these are depicted in figure 1. These passive measures are defined as climate adaptation measures that do not use energy themselves and therefore do not contribute to climate change (Porritt et al., 2012). Even though active cooling might contribute to lower temperatures inside a dwelling, it leads to higher temperatures outside of the dwelling due to anthropogenic heat release (Santamouris, 2007). Therefore, only passive adaptation measures will be discussed.

As heat can enter from outside to inside, heat gain can be prevented by reducing the urban heat island effect as discussed earlier. Furthermore, it can be beneficial to insulate a building to prevent infiltration of warm air (Franck et al., 2013; Lundgren Kownacki et al., 2019). However, another study found that insulation is associated with heat gain (Van Hooff et al., 2014). These contrasting findings could be the result of insulation initially preventing a dwelling from heating up. However, once the dwelling has eventually reached a higher temperature (e.g. due to other heat gain processes), the insulation may prevent the dwelling from cooling down once the temperature outside is cooler, thereby contributing to heat gain (Van Hooff et al., 2014). For this reason, ventilation by opening doors and windows when the temperature outside is cooler than inside can help lower the inside temperature (Nuiten & Leenarts, 2018).

Insulation can also prevent conduction of heat by providing an insulated layer between for example a roof and the indoor air. Another way to prevent conduction is by using materials with favorable thermal properties. These include materials that do not absorb much heat and using reflective high albedo materials, for example by painting roofs white (De Vries et al., 2021). Green roofs and facades can also be beneficial in this regard as they do not absorb a lot of heat, create an insulating layer and shading layer for the actual roof and walls, and they cool down air temperature by evapotranspiration (Castiglia Feitosa & Wilkinson, 2020). However, the cooling effect of a green roof on the inside temperature is limited and only causes a significant cooling effect in buildings that are

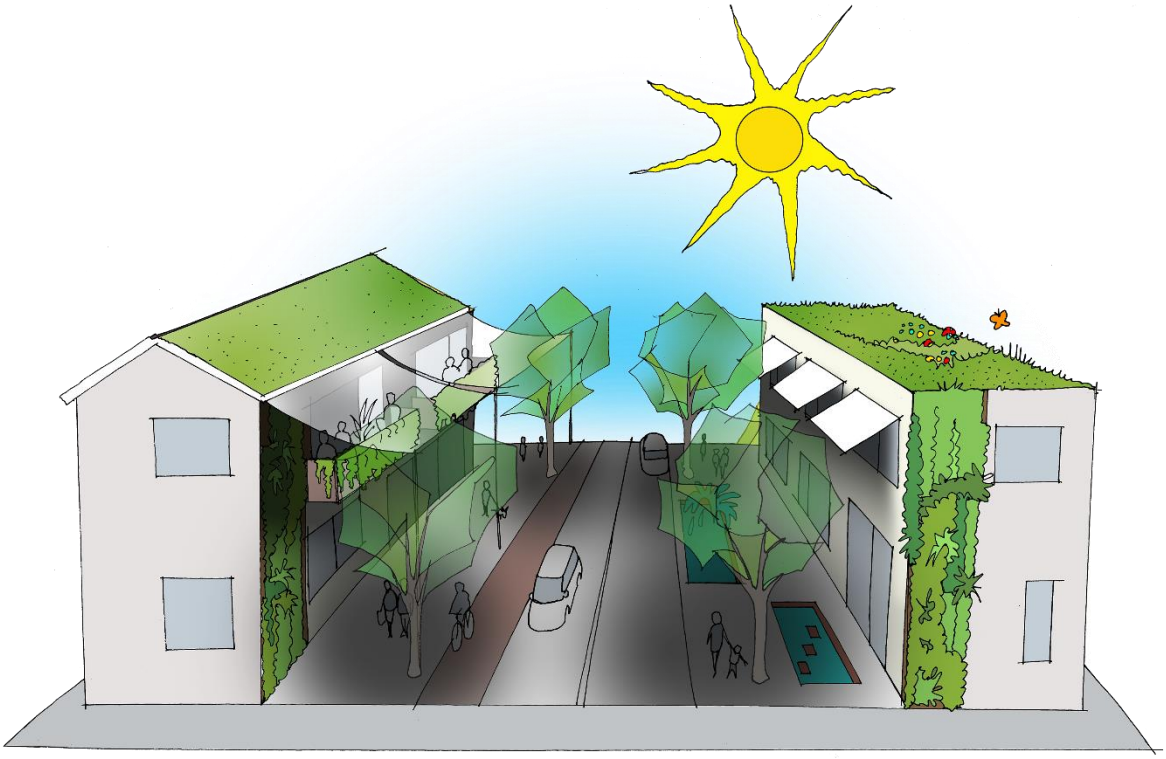
not well insulated (De Vries et al., 2021; Van Hooff et al., 2014). Furthermore, heat conduction can be prevented in the first place by preventing materials from heating up through provision of shade to buildings (Franck et al., 2013).

Furthermore, shading can also prevent solar radiation from entering a home. This can be done with measures such as trees outside and shading devices that block sunlight (De Vries et al., 2021; Franck et al., 2013). Shading devices can be subdivided into two categories: outside and indoor shading devices. Outdoor shading devices are seen as more effective since indoor shading devices may heat up, thereby emitting heat to the air indoor (Kim & Kim, 2010). Furthermore, sun protection glass can prevent heat from entering a home while still letting through light (De Vries et al., 2021).

When it comes to anthropogenic heat production, behavioral measures by residents can prevent heat gain. Anthropogenic heat production can be limited by not using heat generating electrical devices and by limiting cooking activity. However, in general, behavioral measures can make an important contribution to the prevention of heat gain and reduction of temperature inside a building. This mainly includes correct use of shading devices so sunlight cannot enter the home (De Vries et al., 2021; Lundgren Kownacki et al., 2019). Furthermore, ventilation by opening doors and windows can cool down indoor temperature (Nuiten & Leenarts, 2018). However, this should only be done when the temperature outside of the building is lower than inside of the building to prevent heat gain (De Vries et al., 2021). This is often the case at night, early in the morning or late in the evening. However, due to the urban heat island effect, heat is likely to linger in the outside air which makes ventilation at night less effective (De Vries et al., 2021).

Figure 1

Impression of Passive Measures like Shading Devices, Trees, Urban Vegetation and Water in a Street



Note. Adopted from Jansen of Lorkeers (2022).

2.3.2. Implementation of measures in practice

Even though there are many measures that can be implemented, there is no legislation concerning heat stress inside existing buildings. This is in contrast to new construction projects. As of 2021, there is national legislation concerning heat stress inside new construction projects. According to the Dutch building decree, new buildings should meet the 'TO July requirement'. The 'TO July' is a number that serves as an indicator of the risk of a building overheating (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). The TO July is therefore calculated using various parameters that influence the temperature inside a building (RVO, 2017). A higher value of the TO July means a higher chance of a building overheating. It has been determined for newly constructed buildings that the value should not be above 1.2. However, buildings with active cooling automatically meet the TO July requirement, regardless of other parameters related to the inside temperature (RVO, 2017).

Even though there is no legislation concerning heat stress in existing building, there are guidelines to determine whether heat stress can be considered a deficit. These guidelines state that heat inside a home is a deficit when for more than 300 hours a year the temperature reaches above 26.5°C while the temperature outside is at least 6°C cooler (Woonbond, 2021). In this case a judge or the Dutch Rental Tribunal can impose a rent reduction on a landlord which will remain in place until the deficit is resolved (Huurcommissie, 2018).

Since there is no strict legislation, implementation of measures is often dependent on the willingness of involved actors to take action, which is not always present (Woonbond, 2021). Another difficulty that has been described as hindering implantation is related to the heterogeneity of existing urban areas. Compared to climate mitigation efforts, which due to the reduction of greenhouse gasses have a global effect, benefits of climate adaptation measures are often experienced at a more local level as they make that specific place and its surrounding area more resilient against the impacts of climate change (Ayers & Dodman, 2010). Consequently, the concept of climate adaptation should be taken into account in every neighborhood. This presents a significant challenge both due to the quantity of the neighborhoods involved and their specific qualitative characteristics such as urban form and land use. These specific characteristics determine what is and what is not possible when it comes to climate adaptation measures. Even though there are a lot of measures that can be taken, it is important to realize that there is no 'one size fits all solution' (Jones et al., 2017; United Nations, 2021). This emphasizes the need to take the specific local context into account (Kleerekoper, 2016; Williams et al., 2013). Dealing with this complexity can be done by involvement of different stakeholders. This could lead to valuable insights that could aid in the selection of appropriate measures. One particular field of study that focusses on such complexities in the context of climate adaptation is that of urban transformations.

2.4. Urban transformations

Complexity is often an intrinsic part of challenges related to urban areas. Cities can namely be observed as complex systems where social and ecological factors interact with each other and together form a socio-ecological system (Pickett et al., 2013). The aforementioned causes of the urban heat island effect differ per particular urban context due to its urban form characteristics which together partly shape that particular socio-ecological system. Besides urban form characteristics, the socio-ecological system is determined by more intangible factors such as the social and political context.

In the context of climate change, the goal of climate adaptation is to preserve or attain a desirable socio-ecological state (Wolfram, 2016). However, in some cases this necessitates a change of the

socio-ecological system in which case this change is referred to as an urban transformation. An urban transformation can therefore be defined as a process of fundamental irreversible changes in infrastructures, ecosystems, agency configurations, lifestyles, systems of service provision, urban innovation, institutions and governance that thus constitute a systemic change of the urban system (Elmqvist et al., 2019). These changes can thus be spatial, such as retrofitting a neighborhood to become more climate adaptive, but they can also be institutional, such as creating better collaboration to allow for adaptation to occur (IPCC, 2022; Wilson et al., 2020). Furthermore, adaptation can be defined as transformational if it adheres to one of the following characteristics: adoption of a measure at a large scale or intensity, a measure that is newly introduced into a particular context, and lastly, a measure that significantly changes a place or involves a relocation (Kates et al., 2012).

In contrast to transformational adaptation, adaptation can also be incremental or a mix of both (IPCC, 2022). Incremental adaptation refers to adaptation measures that maintain the current socio-ecological system by implementing familiar strategies to existing practices on a smaller scale (Termeer et al., 2016). Transformational adaptation is often seen as more desirable than incremental adaptation as incremental adaptation may be insufficient in addressing more long-term and extreme scenarios of climate change or in addressing some specific vulnerable contexts (IPCC, 2022; Termeer et al., 2016). However, it is important to note that the distinction between both types of adaptation is not always entirely clear as a certain measure may share characteristics from both categories (Kates et al., 2012). Furthermore, uptake of a lot of small incremental changes can also accomplish large transformational changes leading to socio-ecological system changes (Termeer et al., 2016).

While there is an abundance of literature concerning climate adaptive measures that can be implemented, at the same time actual implementation remains lacking behind (Lenzholzer et al., 2020). So far, numerous complexities have been described that could obstruct implementation. These complexities relate to differences in local contexts, such as urban form differences, the involvement of many different stakeholders and their differing visions and responsibilities, the many policy domains that are involved and the multi-scalar character that is often a characteristic of urban transformations. Therefore, in order to actually translate the available adaptation measures to a specific neighborhood and subsequently implement them, an in depth analysis of the stakeholders and their capacities to attain such a transformation can provide a solution. Such a transformational adaptation is especially important when it comes to adapting the social housing stock. Even in one particular neighborhood social housing can often concern a large proportion of the total housing stock which due to the large scale might therefore require transformational adaptation.

2.5. Urban transformative capacity

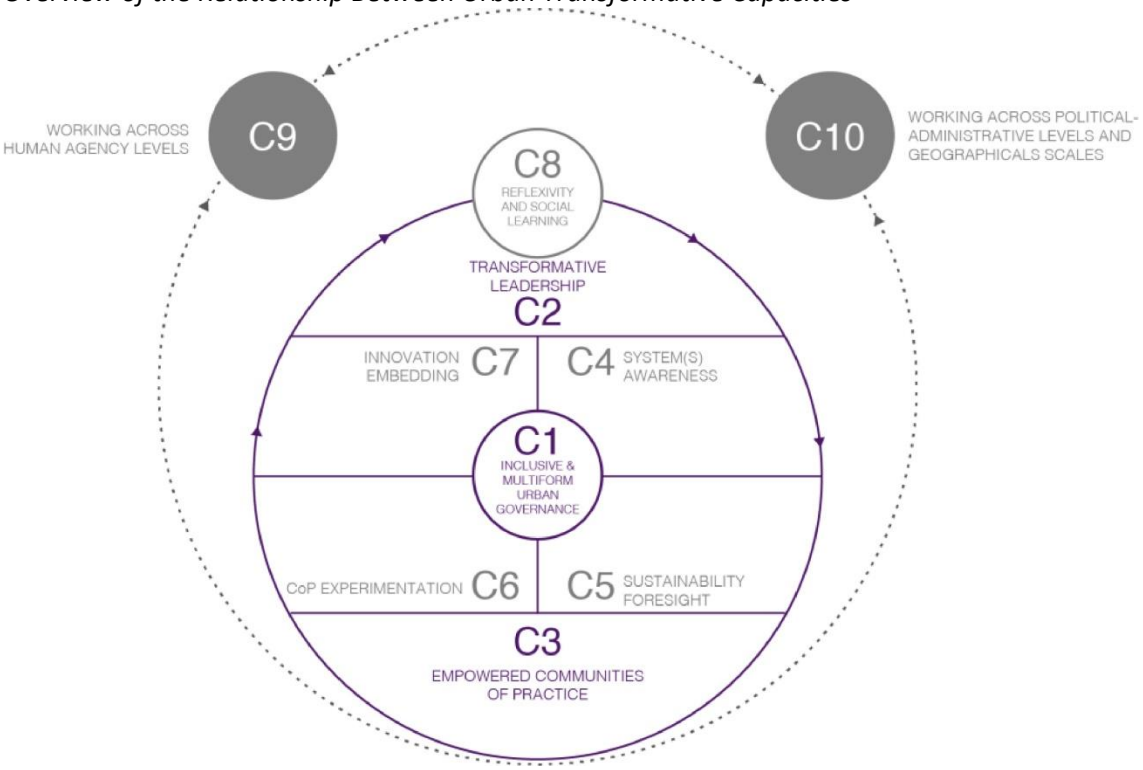
To successfully retrofit the social housing stock to become more climate adaptive, certain capacities that are present or lacking among stakeholders could provide an overview of barriers and opportunities to deal with the complexity that is often involved in urban transformations. These capacities present an important prerequisite as they constitute the abilities of individuals, organizations and societies to shape their development and adapt to changing circumstances (UNDP, 2010). While assessing transitions is an important subject in the literature which spans over multiple research fields, transformative capacity specifically refers to the abilities that enable a successful transition from an unsustainable system to a sustainable one. Wolfram (2016) translated these abilities specifically to the urban scale level by developing an analytical framework focusing on ‘urban transformative capacity’. For this, Wolfram (2016) defined urban transformative capacity as follows: “Urban transformative capacity is defined here as the collective ability of the stakeholders involved in

urban development to conceive of, prepare for, initiate and perform path-deviant change towards sustainability within and across multiple complex systems that constitute the cities they relate to". It therefore mainly looks at capacities of stakeholders in the process leading up to implementation of measures, whether they be technical, behavioral or regulatory.

The analytical framework as developed by Wolfram (2016) consists of 10 separate but interrelated components. These components and how they relate to each other is depicted in figure 2. The framework they form will serve two functions in the current study. First, the framework allows for the evaluation of the current urban transformative capacity that is present in a particular context. Second, the framework can guide the transformative process in the future by identifying gaps in transformative capacity. However, it is important to note that this framework is limited to analyzing whether a place has the ability to attain a sustainability transition and can therefore not assess the extent to which a particular area is sustainable (Wolfram, 2018). To achieve these goals, three sets, together comprising the ten aspects that constitute urban transformative capacity as developed by Wolfram (2016) will be further elaborated on.

Figure 2

Overview of the Relationship Between Urban Transformative Capacities



Note. Adopted from Peris-Blanes et al. (2022).

2.5.1. Agency and forms of interaction

The first set contains three aspects that constitute the core of the framework as agency and interaction are important prerequisites for the following set of criteria. The first aspect of the first set however is '*inclusive and multiform governance'* which encompasses diverse and inclusive stakeholder involvement, interactions between different actors and involvement of intermediary organizations (Shahani et al., 2021; Wolfram, 2016). As has already been highlighted, urban transformations involve many different stakeholders and therefore it is important for governance networks in a transition to be transparent, representative and legitimate (Castán Broto et al., 2018).

Furthermore, because of the multitude of stakeholders, the second aspect, '*transformative leadership'* can aid in formulating visions and shared values that inspire stakeholders to take part in the transformation and help translate across different governance levels and sectors (Castán Broto et al., 2018; Shahani et al., 2021; Wolfram, 2016). Ideally, transformative leadership should be present both bottom-up by arising from the community, as well as top-down from a government for example (Sarabia et al., 2021). *'Empowered and autonomous communities of practice*' forms the third aspect. For urban transformations it is often critical that context-specific social needs are met in the community. Through social learning and discussion of shared experiences, social needs can be articulated (Shahani et al., 2021; Wolfram, 2016). Furthermore, a degree of autonomy and access to resources of a community – whether they are technical, social or material – can further attain this third aspect (Castán Broto et al., 2018).

2.5.2. Development processes

The second set of criteria refers to capacity development processes which encompass criteria four until eight. The fourth aspect is that of '*systems awareness and memory'*. Urban sustainability transitions can be obstructed due to path dependencies of the current urban system or due to other barriers that can range from regulations that are in place, physical barriers and cultural practices and values (Castán Broto et al., 2018). Therefore, prior to formulating ways to mitigate these obstructions, it is important to identify a certain baseline which encompasses existing barriers and creates collective awareness and understanding among stakeholders concerning these barriers (Wolfram, 2016). In addition to a baseline focusing on current circumstances, a future oriented '*urban sustainability foresight'* is needed which constitutes the fifth aspect (Shahani et al., 2021). As there are often many pathways possible towards a sustainable urban future, processes such as co-production of knowledge and negotiation among stakeholders can help lead to transformational knowledge. Thereby such processes can clarify a collective vision and multiple possible scenarios to guide towards a sustainable urban future (Castán Broto et al., 2018; Wolfram, 2016). Another way to gain transformational knowledge is with the use of the sixth aspect, '*community-based experimentation with disruptive solutions'*. Experimentation can contribute to urban transformative capacity by challenging established policies, technologies and practices, which can help gain transformational knowledge and help facilitate social learning (Castán Broto et al., 2018; Wolfram, 2016). The seventh aspect is that of '*embedding and coupling'*. Attaining capacity for an urban transformation often requires access to and sharing of a multitude of resources which can range from knowledge to resources that enable collaboration among stakeholders such as locations for meetings or to more practical aspects such as financial means for the actual transformation (Castán Broto et al., 2018; Wolfram, 2016). This can be further facilitated by both removing barriers that obstruct innovation and by embedding openness to innovation or change into routines, organizations, plans and regulatory frameworks (Wolfram, 2016). As a result of this, mainstreaming may occur, where innovation not only occurs in the specific local context but also in the wider societal context due to the aforementioned changes (Castán Broto et al., 2018; Shahani et al., 2021; Wolfram, 2016). Furthermore, the eight aspect is *'reflexivity and social learning'* which' purpose is twofold. The first purpose is to evaluate and monitor the capacity building process, while the second purpose is to evaluate and monitor the actual urban transformation itself (Shahani et al., 2021; Wolfram, 2016).

2.5.3. Relational dimensions

The third and last set of aspects refers back to all prior aspects. Specifically, the nineth aspect looks at '*agency levels'* as capacity development needs to occur at different levels (Wolfram, 2016). The agency levels involved are for example, individuals, households, groups, organizations, networks or society in general (Wolfram, 2016). The tenth and final aspect focusses on the *'political-administrative levels and geographical scales'*. Due to the involvement of many different scale levels, as well as government levels, even at the local urban level, capacity building needs to occur at all these levels simultaneously (Shahani et al., 2021; Wolfram, 2016).

3. Methods

3.1 Methodological approach

Currently, most existing studies in the field of climate adaptation focus on the outcomes of climate adaptive measures. However, climate adaptation is also dependent on the process preceding a transformation. Based on the existing knowledge gap, the aim was to investigate the process behind climate adaptation among relevant actors to get an idea of how these actors give form to urban transformative capacity and in what areas it might be lacking. This requires an understanding of their roles, views, values and goals, both individually as well as collectively among each other (Brodnik & Brown, 2018). All these factors are interpretive in nature and are dependent on the meaning different actors in a certain context assign to the world around them. Consequently, they are difficult to quantify and therefore qualitative research methods have been chosen in this study. Specifically for this thesis, a case study approach has been chosen.

A case study approach has been chosen for three main reasons. The first reason is that the phenomena studied are contemporary. This allows for a case study as opposed to historical types of research methods as current events and involved actors can be studied directly (Yin, 2008). The second reason is that the phenomena studied concern real life situations over which a researcher has little control (Yin, 2008). Consequently, a case study design from which an outside observer perspective is taken is more suitable than an experimental design (Baškarada, 2014). The third reason relates to the research questions. They concern “how” and “why” questions and the answers are dependent on the specific context studied (Yin, 2008). The phenomena studied should therefore not be separated from the specific context but should be studied as an all-encompassing case (Baškarada, 2014).

Furthermore, a single case study design was chosen as it allows a more intensive study of a phenomena in a certain context in a given time period (Yin, 2008). The intensive nature of this study was further increased by choosing an embedded single case study design. This means that even though a single case was studied, different units of analysis within this case were analyzed (Yin, 2008). In the current study the units of analysis were the actors as representatives of each of the relevant organizations. This allowed for drawing conclusions based on findings within the units of analysis and between the units of analysis of the chosen case (Gustafsson, 2017).

3.1. Case selection

The case that was chosen for the current study was social housing in pre-war neighborhoods in the municipality of Rotterdam. Rotterdam was chosen as it is one of the frontrunners of climate adaptation in the Netherlands (Haupt et al., 2019; Huck et al., 2020). However, in an analysis of nineteen Dutch cities by Boon et al. (2020), Rotterdam was shown to be among the cities experiencing the most heat stress. The temperature in Rotterdam can become up to 8°C higher in urban areas compared to surrounding rural areas (KvK, 2011). Furthermore, Rotterdam is the municipality with the highest proportion of social housing in the Netherlands (CBS, 2016). The combination of heat stress, climate adaptation being high on the political agenda and the proportion of social housing contributed to the selection of Rotterdam as it could provide valuable insights in the context of climate adaptation against heat stress.

The decision to focus specifically on pre-war neighborhoods was based on the exacerbated urban heat island effect that is often associated with this type of neighborhood (Kleerekoper, 2016). They are often highly urbanized, contain a lot of artificial structures and often lack natural vegetation resulting in heat stress (Kleerekoper, 2016). This type of neighborhood typically refers to neighborhoods that have been built between the years 1910 and 1930. Pre-war neighborhoods are characterized by closed urban blocks (Harbers, 2009). They were based on the idea of building houses for as much residents as possible which led to neighborhoods without much public space and urban green (Kleerekoper, 2016). As a result of the lack of public space, they are often seen as challenging to make climate adaptive (Harbers, 2009). Furthermore, as this type of neighborhood is relatively common in the Netherlands, insights could also be generalized to other neighborhoods of the same type.

The selection of the municipality of Rotterdam and specifically its pre-war neighborhoods, classify this study as an extreme case study (Yin, 2008). This due to Rotterdam being a frontrunner when it comes to climate adaptation and specifically the relatively high temperatures that are experienced in its pre-war neighborhoods. According to Flyvbjerg (2006), extreme cases can provide deeper insights into the mechanisms of a problem as they activate more actors and basic mechanisms in a certain context. Consequently, the complexity of an extreme case can more easily be generalized to cases of lesser complexity or cases of similar complexity (Flyvbjerg, 2006).

To identify which neighborhoods to investigate in the current study, data was gathered concerning the proportion of social housing, the proportion of pre-war buildings and the amount of heat stress in each neighborhood. Based on these criteria, only Spangen was originally chosen as the current case. However, as there were not enough housing associations here, the case was expanded to include Tussendijken and Nieuwe Westen. They were included since they are all similar pre-war neighborhoods due to them bordering on each other. Their geographical location relative to each other and within the municipality of Rotterdam is depicted in figure 3. Similar neighborhoods were chosen because differences found between the units of analysis (the relevant organizations) are more likely to be the result of differences within the organizations. Therefore, differences found were less likely to be the result of underlying geographical or contextual factors as the focus of the current study was exclusively on the role of different organizations in one particular neighborhood type.

Figure 3

Location of Neighborhoods Spangen (1), Tussendijken (2) and Nieuwe Westen (3) in Rotterdam.

Note. Adapted from Google Maps (2022).

Furthermore, the neighborhoods Spangen, Tussendijken en Nieuwe Westen were chosen as they all scored relatively high on the aforementioned criteria. The proportion of social housing and of pre-war buildings in each of the neighborhoods and in the entire municipality of Rotterdam can be viewed in Table 1.

Table 1

Percentage of Social Housing and Pre-War Buildings in Each of the Selected Neighborhoods and in the Entire Rotterdam Area.

	Social housing	Pre-war buildings
Spangen	61%	70%
Tussendijken	60%	52%
Nieuwe Westen	47%	80%
Municipality of Rotterdam	43%	31%

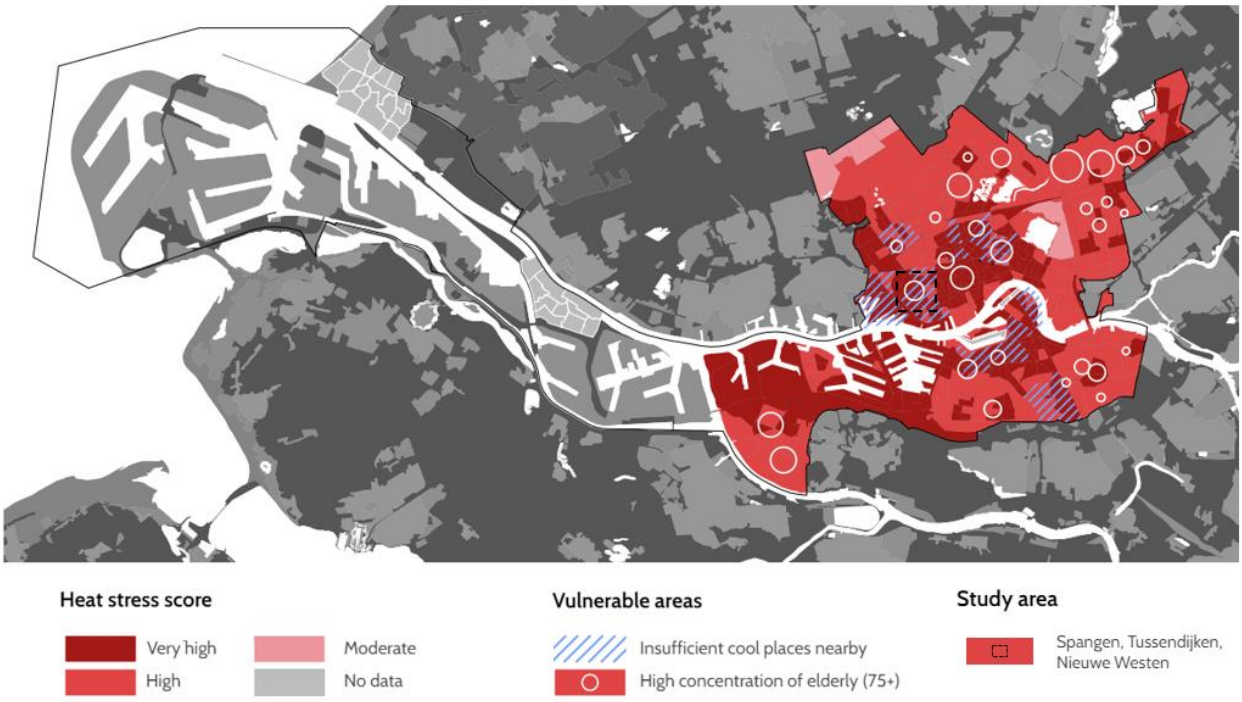
Note. Adapted from Gemeente Rotterdam (2022)

The amount of heat stress, based on the perceived temperature throughout Rotterdam and in the chosen study area can be viewed in figure 4. This figure illustrates that heat stress is relatively common in the selected study area. However, this heat is based on outside temperatures. As aforementioned, outside temperature is just one variable contributing to heat stress inside dwellings, apart from many building dependent characteristics. However, as there is no data available on indoor temperatures, the choice was supplemented with other reasons. For example, as shown in figure 4, the study area has a relatively high concentration of elderly people, one of the groups at risk for heat

stress. As they are more likely to spend more time indoors, it is especially important that their dwellings are heat resistant. Additionally, figure 4 shows that in a large part of the study area, cool places are often not close by, as they are sometimes more than 300 meters away (Rotterdams Weerwoord, 2022). This also makes a comfortable home temperature important in these neighborhoods as not everyone might be able or willing to travel this distance.

Figure 4

Heat Stress Scores, Vulnerable Areas and Study Area in Rotterdam.



Note. Adapted from Gemeente Rotterdam (2019).

Even though there is no data available when it comes to risk factors for indoor heat stress, the choice for these neighborhoods was also supported by personal observations made in the neighborhoods. These observations showed that many of the buildings in these neighborhoods experienced solar radiation through windows which is one of the main contributors to indoor heat stress (Lundgren Kownacki et al., 2019). This phenomenon can be seen in figure 5, 6 and 7. Another observation was that some streets had trees on one side of the road. However, in many cases this was on the side of the road that did not experience solar radiation. Consequently, the trees did not provide shade for buildings. This phenomenon can be seen in figure 6 and 7. Furthermore, in appendix A more pictures have been included to create an image of what these pre-war neighborhoods look like.

Figure 5
Street in Tussendijken.

Figure 6
Street in Spangen.

Figure 7
Street in Spangen.

3.2. Data collection & analysis

After the case was identified, an overview had to be created of relevant organizations within the case. Earlier, the municipality of Rotterdam, housing associations and their tenants associations were identified as relevant actors. To identify the housing associations and tenants associations in the case study area, the overarching federation of housing associations, 'Maaskoepel', was contacted. They provided an overview of five housing associations present in the three neighborhoods. Since each housing association has its own tenants association, these were also identified.

As an overview was created of the relevant actors, data could be collected from these actors. The current study utilized two main data collection methods: policy document analyses and semi-structured interviews. To guide each of these methods, operationalization happened based on each of the components of the urban transformative capacity framework. Furthermore, each of these components were further specified based on current knowledge in the literature in regards to heat stress. Subsequently, all of the components were comprised in a coding scheme that has been created which can be seen in appendix B.

The policy document analysis included multiple documents from multiple involved actors. They were found through searching their respective websites. For the municipality, documents included an urgency document, an implementation agenda, a progress note, a local heat plan and a document mapping each of the climate adaptation challenges. For the housing associations a heat plan of one of the housing associations was included and a webpage of another housing association on heat stress. Furthermore, four performance agreements were included which each were made in collaboration between the municipality, the housing association and its respective tenants

association. The contents of the documents were qualitatively analyzed using the aforementioned coding scheme.

To further expand on the criteria of the framework that were not explicitly mentioned in these documents or required clarification, interviews were held with relevant stakeholders. These stakeholders included policymakers as part of the intermediary of the municipality of Rotterdam who fulfill a role in climate adaptation, policymakers who work on climate adaptation at the different housing associations, and lastly, with representatives of the tenants from the tenants associations. Interviewees for the municipality and housing association were therefore selected based on their experience with climate adaptation against heat stress. Furthermore, interviewees from the tenant association were selected based on either their own experience with heat stress or experiences with heat stress in their surroundings.

This resulted in a total of 10 interviews that were held with twelve different people. Three interviewees were people from the municipality of Rotterdam that were interviewed in three separate interviews. Five interviewees were from four different housing associations that were interviewed in five separate interviews. Finally, four interviewees, together each two representing one tenants association, were interviewed during two interviews, therefore each of the two interviews was with two interviewees. An overview of each of the interviews with each interviewee anonymized can be seen in Table 2.

Table 2

Interview Respondents and their Anonymized Codes and the Organization they represent.

Respondent codes	Organization
R1	Municipality
R2	Municipality
R3	Municipality
H1	Housing association 1
T1[a] & T1[b]	Tenant association of housing association 1
H2[a]	Housing association 2
H2[b]	Housing association 2
H3	Housing association 3
T3[a] & T3[b]	Tenant association of housing association 3
H4	Housing association 4

In total, representatives of four out of the five housing associations present in the case study area have been interviewed. The one housing association that was not interviewed did not respond to interview requests. Therefore, it was also decided not to include their policy documents in this study for two reasons. First, because policy documents may not always accurately represent reality as they might be biased or leave out certain information (Baškarada, 2014). Additional data collection methods such as interviews are a way to compensate for this. Second, because it is likely that not all dimensions can be derived from a policy document. Furthermore, only four interviewees, representing two tenant associations responded to an interview request. Consequently, of the four interviewed housing associations, the data of two of the respective tenant associations is not included in this study. This limits the conclusion that can be drawn when it comes to the role of tenants.

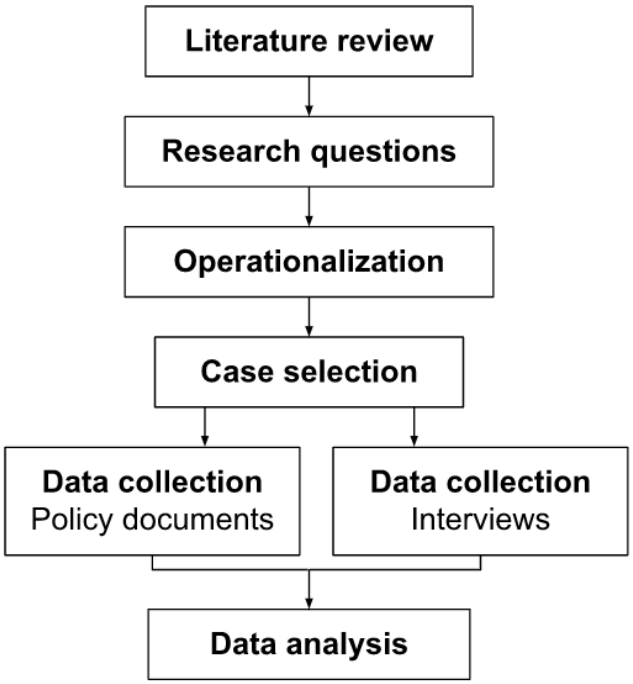
All but one interviewee were recruited online, either by filling in a contact form on an organizations website or by contacting them on LinkedIn. The one interviewee that was not recruited online was recruited via a mutual contact at an internship company. The interviews ranged from half an hour to one and a half hour, although most interviews were about an hour long. All interviews but one were held online, that particular interview took place in-person in Rotterdam. Furthermore, all interviews were held in Dutch. An overview of all the interviews, the anonymized interviewees, the duration of the interviews and the place of the interviews can be viewed in appendix C.

The interviews were held in a semi-structured way. This method has been chosen as each respondent is asked the same questions which allows for comparing responses (McIntosh & Morse, 2015). However, it still provides flexibility as it allows space for additional questions, clarification and other deviations from the interview guide (Horton et al., 2004). Furthermore, the semi-structure interview has been chosen as it is especially useful when there is objective knowledge, while subjective knowledge is lacking (McIntosh & Morse, 2015). In this case, objective knowledge is present due to the gathered theory, while more contextual knowledge of the specific case in practice is lacking. Consequently, theoretical knowledge can inform a semi-structured interview guide and thus determine the questions that are asked (Horton et al., 2004). In the current study, the interview guide is mainly developed using theory concerning adaptation against heat stress and transformative capacity. Each of the components of urban transformative capacity was operationalized into questions that were partly adapted from Castán Broto et al. (2016) and Shahani et al. (2021) and can be seen in appendix B as part of the coding scheme. These questions were further supplemented and specified with questions based on the theory on adaptation against heat stress. The resulting interview guide can be viewed in appendix D.

Interviewees were informed that they would be anonymized and after consent was given, interviews were recorded. Afterwards, the recorded interviews were manually transcribed and color coded based on the coding scheme. This allowed for analyzing the responses of each interviewee and an analysis between the responses of interviewees.

In summary, based on the identified knowledge gap on mitigating heat stress in private space, research questions were formulated. These research questions and a further review of the literature led to the urban transformative capacity framework as a way to answer the formulated research questions. The urban transformative capacity framework was subsequently operationalized into a coding scheme by supplementing it with the found literature on heat stress. Furthermore, three pre-war neighborhoods in Rotterdam were chosen as a case. Data was collected through interviews, for which the questions were based on the coding scheme. Additionally, data was collected through analyzing relevant policy documents. Together, the insights from the interviews and policy document were combined to identify the degree of urban transformative capacity present, based on which the research questions were answered. All these methodological steps are displayed in figure 8.

Figure 8.
Overview of the Methdological Steps of the Current Study



3.3. Validity and reliability

The methodological choices that have been made in terms of the research methods, data collection and data analysis have consequences for the quality of research. The quality of research can be further subdivided into measures of validity and reliability.

Construct validity determines whether the methods applied actually measure the construct that is meant to be measured (Baškarada, 2014). In the current study, the goal is to measure urban transformative capacity. Based on the dimension that constitute urban transformative capacity, questions have been formulated and a coding scheme has been created for analysis. Since urban transformative capacity is an established concept in the literature, multiple sources have been used in the creation of a coding scheme and questions. This has likely benefitted the construct validity as this existing knowledge has informed which type of question to ask and what to look for in data to measure this concept. However, it should be noted that the literature on transformative capacity in the field of climate adaptation and more specifically heat stress is scarce. Therefore, in translating or applying urban transformative capacity to the field of climate adaptation, some degree of construct validity could have been lost.

Next is the external validity or the extent to which the findings in this study can be generalized to a context outside of the current case (Baškarada, 2014). The current study is a single case study focusing on the social housing in a particular geographical area in Rotterdam. Experiences with heat stress and views on how to deal with it might differ from one actor in a certain geographical area to another actor in a different geographical area. The same is true for contextual factors. Therefore, the current study cannot generalize the presence of urban transformative capacity to other contexts. Especially because a single case was studied. However, it might still provide insights on how to achieve urban transformative capacity in other contexts such as other municipalities or other neighborhood types. This might also be the case as the selection of the current case was based on it

being an extreme case. As aforementioned, extreme cases can provide deeper insights into the mechanisms of a problem as they activate more actors and basic mechanisms in a certain context. Consequently, the complexity of an extreme case can more easily be generalized to cases of lesser complexity or cases of similar complexity (Flyvbjerg, 2006). This makes it easier to generalize, therefore contributing to external validity.

Additionally, external validity is strengthened because an embedded single case study design has been chosen. This means that within the same case or context, multiple units of analysis have been investigated. In the current study, different housing associations, different tenants associations and the municipality. This can also be referred to as data source triangulation (Yin, 2013). This allows for a more extensive analysis which contributes to generalization (Yin, 2013).

Another form of triangulation, namely methodological triangulation, has also been applied in the current study. This means that multiple methods of analysis have been applied, in this case interviews and document analyses (Yin, 2013). Therefore, one method can mitigate biases in the other method and vice versa. This is especially necessary for policy documents as they may not always accurately represent reality as they might be biased or leave out certain information (Baškarada, 2014). Because reality is better represented, a construct is more accurately measured, contributing to construct validity, and findings can be generalized better, contributing to external validity (Yin, 2013). However, the methods used in the current study are limited to qualitative methods. The use of mixed methods has the potential to further strengthen validity (Yin, 2008).

Furthermore, even though a single case study limits external validity, it allows for a more extensive analysis of the relation between the case and its context than when multiple cases are studied (Yin, 2013). Therefore, by creating a better understanding of the contextual factors of a case, it might be easier to discover whether insights could be applicable to an outside context (Yin, 2013).

Last is reliability which determines to what extent the same research results can be obtained when the study is repeated (Baškarada, 2014). The current study has used a standardized research approach, namely by using a code scheme for analyses of all data and using a standardized interview guide for collecting data. This standardized approach has likely contributed to obtaining similar results which leads to higher reliability (Baškarada, 2014). Furthermore, due to triangulation of data sources and methodology, the chances of finding accidental results and thus non replicable results is minimized (Yin, 2008).

4. Results

For the results, both the outcomes of the document analyses and interviews are presented. First the general findings and the overall themes found will be discussed among both data collection methods. Consequently, the findings are discussed in more depth, namely, along all dimensions of the urban transformative capacity framework.

4.1. General findings

In today's day and age, the impact of climate change are increasingly being experienced in cities worldwide. This necessitates urban actors to increasingly partake in transitions. Both to prevent climate change to begin with in climate mitigation efforts, and to reduce the impacts of climate change or vulnerabilities to these impacts in climate adaptation efforts. Therefore, it is not surprising that housing associations, as very prominent owners of real estate in the Dutch urban landscape, play a crucial role in these transitions. They face the task of making their housing stock more sustainable by transitioning from the use of fossil fuels to the use of renewable energy in an energy transition, by reducing energy consumption through insulation of their housing stock and by reducing vulnerabilities to extreme weather events such as heavy precipitation, periods of droughts and periods of high temperatures.

As a result of all these transitions, it became clear from the interviews with the housing associations that they all ask a lot from the housing associations in terms of money, time and knowledge. Most housing associations in Rotterdam have one, sometimes two, people working on multiple sustainability themes such as climate adaptation, the energy transition and biodiversity. Therefore, due to limited resources, some themes get more attention than others. In practice, this often results in less attention and resources being devoted specifically to reducing heat stress. According to interviewees from the municipality and from housing associations this is due to frequent heat waves being a relatively new theme compared to heavy precipitation and the energy transition. Therefore, for these latter themes there are already obligations imposed by local and national authorities while such obligations do not exist for heat stress. Furthermore, due to the frequent occurrence of heat waves being a relatively new theme, clear guidelines on how to counteract heat stress inside dwellings do not exist yet. Therefore, the limited resources that exist are mostly invested in transitions for which there are obligations and clear guidelines which results in the transition towards heat resistant buildings lagging behind the other transitions.

However, all interviewees note that this is not due to a lack of urgency on the end of housing associations. Due to multiple heat waves in the last years they are aware of the need to do something against heat stress in their housing stock. Furthermore, most housing associations are aware of lawsuits filed by tenants against fellow housing associations due to heat stress in their homes. However, since there are currently no obligations for existing buildings, any measures taken as of now are for the most part voluntarily and out of benevolence. Furthermore, as no guidelines exist regarding measures, a comprehensive approach is missing.

Hence, the first step towards installation of measures is mapping out which measures should actually be taken. Housing associations often own many different buildings, each built in their own time period and with their own characteristics that also affect how vulnerable a particular building is to

heating up. Therefore, each of these characteristics determine what measures can best deal with such a vulnerability but also which measures can actually be taken as some buildings pose technical limitations on the available measures. For this reason, housing associations are often involved in pilots and studies to investigate which measures are best taken under which circumstances. Furthermore, housing associations are unsure whether they should charge tenants for installation and for maintenance and if so, how much. This uncertainty also stems from uncertainties about how often maintenance is needed for certain measures and thus what the costs of measures are to begin with. Therefore, the pilots most housing associations are involved in are a good way to gain insights into such practical matters.

Because there are no guidelines or obligations when it comes to heat stress inside existing buildings, housing associations are faced with the question when sufficient measures are taken against heat stress. There is no clear target or ambition level formulated at which a housing association can state that their building is climate adaptive or heat resistant. One of the interviewees from one of the housing associations indicated that it is expected that at some point there will come some form of either guidelines or legislation concerning existing buildings. The interviewee acknowledged that this could make housing associations hesitant to take measures pending possible guidelines or legislation as it might turn out that a housing association has installed more measures and has thus invested more than necessary; or vice versa, that a housing association should take more measures on top of measures already taken to adhere to new guidelines or legislation.

Currently, due to a lack of funding, housing associations are for the most part focusing on shading devices such as awnings or blinds as they are according to existing research in general most effective in keeping dwellings cool. However, while the municipality provides subsidies for greening measures such as green roofs and green facades, there are no subsidies for measures specifically against heat stress inside dwellings. The subsidies for green measures exist primarily because greening measures deliver climate adaptation benefits for not just the building itself, but also for public space as it reduces discharge of rainwater into the municipal owned sewage system. Even though greening measures can have a cooling effect, its effects of bringing down the temperature inside a dwelling are relatively limited. Therefore, housing association will only install greening measures at or around buildings where flooding is a problem. In case heat stress is a problem in a particular building, shading devices are more likely to be installed as this is a more cost-effective solution, even without subsidies.

Even though most interviewees from housing associations indicate that subsidies would compensate for a lack of money, they do understand the reasoning behind the fact that there are no subsidies for shading devices. However, one interviewee from the municipality would like to see this changed with subsidies being provided for shading devices as well by referring to the interconnectedness between public and private space. The reason for this is that it could prevent housing associations and other homeowners to purchase and install active cooling measures such as air conditioning units that would bring down the temperature inside the dwelling, but would increase the temperature outside of the dwelling by heating up public space. Furthermore, in the context of the energy transition, such active cooling measures are not desirable due to their high energy usage. Despite this, most housing associations interviewed are aware of the negative impacts of air conditioning. Because of this and because of the high energy costs that air conditioning usage would result in for their tenants, they are unlikely to install active cooling measures. Furthermore, the interviewees noted that public institutes not being allowed to invest in private real estate due to the involvement of public money is understandable but that it does obstruct large scale implementation of shading devices for example.

This limits the role of the municipality to a more facilitating one. Therefore, one way around this would be by providing subsidies.

Correspondingly, housing associations also indicated that large scale implementation of measures to mitigate heat stress is unlikely to happen. Due to of a lack of resources, it is unlikely that every building owned by a housing association will be heat resistant in the next few years. Therefore, it is important that housing associations can prioritize to get an overview of where to start taking measures. There are three ways in which this can be achieved. First is by looking at where the people that are most vulnerable to the effects of heat stress live, such as the elderly, young children and people with chronic diseases. For this purpose, the municipality has created a map of the city that indicates where large populations of elderly and young children live. The second way is by starting with building that will soon be renovated. Linking planned maintenance or renovation with projects to install measures against heat stress presents a more cost-effective opportunity than if each project would be completed separately. The third way to prioritize is by creating an overview of which buildings or homes experience the highest temperature. Of the three ways to prioritize, this is often the most difficult one to gather information on.

Even though the municipality has created maps that indicate which areas in the city experience the highest temperatures, this does not always correlate with high temperatures inside dwellings. There is often no data available on temperatures inside homes which makes it difficult to see which buildings experience the highest temperatures. Two of the housing associations interviewed do have data on the 'TO July' value of all of their buildings which, based on many parameters, indicates how vulnerable a particular building is to heating up. This might serve as an indicator of which buildings experience the highest temperature. However, it should be noted that this is an indicator and the actual relationship with temperature is unclear. One of the housing associations is involved in a research project of an engineering firm in the development of a new 'heat label' that indicates how vulnerable a dwelling is to heating up. This would allow for better prioritization.

Even when a prioritization is made, it could still take a long time before actual structural measures are taken. Therefore, two of the housing associations offer temporary measures to bridge the gap between structural measures. One housing association offers sun-resistant window film, however the tenant needs to pay for this measure. Another housing association offers multiple temporary measures free of charge for now, such as sun-resistant window film, portable air conditioners, ceiling fans and air coolers.

Apart from structural measures, all housing associations emphasize the importance of behavioral measures as certain practices can prevent heat from entering a home or can cool it down. These mainly include not using anthropogenic heat sources inside, correct usage of shading devices and ventilating the home at the right times, which is only if the temperature outside of the dwelling is cooler than inside of the dwelling. Interviewees from the municipality, housing associations and tenants associations indicate that there is still a lot of progress to be made on this front as a lot of tenants are unaware of these behavioral measures. This mainly includes educating tenants on what they themselves can do to keep their homes cool. Two housing associations made a flyer with tips for tenants on how to keep their home cool that their shared on their website and social media channels. However, both interviewees from the housing association and from the tenant association were unsure whether this was the best way to inform tenants. One of the housing associations started with a heat plan last year in which they tried to help tenants whenever they had complaints about high temperatures within their homes. Whenever a tenant had a complaint about heat stress, an employee from the housing association would visit them and give them tips on what they themselves could do. In case this did not help they would be offered one of the aforementioned

temporary measures free of charge. However, in exchange for these measures they were asked to participate in a study investigating the temperature inside and outside of the dwelling and the influence of their behaviors.

The municipality of Rotterdam has also made a local heat plan for all its residents in collaboration with the local health authorities. However, this plan is still relatively new and focusses mostly on preventing heat stress among vulnerable groups. At a later stage this will also be expanded to include communication to all residents, the risks, what they can do against heat stress and also structural measures that can be taken. However, the municipality does try to stimulate housing associations to make their own heat plan. Furthermore, on the website of the intermediary created by the municipality of Rotterdam, called 'Rotterdams Weerwoord', tips are given on how to prevent homes from heating up and maps with information of cool places are shared.

Even though interviewees at the municipality note that heat stress is one of the most commonly experienced issues for residents of Rotterdam, as other impacts of climate change such as floodings are often more locally concentrated at certain places, three out of the four housing associations interviewed noted that they receive a relatively small number of complaints about heat stress. One of the interviewees from one of the tenant associations explained that this dichotomy might be the result of many tenants being unaware of the influence of a building on the indoor temperature and about the existence of possible measures to bring the temperature down. Therefore, people who experience heat stress might not always sent in a complaint. This might also explain why the one housing association that has implemented a heat plan has gotten much more complaints as it made tenants much more aware of the possible measures against heat stress. An interviewee from another housing association indicated that this is one of the reasons why they have not started to extensively inform tenants about heat stress as it might lead to the expectation among tenants that the housing association should take measures for which there in no capacity for the time being. Furthermore, while most housing associations administer a housing satisfaction survey, this survey does not specifically contain questions in regards to heat stress being experienced.

There are some cases of tenants who have installed measures themselves. They need approval for this from the housing association but this means that this tenant should pay for the measures and for its maintenance. However, the large majority of tenants in the social housing sector are unable to make this investment and are thus largely dependent on the housing association. Furthermore, green gardens can provide cooler areas for tenants. However, according to an interviewee at the municipality, if there is a garden present at a building owned by a housing association – which is often not the case in pre-war neighborhoods – they are often not very green and thus do not provide a cool place. Furthermore, tenants are unlikely to take the initiative to make a garden greener. Therefore, most residents are dependent on cool green places in public space. The municipality has a target of having a cool place to reside in within 300 meters walking distance of every dwelling so even those with reduced mobility can seek a cool place. For this reason a map has been created to indicate the walking distance towards a cool place throughout Rotterdam. While the target number is 300 meters, ideally the municipality wants to have a cool place within 100 meters. Especially in the older neighborhoods of Rotterdam such as the pre-war neighborhoods, the walking distances are sometimes further than 300 meters and generally relatively far compared to other neighborhoods.

One way in which public space could deliver cooling benefits for private space is by planting trees that provide shade for buildings of housing associations for example. This would present the municipality with a means to help housing associations to keep their dwellings cool without directly investing into private real estate or providing subsidies. Furthermore, this would attain many other benefits that are associated with urban greenery while simultaneously reducing the need for active

cooling measures inside dwellings. Interviewees indicated that this kind of collaboration between the municipality and housing associations does not happen as of yet which was an unexpected finding. Currently there is a division between public and private space where the municipality is solely responsible for public space while housing associations are solely responsible for the private real estate they own, even though they affect each other when it comes to urban heat. Some housing associations indicated that they would be willing to financially contribute to a measure such as a tree in public space providing shade on their houses and would like to see this kind of collaboration happening. However, interviewees also had some caveats regarding this. Firstly, this requires very close collaboration between the municipality and housing associations, almost at a house-to-house level. Secondly, there are certain technical limitations that require are extensive analysis of suitable places. One of these is the orientation of the building, generally due to the angle of the sun this would only be necessary for a building that receives sunlight from the south. Another technical limitation is that there is not always space for a tree due to underground utilities such as cables and pipelines but also above the ground there is not always enough available public space to plant a tree. The third caveat is that a division of costs would have to be made, both for installation and future maintenance.

Much in the same way, the opposite could take place where the municipality invests into private space to achieve public benefits. Especially in pre-war neighborhoods, targets such as mitigating the urban heat island effect and creating enough nearby cool spaces might be difficult to achieve in the limited public space that is available in these types of neighborhoods. Therefore, collaborating with owners of private real estate could be a solution to deal with this. As most housing associations are focusing on sun shading devices instead of greening measures due to the limited effects of the latter on the temperature inside the dwelling, greening measures might in many instances not be taken. However, such greening measures do not only provide benefits for the inside of the dwelling – albeit relatively limited – but also on the temperature outside in public space due to the cooling effects of evapotranspiration and less retainment and radiation of heat to the surrounding environment. Furthermore, it has benefits such as increased biodiversity, better air quality and less peak discharge during precipitation. However, an interviewee from the municipality noted that this is unlikely to happen as the urban heat island effect does not have to be curbed at such a local scale. Instead, the municipality looks at a larger neighborhood scale. So if there is a need for urban greenery in a particular place, then an area with available public space around this area will be found for this. Therefore, there is no need to invest in greenery in public space particularly for bringing down the temperature on street level. Furthermore, for this to happen, juridical changes would be necessary that would allow public institutions to invest in private space.

4.2. Criteria of Urban Transformative Capacity

The analysis above provides a general overview of the current state of the transition towards heat resistant social housing. However, to further analyze whether the capacities are present to attain an actual transformational change, the perspectives of each of the interviewed stakeholders will be juxtaposed. This has been done by analyzing whether each of the sub-criteria as formulated by Wolfram (2016) in the urban transformative capacity framework are met and which might be lacking. These insights will help to provide answers for the formulated research questions.

4.2.1. Inclusive and multiform urban governance

4.2.1.1. Participation and inclusiveness

When it comes to *participation and inclusiveness*, all housing associations indicate that taking measures will be done in dialogue with tenants. Three of the four housing associations have reported that measures have been taken against heat stress. Even though implementation has remained limited as of yet, participation of tenants has occurred in all these instances. Furthermore, housing associations are obliged to get permission of at least 70% of tenants when making technical changes. This makes some degree of participation mandatory. However, the extent to which tenants can influence the decision making process is limited. Among the housing associations two main reasons are given for this: technical limitations and lack of funding. Due to technical limitations of a building, some measures cannot be taken or will not be effective. Furthermore, due to a lack of funding, the most cost-effective measures are often chosen. All these factors limit the amount of choice there is for tenants. This is also the view of the municipality as M2 noted:

"I often hear that tenants do not have much choice when it comes to measures. I get the sense that there is dialogue, however, I am not sure they are given much influence."

However, within these technical and financial limitations, tenants can indicate their preference for a measure or can indicate whether they do or do not want a certain measure taken. The experiences of both tenant associations with participation differ. T1[a] and T1[b] stated that a large part of the tenants do not get involved in plans. They noted that one of the reasons might be a language barrier as the housing association solely communicates in Dutch even though not every tenant might speak Dutch. This limits their interest in or ability to participate. Furthermore, they indicated that directly involved tenants in a project are consulted, however, they experience a lack of more general focus groups. In contrast, T3[a] and T3[b] are involved in focus groups and are in general satisfied with participation. Therefore, even though participation occurs in the decision-making process, the level of participation differs and is not always high. Consequently, *participation and inclusiveness* is present but limited.

4.2.1.2. Diverse governance modes and network forms

Governance modes and network forms are quite diverse as they take place formally as well as informally. Formally, the housing associations in Rotterdam, in collaboration with the municipality, have signed a declaration of intent to work on climate adaptation. Furthermore, the municipality and each of the housing associations and their tenant associations have agreed to work on reducing heat stress in performance agreements. In regards to informal governance, the municipality tries to invest in good relationships by providing them with a main contact person within the municipality.

Another example of diversity of network forms comes from one of the housing associations working on their own heat plan. According to their performance agreement, they do this in collaboration with the local health authorities which adds to the diversity aspect of this component.

Furthermore, one day in each week the intermediary sends someone from the engineering office of the municipality to each of the four largest housing associations in Rotterdam. This is done to help them with climate adaptation and to motivate them to take action. The experiences with this kind of collaboration among the large housing associations interviewed are positive. Additionally, the large housing associations are involved in meetings, separately and with the municipality where they specifically discuss heat stress and relevant insights and barriers.

However, as one of the housing associations interviewed is relatively small, they are not involved in both of these governance modes. Nevertheless, they are involved in general meetings with the municipality on climate adaptation in general. H4 indicated that this is sufficient as their smaller housing stock is more manageable due to its size. However, H4 also indicated that they do not feel actively pressured by the municipality to mitigate heat stress, even though reducing heat stress is part of their performance agreement. This is in contrast to what respondents of two larger housing associations indicated as they do feel motivated by the municipality to reduce heat stress. Including smaller housing associations in the governance process could therefore lead to them being more motivated to take measures. Moreover, tenant associations are also not involved in such meetings.

Therefore, even though there is sufficient diversity of governance modes and network forms already, the diversity aspect could be strengthened by giving a more prominent role to smaller housing associations as well as tenant associations.

4.2.1.3. Sustained intermediaries and hybridization

Both from interviews with the municipality and from policy documents, it became clear that the primary role of 'Rotterdams Weerwoord', the intermediary of the municipality of Rotterdam, is to facilitate climate adaptation and bridge the gap between relevant actors. One of the climate adaptation themes they focus on is heat stress. Besides their climate adaptation themes, they are subdivided into multiple tracks each with a specific target group. One of their tracks focusses on residents which therefore include tenants. Another track focusses on existing real estate which therefore also encompasses housing associations. As aforementioned, the intermediary aims to facilitate communication and knowledge sharing between housing associations, residents and the municipality.

For the housing association they help with the technical site of adaptation, but also with the governance or administrative side of adaptation. The intermediary is deemed helpful among the interviewed housing associations. When it comes to residents, they give information about what they can do to keep their home cool for example. Furthermore, they provide subsidies for greening measures which one of the representatives of the tenants association, T1[a] has positive experiences with as they facilitate bottom-up initiatives. Consequently, this component is present in the current case.

4.2.2. Transformative leadership

As a consequence of the proceedings of the intermediary, they inspire others and drive collaboration. Therefore, the intermediary and the individuals that are part of it, serve as an example of *transformative leadership*. This is also reflected by the positive experiences of all housing associations with the activities of the intermediary.

The degree to which transformative leadership is present among the housing associations differs. These differences can mainly be explained by capacity in terms of personnel. While there are people responsible for heat stress at every housing association, they are often responsible for multiple sustainability and climate adaptation themes. However, at one particular housing association interviewed, themes are more divided and there are multiple people responsible for these themes. As a consequence, they can take a leading role in terms of reducing heat stress which is reflected by having implemented more measures. In contrast, another housing association has one person working on multiple sustainability themes and as such, there is not enough capacity to take the lead

when it comes to mitigating heat stress. This is also the experience of all three interviewees of the municipality who each indicated experiencing different degrees of resources among housing associations which consequently prevents individuals at these housing associations from addressing heat stress and taking a leading role.

One of the tenant associations also experiences this lack of leadership and furthermore, lack an overview of who is responsible for what at the respective housing association. Representatives at this particular housing association take a leading role themselves by starting sustainable bottom-up neighborhood initiatives. However, multiple times they did not receive a reaction from the housing association or could not find the person responsible when making a suggestion or asking for funding and permission for an initiative. The other tenant associations also does not see a leading role being taken by the housing association in terms of heat stress. However, both tenant associations agreed that this is due to the large workload of the housing associations.

Even though there is transformative leadership present among many of the involved actors, actual transformations is dependent on leadership among all actors. Housing associations are a key actor and if leadership is limited here, than this obstructs the transformational process.

4.2.3. Empowered communities of practice

4.2.3.1. Addressing social needs and motives

Mitigation of heat stress is in itself a way to address social needs and motives of tenants as it serves as a way to provide them with a comfortable home. Even though housing associations are for the most part not obliged to mitigate heat stress in their housing stock, the interviewees across all housing associations are willing to take measures. However, actual implementation of measures has been limited and therefore, it is difficult to determine whether other social needs and motives are addressed besides reducing heat stress.

However, it is likely that housing association will primarily focus on the most cost-effective measures and measures that are actually possible in spite of technical limitations. Therefore, due to social needs and motives, tenants might have a certain preference for a measure, but it could be that there is not much choice when it comes to measures. A frequent social motive for tenants as indicated by the tenant association is reducing costs as it concerns social housing. All housing associations interviewed are aware of this. Consequently, two of the housing associations interviewed indicated that they are hesitant to provide tenants with active cooling measures as this might lead to higher energy costs. Furthermore, all housing associations are still looking for ways to finance measures and whether they will fully pay for a measure and its maintenance or whether they will increase rent or the service fee. In this context, cost-effective measures are also important for the tenants themselves.

One of the most cost-effective measures are behavioral measures tenants can take themselves such as ventilation at the right moment. This aspect is addressed by both the intermediary and two housing associations who provide tenants with information to keep their home cool.

In conclusion, even though actual implementation is limited, the willingness to address social needs and motives of tenants indicates that this capacity is present among involved actors.

4.2.3.2. Community empowerment and autonomy

The aforementioned behavioral measures are also one of the most important aspects of increasing *community empowerment and autonomy* as it provides tenants with the skills to independently prevent heat stress in their home. All interviewees across the intermediary, the housing associations and the tenant associations indicated that there is room for improvement in this regard. H2[b] describes this as follows:

"In the Netherlands, we tend to think that ventilation automatically leads to fresh air and a cooler home, however, this is false. When it is warmer outside than inside, you will only heat up your home. This is probably the most important behavioral component and it is something where a lot of progress can be made."

In practice, the degree to which housing associations help tenants with behavioral measures differs. Two of the four housing associations indicated that they provide tenants with information on behavioral measures. One of the housing associations does this extensively as part of their heat plan by informing them online, with a newsletter, via the tenant contact center and on-site by complex managers. The other housing association has made an infographic that is posted on the website of the housing association. However, H1 was not sure whether informing is sufficient. This corresponds with the views of T1[a] and T1[b] as they believe that personal on-site visits by complex managers are a better way to reach people. Furthermore, they indicated that the infographic was difficult to find, was posted in the late summer and as the infographic could only be found on the website, it would not reach all tenants due to lack of digital literacy among some tenants. Among the other two housing associations who do not inform tenants of behavioral measures one stated that this is due to a lack of time. The other housing association stated that this is something they have not thought of. In case of the latter, this concerns the smaller housing association which is as aforementioned not as involved in the governance process as the larger housing associations. Consequently, it is possible that they have not been informed or motivated by the municipality of this measure. This is in contrast to the three larger housing associations that indicated that they are motivated by the intermediary to create a heat plan including behavioral measures. The intermediary of the municipality itself also contributes to provision of knowledge on ways to keep the homes of residents of Rotterdam cool.

Besides behavioral measures, implementation of technical measures and knowledge on how to properly use them can also lead to community empowerment. Technical measures provide tenants with the tools to keep their home cool independently. However, all interviewed actors indicated that actual implementation has been limited so far. Consequently, community empowerment and autonomy in this regard is also limited.

Furthermore, the tenant association serves as a way to empower tenants as they can voice their needs and concerns via them to the housing associations. However, in practice not many complaints about heat stress are sent by tenants to the tenant association. Even though both tenant associations do not receive a lot of complaints, the interviewed representatives know from their personal surroundings that heat stress is a common occurrence in Rotterdam. This was emphasized by the municipality where heat stress is described as one of the most widely experienced effects of climate change in Rotterdam. However, three of the four housing associations also indicated that they do not receive many complaints about heat stress. In regards to complaints about heat stress, T1[b] noted the following:

“I think a very small proportion of complaints is voiced to the tenant association. If there are a thousand complaints, probably two will reach us. I also think that many people do not send complaints to their housing association”.

This view is shared among the two tenant associations with two reasons given. T1[a] noted that tenants might feel that based on past experiences, sending in a complaint will not lead to any measures taken. Furthermore, T3[b] indicated that tenants might not realize that building characteristics can lead to a high indoor temperature and that measures exists that can mitigate this. These two explanations can be further supported based on the experience of the one housing association that did receive a lot of complaints. This particular housing association provides tenants with advice and temporary or long-term technical measures with their heat plan. Based on the experiences with the heat plan, H2[a] noted that requests for measures would come in more frequently as more people became aware of the possibility of measures. Consequently, knowing that measures can be taken and that they are available could contribute to tenants voicing their complaints and asking for help in regards to heat stress. This can therefore empower communities as they are aware of what can be done and consequently, they are more likely to take action by voicing their hardship regarding heat stress.

In conclusion, there is a contrast between the housing associations in terms of what they provide tenants with in terms of information and actual implementation of measures. Consequently, the degree of community empowerment and autonomy varies as not all tenants are enabled to address heat stress in their dwellings. Therefore, holistically viewed, there is limited presence of this capacity among actors.

4.2.4. Systems awareness and memory

4.2.4.1. Baseline analysis and system(s) awareness

Across all interviewees, the lack of resources among housing associations has been identified as one of the main barriers for large scale implementation of measures. This is a lack of resources in terms of time, money and knowledge. Across all interviewees this is explained by the numerous sustainability transitions housing associations are faced with. Particularly, climate adaptation in terms of heavy precipitation and climate mitigation by limiting energy use of their housing stock. These are transitions that, in contrast to heat stress, originated earlier and have a higher priority as there are obligations due to existing legislation. As a consequence, the limited resources that exists are devoted to these mandatory transitions. Consequently, this leads to less attention being devoted to addressing heat stress, which is a transition without any legal obligations when it comes to existing buildings.

As a consequence of the lack of resources, housing associations expressed that the resources that are present should be used as effectively as possible. Therefore, they indicated that it is important to prioritize and to determine where measures are most urgently needed when it comes to heat stress. Housing associations and the municipality do this based on the presence of risk groups such as the elderly in a certain area, a lack of public cool spaces in the vicinity of a building and on buildings that are likely susceptible to heat stress such as outdoor temperature.

However, as outside temperature is just one factor influencing the temperature in a building, a view of the actual indoor temperature is lacking as stated by the housing associations. Both tenant associations noted that tenants sometimes receive general satisfaction surveys. However, whether

heat stress is experienced is not explicitly asked even though this could contribute to an overview of where heat stress is experience throughout the housing stock. Furthermore, one of the tenant associations noted that currently the burden of proof for heat stress lays on the tenants as they have to proof that they experience heat stress. However, T3[a] noted that not every tenant has the resources to proof this to a housing association. However, mapping indoor heat stress is something that two out of the four housing associations interviewed are working on in research projects.

Besides the question where measures should be taken, another important question among the interviewees is what measures to take. The housing associations indicated that they own many different kinds of houses in many different neighborhoods. All these factors determine which measures will be most effective. Currently, there is no view of which measures work best in a certain kind of place. Furthermore, it is unknown how a measure will influence the indoor temperature and consequently, when sufficient measures are taken. For this purpose, two of the interviewed housing associations are involved in multiple pilots and research projects, including tenants and often also including the municipality.

In conclusion, the knowledge gaps and how they are filled among actors indicate a presence of a baseline analysis and system awareness.

4.2.4.2. Recognition of path dependencies

While building characteristics determine which measures are most effective, they can also impose technical limitations on the technical measures that can be taken. These characteristics can therefore be seen as path dependencies. Interviewees from housing associations gave examples of buildings with balconies that make it impossible to install shading devices and facades that are unable to hold shading devices. As there is a large variety of buildings, almost every building needs to be analyzed individually to determine which measures are technically possible.

One of these building related characteristics deserves further attention when it comes to path dependency. Interviewees from both the municipality and housing associations are aware of the influence of insulation on the temperature inside buildings. Insulation of buildings is a different sustainability transition aimed at reducing the need for energy use in the winter by reducing the energy needed to heat up a home. While in theory, insulation should prevent heat gain in a building, it is unlikely that this can prevent a dwelling from warming up during long periods of warm weather which are more likely to occur in the future. As soon as the inside of a dwelling has warmed up, then it is difficult to reduce the temperature as insulated buildings retain temperatures. Therefore, respondents from three of the housing associations and one from the municipality fear that even though it might reduce energy usage in the winter, it might also increase energy usage in the summer as more people will use active cooling measures as it is more difficult to cool down an insulated dwelling. However, the transition related to insulation of buildings is one that is already well underway, for which there are already legislative obligations and in which housing associations and multiple government levels have already invested significant resources. H3[b] noted in this regard that it is therefore even more important to take preventive measures that prevent dwellings from heating up in the first place:

“Among housing associations we have a running joke that as soon as a house is being insulated, you might as well install awnings at the same time”.

This illustrates how measures to reduce heat stress are adjusted to another ongoing sustainability transition that is already at a later stage.

Furthermore, a more regulatory path dependency that has been identified is that municipalities are not allowed to invest in private real estate and cannot provide subsidies for shading devices which prevents large scale implementation of shading devices. The interviewed housing associations indicated that they fully understand this as shading devices deliver mainly private benefits and no public benefits. However, they did also indicate that it would help them. Consequently, one interviewee from the municipality is trying to change these regulations with the aim of being able to provide a subsidy for shading devices, indicating system awareness.

In contrast to subsidies for shading devices, there are subsidies available for greening. One interviewee from one of the housing associations mentioned in this regard that subsidies provided by the municipality are only available for a short duration and if all available funding is gone, than the subsidy cannot be requested anymore. This is specifically a problem for housing associations as their processes can take a very long time to complete and during such a long process they are unsure if they can factor in a subsidy in their financial calculations. H2^{b} illustrated this as follows:

"A houseowner can just decide one day to install a green roof and can immediately start working on it, however, before we take such a measure here, the process preceding implementation can take as much as three years."

However, H2^{b} noted that this path dependency is currently being addressed in talks with the municipality.

The last obduracy mentioned among all interviewees is that outdoor shading devices are not allowed to be installed everywhere. Some parts of the city are part of "protected city views" due to their historic value and before outside shading devices are allowed to be installed here, a permit is needed from the municipality. However, some housing associations also own monumental buildings where outside shading devices are not allowed. One of the interviewees from one of the tenant associations lives in a monumental building and experiences high temperatures inside during the summer. Therefore, blinds have been installed inside. However, as indoor shading devices are not as effective as outdoor shading devices, this tenant would like to be able to install an outdoor shading device but is not allowed to. Among the housing associations this is also seen as a barrier. In this regard, one of the interviewees from the municipality noted that this is also a topic of discussion within the municipality of Rotterdam. On the one hand there are people within the municipality whose job it is to protect the cultural value of the city. But on the other hand there are people who try to make the city climate adaptive. Those two goals conflict here. The same is seen for other relatively new measures against urban heat such as street shade cloths providing shading on the street. M2 noted the following about them:

"They are often seen as something South-European and not fitting in the Dutch urban landscape. People want to retain how the city looks, however, a changing climate also asks for a new way of looking at the city".

M2 indicated that there are no goals to actively change these views but that this might gradually happen over time. Consequently, for these case, alternative measures should be found for the time being.

Since there seems to be mutual awareness of path dependencies among the interviewed actors, this indicates that path dependencies are sufficiently recognized. Furthermore, most path dependencies are actively being tackled, with the exception of the last mentioned path dependency of view of the city, therefore it can be concluded that this component is for the most part present.

4.2.5. Urban sustainability foresight

4.2.5.1. Diversity and transdisciplinary co-production of knowledge

Since there are still many knowledge gaps concerning mitigation of heat stress, diversity and transdisciplinary co-production of knowledge is crucial for this particular transformation. This dimension comes forward in the studies and pilots that often all three relevant actor types are involved in. Based on examples given in the interviews, these projects include both top-down initiatives as initiated by housing associations or the municipality, as well as bottom-up initiatives as initiated by a tenant association. The latter initiative concerns a tenants day which also involves the housing association and aims to create an understanding of relevant themes among tenants. The top-down initiatives mainly concern studies and pilots. Concerning heat stress, two of the interviewed housing associations are involved in studies and pilot projects. This is done in collaboration with tenants, the housing association and in multiple studies also research institutes, engineering firms and other housing associations outside of Rotterdam. Furthermore, one of the housing associations has collaborated with the local health authorities in the creation of their heat plan.

The fact that two housing associations interviewed are not involved in any studies can be attributed to heat stress being a relatively new theme and due to a lack of capacity to work on it. Unsurprisingly, the housing associations with the most resources in terms of addressing heat stress, are also the ones involved in studies. However, including both smaller and housing associations with less resources might contribute to the diversity aspect of this dimension. It should be noted however, that insights from other studies are shared with them via the intermediary and via other housing associations.

As a consequence of certain types of housing associations not being involved in studies, namely those with less resources, it can be concluded that diversity and transdisciplinary co-production of knowledge is present to some extent but not fully.

4.2.5.2. Collective vision for radical sustainability changes

As of right now, there is not a very specific collective vision among actors besides addressing heat stress in general terms as formulated in the performance agreements. The municipality indicated that as it concerns private space, that it is up to housing associations to decide what measures to take. However, among the municipality, the housing associations and the tenant associations, a preference is given to passive measures instead of active cooling measures such as air conditioning. For the municipality, the main reason for this is due to consequent heat gain of public space and due to its energy use. For housing associations the same sustainability concerns are mentioned. Furthermore, both the housing associations and the tenants association noted that it would lead to higher energy costs which is undesirable in the social housing sector.

Furthermore, among housing associations there is a preference for shading devices as they are one of the most cost-effective measures. In contrast, green roofs and green facades are seen as measures for addressing precipitation but not for addressing heat stress among housing associations as their indoor cooling benefits are limited. However, T1[a] noted that there is much interest among tenants for green roofs. To deal with such contradictions, H3 stated that creating a mutual understanding in the participation process of what measures have what effects is crucial. By creating more awareness

among tenants about what measures are most effective, a mutual understanding can be created among actors as to which measures are most appropriated in a certain situation.

Although there is somewhat of a collective vision among actors, it remains relatively unspecific. This can mainly be attributed to the existing knowledge gaps indicated by the housing associations and municipality regarding the measures that should be taken and their effects. It is difficult for the relevant actors to formulate a collective ambition level as there is no clear target for when a housing association has taken sufficient measures to make a dwelling heat resistant. Consequently, all interviewees from the housing associations indicated that guidelines or a specific agreement indicating what housing associations can do would help them take measures. This would make it easier to create policies on heat stress by having for example a target value to work towards. M2 indicated that the municipality is working on creating guidelines for which measures are best taken but it is up to housing associations to determine when sufficient measures are taken. Furthermore, two of the housing associations hope that their studies will help inform them take sufficient measures.

In regards to the process side of climate adaptation, H2[b] would like to see closer collaboration with the municipality when it comes to the interaction between public and private space. H2[b] explained this as follows:

"That is one of my ambitions. A collaboration with the municipality that is so close that property boundaries between public and private space practically disappear."

Planting a tree in public space that provides shade for a building owned by a housing association could reduce the temperature inside a dwelling. Furthermore, it could also produce public benefits by for example preventing installation of air conditioning and by delivering other benefits association with urban vegetation such as cooling of public space, biodiversity and creating an attractive urban environment. In practice, this does not happen according to the municipality and the housing associations. The municipality mainly plants trees for the purpose of providing shade for public space and for lowering the temperature in public space which has an indirect cooling benefit for private space. Two reasons for this are shared among all three actors. First, because it would require an extensive analysis as there are a lot of technical limitations such as the orientation of the building and lack of space due to other functions, both in public space and beneath the surface such as underground utilities. Part of this analysis would also have to include tenants as the tenant association indicated that even though some tenants may want a tree providing shade on their home, some would not want indoor sunlight to be blocked. Second, it would require a division in costs of implementation and maintenance, based on the proportion of benefits each of the actors receive. In this regard both H2[a] and H2[b] indicated that their housing association would be willing to contribute to the costs of such a tree.

Furthermore, all housing associations indicated that they are unlikely to install green roof or green facades to specifically address heat stress. This is due to their relatively limited cooling effects on the indoor temperature, compared to shading devices for example. However, such greening measures do have cooling benefits for public space by reducing the urban heat island effect, as well as other public benefits such as increased biodiversity, more attractive neighborhoods and climate adaptation benefits in terms of precipitation. Therefore, H2[b] noted that if the municipality would be willing to contribute to such measures in collaboration with housing associations, then housing associations could be swayed to install these greening measures. This would be especially useful in pre-war neighborhoods as there is often not a lot of public space for the municipality to work on sustainability transitions for example. However, this also does not take place in practice. In terms of

urban heat, the municipality does not look at such a local scale but looks at a neighborhood scale to see if there is enough urban vegetation. If not, then it is compensated elsewhere in public space. M2 further noted that to produce such local cooling effects from private space to public space, you would need a lot of greenery throughout the entirety of the city.

Through this vision of closer collaboration between municipality and housing associations it would be possible to take a more comprehensive approach towards climate adaptation as both public and private space affect each other when it comes to themes such as heat stress. Closer collaboration could help to provide a vision in which make maximal use is made of the available urban space to create a climate adaptive city. Furthermore, this type of collaboration could extend beyond the theme of heat stress to other sustainability themes. However, currently this vision is not shared among all relevant actors and as such, cannot be deemed collective. Furthermore, a vision of actual implementation of certain measures is lacking. However, for this, more studies on the effects of measures are currently being conducted. Consequently, a collective vision for radical sustainability changes is for the most part not yet present.

4.2.5.3. Alternative scenarios and future pathways

As aforementioned, the theme of heat stress is still at an early stage of development. However, among the actors it is addressed in multiple ways. One way is by providing technical measures that can either reduce the temperature such as through active cooling, or by preventing heat gain such as through shading devices. For this purpose, multiple studies are carried out to discover which technical measures are best taken for which type of buildings.

Another way heat stress is addressed is by behavioral measures that tenants can take. Two of the four housing associations and the intermediary have provided information so far. Furthermore, one of the housing associations is involved in a study which monitors the connection between the behavior measures tenants take and the indoor temperature to gain new insights.

The same housing association is also involved in a more physiological study, investigating how people can prepare their body for higher temperatures.

It can be concluded that even though no real scenarios have been made so far, heat stress is addressed in multiple different ways opening up possibilities for multiple future pathways in regards to measures. However, as this is mostly among two housing associations, the presence of this dimension is limited.

4.2.6. Diverse community-based experimentation with disruptive solutions

The aforementioned studies focusing on technical, behavioral and physiological aspects of heat stress measures all involve tenants and are thus community-based. This is mainly because in most of these studies perception of temperature of tenants and their experiences with measures are key variables. Furthermore, since these studies focus on multiple different aspects and solutions for mitigating heat stress, some differ from existing practices such as the physiological study investigation whether gradually increasing the temperature before warmer periods can prepare people's bodies as a way to prevent heat stress.

However, as just two housing associations are involved in this study, it can be concluded that this dimension is present. However as this is not the case among all housing associations, the presence of this dimension is limited.

4.2.7. Innovation embedding and coupling

4.2.7.1. Access to resources for capacity development

As indicated earlier, all actors interviewed are aware of the lack of resources among housing associations that obstruct addressing heat stress in their housing stock. The municipality tries to compensate for this but is limited in this regard. M2 illustrated this as follows:

"As a municipality or as a government institution we are not allowed to invest in private real estate which limits the role of the municipality to giving advice, distributing knowledge and sometimes investing in a pilot. However, we cannot contribute to large scale implementation of measures."

Instead, the municipality shares resources in multiple ways. For example, by sending a climate adaptation expert from the engineering office to each of the large housing associations, with the creation of 'neighborhood passports' that indicate per neighborhood what vulnerabilities and possibilities are for real estate, by working on guidelines, by investing and collaborating in pilots and by facilitating meetings. Furthermore, these meetings also serve as a way for sharing of knowledge between housing associations and the municipality. Therefore, they are an important way to compensate housing associations who may not have the resources to work on knowledge production.

These differences between the housing associations in terms of resources available for addressing heat stress is also something the municipality takes into account. The municipality adjusts for this by chancing its approach depending on the level of resources available within a housing association. When there are more resources available, they collaborate with housing associations in more in depth studies. In contrast, when there are less resources available, the municipality provides housing associations with more straightforward guidelines. However, ultimately, it is the responsibility of housing associations to address heat stress as the municipality is limited to a facilitating role.

Even though housing associations have no obligations, they are all aware that it is mainly their own responsibility. While all housing associations indicate that subsidies from the municipality for shading devices would help them, they understand why they do not exist. Currently, only greening measures are subsidized by the municipality as they also deliver public benefits when it comes to precipitation while measures specifically against heat stress such as shading devices do not have direct benefits for public space. However, M2 noted that indirectly shading devices can deliver public benefits as it can prevent installation of active measures that are unsustainable and heat up public space. Therefore, M2 is trying to accomplish that subsidies become available for shading devices as they are one of the most effective measures to make buildings heat resistant and reduce need for active cooling.

Furthermore, in terms of subsidies, T1[a] would also like to see subsidies being provided for shading devices. However, currently T1[a] noted that subsidies from the municipality and the respective housing association are used for greening measures by tenants. However, the experience with these subsidies is that not much people are aware of them or they are difficult to request. The municipality is aware of this and works on making them more accessible.

In terms of knowledge sharing, the role of tenants is limited so far. Two of the four housing associations and the intermediary are providing tenants with information on behavioral measures. When it comes to technical measures, knowledge sharing happens through studies in which tenants are involved. However, beyond these studies, T3[b] noted that there is not always awareness among

tenants of the role of the building on heat gain. Knowledge on which measures are available could help build capacity among tenants as they could voice their wants, needs and insights. However, H3 stated that informing people also imposes an obligation on the housing association to actually provide measures, which is as of now not possible due to a lack of resources.

In conclusion, the municipality mainly facilitates sharing of knowledge among the housing associations thereby compensating for a part of their lack of resources. This consequently leads to building capacity as it helps them in their decision making. However, due to regulations, the municipality is limited in sharing financial resources but is working on changing this. While tenants are involved in the process, this mainly involves a select group that is involved in studies. Therefore, by facilitating awareness among all tenants, capacity building could also occur among them. Consequently, this capacity is present but there is room for improvement.

4.2.7.2. Planning and mainstreaming transformative action

Addressing heat stress in buildings is a relatively new theme. Consequently, no specific insights have been generated that have been applied to contexts outside of heat stress. However, as heat stress is one of the climate adaptation themes of the intermediary, a similar approach is taken for addressing all these climate adaptation themes. All these climate adaptation themes are addressed in terms of public space, private space and residents of Rotterdam. Consequently, procedural insights from one theme can inform the approach that is taken for other themes. Furthermore, Rotterdam plans on mainstreaming climate adaptation throughout all policy domains and has a target that all relevant actors, such as housing associations, take climate adaptation into consideration by 2030.

Housing associations deal with multiple sustainability transitions. Similar to the municipality, insights generated from a particular transition can inform the transition to heat resistant social housing. Furthermore, in general the housing associations note taking the same steps for each transition. First formulating an ambition level, then a technical analysis of real estate, consequently creating an overview of the wishes of tenants and after that looking for collaboration with external actors. Furthermore, all housing associations note the importance of combining planned maintenance with climate adaptation measures such as heat stress as this is a way to save costs.

In conclusion, as of yet, no specific insights have been generated that have been applied to contexts outside of heat stress. However, based on experiences with other transitions in the past, it is likely that this will happen in the future. Furthermore, policies and plans among the actors surrounding climate adaptation support planning and mainstreaming of transformative action. Consequently, this capacity is present.

4.2.7.3. Reflexive and supportive regulatory framework

One of the goals within the municipality of Rotterdam is embedding climate adaptation in policy and regulations according to the implementation agenda. In the interviewees with the municipality, it became clear that no regulations will be implemented that make a certain level of measures mandatory in private spaces. Instead, the municipality is focusing on creating guidelines that can inform housing associations on which measures to take in certain contexts. Other policies from the municipality focus on creating awareness of the issue of heat stress and facilitation of collaboration among housing associations.

Since there are no guidelines concerning measures for buildings, the degree to which policy is present among housing associations varies. One housing association has formulated the aforementioned heat plan. However, among other housing associations not many policies exist,

besides policies on self-applied measures. Two of the interviewed housing associations indicated that they are planning on changing these policies to make it easier for tenants to install measures themselves if they can afford it. However, beyond this no policies have been formulated. The main reasons given for this among housing associations is that there are no guidelines or regulations. Policy would need to be based on a certain ambition level that determines to what extent measures and which particular measures should be taken. However, this is something being worked on as two housing associations and the municipality are involved in studies to create guidelines that can inform policy.

Consequently, examples of new regulations or policies are scarce. However, this is something that is likely dependent on the aforementioned studies that could inform policy and an association ambition level. Additionally, policies surrounding self-applied measures are changed for the benefit of tenants. This consequently indicates that this capacity will likely be present in the future.

4.2.8. Reflexivity and social learning

Another aspects is reflexivity and social learning. Even though actual measures against heat stress have not been implemented at a large scale, the instances where implementation has taken place did also involve evaluation of the measures among tenants. Furthermore, as implementation in some cases was combined with a study, this allowed to measure the effect of measures. These studies involve monitoring, assessment and evaluation of measures as a way to figure out which measures are best taken for which type of buildings. Furthermore, reflexivity comes forward in the heat plan of both the municipality and one of the housing associations. A hallmark of heat plans is that they are evaluated each year and consequently improved and expanded which also happens among the municipality and the housing association.

The second aspect of this component, social learning, becomes visible in the meetings between the municipality and the housing associations. The municipality notes in the implementation agenda that it tries to facilitate knowledge sharing and sharing of best practices. According to the housing associations these meetings contribute to these goals as they help them to gain new insights.

Furthermore, social learning among tenants also came forward in the interviews. H2[a] noted the following about this:

“If one or two people have sent in a complaint and have received a temporary measure, then it spreads like wildfire though the complex and suddenly everyone comes to request a measure”.

This view is shared among one of the tenants associations where the experience is that implementation of sustainable measures in one neighborhood can help stimulate other neighborhoods to do the same.

In conclusion, reflexivity is for now an important part of implementing measures as they mainly serve as studies to determine their effect. However, it is important that reflexivity keeps being a part of the process of transforming social housing to be heat resistant. Furthermore, social learning among all three actor groups takes place, however, it is dependent on actual implementation of measures as they can give new insights and stimulate others to take action. Therefore, this capacity is present.

4.2.9. Working across human agency levels

The main agency levels identified in the current case are: the municipality, housing associations, tenants associations, households and individuals. The intermediary plays an important role in connecting all these levels in the context of Rotterdam. This is a consequence of the tracks that the intermediary focusses on. They bridge the gap between the municipality, the housing associations and tenants as they have a specific approach suited for each of these groups. However, on the level of the household and the individual, agency might be lacking among tenants. This is mainly because they are not always aware of behavioral measures and technical measures as indicated by the housing associations and the tenant associations. Currently, information is mainly being provided online to individuals and households among housing associations. However, as indicated by the tenant associations, this might not reach all individuals and households. For this reason, other approach such as personal information by a complex manager could contribute to this.

Creating more awareness of heat stress and particularly of possible technical measures will enable them to indicate their wants and needs, thereby contributing to capacity building. Consequently, this capacity is present but there is room for improvement.

4.2.10. Working across political-administrative levels and geographical scales

It can be stated that within Rotterdam, both on a local level and on a municipal level, initiatives among actors build capacity. According to the municipality and two of the housing associations that are involved in initiatives, they serve as a way to inform what measures are best implemented at certain buildings or in a particular neighborhood type. Furthermore, these insights are spread at the municipal level as multiple housing associations are involved and it is indicated by the municipality that these insights could also guide transformation of buildings owned by other actors. At the regional level, capacity can be built as three of the four interviewed housing associations also own buildings outside of Rotterdam. Additionally, multiple research projects also involve other municipalities, housing associations outside of Rotterdam, research institutes and engineering firms which facilitates capacity building across scale levels. Lastly, meetings are organized on a national level by national housing sector association in which three of the four housing associations partake.

In conclusion, capacity building happens across political-administrative levels and geographical scales, as multiple actors beyond the context of social housing in Rotterdam are involved. Therefore, this capacity is present.

4.3. Overview of components

In summary, the degree of transformative capacity that is present among each of the dimension differs. Based on these findings, an overview is created in table 3 of factors that contribute to transformative capacity and factors that, based on the collected data, could be improved.

Table 3
Overview of the Results for each Component of Urban Transformative Capacity

Component	Factors contributing to transformative capacity	Factors that could improve transformative capacity
Inclusive and multiform urban governance (C1)	Participation before implementation	Communication in multiple languages
	Permission asked for measures at the household level	General focus groups beyond directly involved tenants
	Short communication lines between actors	Inclusion of smaller housing associations in governance processes
	Formal and informal governance modes	Inclusion of representatives of tenant associations during meetings
	Intermediary bridging gap between actors	
Transformative leadership (C2)	Intermediary motivates relevant actors to take action	More resources being devoted to addressing heat stress among housing associations
		Establishing better communication lines between community leaders and the housing association
Empowered communities of practice (C3)	Sense of urgency among housing associations and municipality	Employing multiple communication strategies to inform tenants of measures
	Awareness of tenants motives' and what measures fit them	Collaboration among housing associations and municipality to spread knowledge on behavioral measures
	Provision of (temporary) measures among some housing associations	Provision of relatively cheap temporary measures among all housing associations
Systems awareness and memory (C4)	Collective awareness of current barriers and how to deal with them	Providing tenants with tools to proof heat stress in their home
	Research projects are undertaken to inform where measures should be taken and what measures should be taken	Incorporating heat stress in satisfaction surveys
		Reservation of subsidies for housing associations
	Measures are adjusted to other ongoing transitions	

		Creating guidelines for effective measures for monuments and protected city views
Urban sustainability foresight (C5)	Presence of top-down and bottom-up knowledge-generating initiatives Collaboration between diverse actors within and outside of Rotterdam Sharing of insights from studies Collective vision focusing on sustainable passive measures Studies are undertaken to inform the creation of a collective vision Multiple pathways are explored when it comes to measures	Studies involving smaller housing associations and housing associations with less resources Creating more awareness of the effects of measures among tenants to help them formulate a vision Closer collaboration between properties of housing associations and municipality could maximize the use of available urban space to become climate adaptive
Community-based experimentation (C6)	Tenants and their perceptions play a key role in studies Studies are conducted focusing on new (physiological) ways of addressing heat stress	Community-based experimentation could be more widespread among housing associations
Innovation embedding and coupling (C7)	Municipality compensates for lack of resources experienced among housing associations by knowledge provision Mainstreaming of climate adaptation Studies are being conducted to inform policy guidelines	Provision of subsidies for shading devices Making subsidies more accessible Regulations could motivate actors to take (more) action and spend more resources on addressing heat stress
Reflexivity and social learning (C8)	Heat plans are being evaluated Meetings between housing associations and the municipality help to spread best practices	More prominent examples of measures that reduce heat stress could encourage both tenants and housing associations to take action
Working across human agency levels (C9)	The intermediary involves each agency level with an individual approach	Personally providing households and individuals with information

Working across administrative and geographical scales (C10)	Studies are focusing on what measures to implement at the local level Insights are shared with actors beyond the context of the city as there is collaboration with multiple external actors	-

5. Discussion

By analyzing the transition towards heat resistant social housing through each of the different dimensions of the Urban Transformative Capacity framework, an overview could be created of capacities that are already present and capacities that might still be missing. These capacities give insights into the governance aspect of this transformation, the barriers and the visions among the involved actors. Therefore, each of these aspects will be used to answer the sub-questions. Furthermore, the combination of these aspects can inform how heat stress in existing dwelling owned by housing associations can be addressed, which is the main research question.

5.2. Sub-questions

5.2.1. Governance

The first sub-question focused on the governance aspect of the transformation towards heat resistant social housing. Based on the results, it can be concluded that governance happens through extensive collaboration among primarily the municipality and its intermediary and the housing associations. The intermediary plays a key role in bridging the gap between the municipality and housing associations and can therefore be defined as a transformative leader.
Tenants are primarily involved when a housing association actually starts implementing measures or in pilot studies. However, due to a lack of resources actual implementation is hampered among housing associations. The governance process is used as a way to deal with this issue through creating awareness of the theme of heat stress and by sharing of resources. The latter happens through sharing of insights among actors through experts sent by the intermediary to each of the large housing associations, sharing of best practices and the municipality investing in research projects. Furthermore, collaboration takes place outside the context of Rotterdam, increasing the diversity of the network.

5.2.2. Barriers

The second sub-question focused on barriers actors experience in this transformation. As a results of the strong collaboration, there is to a large degree system awareness as actors are aware of current barriers. One of the main barriers experienced is a lack of resources among housing associations. This can be explained by multiple other transitions housing associations are faced with, which in contrast to addressing heat stress, have regulatory obligations. Therefore, there is not always time or funding to address heat stress. Consequently, housing associations are prioritizing where to take measures first but lack a comprehensive way to prioritize which is therefore a barrier. Furthermore, there is uncertainty about which measures are most effective for which type of buildings. However, both of these questions are being addressed in studies among the actors. Another barrier housing associations and tenants face is that measures cannot be taken everywhere as some buildings are monuments. Additionally, a barrier experienced by the tenant association is communication with the housing association. Currently, awareness among tenants about both behavioral and technical measures is sometimes lacking which requires are more effective communication strategy.

5.2.3. Visions

The focus of the third sub-question is one the visions among different actors. It can be concluded that due to knowledge gaps pertaining to the measures that can be taken, there is not really a collective vision yet. However, due to the co-production of knowledge through studies and pilots taking place, a first step can be taken towards a collective vision. Furthermore, through closer

collaboration between municipality and housing associations it would be possible to take a more comprehensive approach towards climate adaptation as both public and private spaces affect each other when it comes to themes such as heat stress. Closer collaboration could help to provide a vision in which make maximal use is made of the available urban space to create a climate adaptive city.

5.3. Main research question

5.3.1. General recommendations

First of all, due to the lack of resources as a result of the many transitions housing associations face, it would be advisable if in the coming years national guidelines would be created instead of legislation, as obligations associated with the latter would likely be unattainable for some housing associations. These guidelines could inform housing associations and give them a target value as a way to know when they have provided tenants with a sufficiently heat resistant home. This could therefore lead to a collective vision of measures, thereby strengthening the capacity of *urban sustainability foresight*.

Furthermore, the creation of a scientifically supported heat label that takes into account the characteristics of a building and how possible measures influence heat gain could prove beneficial as it could help with both prioritization of which buildings to start with and it could inform how measures influence heat gain and which measures are necessary for a heat resistant building. This knowledge of where to start would therefore contribute to the capacity of *system awareness and memory*.

As large scale implementation of structural measures is unlikely to happen in the coming years, it is important to bridge this period with other measures. One good example of this are two of the interviewed housing associations providing temporary measures that are relatively easy and affordable to install. Furthermore, education when it comes to which behavioral measures can be taken is crucial as there is still a lot of unawareness in this regard. Behavioral measures only require a small investment to teach tenants when and how to ventilate but are otherwise free of charge and relatively effective. When to open doors and windows for ventilation is something that is often unknown. This knowledge can even be transferred by the use of modern technology. Many dwellings these days have a smart thermostat that measures the inside temperature. By comparing the inside temperature to data about the likely temperature outside, it could give a nudge on an app to ventilate. Providing both knowledge of behavioral measures and either temporary or structural measures would strengthen the capacity of *empowered communities of practice* as it both addresses the social need of reducing heat stress and it empowers tenants with the tools and knowledge to keep their home cool.

Moreover, housing associations can create a heat plan that is specifically catered to their tenants. In addition to this, the municipality could create a heat plan for all residents of Rotterdam, including the tenants and could do this in collaboration with housing association to give them a platform. Moreover, the municipality has likely more means to communicate this to its residents. Housing associations often do not have the resources to work on provision of behavioral measures for example. Therefore, by doing this in collaboration with the municipality this would be a way to share resources, which is part of the capacity of *innovation embedding and coupling*.

Furthermore, evaluation of structural, temporal and even behavioral measures could provide valuable insights into opportunities and barriers. This became clear in interviews with the tenant associations where it was indicated that ventilation was not always possible due to noise pollution and risk of burglaries. For such barriers solutions can then be found such as installing windows that can only be opened from the inside. Additionally, it is important to inform tenants about the influence of their building on the temperature inside and about possible measures to create awareness of the problem of indoor heat stress. Their experiences might provide valuable insights into what measures would work in or around their dwelling. The process of evaluation would therefore strengthen the capacity of *inclusive and multiform urban governance*. The insights that would be generated would contribute to the capacity of *system awareness and memory*.

Furthermore, providing subsidies for sun shading devices would be a way to compensate at least for the lack of financial resources among most housing associations which is expected by interviewees to make large scale implementation possible. This could as noted before, also be seen as achieving sustainability goals and delivering public benefits as it will prevent the installation of active cooling measure that are unsustainable and in many cases warm up public space. The aspect of sharing of resources would therefore build capacity as it strengthens *innovation embedding and coupling*.

Even though the municipality faces obstructions in regards to stimulating installation of passive measures, the municipality could help by using its public space to provide cooling to private real estate. By planting trees that give shade to private real estate, less passive cooling measures have to be taken by a housing association and there is less need for active cooling measures. While there are still barriers such as underground utilities leaving no room for trees, renovation work of said utilities could provide an opportunity to create space to plant a tree. Furthermore, some smaller trees would fit inside a pot. According to the interviews, some housing associations would even want to pay for such measures. Furthermore, this type of collaboration between the public and private sphere is transformative in the sense that it could close the gap that currently exists between public and private space, even though they both affect each other. This would require very extensive collaboration between stakeholders as it would be necessary to be aware of each other's challenges and possible opportunities for collaboration such as one stakeholder renovating something. Furthermore, an analysis would be necessary of places where these measures are suitable. A map of such opportunities could serve as a decision support tool. Additionally, a division of costs would be made based on the benefits for each of the stakeholders. A cost-benefit analysis could aid in this. By mainstreaming this type of collaboration, not only benefits for reducing urban heat stress can be reduced, but also other sustainability themes could be tackled in the same way. Such a collaboration would contribute to a collective vision, thereby strengthening the capacity of *urban sustainability foresight*.

5.4. Conclusion

The current study has investigated whether transformative capacities were present among multiple stakeholders involved in the process of making social housing heat resistant. For this purpose, the context of Rotterdam has been chosen as it is often one of the frontrunners when it comes to climate adaptation. Furthermore, pre-war neighborhoods have been selected due to the relatively small amount of public space they are often associated with. Therefore, it should be noted that generalization of these findings to other types of neighborhoods and other municipalities might not always be possible. Since the current study looked at four housing associations within the municipality of Rotterdam, it might also mean that they face different challenges and opportunities than other housing associations outside of this context. Moreover, the current study has interviewed four housing associations of which three belong to the four largest housing associations of the

municipality of Rotterdam. Therefore, conclusions might not always be applicable to smaller housing associations.

Furthermore, the current study has, due to time constraints, focused on the geographical level of the three neighborhoods in the municipality of Rotterdam and stakeholders who are directly relevant in this particular context. However, on a wider scale level, other institutions such as the representation association of all housing associations and the national government could also have an important influence on the capacities of stakeholders. While interviewees were asked about their experiences with these institutions, these institutions themselves were not interviewed and as such, this limits the conclusions that can be drawn in this regard.

Another limitation of the current study is that data was collected by means of interviews. This type of data collection is highly dependent on collaboration of relevant stakeholders in the interviews. Therefore, it could be possible that some questions were not fully answered or were answered untruthfully. However, the current study has tried to limit this by anonymizing the interviewees, interviewing multiple stakeholders to get different perspectives and juxtaposing their views.

As the current study indicates, there are still a lot of knowledge gaps regarding the transition towards heat resistant social housing. While the current study aimed to close a more procedural knowledge gap by providing insights into how to shape the transformative process towards addressing heat stress in social housing, many technical knowledge gaps remain that require further research. Housing associations would for example benefit from a comprehensive overview of which measures can be taken for a building with certain characteristics and to what extent these can contribute towards the provision of adequate housing. As became clear from the interviews, these knowledge gaps are currently being addressed. These results might also provide new insights for effective measures for other private building owners, such as the private rental sector, private homeowners and different types of companies. While these quantitative measures indicating the effect of a measure on a building can for the most part be translated to buildings owned by these other actors, this might not be the case for more procedural factors. Their goals, interests, values, perceptions and power likely differ and therefore, there transformative capacity might also be different (Trell & van Geet, 2019). Future research could therefore, focus on these other actors who own private property in city, to gain insights in their transformative capacities in regards to addressing climate adaptation or heat stress in particular. This is especially of importance as cities consist of many different types of property owners beyond housing associations. Therefore, the insights provided by this study contribute to solving one part of a larger climate adaptation challenge that cities are faced with.

Literature

Arifwidodo, S. D., & Chandrasiri, O. (2020). Urban heat stress and human health in Bangkok, Thailand. *Environmental Research*, *185*, 1–8. https://doi.org/10.1016/j.envres.2020.109398

Ayers, J., & Dodman, D. (2010). Climate change adaptation and development I. *Progress in Development Studies*, *10*(2), 161–168. https://doi.org/10.1177/146499340901000205

Balaban, O. (2012). Climate Change And Cities: A Review On The Impacts And Policy Responses. *Metu Journal of the Faculty of Architecture*, *29*(1), 21–44. https://doi.org/10.4305/metu.jfa.2012.1.2

Baškarada, S. (2014). Qualitative case studies guidelines. *The Qualitative Report*, *19*, 1–25. http://www.nova.edu/ssss/QR/QR19/baskarada24.pdf

Bhargrava, A., Lakmini, S., & Bhargava, S. (2017). Urban Heat Island Effect: It's Relevance in Urban Planning. *Journal of Biodiversity & Endangered Species*, *05*(02), 1–4. https://doi.org/10.4172/2332-2543.1000187

Boerbooms, M., & Verhaeghe, B. (2020). *Corporaties en klimaatadaptatie: hittestress*. https://groenehuisvesters.nl/wp-content/uploads/2020/06/Corporaties-en-klimaatadaptatie-Hittestress.pdf

Boezeman, D., & de Vries, T. (2019). Climate proofing social housing in the Netherlands: toward mainstreaming? *Journal of Environmental Planning and Management*, *62*(8), 1446–1464. https://doi.org/10.1080/09640568.2018.1510768

Brasche, S., & Bischof, W. (2005). Daily time spent indoors in German homes – Baseline data for the assessment of indoor exposure of German occupants. *International Journal of Hygiene and Environmental Health*, *208*(4), 247–253. https://doi.org/10.1016/j.ijheh.2005.03.003

Brodnik, C., & Brown, R. (2018). Strategies for developing transformative capacity in urban water management sectors: The case of Melbourne, Australia. *Technological Forecasting and Social Change*, *137*, 147–159. https://doi.org/10.1016/j.techfore.2018.07.037

Bulkeley, H. (2010). Cities and the Governing of Climate Change. *Annual Review of Environment and Resources*, *35*(1), 229–253. https://doi.org/10.1146/annurev-environ-072809-101747

Castán Broto, V., Trencher, G., Iwaszuk, E., & Westman, L. (2018). Transformative capacity and local action for urban sustainability. *Ambio*, *48*(5), 449–462. https://doi.org/10.1007/s13280-018-1086-z

Castiglia Feitosa, R., & Wilkinson, S. J. (2020). Small-scale experiments of seasonal heat stress attenuation through a combination of green roof and green walls. *Journal of Cleaner Production*, *250*, 1–10. https://doi.org/10.1016/j.jclepro.2019.119443

CBS. (2022). *Voorraad woningen; gemiddeld oppervlak; woningtype, bouwjaarklasse, regio* [Dataset]. Centraal Bureau voor de Statistiek. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82550NED/table?fromstatweb

Cortesão, J., Lenzholzer, S., Klok, L., Jacobs, C., & Kluck, J. (2018). Cooling Urban Water Environments: Design Prototypes for Design Professionals. *Proceedings of the 34th International Conference*

on Passive and Low Energy Architecture, 520–525. https://pure.hva.nl/ws/portalfiles/portal/6311144/Cortesao_Cooling_urban_water_environments_PLEA2018.pdf

CBS. (2016). *Corporatiebezit neemt af*. Centraal Bureau voor de Statistiek. https://www.cbs.nl/nl-nl/nieuws/2016/50/corporatiebezit-neemt-af

CBS. (2021). *Voorraad woningen; eigendom, type verhuurder, bewoning, regio* [Dataset]. Centraal Bureau voor de Statistiek. https://www.cbs.nl/nl-nl/cijfers/detail/82900NED

Cortesão, J., Lenzholzer, S., Klok, L., Jacobs, C., & Kluck, J. (2018). Cooling Urban Water Environments: Design Prototypes for Design Professionals. *Proceedings of the 34th International Conference on Passive and Low Energy Architecture*, 520–525. https://pure.hva.nl/ws/portalfiles/portal/6311144/Cortesao_Cooling_urban_water_environments_PLEA2018.pdf

Derkzen, M. L., van Teeffelen, A. J., & Verburg, P. H. (2017). Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? *Landscape and Urban Planning*, *157*, 106–130. https://doi.org/10.1016/j.landurbplan.2016.05.027

De Vries, S. B., Mesdaghi, B., Hagens, W., de Nijs, T., & Kluck, J. (2021). *Bureaustudie rondom de invloed van omgevings- en gebouwkenmerken op hitte in de woning*. Tauw. https://pure.hva.nl/ws/portalfiles/portal/24428937/bureaustudie_hitte_gebied_en_gebouw_.pdf

Dimoudi, A., Kantzioura, A., Zoras, S., Pallas, C., & Kosmopoulos, P. (2013). Investigation of urban microclimate parameters in an urban center. *Energy and Buildings*, *64*, 1–9. https://doi.org/10.1016/j.enbuild.2013.04.014

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability*, *2*(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Fan, J. Y., & Sengupta, R. (2021). Montreal's environmental justice problem with respect to the urban heat island phenomenon. *The Canadian Geographer / Le Géographe Canadien*, *66*(2), 307–321. https://doi.org/10.1111/cag.12690

Fischer, E. M., Oleson, K. W., & Lawrence, D. M. (2012). Contrasting urban and rural heat stress responses to climate change. *Geophysical Research Letters*, *39*(3), 1–8. https://doi.org/10.1029/2011gl050576

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, *12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Franck, U., Krüger, M., Schwarz, N., Grossmann, K., Röder, S., & Schlink, U. (2013). Heat stress in urban areas: Indoor and outdoor temperatures in different urban structure types and subjectively reported well-being during a heat wave in the city of Leipzig. *Meteorologische Zeitschrift*, *22*(2), 167–177. https://doi.org/10.1127/0941-2948/2013/0384

Gemeente Rotterdam. (2019). *Hitte* [Kaart]. Rotterdam.Nl. https://www.rotterdam.nl/wonen-leven/rotterdams-weerwoord/Urgentiedocument-2020_NL.pdf

Gemeente Rotterdam. (2021). *Subsidie Klimaatadaptatie*. https://www.rotterdam.nl/wonen-leven/subsidie-klimaatadaptatie/

Gemeente Rotterdam. (2022). *Wijkprofiel Rotterdam* [Dataset]. Gemeente Rotterdam. https://wijkprofiel.rotterdam.nl/nl/2022/rotterdam

Gunawardena, K., Wells, M., & Kershaw, T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. *Science of The Total Environment*, *584–585*, 1040–1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Gustafsson, J. (2017). *Single case studies vs. multiple case studies: A comparative study*. https://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf

Harbers, A. (2009). *De stedenbouwkundige kwaliteiten van de Nederlandse probleemwijken*. Planbureau voor de Leefomgeving. https://www.researchgate.net/profile/Arjan-Harbers/publication/304570888_De_stedenbouwkundige_kwaliteiten_van_de_Nederlandse_probleemwijken/links/57739d2908ae1b18a7de00b4/De-stedenbouwkundige-kwaliteiten-van-de-Nederlandse-probleemwijken.pdf

Haupt, W., Chelleri, L., Van Herk, S., & Zevenbergen, C. (2019). City-to-city learning within climate city networks: definition, significance, and challenges from a global perspective. *International Journal of Urban Sustainable Development*, *12*(2), 143–159. https://doi.org/10.1080/19463138.2019.1691007

He, B. J. (2019). Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building. *Sustainable Cities and Society*, *50*, 1–14. https://doi.org/10.1016/j.scs.2019.101647

Hegger, D. L., Mees, H. L., Driessen, P. P., & Runhaar, H. A. (2017). The Roles of Residents in Climate Adaptation: A systematic review in the case of the Netherlands. *Environmental Policy and Governance*, *27*(4), 336–350. https://doi.org/10.1002/eet.1766

Holmes, S. H., Phillips, T., & Wilson, A. (2015). Overheating and passive habitability: indoor health and heat indices. *Building Research & Information*, *44*(1), 1–19. https://doi.org/10.1080/09613218.2015.1033875

Horton, J., Macve, R., & Struyven, G. (2004). Qualitative Research: Experiences in Using Semi-Structured Interviews. In *The Real Life Guide to Accounting Research* (1st ed., pp. 339–350). Elsevier.

Hsu, A., Sheriff, G., Chakraborty, T., & Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major US cities. *Nature Communications*, *12*(1), 1–11. https://doi.org/10.1038/s41467-021-22799-5

Huck, A., Monstadt, J., & Driessen, P. (2020). Mainstreaming resilience in urban policy making? Insights from Christchurch and Rotterdam. *Geoforum*, *117*, 194–205. https://doi.org/10.1016/j.geoforum.2020.10.001

Humphrey, C., Lee, B. J., & Lee, B. J. (2004). *The Real Life Guide to Accounting Research*. Elsevier.

Huurcommissie. (2018). *Huurverlaging op grond van onderhoudsgebreken (art. 7:257 BW)*. https://www.huurcommissie.nl/data/or_files/16555.pdf

IPCC. (2001). *Climate Change 2001: Synthesis Report*. Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/08/TAR_syrfull_en.pdf

IPCC. (2007). *Climate Change 2007 Synthesis Report*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf

IPCC. (2021). *Climate Change 2021 The Physical Science Basis Summary for Policymakers*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability*. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Jansen Of Lorkeers, W. (2022). Impressie Hittebestendige Straat [Illustration]. In *Arcadis Infographic Hittestress*.

Jones, L., Harvey, B., Cochrane, L., Cantin, B., Conway, D., Cornforth, R. J., de Souza, K., & Kirbyshire, A. (2017). Designing the next generation of climate adaptation research for development. *Regional Environmental Change*, *18*(1), 297–304. https://doi.org/10.1007/s10113-017-1254-x

Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, *109*(19), 7156–7161. https://doi.org/10.1073/pnas.1115521109

Khajehzadeh, I., & Vale, B. (2016). How New Zealanders distribute their daily time between home indoors, home outdoors and out of home. *Kōtuitui: New Zealand Journal of Social Sciences Online*, *12*(1), 17–31. https://doi.org/10.1080/1177083x.2016.1187636

Kim, J. T., & Kim, G. (2010). Advanced External Shading Device to Maximize Visual and View Performance. *Indoor and Built Environment*, *19*(1), 65–72. https://doi.org/10.1177/1420326x09358001

Kleerekoper, L. (2016). *Urban Climate Design. Improving Thermal Comfort in Dutch Neighbourhoods*. TU Delft. https://journals.open.tudelft.nl/abe/article/view/1359/pdf_kleerekoper

Kleerekoper, L., van Esch, M., & Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling*, *64*, 30–38. https://doi.org/10.1016/j.resconrec.2011.06.004

KNMI. (2021). *KNMI Klimaatsignaal '21*. Koninklijk Nederlands Meteorologisch Instituut. https://cdn.knmi.nl/knmi/asc/klimaatsignaal21/KNMI_Klimaatsignaal21.pdf

Kongsager, R. (2018). Linking Climate Change Adaptation and Mitigation: A Review with Evidence from the Land-Use Sectors. *Land*, *7*(4), 1–19. https://doi.org/10.3390/land7040158

Kovats, R. S., & Hajat, S. (2008). Heat Stress and Public Health: A Critical Review. *Annual Review of Public Health*, *29*(1), 41–55. https://doi.org/10.1146/annurev.publhealth.29.020907.090843

KvK. (2011). *Hittestress in Rotterdam*. Gemeente Rotterdam. https://klimaatadaptatienederland.nl/publish/pages/115227/hittestress_in_rotterdam.pdf

Lenzholzer, S., Carsjens, G. J., Brown, R. D., Tavares, S., Vanos, J., Kim, Y., & Lee, K. (2020). Awareness of urban climate adaptation strategies –an international overview. *Urban Climate*, *34*, 1–19. https://doi.org/10.1016/j.uclim.2020.100705

Lundgren Kownacki, K., Gao, C., Kuklane, K., & Wierzbicka, A. (2019). Heat Stress in Indoor Environments of Scandinavian Urban Areas: A Literature Review. *International Journal of Environmental Research and Public Health*, *16*(4), 560. https://doi.org/10.3390/ijerph16040560

Mees, H. L., Driessen, P. P., & Runhaar, H. A. (2012). Exploring the Scope of Public and Private Responsibilities for Climate Adaptation. *Journal of Environmental Policy & Planning*, *14*(3), 305–330. https://doi.org/10.1080/1523908x.2012.707407

McIntosh, M. J., & Morse, J. M. (2015). Situating and Constructing Diversity in Semi-Structured Interviews. *Global Qualitative Nursing Research*, *2*, 1–12. https://doi.org/10.1177/2333393615597674

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. (2020, December 18). *BENG-eisen treden van 1 januari 2021 in werking* [Press release].

https://www.rijksoverheid.nl/actueel/nieuws/2020/12/18/beng-eisen-treden-van-1-januari-2021-in-werking

Nuiten, P., & Leenarts, C. (2018). *Temperatuuroverschrijding in nieuwe woningen in relatie tot voorgenomen BENG-eisen*. W/E Adviseurs. https://www.rvo.nl/sites/default/files/2019/05/Temperatuuroverschrijding%20in%20nieuwe%20woningen%20in%20relatie%20tot%20voorgenomen.pdf

Nuruzzaman, M. (2015). Urban Heat Island: Causes, Effects and Mitigation Measures - A Review. *International Journal of Environmental Monitoring and Analysis*, *3*(2), 67–73. https://doi.org/10.11648/j.ijema.20150302.15

Obradovich, N., Migliorini, R., Paulus, M. P., & Rahwan, I. (2018). Empirical evidence of mental health risks posed by climate change. *Proceedings of the National Academy of Sciences*, *115*(43), 10953–10958. https://doi.org/10.1073/pnas.1801528115

Peris-Blanes, J., Segura-Calero, S., Sarabia, N., & Ribó-Pérez, D. (2022). The role of place in shaping urban transformative capacity. The case of València (Spain). *Environmental Innovation and Societal Transitions*, *42*, 124–137. https://doi.org/10.1016/j.eist.2021.12.006

Pickett, S. T., McGrath, B., Cadenasso, M., & Felson, A. J. (2013). Ecological resilience and resilient cities. *Building Research & Information*, *42*(2), 143–157. https://doi.org/10.1080/09613218.2014.850600

Pielke, R., Prins, G., Rayner, S., & Sarewitz, D. (2007). Lifting the taboo on adaptation. *Nature*, *445*(7128), 597–598. https://doi.org/10.1038/445597a

Porritt, S., Cropper, P., Shao, L., & Goodier, C. (2012). Ranking of interventions to reduce dwelling overheating during heat waves. *Energy and Buildings*, *55*, 16–27. https://doi.org/10.1016/j.enbuild.2012.01.043

PBL. (2011). *Climate Adaptation in the Dutch Delta. Strategic options for a climate-proof development of the Netherlands*. RIVM. https://www.pbl.nl/sites/default/files/downloads/PBL-2012-Climate-Adaptation-in-the-Dutch-Delt-500193002.pdf

Roders, M., Straub, A., & Visscher, H. (2013). Evaluation of climate change adaptation measures by Dutch housing associations. *Structural Survey*, *31*(4), 267–282. https://doi.org/10.1108/ss-01-2013-0009

Rotterdams Weerwoord. (2022). *Klimaatopgaven in Kaart*. https://rotterdamsweerwoord.nl/app/uploads/2022/03/DEF_klimaatopgaven-2030-in-kaart_toegankelijk_WT3.pdf

Runhaar, H. (2009). Putting SEA in context: A discourse perspective on how SEA contributes to decision-making. *Environmental Impact Assessment Review*, *29*(3), 200–209. https://doi.org/10.1016/j.eiar.2008.09.003

Runhaar, H., Mees, H., Wardekker, A., Van der Sluijs, J., & Driessen, P. P. J. (2012). Adaptation to climate change-related risks in Dutch urban areas: stimuli and barriers. *Regional Environmental Change*, *12*(4), 777–790. https://doi.org/10.1007/s10113-012-0292-7

RVO. (2017). *Energieprestatie indicatoren - BENG*. Rijksdienst voor Ondernemend Nederland. https://www.rvo.nl/onderwerpen/wetten-en-regels-gebouwen/beng/indicatoren

Santamouris, M. (2007). Heat Island Research in Europe: The State of the Art. *Advances in Building Energy Research*, *1*(1), 123–150. https://doi.org/10.1080/17512549.2007.9687272

Sarabia, N., Peris, J., & Segura, S. (2021). Transition to agri-food sustainability, assessing accelerators and triggers for transformation: Case study in Valencia, Spain. *Journal of Cleaner Production*, *325*, 1–12. https://doi.org/10.1016/j.jclepro.2021.129228

Shahani, F., Pineda-Pinto, M., & Frantzeskaki, N. (2021). Transformative low-carbon urban innovations: Operationalizing transformative capacity for urban planning. *Ambio*, 1–20. https://doi.org/10.1007/s13280-021-01653-4

Sharmin, T., Steemers, K., & Matzarakis, A. (2017). Microclimatic modelling in assessing the impact of urban geometry on urban thermal environment. *Sustainable Cities and Society*, *34*, 293–308. https://doi.org/10.1016/j.scs.2017.07.006

Swart, R., & Raes, F. (2007). Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? *Climate Policy*, *7*(4), 288–303. https://doi.org/10.1080/14693062.2007.9685657

Tamerius, J. D., Perzanowski, M. S., Acosta, L. M., Jacobson, J. S., Goldstein, I. F., Quinn, J. W., Rundle, A. G., & Shaman, J. (2013). Socioeconomic and Outdoor Meteorological Determinants of Indoor Temperature and Humidity in New York City Dwellings*. *Weather, Climate, and Society*, *5*(2), 168–179. https://doi.org/10.1175/wcas-d-12-00030.1

Termeer, C. J., Dewulf, A., & Biesbroek, G. R. (2016). Transformational change: governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, *60*(4), 558–576. https://doi.org/10.1080/09640568.2016.1168288

Tompkins, E. L., & Eakin, H. (2012). Managing private and public adaptation to climate change. *Global Environmental Change*, *22*(1), 3–11. https://doi.org/10.1016/j.gloenvcha.2011.09.010

Trell, E. M., & van Geet, M. (2019). The Governance of Local Urban Climate Adaptation: Towards Participation, Collaboration and Shared Responsibilities. *Planning Theory & Practice*, *20*(3), 376–394. https://doi.org/10.1080/14649357.2019.1629573

Uittenbroek, C. J., Mees, H. L. P., Hegger, D. L. T., & Driessen, P. P. J. (2019). The design of public participation: who participates, when and how? Insights in climate adaptation planning from the Netherlands. *Journal of Environmental Planning and Management*, *62*(14), 2529–2547. https://doi.org/10.1080/09640568.2019.1569503

UNDP. (2010). *Measuring Capacity*. United Nations Development Programme. https://www.undp.org/sites/g/files/zskgke326/files/publications/UNDP_Measuring_Capacity_July_2010.pdf

UN-Habitat. (2018). *Addressing Urban and Human Settlement Issues in National Adaptation Plans*. United Nations. https://unhabitat.org/sites/default/files/download-manager-files/1554886066wpdm_NAP-Human%20Settlement.pdf

United Nations. (2018). *World Urbanization Prospects The 2018 Revision*. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

United Nations. (2021). *What do adaptation to climate change and climate resilience mean?* UNFCCC. https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

Van Hooff, T., Blocken, B., Hensen, J., & Timmermans, H. (2014). On the predicted effectiveness of climate adaptation measures for residential buildings. *Building and Environment*, *82*, 300–316. https://doi.org/10.1016/j.buildenv.2014.08.027

Vujovic, S., Haddad, B., Karaky, H., Sebaibi, N., & Boutouil, M. (2021). Urban Heat Island: Causes, Consequences, and Mitigation Measures with Emphasis on Reflective and Permeable Pavements. *CivilEng*, *2*(2), 459–484. https://doi.org/10.3390/civileng2020026

Wigley, T. M. L. (2005). The Climate Change Commitment. *Science*, *307*(5716), 1766–1769. https://doi.org/10.1126/science.1103934

Williams, K., Gupta, R., Hopkins, D., Gregg, M., Payne, C., Joynt, J. L. R., Smith, I., & Bates-Brkljac, N. (2013). Retrofitting England's suburbs to adapt to climate change. *Building Research & Information*, *41*(5), 517–531. https://doi.org/10.1080/09613218.2013.808893

Wilson, R. S., Herziger, A., Hamilton, M., & Brooks, J. S. (2020). From incremental to transformative adaptation in individual responses to climate-exacerbated hazards. *Nature Climate Change*, *10*(3), 200–208. https://doi.org/10.1038/s41558-020-0691-6

Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities*, *51*, 121–130. https://doi.org/10.1016/j.cities.2015.11.011

Wolfram, M. (2018). Assessing transformative capacity for sustainable urban regeneration: A comparative study of three South Korean cities. *Ambio*, *48*(5), 478–493. https://doi.org/10.1007/s13280-018-1111-2

Wolfram, M., Frantzeskaki, N., & Maschmeyer, S. (2016). Cities, systems and sustainability: status and perspectives of research on urban transformations. *Current Opinion in Environmental Sustainability*, *22*, 18–25. https://doi.org/10.1016/j.cosust.2017.01.014

Wong, N. H., & Yu, C. (2005). Study of green areas and urban heat island in a tropical city. *Habitat International*, *29*(3), 547–558. https://doi.org/10.1016/j.habitatint.2004.04.008

Woonbond. (2021). *Hitte in huis is een gebrek*. https://www.woonbond.nl/nieuws/hitte-huis-gebrek#:%7E:text=De%20TO%2Dmethode%20gaat%20ervan,zelfs%20in%20de%20winter%2C%20gebeuren.

Yin, R. K. (2008). *Case Study Research: Design and Methods* (4th ed.). SAGE Publications, Inc.

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*(3), 321–332. https://doi.org/10.1177/1356389013497081

Zander, K. K., Botzen, W. J. W., Oppermann, E., Kjellstrom, T., & Garnett, S. T. (2015). Heat stress causes substantial labour productivity loss in Australia. *Nature Climate Change*, *5*(7), 647–651. https://doi.org/10.1038/nclimate2623

Appendices

Appendix A

Figure 9
Square in Spangen

Figure 10
Street in Spangen

Figure 11.
Street in Nieuwe Westen

Figure 12
Street in Spangen

Figure 13

Nieuwe Westen as Seen From Spangen

Figure 14

Border Between Tussendijken (Left) and Spangen (Right)

Figure 15
Street in Spangen

Figure 16
Street in Tussendijken

Appendix B

Table 4

Coding Scheme of Urban Transformative Capacity

Component	Sub-component	Guiding questions
Inclusive and multiform urban governance	Participation and inclusiveness	To what extent can tenants participate in the decision-making process?
	Diverse governance modes and network forms	Does the governance process include a diverse set of stakeholders? How diverse are the governance modes (e.g. top-down / bottom-up)
	Sustained intermediaries and hybridization	Are intermediaries involved that bridge gaps between the directly involved stakeholders?
Transformative leadership		Is constructive leadership present in multiple domains and sectors that fosters a good transformational process?
Empowered and autonomous communities of practice	Addressing social needs and motives	Do discussions include plans to address social needs and thereby improve quality of life and social justice?
	Community empowerment and autonomy	Do implementations aid in creating empowered communities that can act autonomously?
System(s) awareness and memory	Baseline analysis and system(s) awareness	Are current systems analyzed in order to identify room for improvement when it comes to becoming more sustainable?
	Recognition of path dependencies	Are systemic barriers identified so they can be addressed to allow for sustainable transformations?
Urban sustainability foresight	Diversity and transdisciplinary co-production of knowledge	Is knowledge co-produced by a diverse group of actors (scientific, societal, etc.)?
	Collective vision for radical sustainability changes	Are vision supported by a wide range of societal actors?
	Alternative scenarios and future pathways	Are multiple scenarios to change socio-ecological-technical pathways evaluated?

Diverse community-based experimentation with disruptive solutions		Are experiments being conducted that differ from existing ways of practice and policy?
Innovation embedding and coupling	Access to resources for capacity development	Do stakeholders share resources (knowledge, money, time, etc.)
	Planning and mainstreaming transformative action	Are outcomes and insights generalized to other similar contexts?
	Reflexive and supportive regulatory frameworks	Is room for transformative action expanded by better alignment of local/national policies as a result of a project?
Reflexivity and social learning		Does reflection occur among stakeholders? Does social learning occur among stakeholders?
Working across human agency levels		Do project activities build capacity across different levels of society?
Working across political-administrative levels and geographical scales		Do initiatives build capacity across different government levels and geographical scales?

Note. This table demonstrates the prototypical questions for each of the components of the framework. The actual interview questions are based on these questions but are further specified to the case and the specific stakeholder that is interviewed.

Appendix C

Table 5

Overview of Anonymized Interviewees, Place, Date and Duration.

Municipality / Rotterdams Weerwoord	Housing association	Tenants association
R1 Online 07-06-2022 00:53:46	H1 Online 29-04-2022 01:17:16	T1[a] & T1[b] Online 16-06-2022 00:58:41
R2 Online 14-06-2022 00:48:55	H2[a] Online 07-06-2022 00:57:16	
R3 Online 17-06-2022 00:57:29	H2[b] Rotterdam 14-06-2022 00:50:03	
	H3 Online 30-06-2022 01:28:46	T3[a] & T3[b] Online 20-06-2022 1:00:56
	H4 Online 01-07-2022 00:30:00	

Appendix D

Table 6

Overview of the Questions based on the Components of the Analytical Framework, Subdivided into Groups of Interviewees.

Component	Sub-component	Municipality	Housing associations	Residents
To what extent is heat stress experienced in the social housing of Spangen, Tussendijken and Nieuwe Westen?				
Empowered and autonomous communities of practice	Addressing social needs and motives	Do you get a lot of complaints about the heat in neighborhood X? If so, from who (users of public space or private space?). What are their complaints? What is done with the complaints?	Do you receive signals from your tenants that heat is a problem in homes in neighborhood X? What is done with the complaints?	Do you have days that you feel uncomfortable in your home because of the heat? Around which time span of the year? During which times of the day?
Empowered and autonomous communities of practice	Addressing social needs and motives	What do the signals (e.g. complaints) usually entail?	What do the signals (e.g. complaints) usually entail?	And when a moment occurs at which you feel uncomfortable due to heat stress, how does this affect you in your daily life?
System(s) awareness and memory	Baseline analysis and system(s) awareness	Do you get the sense that some buildings experience more heat than others?	Are the complaints evenly distributed over the buildings or do you get more complaints from some buildings than from others? In case of the latter, what do you think are the reasons for this?	Would you say that the heat is something that is experienced throughout the entire neighborhood of neighborhood X, for example based on contact with neighbors or more in specific buildings than in others?

Empowered and autonomous communities of practice	Addressing social needs and motives	What is done with the complaints?	What is done with the complaints?	Do you know who to reach when you want to discuss something related to excessive heat in your home? Have you ever sent a complaint to the municipality or a housing association? If so, how was the complaint handled?
Which measures, both structural as well as behavioral, are already taken to mitigate heat stress?				
System(s) awareness and memory	Baseline analysis and system(s) awareness	Who is responsible for making social housing heat resistant?	Who is responsible for making social housing heat resistant?	Who is in your view responsible for making sure that there is a comfortable temperature in your home?
Diverse community-based experimentation with disruptive solutions	-	What measures have been taken so far to make social housing more heat resistant? What was the role of the municipality in implementing these measures?	What measures have been taken so far to make social housing more heat resistant? What was the role of the housing association in implementing these measures?	What measures have been taken so far around your home to keep your home cooler?
Reflexivity and social learning	-	Are the measures evaluated? How and by whom are they evaluated?	Are the measures evaluated? How and by whom are they evaluated?	What are your experiences with the measures that are already taken? Do you feel like they help?

		Who is responsible for evaluating? What are the results of the evaluation?	Who is responsible for evaluating? What are the results of the evaluation?	Have you been reached out to, to give your opinion about the measures?
Empowered and autonomous communities of practice	Community empowerment and autonomy	What things can people living in social housing do themselves to ensure that their home has a comfortable temperature?	Can tenants themselves do anything to keep their home cooler? Do you think there is enough awareness among tenants about what they can do against heat in their home?	Have you done anything yourself to make your home cooler or make it ? Are there any other things you do differently in your daily life when it gets hot in your home?
Empowered and autonomous communities of practice	Community empowerment and autonomy	How are your tenants informed about the measures they can take to deal with the heat? Do you feel like that information is accessible to all tenants (e.g. different languages, cultures, people with different levels of digital literacy? → how do you reach these groups?)	How are your tenants informed about the measures they can take to deal with the heat? Do you feel like that information is accessible to all tenants (e.g. different languages, cultures, people with different levels of digital literacy? → how do you reach these groups?)	Do you receive information about what you can do against the heat or what you can do to stay cool and healthy? Do you look for information yourself when it comes to what you can do against heat?
Empowered and autonomous communities of practice	Community empowerment and autonomy	Are there specific public places with adequate cooling in or around neighborhood X (cooling centers) where they can	Are there specific public places with adequate cooling in or around neighborhood X (cooling centers) where they can go	Do you feel like there are enough spaces available outside of your home where you can go to cool-off?

		go during heat waves for example?	during heat waves for example?	
What are the visions of stakeholders when it comes to making social housing in pre-war neighborhoods heat resistant?				
Urban sustainability foresight	-	Is there a clear view on all the measures that can be taken to do something against the heat in the specific case of neighborhood X?	Is there a clear view on the measures that can be taken to do something against the heat in the specific case of neighborhood X?	What are measures that you would like to see in/on/around your home to keep your house cooler?
Urban sustainability foresight	Diversity and transdisciplinary co-production of knowledge	Based on what specific factors would these measures be suitable for neighborhood X?	Based on what specific factors would these measures be suitable for neighborhood X?	Why do you think these measures are suitable for your specific home/ neighborhood X?
Inclusive and multiform urban governance / Urban sustainability foresight	Participation and inclusiveness / Diverse governance modes and network forms / Alternative scenarios and future pathways	How is eventually decided which measures will actually be taken in the future?	How is eventually decided which measures will actually be taken in the future?	-
Urban sustainability foresight	Alternative scenarios and future pathways	Is there a specific timeline for when these measures will be implemented? What is this timeline based on (e.g. maintenance)?	Is there a specific timeline for when these measures will be implemented? What is this timeline based on (e.g. maintenance)?	-
How are stakeholders involved in the process of making social housing heat resistant?				
Inclusive and multiform urban governance	Participation and inclusiveness / Diverse	How does participation occur?	How does participation occur?	How are you and other tenants involved in plans

	governance modes and network forms	Who is responsible for the participatory process?	Who is responsible for the participatory process?	with the goal of doing something about the heat?
Inclusive and multiform urban governance	Participation and inclusiveness / Diverse governance modes and network forms	How is ensured that all tenants / social groups can have a say in this process? Do you feel like this results in a process where all groups can voice their opinion and no one gets left out?	How is ensured that all tenants / social groups can have a say in this process? Do you feel like this results in a process where all groups can voice their opinion and no one gets left out?	Do you feel heard and involved enough in this process? Why/why not?
Empowered and autonomous communities of practice	Community empowerment and autonomy	Who is responsible for measures bordering between public and private spaces (e.g. roofs/facades)? Are private spaces taken into account when implementing measures in public space (e.g. trees providing shade for buildings?)	Who is responsible for measures bordering between public and private spaces (e.g. roofs/facades)? Are private spaces taken into account when implementing measures in public space (e.g. trees providing shade for buildings?)	Do you feel like measures on the street such as trees providing shade for houses are a good idea in neighborhood X? Why/why not?
Inclusive and multiform urban governance	Participation and inclusiveness / Diverse governance modes and network forms	To what extent is participation a part of performance agreements between the municipality and housing associations?	To what extent is participation a part of performance agreements between the municipality and housing associations?	-
System(s) awareness and memory	Recognition of path dependencies	Do you feel like there is enough awareness	Do you feel like there is enough awareness among	Do you feel like there is enough awareness about

		among tenants or other stakeholders about the problem of heat in social housing?	tenants or other stakeholders about the problem of heat in social housing?	high temperatures that tenants like you experience (e.g. among the municipality, the housing association)?
Empowered and autonomous communities of practice	Community empowerment and autonomy	Who is responsible for maintaining measures to mitigate the heat?	Who is responsible for maintaining measures to mitigate the heat?	Whose responsibility should it be to maintain measures such to keep a comfortable temperature?
Which barriers do stakeholders experience when it comes to making social housing heat resistant?				
System(s) awareness and memory / Innovation embedding and coupling	Baseline analysis and system(s) awareness / Reflexive and supportive regulatory frameworks	Do you feel like laws and policies – both on national and municipal level – regarding heat in social housing suffice?	Do you feel like laws and policies – both on national and municipal level – regarding heat in social housing suffice? Do you feel like tenants experience hindrance from rules that prevent them from doing something against the heat?	Do you experience rules (from the housing association) who prevent you from bringing down the temperature in your home?
Innovation embedding and coupling	Reflexive and supportive regulatory frameworks	Did any policies or laws change or are planned to change in order to make it easier to implement measures to mitigate heat stress?	Did any policies or laws change or are planned to change in order to make it easier to implement measures to mitigate heat stress?	Did any rules change to make it easier to do something against the heat?
Innovation embedding and coupling	Access to resources for capacity development	Are there enough resources such as money, time and knowledge present among the	Do housing associations have enough resources such as money, time and knowledge to make their	Do the residents of neighborhood X have enough time to do something about the heat,

		municipality or other stakeholders?	housing stock climate adaptive? If these resources are lacking, is it possible to get it from another stakeholder?	such as being involved in participation? Do the residents of neighborhood X have enough money to do something against the heat? Is there enough awareness among residents of neighborhood X concerning what can be done against the heat?
System(s) awareness and memory	Baseline analysis and system(s) awareness / Recognition of path dependencies	Do you experience any other barriers when it comes to doing something against the heat?	Do you experience any other barriers when it comes to doing something against the heat?	Do you experience any other barriers when it comes to doing something against the heat?
Which opportunities do stakeholders experience when it comes to making social housing heat resistant?				
Reflexivity and social learning		Is there collaboration among municipalities in regards to implementing climate adaptation? Can you learn from each other?	Is there collaboration among housing associations in regards to implementing climate adaptation? Can you learn from each other?	Do you learn from others around you what you can do to keep a comfortable temperature in your home?
Inclusive and multiform urban governance	Sustained intermediaries and hybridization	What role do organizations such as 'Rotterdams Weerwoord' (intermediaries) play in this process?	What role do organizations such as 'Rotterdams Weerwoord' (intermediaries) play in this process?	What is your experience with the organization 'Rotterdams Weerwoord'? Does this organization benefit you in any way when it comes to reducing the heat in your home?

		Are there any other intermediaries who play a role?	Are there any other intermediaries who play a role?	
Diverse community-based experimentation with disruptive solutions		Were / are any experiments being conducted regarding heat in social housing; in neighborhood X as well as outside of neighborhood X? What were the outcomes? What role do tenants play in these experiments?	Were / are any experiments being conducted regarding heat in social housing; neighborhood X as well as outside of neighborhood X? What were the outcomes? What role do tenants play in these experiments?	Have you heard of or were you involved in any experiments being conducted with measures to do something against the heat in neighborhood X?
Transformative leadership		Do you feel like there are specific leaders among the different stakeholders who take the lead when it comes to making social housing heat resistant?	Do you feel like there are specific leaders among the different stakeholders who take the lead when it comes to making social housing heat resistant?	Do you feel like there are specific people in the community of neighborhood X who take the lead when it comes to doing something against the heat?
System(s) awareness and memory	Baseline analysis and system(s) awareness / Recognition of path dependencies	Do you see any other current or future opportunities when it comes to making social housing more resistant to the heat?	Do you see any other current or future opportunities when it comes to making social housing more resistant to the heat?	Do you see any other ways that could make it easier in the future to do something about the heat in homes in neighborhood X?
General question: can you recommend any other people that might be relevant to talk to?				