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Barriers to Climate Change Adaptation in Urban Areas in Germany

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Report 26

Barriers to Climate Change Adaptation in Urban Areas in Germany

Master's Thesis
M.Sc. Global Change Ecology
University of Bayreuth

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APA	Adaptation Action Plan of the German Strategy for Adaptation to Climate Change
AR4	IPCC Fourth Assessment Report
BMVBS	Federal Ministry of Transport, Building and Urban Development
BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development
C40	C40 Cities Climate Leadership Group
DAS	German Strategy for Adaptation to Climate Change
DIN	*Deutsches Institut für Normung*
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
NAO	North Atlantic Oscillation
NAS	National Adaptation Strategy
NGO	Non-Governmental Organization
OECD	Organisation for Economic Cooperation and Development
RCP	Representative Concentration Pathway
UCLG	United Cities and Local Governments
UHI	Urban Heat Island
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

1. Introduction

Recently, climate change has become one of the most urgent challenges for today's society. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) emphasizes that the warming of the climate system is unequivocal (IPCC, 2013). It is now widely accepted that the climate observed today and in the near future will be influenced by both variability of the natural system and anthropogenic forcing (Biesbroek et al., 2011; IPCC, 2013; Stocker et al., 2013). Same as the entire planet, Germany will be affected by future impacts of climate change, which will be especially pronounced in urban areas (Bundesregierung, 2008; Biesbroek et al., 2010; Carter, 2011; European Environment Agency, 2012; IPCC, 2013).

Compared to rural areas, urban areas are especially vulnerable (Revi et al., 2014). More than half of the world population currently lives in cities and, given the rising levels of urbanization, the proportion of people exposed to direct climate change impacts in urban centres will further increase in the future (Carter, 2011; Hunt & Watkiss, 2011; Revi et al. 2014; United Nations Department of Economic and Social Affairs, 2014). Moreover, urban areas concentrate most of a nation's built assets, as well as economic and political activities (Carter, 2011; Hunt & Watkiss, 2011; Revi et al., 2014). However, the vulnerability of urban populations associated with climate change depends not only on their exposure to specific stressors and their sensitivity to climate change impacts, but also on their ability to adapt to a changing environment (Emrich & Cutter, 2011; Rosenzweig et al., 2011; Depietri et al., 2012; Douglas et al., 2012; Cutter & Solecki, 2014). Thus, adaptation strategies are crucial and could reduce overall vulnerability of urban populations (Kern & Mol, 2013, Revi et al., 2014). In this context it is also important to emphasize the key role urban governments can play in developing responses to the impacts of climate change (Revi et al., 2014). However, adaptation to climate change has only recently emerged in the academic research and development of city-scale adaptation strategies are still in their beginning stages.

Since the beginning of the 21st century, adaptation to climate change has become an important topic in the scientific community, in local to international policy and planning, in the media and consequently in public awareness (Moser & Ekstrom, 2010; Biesbroek et al., 2013; Klein et al., 2013). Even though mitigation strategies are still the dominant policy approach to climate change, the IPCC states that the inertia of the climate system will make it impossible to avoid the impacts of climate change in the future (Klein et al., 2014). Furthermore, effective mitigation of climate change is a political issue and as it currently seems, the objective of limiting global warming to below 2°C in relation to preindustrial levels will be more and more difficult to achieve, even though the Paris Agreement leaves some hope in this respect (Stocker et al., 2013; Huggel et al., 2014). Managing these unavoidable impacts of climate change through adaptation strategies has become a policy priority, complementary to mitigation strategies (de Oliveira, 2008; Biesbroek et al., 2011; Stocker et al., 2013; Huggel et al., 2014). This paradigm shift in complementing mitigation by adaptation can be observed at different policy levels, however with a stronger focus at the local level (Kern, 2008; Burch, 2010b). Even though the nature of adaptation requires involving actors from all levels of governance, the local level appears to be crucial as climate change impacts will occur and be differentiated mainly at this level (Crabbe & Robin, 2006; de Oliveira, 2008;

Briesbroek et al., 2010; Hunt & Watkiss, 2011; Oberlack & Eisenack, 2014). Therefore, adaptation is inevitably and unavoidably local (Agrawal, 2009).

Since the IPCC's Fourth Assessment Report (AR4), there has been a growing interest regarding the understanding, planning and implementation of adaptation as a strategy for climate risk management (Preston et al., 2011; Park et al., 2012; Klein et al., 2014). However, there are substantial limits and barriers to adaptation, which influence the ability of a society to deal with climate change impacts and which are not limited to the developing world (Adger et al., 2007; Pielke et al., 2007; Moser & Ekstrom, 2010; Klein et al., 2014; Mimura et al., 2014). Scientists have started investigating barriers that could hamper the governance process of understanding, developing, planning and implementing climate change adaptation strategies, policies, and plans (Burch, 2010a; Moser & Ekstrom, 2010; Measham et al., 2011; Biesbroek et al., 2014). Case studies and surveys have been conducted on a global scale in order to identify barriers which hinder the adaptation process, ranging from cultural and cognitive factors to lack of awareness, data availability and resources (Biesbroek et al., 2011; Measham et al., 2011; Biesbroek et al., 2013). Although most case studies and surveys conclude that barriers to adaptation exist, research is still very far from conclusive and causal explanations for the occurrence of barriers. Furthermore, only few studies have focused on the relative importance of barriers to adaptation and on how to overcome them (Burch, 2010b; Moser & Ekstrom, 2010; Biesbroek et al., 2011; Ekstrom & Moser, 2014; Eisenack et al., 2014). This study will address this gap by focussing on a comparative and actor-centred approach to identify and analyse barriers to adaptation. An actor-centred approach was necessary as key actors can provide important insights about conditions and factors that impede adaptation to climate change (Biesbroek et al., 2011; Eisenack et al., 2014). Moreover, barriers can only be addressed and overcome by those actors who are leading the adaptation process in the sectors within their jurisdiction as decision-makers. Finally, a comparative research design can increase the causal understanding of the multiple conditions that create barriers, explain differences and commonalities and identify cross-cutting findings (Biesbroek et al., 2011; Eisenack et al., 2014).

2. Climate change in urban areas in Germany

2.1. Observed changes worldwide and in Germany

Since the keeping of instrumental records, each one of the past three decades has been successively warmer than all the previous decades, with the first decade of the 21st century being the warmest on record (Hartmann et al., 2013). Not only the atmosphere, but also the oceans heat up and most of the energy - so far - was stored in the upper ocean (IPCC, 2013). Since 1850, the mean rates of sea level rise have been increasing, mainly due to melting glaciers and ocean thermal expansion (IPCC, 2013). Furthermore, extreme events have been found to change in past years, where the severity of some (e.g. heat waves and heavy precipitation) is increased by climate change (IPCC, 2012). According to the IPCC it is more than likely (95 percent confidence) that these changes in the climate system are caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcing (Hartmann et al., 2013). Largely driven by economic and population growth, the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have risen to levels which have not been reached in at least the last 800,000 years (Stern, 2006; IPCC, 2013). Concentration levels of the most important greenhouse gas; carbon dioxide, have increased by 40% since pre-industrial times, reaching 390.5 ppm in 2011 (IPCC, 2013; Hartmann et al., 2013). Fossil fuel combustion, cement production, deforestation and other land-use changes are the most important drivers of increased greenhouse gas emissions due to human activity (Hartmann et al., 2013).

Already to date, Germany is affected by increasing temperatures, changing precipitation patterns and an increased frequency of extreme events (Zebisch et al., 2005; Schönwiese & Janoschitz, 2008; Umweltbundesamt, 2015a). During the period 1881–2013, the average near surface temperature in Germany has increased by 1.2 °C (Fig. 1), whereupon the strongest warming occurs during spring (1.3 °C) and the weakest warming during winter-time (1.0 °C on average) (Umweltbundesamt, 2015a). Compared to the reference baseline period 1961-1990, the period representing present climate 1981–2010 exhibits an average near surface temperature increase of 0.7 °C (from 8.2°C to 8.9°C in absolute values) (Umweltbundesamt, 2015a). Nevertheless, the warming during the last century was not linear, but was interrupted by several cooling trends, as well as more heterogeneous periods (Fig. 1) (Schönwiese & Janoschitz, 2008). Since the 1970s, however, a continuous and rapid temperature increase has been observed, not only in Germany but in most parts of the world (Zebisch et al., 2005; Schönwiese & Janoschitz, 2008; Hartmann et al., 2013). At the same time, a stronger regional variation has been observed, ranging from 1.0 to 1.4 °C for the same period (1881–2013) (Zebisch et al., 2005; Umweltbundesamt, 2015a). The temperature rise in federal states in southern and western Germany is stronger than in northern and north-eastern states on average, while the greatest differences are observed during winter months. Changes in temperature are also the reason for changes in the duration of snow cover (Zebisch et al., 2005). With regards to temperature extremes, the number of hot days ($T_{day,max}$>=30ºC), tropical nights ($T_{night,min}$>=20°C) and heat wave occurrences is increasing (Zebisch et al., 2005; Barriopedro et al., 2011; Deutschländer & Dalelane, 2012; Umweltbundesamt, 2015a; Zacharias & Koppe, 2015). For instance, since 1951 the occurrence of hot days has increased significantly from three to eight hot days per year, however, showing large spatial differences. At the same time, the number of ice days (T_day,max<0°C) per year has decreased on average (Umweltbundesamt, 2015a). Moreover, Jacobeit et al. (2009) have investigated how temperature (and precipitation) extremes are related to large-scale atmospheric circulation types. They concluded that only a few of the seasonal circulation types were conducive to the occurrence of daily extremes for the central European region. However, positive temperature extremes in central Europe during winter can be associated with zonal circulation patterns (positive mode of the North Atlantic Oscillation (NAO)) (Jacobeit et al., 2009).

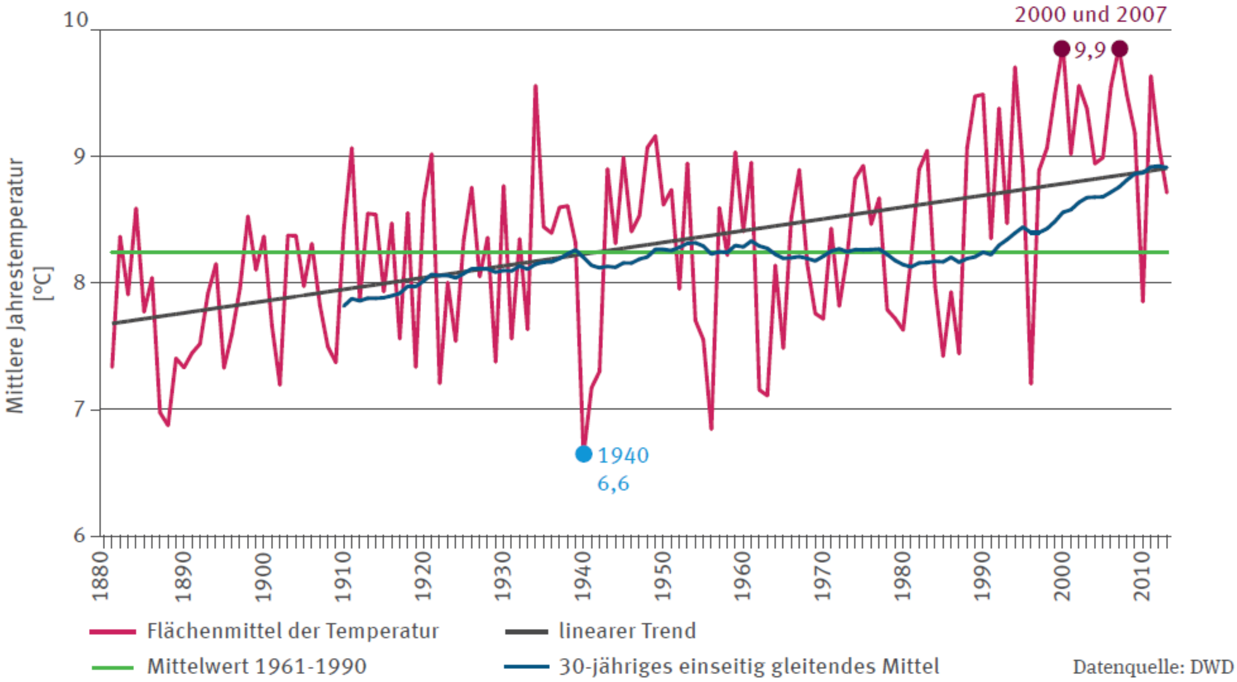

Figure 1: Time series of mean annual temperature in Germany with average temperature for the period 1961–1990, linear trend and 30-year one-sided moving average to illustrate the long term trend from 1880–2013 (Umweltbundesamt, 2015b).

Beside the significant changes in temperature, important changes in precipitation over Germany can be observed as well, varying among regions and within seasons (Zebisch et al., 2005; Grieser & Beck, 2002; Umweltbundesamt, 2015a). While average summer precipitation remained mainly unchanged at the national scale, winter precipitation increased significantly (by 28.0%), leading to an overall increase in average precipitation amounts by 10.6% since 1881 (Grieser & Beck, 2002; Umweltbundesamt, 2015a). However, spatial differences emerge. During winter, the increase in precipitation in north-eastern regions is weaker than in south-western Germany, and thus shows an equivalent spatial distribution as the differences in temperature (Zebisch et al., 2005; Umweltbundesamt, 2015a). This spatial disparity in temperature and precipitation during the winter months depicts the respective influence of a continental and maritime climate (Umweltbundesamt, 2015a). With regards to precipitation extremes, Malitz et al. (2011), and Grieser and Beck (2002) highlight a spatial and seasonal differentiation, but show an overall positive and progressive trend for the intensity and frequency of occurrences of extreme precipitation during the 20th century. During summer, the intensity of heavy precipitation events has increased especially over the last 40 years, whereas the occurrence of heavy precipitation events (P_day>20 mm) has almost remained unchanged since 1881 (Grieser & Beck, 2002; Umweltbundesamt, 2015a). During winter, heavy precipitation events have become more frequent and more intense, especially in north-western Germany, and the annual maximum 5-day precipitation has increased from 38 mm to 45 mm (Zebisch et al., 2005; Malitz et al., 2011; Grieser & Beck, 2002; Umweltbundesamt, 2015a). Furthermore, Jacobeit et al. (2009) have revealed that heavy winter precipitation over central Europe is clearly linked to less zonal circulation patterns implying only a weak correlation with the NAO. Last but not least, particular indices reveal that changing frequencies in precipitation (and temperature) extremes are not only "due to corresponding frequency changes of these conducive circulation types, but also to changes of their association to precipitation or temperature extremes" (Jacobeit et al., 2009).

2.2. Projected changes worldwide and in Germany

Based on state-of-the-art climate projections under future greenhouse gas emission scenario pathways, researchers report to expect further warming and changes in all components of the climate system as emissions of greenhouse gases continue to rise (IPCC, 2013). Furthermore, changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events are expected (IPCC, 2012). In order to limit climate change and its associated impacts, substantial and sustained reductions of greenhouse gas emissions are required (IPCC, 2013).

Projections of regional climate models indicate a significant and robust positive trend of temperature for Germany (Fig. 2) (Zebisch et al., 2005; Bundesregierung, 2008, Jacob et al., 2014). The mean annual temperature is projected to rise by 2.5 to 4°C (under EURO-CORDEX model ensemble RCP4.5 and RCP8.5) for the period 2071–2100, compared to the reference baseline period 1971–2000 (Jacob et al., 2014). However, the projections differ slightly, depending on the scenario pathway of future anthropogenic greenhouse gases emissions, as well as on the choice of regional climate model (Bundesregierung, 2008). In consistency with the observed trends, the EURO-CORDEX model ensemble (RCP4.5 and RCP8.5) projects a stronger warming for southern Germany (Jacob et al., 2014).

Precipitation patterns are projected to be strongly affected by climate change, too (Zebisch et al., 2005; Schönwiese & Janoschitz, 2008; Bundesregierung, 2008; Hartmann et al., 2013). Based on IPCC's A1B emission scenario, annual precipitation is projected to undergo only minor changes in Germany. However, a new set of high-resolution regional climate model simulations for Europe following the next generation of climate change scenarios, the representative concentration pathways (RCPs), has been newly created (Moss et al., 2010; van Vuuren et al., 2011). This EURO-CORDEX ensemble (e.g. Jacob et al., 2014) projects a statistically significant increase in large parts of Central Europe (and Germany) of up to about 25% (under RCP8.5) (Fig. 2) (Jacob et al., 2014). Pfeifer et al. (2015) have found that the regional patterns of winter precipitation differ between the ENSEMBLES A1B and the EURO-CORDEX simulations. In the EURO-CORDEX simulations, the largest increase is projected for southern Germany, whereas the ENSEMBLES A1B simulations project the strongest increase in northeast Germany. For summer precipitation, both the ENSEMBLES A1B and the EURO-CORDEX RCP8.5 simulations project a decreasing trend for southwestern

Germany, while there is no significant trend in the EURO-CORDEX RCP4.5 simulations due to comparatively lower radiative forcing (Pfeifer et al., 2015).

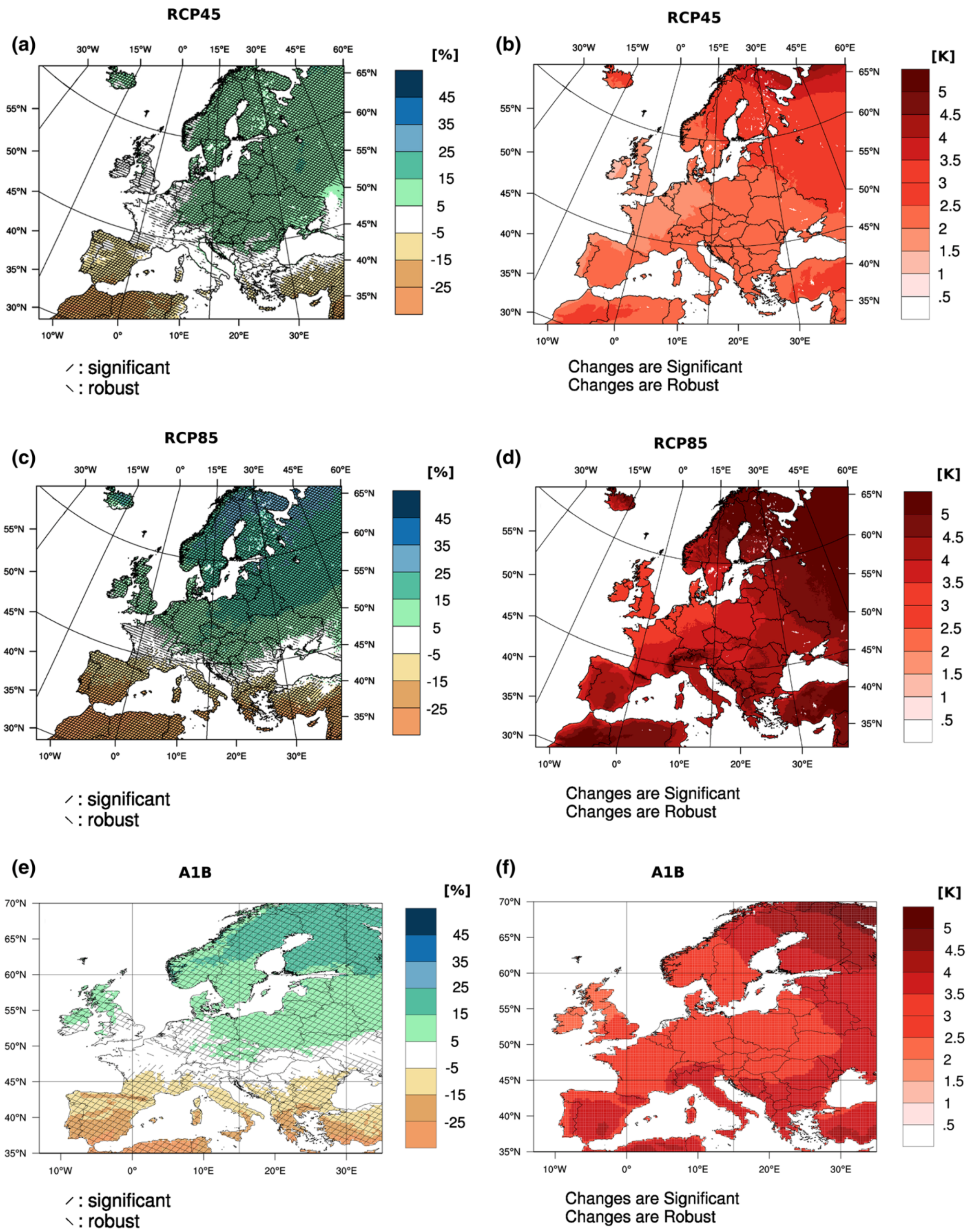

Figure 2: Projected changes of total annual precipitation (%) (left) and annual mean temperature [K] (right) for 2071–2100 compared to 1971–2000, for A1B (e, f), RCP8.5 (c, d) and RCP4.5 (a, b) scenarios. *Hatched areas* indicate regions with robust and/or statistical significant change (a, c, e). Changes are robust and significant across the entire European continent (b, d, f) (Jacob et al., 2014).

Beside these gradual changes in near surface temperature and precipitation, changes in extreme events are also projected to occur and knowledge about these alterations is crucial for adaptation strategies (IPCC, 2012). Temperature and precipitation extremes are likely to occur more frequently on the national scale (Bundesregierung, 2008; 2011). For instance, the duration of extended dry spells is expected to increase slightly as projected by the EURO-CORDEX RCP4.5 and ENSEMBLES A1B simulations (Jacob et al., 2014). Towards the end of this century, the number of heat waves is projected to increase throughout Europe (especially under RCP8.5); however, the change in the number of heat waves depends on the respective definition of 'heat wave' (Jacob et al., 2014). Concerning the projected seasonal mean changes of heavy precipitation, the three emission scenarios (A1B, RCP4.5 and RCP8.5) show relatively similar results (Jacob et al., 2014). Jacob et al. (2014) have found that RCP8.5 projects the strongest increases in heavy precipitation (up to 35%) during winter in Central Europe, whereas A1B projects a less intense increase (up to 25%) for the same area. This is in agreement with the work of Pfeifer et al. (2015), who further highlight that none of the considered scenarios projects a robust increase of summer extreme precipitation.

2.3. Climate change in urban areas

Cities (defined in the broad sense of 'urban areas', transformed from a natural environment into a built environment) are especially vulnerable to climate change (Weeks, 2010; Revi et al., 2014). The concentration of people, assets, critical infrastructure, as well as political and economic activities exacerbates the potential of climate change impacts, and especially of extreme events. These elements at risk are confronted with climate and weather impacts, such as heatwaves, floods and droughts, which are projected to happen more frequently in many parts of Europe and Germany in the future (Dankers & Feyen, 2008; Carter, 2011; Barriopedro et al., 2011; Deutschländer & Dalelane, 2012; European Environment Agency, 2012; IPCC, 2014a; Zacharias & Koppe, 2015). Moreover, hot weather exacerbates air pollution (e.g. through increased formation of ground-level ozone), whereby the topographical situation can make such events more severe. In this light, urban areas located in the lower reaches of river basins are especially sensitive to extensive floods, or the location of a city in a valley basin can decrease air quality by preventing air from moving through the city (European Environment Agency, 2012). Impacts are significant: heatwaves can put infrastructures at risk or compromise public health, reduce the ability to work and result in lower productivity (European Environment Agency, 2012). Whereas flooding can cause substantial economic losses including damage to infrastructure, public and private property and indirect losses such as deteriorated groundwater quality caused by pollution or salinization in coastal areas, droughts can place cities in competition for water with other sectors (e.g. energy generation) (European Environment Agency, 2012). Moreover, cities will have to face socio-economic challenges including failure of services, loss of jobs and income sources, and lower productivity (European Environment Agency, 2012). However, climate change can also have positive effects and even though this study has a different focus, it should be mentioned. For example, increased winter temperatures may bring some localized benefits, such as fewer winter deaths, reduced energy consumption or increased food production (from which cities would benefit too) (IPCC, 2014a).

Another important aspect in cities is the substitution of natural vegetation with artificial surfaces, which creates, among others, unique microclimates affecting temperature, wind direction and precipitation patterns (European Environment Agency, 2012). Already today the high amount of sealed surfaces poses a serious threat to cities, and will further increase with rising urban populations and sprawling settlement patterns (European Commission's Directorate-General Environment, 2012). In 2007, 12.8% of the land in Germany was used for settlement and transport purposes, compared to 7.1% in 1950 (European Commission's Directorate-General Environment, 2012). Although not all of the urban land area has been sealed, most of it is impervious (European Commission's Directorate-General Environment, 2012).

The high proportion of sealed surfaces increases flood risk (Carter, 2011; European Environment Agency, 2012). For some cities, their location is the primary reason for flooding, for instance, cities near the coastline can be affected by coastal floods due to a combination of factors, such as rising sea levels and storm surges, or low lying areas of river basins can be affected by river floods (European Environment Agency, 2012). However, most cities share a high risk of urban flooding (Carter, 2011; Rosenzweig et al., 2011; European Environment Agency, 2012). Increased urbanization via land take and soil sealing decrease air quality, and combined with deforestation and the reduction of wetlands in the surroundings reduces the amount of infiltration and the natural water retention capacity of the area. Thus, during an event with heavy precipitation, surface run-off increases in volume and speed (Carter, 2011; European Environment Agency, 2012; European Commission's Directorate-General Environment, 2012). Furthermore, urban drainage systems have already proved to be inadequate in a number of cities with respect to projected climate impacts and on-going urbanization (Carter, 2011; European Environment Agency, 2012). In addition, increased surface run-off reduces the amount of water available for evaporation, which decreases the cooling effect ordinarily caused by evaporation (European Commission's Directorate-General Environment, 2012). Rosenzweig et al. (2011), in accordance with the IPCC Special Report on Extreme Events (2012), highlight that most cities are projected to experience an increase in the percentage of their precipitation in the form of heavy rainfall, which is true for Germany as well.

Furthermore, heat poses a serious challenge to cities. For instance, heatwaves are projected to increase in frequency, duration and intensity in most cities (Rosenzweig et al., 2011). Artificial surfaces and buildings constructed from concrete, asphalt and stone absorb more heat and retain it for a longer period of time than vegetation would. Thus, the cooling effect of vegetated surfaces is missing, which results in an increase in the intensity of heatwaves, as well as in the occurrence of hot days and tropical nights in urban areas (Barriopedro et al., 2011; IPCC, 2012; European Environment Agency, 2012). The so-called 'Urban Heat Island' (UHI) is the most prominent phenomenon for heat stress in urban areas, and describes the rise in urban temperatures compared to the rural surroundings (Susca et al., 2011). The difference is particularly strong during the night and can also be observed in relatively small towns (Steeneveld et al., 2011). Urban heat islands mainly depend on the modification of the energy balance in urban areas, which is caused by four major factors identified by Susca et al. (2011) from scientific literature: urban canyons (Landsberg, 1981), thermal properties of the building materials (Montavez et al., 2000), replacement of green areas with non-porous surfaces that limit evapotranspiration (Takebayashi & Moriyama, 2007; Imhoff et al., 2010), and a decrease in urban albedo (Akbari & Konopacki, 2005). Furthermore, the size and location of the city, the configuration of buildings, air pollution and reduced wind speeds are further minor factors contributing to UHIs (European Commission's Directorate-General Environment, 2012; Kleerekoper et al., 2012). Beside the absorption of heat by the built environment, human and industrial activities in urban areas also contribute to higher surface and ambient temperatures than in the surrounding rural areas (Kim, 1992). Although further research is needed on the impacts of global warming on urban heat islands, it can be suggested that the intensity of urban heat islands will increase with ongoing climate change (Alcoforado & Andrade, 2008; Kleerekoper et al., 2012; Wilby, 2008). Urban heat islands aggravate the impacts on economy and infrastructure, as well as heat stress, thereby influencing human well-being and health (Alcoforado & Andrade, 2008; Kleerekoper et al., 2012).

Finally, droughts are projected to become longer, more frequent and more severe in many cities (Rosenzweig et al., 2011). Urban areas in Germany are also challenged by droughts and water scarcity (European Environment Agency, 2012). For instance, Lehner et al. (2006) point out an increased drought risk for southwestern Germany. Thus, climate change will further exacerbate impacts on already declining water resources, even though Germany will only be affected punctually. Due to the increasing imbalance between water demand and water availability, water resources are projected to further decrease in southern Europe (European Environment Agency, 2012). In this context, the reliance of urban areas on their surrounding regions to provide them with indispensable services, such as (drinking) water, becomes obvious. Ultimately, the availability of water is necessary for a sustainable development, to ensure human health and to fuel the economy (European Environment Agency, 2012).

3. Climate change adaptation in urban areas

3.1. Adaptation and adaptation strategies

Adaptation has gained ground in the policy debate following its appearance in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) (Adger et al., 2008; Huggel et al., 2014). Nevertheless, in the scientific, policy and public discourse, mitigation has traditionally received much greater attention in the debate on climate change than adaptation (Füssel, 2007; Kern, 2008; Adger et al., 2008; Biesbroek et al., 2010). Füssel (2007) enumerates four different reasons for this: (1) mitigation reduces impacts on all climate-sensitive systems, whereas the potential of adaptation is limited for many systems, (2) mitigation focuses on the cause of the problem and therefore, benefits are sure, whereas successful adaptation partly depends on projections, which are more or less uncertain, (3) mitigation policies can apply the polluter-pays principle, and (4) measuring avoided impacts of climate change due to effective adaptation is less straightforward than measuring greenhouse gas emissions. Moreover, adaptation to climate change depends on the climatic, environmental, social, and political factors in the target region and sector and is therefore highly context specific (Füssel, 2007; Ekstrom & Moser, 2010; Eisenack & Stecker, 2012; Biesbroek et al., 2013; Eisenack et al., 2014; Huggel et al., 2014).

Nevertheless, with increasing evidence of climate change impacts, and despite progressive mitigation policies and strategies, adaptation has ceased to be seen as a “fatalistic strategy”, but has come to be acknowledged as an explicit policy response to deal with these impacts. Relevant academic literature has expanded rapidly since (Biesbroek et al., 2010; 2011; 2013). Moreover, several authors argue that mitigation and adaptation are not substitutable or mutually exclusive alternatives, but rather complementary, because they create benefits on different spatial and institutional scales, they have different characteristic time-scales and the actors concerned are largely distinct (Füssel, 2007; Kern, 2008; Klein et al., 2014). Klein et al. (2014) and Stern et al. (2006) highlight that, without mitigation, climate change impacts on human systems could become so severe that adaptation would require very high social and economic costs. Nevertheless, adaptation will not be “smooth or costless” (Hulme et al., 2007).

Climate change is rarely the sole or primary reason for adaptive action (Berrang-Ford et al., 2011). Adaptation is iterative and on average proceeds autonomously, often in response to climate change impacts that have been experienced in a local or regional context (Berrang-Ford et al., 2011; Preston et al., 2011; Huggel et al., 2014). Climate-related stimuli, such as extreme weather events and increasing climate variability are important to motivate adaptation responses in human systems (Berrang-Ford et al., 2011). Berrang-Ford et al. (2011) have shown that individuals tend to be reactive in their response to climate change impacts, whereas higher levels of governments undertake anticipatory, proactive responses. Nevertheless, since AR4 there has been a significant increase in the number of planned adaptation responses; adaptation that is the result of a “deliberate policy decision, based on climate change knowledge and an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state” (IPCC, 2007) at the local level in rural and urban communities (IPCC, 2007; Mimura et al., 2014).

This implies that adaptation is actor-, place- and context-specific (Berrang-Ford et al., 2011; Huggel et al., 2014).

Acknowledging the need for comprehensive adaptation strategies in Member States, the European Commission has published its Green Paper 'Adapting to climate change in Europe – options for EU action' in June 2007 and the subsequent White Paper 'Adapting to climate change: Towards a European framework for action' in April 2009, that both should have given incentives to Member States to develop National Adaptation Strategies (NASs) (Commission of the European Communities, 2007; Commission of the European Communities, 2009; Biesbroek et al., 2010). In 2013, the EU Strategy on adaptation to climate change set out a framework and mechanism to further develop the EU's preparedness for current and future climate impacts (Commission of the European Communities, 2013). Supranational and national strategies assume a coordinating role for regional and local levels of government, providing policy frameworks, guiding action in key sectors and thus, supporting and enabling local and regional strategies (European Environment Agency, 2012; Mimura et al., 2014). The German Strategy for Adaptation to Climate Change (DAS) created the framework for a medium-term national adaptation process in which risks will be identified, actions specified, objectives defined and adaptation measures developed and implemented, thus showing a new political commitment to adaptation at the national policy level (Bundesregierung, 2008, Biesbroek et al., 2010). The Adaptation Action Plan (APA), released in 2011, elaborated these objectives and options, finalizing concrete activities, which are continuously evaluated and revised to further develop the strategy (Bundesregierung, 2011). Furthermore, the Federal Government is funding adaptation research, e.g. exemplary model schemes at local and regional level (Bundesregierung, 2008). Vital elements of this research include the integration of climate concerns into local and regional policy processes and the investigation of interdependencies between climate-sensitive sectors, organizations and other actors (Biesbroek et al., 2010).

Local and regional adaptation strategies have only been developed recently (Biesbroek et al., 2010; Carter, 2011; Measham et al., 2011). Regional governments often have a complementary role to NASs (Kern, 2008; Mimura et al., 2014). As they are closer to where impacts of climate change will occur, they play a critical role in the implementation of climate change related policies (de Oliveira, 2008). Moreover, they play an important role when adaptation issues exceed municipal borders. Coordinating the collaboration between cities or municipalities can, for example, result in higher efficiency and reduce the costs (e.g. it is more sustainable to build flood measures beyond city borders from an adaptation perspective) (European Environment Agency, 2012). In addition to this, the federal system in Germany guarantees each state the right of 'self-government' (Bulkeley & Kern, 2006). Thus, most states have developed their own policy-based adaptation processes and strategies (Bundesregierung, 2011). The development of such adaptation strategies is far from being a trivial process. Lindseth (2005) highlights the need for a scientific basis. Biesbroek et al. (2010) further argue that there is not only a need for scientific knowledge on the climate system, but also of context-specific knowledge of (multiple) impacts, vulnerabilities and adaptation options, as well as knowledge of interactions and cascading effects. Compared to regional strategies, local level strategies are more diverse as adaptation is context-dependent (Carter, 2011; Measham et al., 2011; Mimura et al., 2014). Carter (2011) stresses the need for cities to develop adaptation strategies and measures specifically for their particular circumstances, as patterns of exposure and vulnerability differ spatially. These strategies should consider local climate and biophysical conditions and include the particular characteristics of elements at risk, as well as account for other issues including levels of political will, the existence of relevant governance frameworks and stakeholder networks, and the availability of financial and human resources (Carter, 2011). Thus, bottom-up approaches are likely to be an important element (Biesbroek et al., 2010).

However, a great number of cities have not yet developed comprehensive adaptation strategies to respond to climate change, even though strategies at the supra- or national scale have existed for some time (Kern, 2008; Revi et al., 2014). Numerous authors (Bulkeley & Kern, 2006; Kern, 2008; Biesbroek et al., 2010; Berrang-Ford et al., 2011; Carter, 2011; Revi et al., 2014; Roggero et al., 2014) emphasize that a large number of cities are still focusing on mitigation strategies, and that they only start prioritizing the development of an adaptation strategy once they have been affected by an extreme weather event. In Germany, most municipalities have adopted climate mitigation concepts several years ago, but lag behind in adaptation strategies (BMVBS, 2010; Mahammadzadeh et al., 2013). Mahammadzadeh et al. (2013) found that almost 63% of German municipalities have not dealt with adaptation to climate change at all yet. This has several reasons; in many cases climate change impacts are often not very tangible yet, climate projections are still too uncertain according to the opinion of many municipalities, potential damages are too far away and legal certainty is not strong enough to promote any actions (BMVBS, 2010; 2011). In contrast to urban mitigation strategies, which are spatially independent and can be implemented without special local knowledge, urban adaptation strategies require differentiated, site-specific argumentations as described above (BMVBS, 2011). However, if a city is affected by an extreme event or when other climate change impacts become tangible or generate high costs, the benefits of climate change adaptation become visible (Kern, 2008; Berrang-Ford et al., 2011; Carter, 2011). In addition, the Federal Government has been promoting the maxim of inner-development before outer-development (‘*Innenentwicklung vor Außenentwicklung*’) for many years. This makes sense in a mitigation perspective, as heavily urbanized areas contribute to a high degree of utilization of social and technical infrastructure, avoid greenhouse gas emissions through short distances, and limit urbanization in the surrounding areas (BMVBS, 2011; NVK Karlsruhe, 2013). However, densification and inner-development increase the risks of flooding and urban heat islands as they increase the proportion of non-porous surfaces, and are not really consistent with climate change adaptation strategies which would require large, open spaces (e.g. green and blue areas) within the city (BMVBS, 2011). Meanwhile, the Federal Government has recognized the need for adaptation strategies and in 2010 initiated the research field ‘Urban Strategies to combat Climate Change’, which focuses, not only on mitigation, but also on adaptation (NVK Karlsruhe, 2013). Nowadays, adaptation to climate change is an essential part of sustainable urban planning (BMVBS, 2011; NVK Karlsruhe, 2013). Bulkeley and Kern (2006) highlight that climate change adaptation in municipalities in Germany is considered a “voluntary task”, depending on the financial and personnel capacities of the local government, which could explain the belated development of adaptation strategies. In addition, the focus on self-governing and enabling modes of governing has significantly reduced the capacity of the local state in Germany to undertake adaptation actions

(Bulkeley & Kern 2006). Therefore, to most municipalities in Germany, climate adaptation is a new, additional challenge and thus, adaptation strategies at the city- or metro-region scale have, if at all, only very recently begun to emerge.

For such local strategies, two main approaches can be differentiated. In most cases an integrated strategy is developed, which is only one element of wider climate change and sustainability strategies that incorporate climate change mitigation, as well as other pressing issues of urban development, such as demographic change (Carter, 2011; BMVBS, 2010). The model cities in the StadtKlima project, for instance, have developed integrated urban adaptation strategies, taking into account adaptation and mitigation, embedded in comprehensive sustainable urban development, thus considering an aging, heat-sensitive population, as well as vulnerable technical infrastructure (BMVBS, 2010). These integrated approaches can be very diverse, according to the experienced or projected impacts and the sectors focused on. This promotes opportunities for creating and strengthening adaptation planning and its implementation (Mimura et al., 2014). The Klimzug-Nord project, for example, developed innovative adaptation strategies for the metropolitan area of Hamburg by focusing on interdisciplinary, cross-sector strategies that should reflect the complexity of climate change adaptation (Klimzug-Nord Verbund, 2014; Kruse et al., 2014). In contrast, stand-alone approaches only focus on responding to consequences of climate change. London’s Climate Change Adaptation Strategy, or those developed in Rotterdam and Copenhagen, are examples of stand-alone approaches (Carter, 2011). In Germany, strategies are almost exclusively integrated approaches at all levels of governance (Bundesregierung, 2011; Roggero et al., 2014). Such approaches appear to be more effective as they are not in competition for resources with other agendas, and the implementation of adaptation options is especially successful when they are consistent with other pressing issues of urban development (BMVBS, 2010; Carter, 2011). For example, initiatives that primarily have another function, such as urban green spaces for recreation or biodiversity reasons, can support adaptation functions too (Carter, 2011; Mahammadzadeh et al., 2013). Thus, climate change adaptation is an elementary part of comprehensive urban development.

Last but not least, the Fifth IPCC Assessment Report stresses that climate change adaptation has to be integrated into plans and policies immediately (Revi et al., 2014). Furthermore, the European Environment Agency (2012) notes that adaptation to climate change offers the opportunity for creating new jobs, for stimulating innovation and for implementing the profound changes needed in managing the cities of Europe. Independent from their direct benefits of reducing vulnerability to climate change, adaptation options can actually provide “ancillary or co-benefits” (Klein et al., 2014). Such benefits can facilitate adaptation planning, as they make certain adaptation options more cost-effective and thus help to integrate climate change adaptation into existing processes (Hallegatte, 2009; Klein et al., 2014). Klein et al. (2014) highlight three ways in which such benefits may emerge from adaptation responses: (1) stimulating adaptation to current climate variability, (2) generating climate adaptation goods and services and (3) advancing sustainable development. For example, Stern et al. (2006) indicate that the market opportunities for new infrastructure and buildings resilient to climate change in OECD countries could be very important. At the same time, the IPCC assessment reports, as the Global Monitoring Report, emphasize the importance of actions in urban areas to successful global climate change adaptation and the Fifth IPCC Report states that high levels of adaptation can reduce risk levels significantly in cities (Revi et al., 2014; World Bank Group, 2016).

3.2. The local scale matters

Climate change adaptation is context dependent and linked to a particular location. The predominant opinion in the adaptation literature is that most climate change impacts will be felt and differentiated at the local level due to inhomogeneous vulnerability and adaptive capacity (Crabbe & Robin, 2006; Briesbroek et al., 2010; Measham et al., 2011; Hunt & Watkiss, 2011; Oberlack & Eisenack, 2013). Satterthwaite (2013), for instance, emphasises that urban risks and vulnerabilities are highly context-specific and climate change impacts depend, among others, on geographical location, climate-proof infrastructure and buildings, regulatory frameworks, early warning systems, and the socio-economic status and adaptive capacity of the residents. Furthermore, Measham et al. (2011) point out the need for ‘place-based’ approaches to adaptation as local governance systems are often the responsible and legitimate unit for addressing and managing such impacts (Agrawal, 2009; Measham et al., 2011). Hulme et al. (2007) underline the advantage of small-scale decision-making to resolve dilemmas around incomparable values. Moreover, the IPCC emphasizes that local governments play a central role in the adaptation process, because much adaptation depends on “local assessments and integrating adaptation into local investments, policies, and regulatory frameworks” (Revi et al., 2014). For example, climate change adaptation concerns need to be incorporated into building standards and other activities, such as guaranteeing that sewage systems can cope with extreme rain events, checking building designs to better insulate against heat and adapting the energy system to cope with flooding, higher temperatures or water scarcity (European Environment Agency, 2012).

In order to ensure effective local adaptation, local institutions need to be responsive, flexible and able to adapt to new situations associated with climate change (Agrawal, 2009). De Oliveira (2008) emphasizes the role of flexibility in local governments, and argues that implementation of new policies is easier at the local level. Smaller entities, where preferences and values are more homogeneous, can take decisions quicker and adapt their structure faster to new issues. Thereby, they provide opportunities for leadership and innovative policies that could serve as examples for other localities (Hulme et al., 2007; de Oliveira, 2008; Ostrom, 2009).

Even though local governments are the ‘fulcrum’ of adaptation planning and are central to successful local climate adaptation, the nature of adaptation requires combined efforts of actors at all levels of governance (Biesbroek et al., 2010; Kern & Mol, 2013; Revi et al., 2014). Although local governments can have the authority to decide on adaptation measures, they can be enabled, bounded or constrained by regional, national or supranational strategies, laws or funding (Bulkeley & Kern, 2006; 2008; OECD, 2010; Carter, 2011; Revi et al., 2014). Therefore, policies and incentives need to ensure a harmonious work flow across multiple levels of governance, thereby involving different institutions with different scopes of authority (Bulkeley & Kern, 2006; Kern, 2008; European Environment Agency, 2012; Revi et al., 2014).

3.3. Urban areas are key

The cities of the world consume about 75% of the natural resources of the planet, 80% of the global energy supply, produce large amounts of waste and approximately 75% of the global carbon emissions (United Nations Environment Programme, 2013; Satterthwaite, 2008). Thus, they play key roles in climate change mitigation and adaptation. On the one hand, cities with their high demands in energy, land and water have always had an effect on the natural environment and have been accelerating the loss of environmental services (e.g. urban cooling through green areas) (Carter, 2011; Fischer et al., 2015). However, cities have also managed to find responses to various manmade 'natural' challenges by focussing on rigorous, empirical and systematic strategies, such as the development of water distribution networks to prevent the degradation of drinking water, or regulations for black smoke industries to increase air quality in the 19th century (Fischer et al., 2015). On the other hand, the sustainable growth and development of urban areas is crucial for the fundamental role of cities in the creation of wealth (Carter, 2011; European Environment Agency, 2012). As already mentioned previously, they exercise important economic and socio-cultural functions, and in the future their importance will further increase through a growing urban population (see section 2.3).

Three groups of actors can be distinguished in urban areas: local government, city networks (between cities) and private actors (Fischer et al., 2015). Much of the potential for cities to play a critical role in climate change adaptation lies in the interplay between these groups (Fischer et al., 2015). First, the concentration of assets, critical infrastructure, political and economic activities does not only make cities vulnerable to climate change impacts, but also allows local governments to take a leading role in adapting to climate change, as they are the centres of economic and political activity (Rosenzweig et al., 2011). Urban governments are in principal in a unique position to take the leadership role and to develop tailored responses to the impacts of climate change. Not only do they understand the local context best, but can also raise awareness, promote understanding of climate change, work to build inclusive policy space, and ultimately encourage, support and prepare individuals, communities and local industry to contribute to climate change adaptation (Cash & Moser, 2000; Moser 2006; Ostrom, 2009; Revi et al., 2014). Furthermore, urban governments supply essential services and infrastructure, and are also responsible for maintaining the functionality of critical infrastructure (Crabbe & Robin, 2006; Bulkeley & Kern, 2006; Revi et al., 2014). In Germany, they are directly elected bodies with several roles covering areas such as education, health, regeneration, promotion of economic development, waste management, land use planning and transport (Bulkeley & Kern, 2006; Mahammadzadeh et al., 2013). At the same time, urban governments are the executing authority for duties and responsibilities from the federal and state-level (Mahammadzadeh et al., 2013). Hence, having quasi-monopolies over the above-mentioned sectors should facilitate the development of integrated adaptation strategies. Therefore, the development and implementation of many adaptation measures depend on the competence and capacities of urban governments, as well as on what they decide on, enable, prohibit, and control (Ostrom, 2009; Revi et al., 2014). Beside municipal councils and real estate developers, who can directly implement large structural measures (e.g. the construction of green areas), housing cooperations, companies and private property owners also play an important role (European Environment Agency, 2012). They can make single buildings and parking areas climate-proof through insulation or modified street paving for water retention for example. By incorporating climate resilience (see section 4.1.1 for definition) into their investments in the urban environment, actors cannot only reduce additional costs of adaptation, but also deploy opportunities by combining climate adaptation tasks with other objectives, such as improving the quality of life or reducing energy consumption (European Environment Agency, 2012).

Second, several city networks have emerged in the last decade. As climate change impacts do not stop at regional or national boundaries, international city networks, like Local Governments for Sustainability (ICLEI), C40 Cities Climate Leadership Group (C40), United Cities and Local Governments (UCLG), or more locally oriented associations have shown up (Kernaghan & da Silva, 2014; Fischer et al., 2015). They support and facilitate the sharing of knowledge, experiences and best practices between cities and regions, and thus can accelerate local adaptation (Dannevig et al., 2012; European Environment Agency, 2012; Kernaghan & da Silva, 2014; Fischer et al., 2015). Policy coordination and exchange among cities, for instance, is crucial for the circulation of innovative ideas on how to adapt to climate change (Fischer et al., 2015). Such organizations can further call for commitments to global incentives, such as the Compact or Covenant of Mayors, which aim to help nations set more ambitious climate targets, or to adopt an integrated approach to tackling adaptation (Kernaghan & da Silva, 2014). In addition, the proliferation of city networks proves that the importance of cities to the environmental agenda is overall recognized, even though only a minority of projects approved by climate-related funds between 2010 and 2014 had a particular focus on promoting urban climate change mitigation and adaptation activities (Barnard, 2015; Fischer et al., 2015). Nevertheless, Simon and Leck (2014) emphasise that strategies for adapting to climate change increasingly “resonate across distally connected and networked cities” around the world. Last but not least, city networks also support concrete action, as they link global climate policy to urban practice, and thus increase the capacity of cities to act as major players in environmental governance (Fischer et al., 2015).

Third, in recent years city networks have started to cooperate with the private sector (Bulkeley & Schroeder, 2012). The participation of business and industry, or of non-profit actors, such as Non-Governmental Organizations (NGOs), have increased public-private partnerships oriented towards adaptation and mitigation, which is important in “enhancing the global reach and policy-to-practice capacity of cities” (Fischer et al., 2015). Finally, the private sector has strongly supported the extension of city-to-city cooperation and played an important role in the growth of city diplomacy (Fischer et al., 2015).

Considering all of the above, it can be claimed that, adaptation is a multi-level governance issue, but local governments in urban areas are at the heart of successful adaptation and are increasingly acknowledged as an important player in climate action and global environmental governance. As Magnussen (2013) highlights, climate change adaptation in urban areas is a complex field of action where authority structures change depending on the target sector and its spatial scale, as well as on the current power relations at play (Fischer et al., 2015). Nevertheless, cities can better adapt to such a “complex reality of governance”, as they are more flexible, and fast learning the benefits of transnational (e.g. city networks) and other arrangements (with the private sector and NGOs) (Fischer et al., 2015). Urban areas are essential elements and active actors in multilevel governance systems and their administrations have the possibilities to undergo an incremental process of understanding the adaptation issue, identifying adaptation options, making decisions and revising their strategies (Kern, 2008; Kern & Mol, 2013; Revi et al., 2014). However, multiple constraints have risen which hinder the successful application of this process.

4. Barriers to adaptation

Before establishing clusters of barriers to adaptation, it is necessary to define what is meant exactly by ‘adaptation’ in order to delineate the actions and contexts in which barriers might emerge. It is equally important to clarify what counts as ‘barriers to adaptation’ and explain the difference between barriers and limits. Furthermore, it is crucial to define a framework for identifying barriers to climate change adaptation.

4.1. Defining key terms

4.1.1. Adaptation

Studies on ‘adaptation’ have a long history and the term has been used in a variety of ways by researchers from different fields (Ekstrom, Moser & Torn, 2011). In the context of climate change, most studies (e.g. Moser & Ekstrom, 2010; Eisenack & Stecker, 2012, Huggel et al., 2014) work with the definition provided by the IPCC and define adaptation as a response to “actual and expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2007) (Ekstrom, Moser and Torn, 2011; IPCC, 2014a). In contrast, Adger et al. (2008) use an approach to adaptation, in which everything depends on goals, values, risks and social choice, and argue that barriers (called limits) are endogenous and emerge from “inside society”, thus being contingent on ethics, knowledge, attitudes towards risk and culture. Moser and Ekstrom (2010) derive a definition that deviates from the IPCC definition by only focusing on the human or socio-ecological systems. In addition, Moser and Ekstrom (2010) highlight that adaptation might not be justified by climate change alone. This is supported by Tompkins et al. (2009) and Berrang-Ford et al. (2011), who emphasise that climate change is rarely the primary reason for adaptation actions. In addition, the IPCC definition implicitly assumes effectiveness in the output, which is premature (Moser & Ekstrom, 2010). Whether harm will be avoided, or opportunities exploited, is dependent on many factors, not just the adaptive action itself. Some actions may turn out to be maladaptive at later stages (Moser & Ekstrom, 2010). Therefore, by focusing on the intentional, planned adaptation process, the generic, but inclusive definition of Moser and Ekstrom (2010), which takes into consideration the above-mentioned remarks, is used in the present study:

> “Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities.”

Furthermore, it is important to stress the differences between adaptation, resilience and vulnerability, as they are strongly related. The IPCC defines vulnerability as the “propensity or predisposition to be adversely affected” (IPCC, 2014b) and Gallopin (2006) as a function of sensitivity, capacity of response and exposure, which is the definition that will be used. Lastly, resilience is the “capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation" (IPCC, 2014b). Therefore, a resilient system is less vulnerable than a non-resilient system, but this relation does not necessarily imply symmetry, and hence vulnerability is not the opposite of resilience (Gallopin, 2006).

4.1.2. Barriers to adaptation

Still today there is no consensus definition of 'barriers to adaptation', and most studies do not provide an explicit definition on what they mean by 'barriers' (Biesbroek et al., 2013; Eisenack et al., 2014). Moser and Ekstrom (2010), and Eisenack and Stecker (2012) constitute two exceptions to this trend. Furthermore, the concepts of barriers and limits are often used interchangeably (Moser & Ekstrom, 2010). For instance, Adger et al. (2008) identifies 'limits to adaptation' but qualifies them as mutable, whereas other researchers refer to limits as obstacles which are absolute (Moser & Ekstrom, 2010; Eisenack & Stecker, 2012).

The IPCC clearly distinguishes between 'barriers' and 'limits'. 'Limits' are absolute and constitute thresholds beyond which the objective of an actor cannot be protected from intolerable risks through adaptation measures (Klein et al., 2014). By 'barriers to adaptation', Klein et al. (2014) understand a set of conditions or processes that make it harder to plan and might hinder the implementation of adaptation actions. Beside social barriers they also include biological and physical barriers. For this analysis the IPCC definition provides a useful starting point. Furthermore, the publications of Moser and Ekstrom (2010), and Eisenack and Stecker (2012), which both provide a clear-cut definition of barriers to adaptation, are primarily considered in order to derive a definition, which will fully serve the purpose of this research.

Moser and Ekstrom (2010) identify barriers as malleable obstacles that make adaptation less efficient and less effective. They can be overcome by individuals or groups with concerted efforts, social support, creative management, innovative ways of thinking, political will and reprioritization of resources, land uses and institutions. According to Moser and Ekstrom (2010), barriers arise either from the actor, the larger context or the system at risk. This concept of barriers to adaptation includes a positive approach that is descriptive rather than normative, and in which barriers are just obstacles that hinder or stop the adaptation process. Eisenack and Stecker (2012) also use a positive approach and highlight that barriers are obstacles to specified adaptations, requiring certain needs in order to be overcome or avoided. Thus, barriers are relative to the specified adaptive actions conducted, to the actors that may execute them and to the specific situation in which they may be taken. Moreover, Moser and Ekstrom (2010), and Eisenack and Stecker (2012), as well as Adger et al. (2008), and Hulme et al. (2007), emphasize the role of norms and values in understanding barriers. A barrier might be viewed by one actor as problematic, while another actor sees a benefit in it (Eisenack et al., 2014). Biesbroek et al. (2011) distinguish explicitly between social barriers (institutional, cultural, political, economic and informational dimensions) and biophysical (physical and technical dimensions) barriers. Burch (2010b), Ekstrom and Moser (2010), and Eisenack et al. (2014) emphasize that barriers are not static, but change over time as several components, such as actors or context, can be dynamic. Moreover, barriers are often interdependent, which might influence their occurrence, persistence and resolution (Moser & Ekstrom, 2010; Eisenack et al., 2014).

Barriers to adaptation are explored from the context of social actors and, more specifically, from the context of actors from government agencies. For the purpose of this study, based on the definition derived from Eisenack et al. (2014), barriers to adaptation are defined, as (1) obstacles (2) to specified adaptations (3) for specified actors in their given context that (4) emerge in the adaption process from climate and non-climate factors and conditions (which are the actor, the system of concern and the larger context). The focus lies on barriers that have a (5) social dimension, that can be (6) dynamic, (7) interdependent and (8) valued differently according to the actors. Finally, a barrier is (9) malleable and can be overcome. Here, consistent with the IPCC, 'barriers', 'constraints' and 'obstacles' are used as synonyms.

4.2. Explanation of the underlying framework

Current barrier research offers a diverse conceptual base (Eisenack et al., 2014). There is no consistent framework for the identification and assessment of barriers to adaptation (Biesbroek et al., 2013). Therefore, the decision was taken to guide this study along a diagnostic framework which was developed by Moser and Ekstrom (2010) on the basis of an extensive literature review on barriers to adaptation (Moser & Ekstrom, 2010; Ekstrom, Moser & Torn, 2011). The framework is a systematic approach to detect barriers in each stage of an idealized adaptation process, and is proposed for the analysis of socio-ecological systems. A systematic diagnostic framework was chosen as adaptation measures are context-specific and depend very much on the actors, object and governance involved (Moser & Ekstrom, 2010; Ekstrom, Moser & Torn, 2011). In a more recent literature review, Biesbroek et al. (2013) deliver almost the same results and argue that Moser and Ekstrom's (2010) scheme is the "only policy framework purposefully designed to identify and analyse barriers to adaptation" (Biesbroek et al., 2013). This proves the usefulness of the framework. Furthermore, this theoretical structure has been tested in practice and found to support the empirical research in identifying, organizing and understanding barriers (Ekstrom & Moser, 2014).

Several authors have developed other approaches to identify and organize barriers. Even though this analysis does not rely on these frameworks, they deserve to be briefly assessed in the following lines. Huggel et al. (2014) propose a similar framework than Moser and Ekstrom (2010); however they do not include information on how to overcome barriers and only focus on the science contribution to climate change adaptation. Their idealized adaptation process is structured into (1) framing and problem definition, (2) the scientific assessment of climate, impacts, vulnerabilities and risks, and (3) the evaluation of adaptation options and their implementation. Eisenack and Stecker (2012) present a different approach by creating a framework that conceptualizes adaptations to climate change as actions. The concept distinguishes between exposure unit, which is influenced by a stimulus, actor (called operator) and receptor, which is the actor or system that is targeted. The so-called means (resources, knowledge and power) are used by the operator to understand, develop and implement the adaptation. This approach contributes to clarify the concept of adaptation and helps to deduce barriers to adaptation which appear due to a mismatch of a set of conditions, in systematic ways, (see section 4.3). Finally, Biesbroek et al. (2014) provide an innovative framework, focusing on barriers in the governance of climate change adaptation. By analysing the three dominant philosophies in the study of governance, they investigated barriers to adaptation through four empirically rooted analytical lenses. This allowed the researchers to identify different causes of barriers, as well as strategies on how to overcome them (Biesbroek et al., 2014).

The framework of Moser and Ekstrom (2010) was guided by four principles, which should make it applicable to a large number of adaptation cases. The framework intends to be “(1) socially focused but ecologically constrained; (2) actor-centric but context-aware; (3) process focused but action/outcome-oriented; and (4) iterative and messy but linear for convenience”. First, the primary focus is on the social sphere, as the study concentrates on planned adaptation. Thus, the focus is on actors which are not just autonomously reacting to climate change, but who are actually acting and responding to a changing environment. Nevertheless, as in all human systems, the actors are embedded in, and interact with, biophysical systems. Second, an actor‐centred approach is explicitly chosen as many barriers are related to the actors themselves, and constraints can only be addressed and overcome by actors and actions (Ekstrom, Moser & Torn, 2011; Biesbroek et al., 2011; Eisenack et al., 2014). However, the larger context in which the actors are embedded can enable or constrain the action space they have (Ekstrom, Moser & Torn, 2011). Third, adaptation is dynamic in nature and is a continuous process. Nevertheless, actors have to make decisions as well, from which they are expecting certain outcomes (Ekstrom, Moser & Torn, 2011). Consequently, the framework needs to consider processes with attention to actions and outcomes. Last but not least, a structured framework is simpler, more static and convenient for analysing, even though such a framework imposes more order than exists in reality (Ekstrom, Moser & Torn, 2011).

The diagnostic framework contains three components (Ekstrom, Moser & Torn, 2011). First, the idealized stages of the adaptation process in decision-making represent the framework’s dynamic component (Fig. 3). It organizes the barriers by the ideal-type stages in the adaptation process. Second, the fundamental sources for the existence of barriers constitute the structural dimension of the framework (Fig. 4). These interconnected structural elements are (1) the actors involved in the adaptation process, (2) the larger context in which they act, and (3) the object or system of concern upon which they act. The third component is a simple matrix that helps to locate the source of the barrier relative to the influence of the actor over it (Fig. 5). Consequently, this can be the first step towards identifying interventions to overcome the barriers, which have been previously identified.

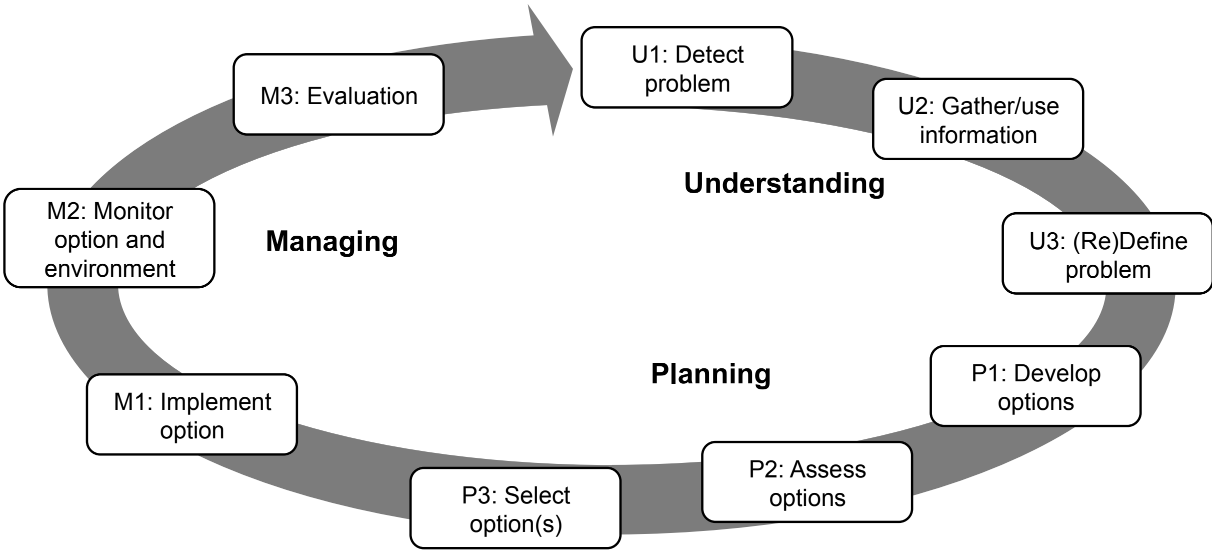

Figure 3: Dynamic component of the diagnostic framework: phases and stages throughout the adaptation decision-making process (Moser and Ekstrom, 2014).

The process of adaptation presents the foundation for identifying and organizing the barriers. The process is defined by three phases which help to understand the problem, plan adaptation actions and manage the implementation of the selected options. Each phase includes three stages (Fig. 3). In the understanding phase, the focus lies on (i) problem detection and awareness raising; (ii) information gathering to deepen the knowledge; and (iii) problem (re)definition to position the actor adequately to begin the exploration of responses. Planning includes (iv) development of adaptation options; (v) assessment of options; and (vi) selection of option(s). Last but not least, the management phase involves (vii) implementation of the selected option(s); (viii) monitoring the environment and outcome of the realized option(s); and (ix) evaluation. Although the decision process is less accurate and linear in practice, for the purpose of identifying barriers to adaptation it provides a favourable ordering heuristic (Moser & Ekstrom, 2010).

As adaptation is context-sensitive, the structural elements of adaptation are very critical (Fig. 4). The actors are not static, but dynamic, as they can be exchanged or change over time. The object or system of concern is the system that is exposed to climate change impacts and that has to be managed. Both the actor and system of concern are embedded in the greater context (e.g. governance and socio-economic conditions), which enables or constrains possible adaptation cases. Biesbroek et al. (2013) identified identical elements of adaptation, although they are partly named differently.

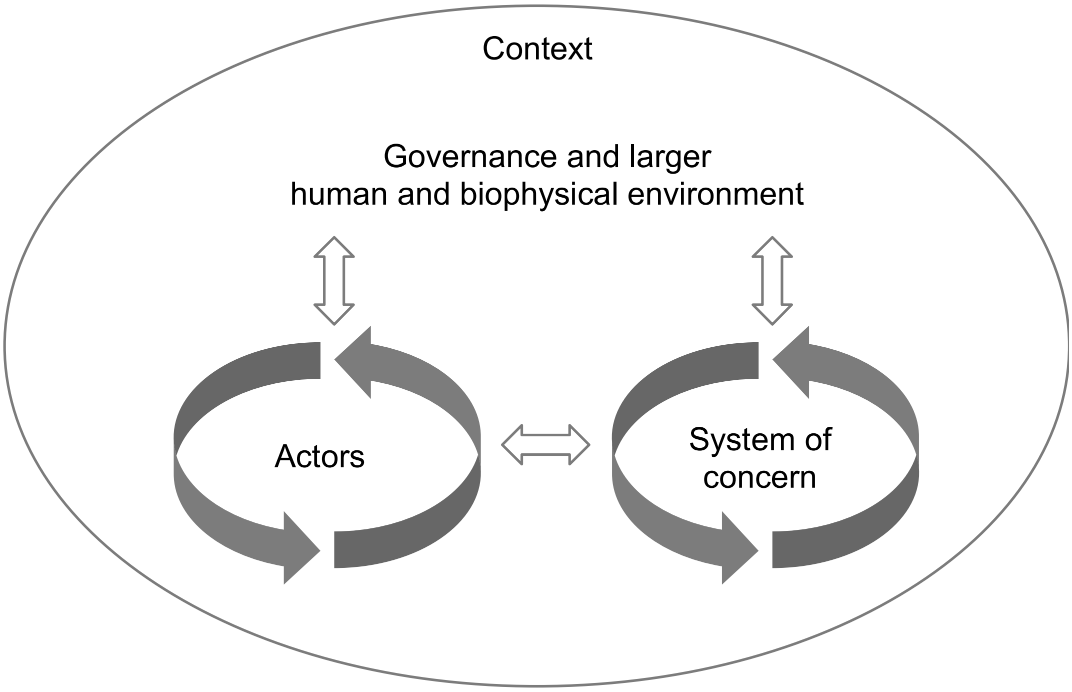

Figure 4: Structural component of the diagnostic framework: three fundamental sources for the existence of barriers (Moser and Ekstrom, 2010).

Overcoming barriers is the third and final step of the framework. Figure 5 displays the matrix that helps to locate possible points of suitable intervention. Moser and Ekstrom (2010) argue that, beside the capability of an actor to deal with a barrier, the origin of the barrier, which is influenced by spatial jurisdictional and temporal dimensions (relative to the place and situation in which the actor finds him or herself), is crucial for overcoming barriers. Each barrier varies along both dimensions, whereas the temporal dimension includes contemporary versus legacy barriers and the spatial/jurisdictional dimensions proximate versus remote barriers.

		Temporal	
		Contemporary	Legacy
Spatial / Jurisdictional	Proximate	A	C
	Remote	B	D

Figure 5: Locus of control over barriers to climate change adaptation along temporal and spatial/jurisdictional scales (Moser and Ekstrom, 2010).

The first two components of the diagnostic framework help to identify the nature of barriers which hinder the adaptation process, and how the different elements contribute to the barriers. In addition, by asking diagnostic questions, potential barriers are systematically identified at each stage. Thereby, the framework facilitates to answer the fundamental questions of this research: what kinds of barriers occur, where they occur in the adaptation process and what causes the impediments (or: how do actors, context and system of concern contribute to those barriers). Finally, mapping the barriers across their temporal and spatial/jurisdictional scales will show possible opportunities for intervention, and thus help to remove or bypass any possible barriers to adaptation.

4.3. Literature review to summarize barriers to adaptation into clusters

Since the AR4 findings on barriers to climate change adaptation, a growing body of scientific research on this issue has been recorded (Adger et al., 2008; Klein et al., 2014; Mimura et al., 2014). Furthermore, the examination of the ability of richer nations to adapt to climate change and the persistent ‘adaptation deficit’ in developing nations have stimulated even more research on barriers and limits to adaptation (Burton, 2009; Moser & Ekstrom, 2010). A recent review paper from Biesbroek et al. (2013) synthesized results of 81 peer-reviewed papers on barriers to climate change adaptation and shown that two thirds of the analysed papers were published after 2009, which is in accordance with the observed scientific progress on climate change adaptation (Berrang-Ford et al., 2011; Biesbroek et al., 2013; Mimura et al., 2014). Furthermore, they identified more than 200 context-dependent barriers, whereupon most studies were small-N inductive case studies, focusing on the regional or local levels within the context of water management, coastal zone management, or considered multiple sectors (Biesbroek et al., 2013). In general, the growing number of case studies and theoretical work has contributed to the development of an extensive list of commonly reported barriers (Eisenack et al., 2014).

Adaptation literature carefully describes and categorizes barriers in different ways, as current barrier research does not provide any specific framework or categorization scheme (Biesbroek et al., 2013; Eisenack et al., 2014). This is partly linked to the nature of social barriers that are highly context- and actor- specific, and in contrast to biophysical or technical barriers they cannot be observed or measured directly, but can only be reported by those who encounter them, making it difficult to achieve a consistent categorization (Biesbroek et al., 2011). Even though any kind of categorization is arbitrary, several scholars have tried to cluster the seemingly endless list of barriers into smaller sets (Biesbroek et al., 2011; 2013). The most important attempts made by scientists to categorize barriers to climate change adaptation are summarized in table 1.

Some scholars derive categories of barriers from their framework (Tab. 1). Eisenack and Stecker (2012), for instance, deduce four types of barriers which are grouped along the dimension of the operator and the means: (1) missing operator, (2) missing means, (3) unemployed means and (4) complex actor relations. First, when there is no operator (e.g. ignorance of impacts by all involved actors), no adaptation takes place. Second, although there is an operator (e.g. an exposure unit) who perceives a need to proceed, the necessary means are not available. Third, there is an operator and means are available, but not sufficiently employed. Fourth, the network of operators, exposure units and receptors is too complex to reach a decision (Eisenack & Stecker, 2012). Moreover, Biesbroek et al. (2014)

distinguish between four empirically rooted analytical lenses which frame barriers in a specific way: (1) governance as problem solving, (2) governance as competing values and interests, (3) governance as institutional interactions, and (4) governance as dealing with structural constraints. These categorizations of barriers are specific to the governance of climate change adaptation. However, such classification schemes only make sense if the respective frameworks are being considered as well. As the decision was taken to base the present study on the framework of Moser and Ekstrom (2010) and to identify barriers in the adaptation process itself, such a categorization is excluded.

Other scholars base their categorization on literature reviews and results from empirical research (Tab. 1). Biesbroek et al. (2011) identify seven barrier categories: (1) conflicting timescales, (2) substantive, strategic and institutional uncertainty, (3) institutional crowdedness and institutional void, (4) institutional fragmentation, (5) lack of awareness and communication, (6) motives and willingness to act, and (7) lack of resources. Beside the review of literature, Burch (2010b) focuses on barriers to adaptation in municipalities in her research and deviates four categories of barriers: regulatory, structural or operational, behavioural or cultural, and contextual or capacitive. Huggel et al. (2014), who focus on barriers in the science-policy process, suggest, that barriers may be grouped into (1) divergent objectives, needs, scope, and priorities; (2) different institutional settings and standards, and timeframes; and (3) differing cultural values, understanding, and mistrust. This setting includes a complicating factor, as the three groups are highly interdependent; prioritization for instance depends on considered cultural means and values, and on institutional settings. Furthermore, due to the focus on the science-policy interface, political barriers and resource constraints (human and financial) are neglected. In general, many of these barrier categories are not specific to the governance of climate change adaptation, but can be found in other processes (e.g. management) as well (Eisenack et al., 2014). However, Eisenack et al. (2014) underline that certain types of barriers are particular problematic for adaptation, namely those related to conflicting timescales and institutional fragmentation.

Furthermore, several attempts have been made to categorize barriers based on results from case studies (Tab. 1). Ekstrom and Moser (2014) apply their framework in a local urban context, namely the San Francisco Bay Area. They identify a total of twelve categories of barriers, among which institutional, attitudinal, financial and political barriers, as well as leadership issues, are most commonly encountered. Also within the urban context, Measham et al. (2011) identify leadership, competing priorities, planning processes, as well as informational and institutional constraints as major impediments to adaptation in municipalities in Sydney. Crabbé and Robin (2006) focus on institutional barriers in the water sector in municipalities in Canada, where they explicitly distinguish between external and internal institutional constraints for municipal adaptation. Last but not least, Mahammadzadeh et al. (2013) have analysed the current status of climate adaptation in 317 different municipalities throughout Germany and have also focused on barriers to adaptation. They identify five categories: (1) resources, (2) institutional barriers, (3) awareness, (4) conflicts of interests, and (5) climate change related concerns (Mahammadzadeh et al., 2013). Many more case studies exist which identify barriers to adaptation (e.g. Mozumder et al., 2011; van Stigt et al., 2015); however these studies do not propose a distinct categorization of barriers.

Table 1: Attempts made to categorize barriers to climate change adaptation.

Research basis	Examples	Context
Categories derived from frameworks	Four types of barriers grouped along the dimension of the operator and the means: (1) missing operator, (2) missing means, (3) unemployed means and (4) complex actor relations (Eisenack & Stecker, 2012)	---
	Four barriers framed by empirically rooted analytical lenses: (1) governance as problem solving, (2) governance as competing values and interests, (3) governance as institutional interactions, and (4) governance as dealing with structural constraints (Biesbroek et al., 2014)	---
	Four crosscutting issues: (1) leadership, (2) resources, (3) communication and information, and (4) values and beliefs (Moser & Ekstrom, 2010)	---

Table 1 continued: Attempts made to categorize barriers to climate change adaptation.

Research basis	Examples	Context
Categories derived from literature review and empirics	Seven types of barriers: (1) conflicting timescales, (2) substantive, strategic and institutional uncertainty, (3) institutional crowdedness and institutional void, (4) institutional fragmentation, (5) lack of awareness and communication, (6) motives and willingness to act, and (7) lack of resources (Biesbroek et al., 2011)	The Netherlands
	Four types of barriers: (1) regulatory, (2) structural or operational, (3) behavioural or cultural, and (4) contextual or capacitive (Burch, 2010b)	Urban municipalities in Vancouver
	Three types of barriers: (1) divergent objectives, needs, scope, and priorities; (2) different institutional settings and standards, and timeframes; and (3) differing cultural values, understanding, and mistrust (Huggel et al., 2014)	Focus on science-policy interface in the Andes region in South America
Categories derived from results of case studies	Twelve categories of barriers: (1) institutional and governance, (2) attitudes, values and motivations, (3) resources and funding, (4) politics, (5) leadership, (6) adaptation options/process, (7) understanding, (8) science, (9) expertise, (10) communication, (11) personality issues, and (12) technology/structural (Ekstrom & Moser, 2014)	Urban areas in the San Francisco Bay area
	Five types of barriers: (1) leadership, (2) competing priorities, (3) planning process, (4) informational and (5) institutional constraints (Measham et al., 2011)	Urban municipalities in Sydney
	Five categories: (1) resources, (2) institutional barriers, (3) awareness, (4) conflicts of interests, and (5) climate change related concerns (Mahammadzadeh et al., 2013)	Municipalities in Germany
	Many more, though similar categorizations (e.g. Mozumder et al., 2011; van Stigt et al., 2015)	Several

These general and descriptive barrier categories summarize a broad variety of particular barriers that are actor and context specific across sectoral, spatial, and temporal scales. Each study identifies a unique set of factors and conditions that pose constraints to adaptation in their specific context, making generalization a challenge. Thus, it is difficult to create a general classification which can serve varying sorts of studies on barriers. As illustrated, a barrier can be viewed in different lights depending on the location, or might interact with other obstacles, and the importance and severity of barriers might alter over time (Burch, 2010b; Moser & Ekstrom, 2010; Biesbroek et al., 2011; 2013). Thus, it is difficult to compare the barriers identified in different research studies. The same is true for strategies to overcome barriers. If explanations are given, they only apply to the specific case under investigation, making generalization a challenge (Biesbroek et al., 2011; 2013; Eisenack et al., 2014).

Nevertheless, based on the aforementioned streams of literature and especially those, which apply to the framework of Moser and Ekstrom (2010), focus on urban areas, are special to adaptation and derived from literature review, nine clusters of barriers are proposed (Tab. 2). These clusters seem to serve best for the classification of barriers in urban areas. By grouping the constraints, it is possible to go beyond the influence of individual barriers in the interpretation of those identified by the experts. The clusters are: (1) conflicting timescales and conflicts of interest, (2) leadership, (3) resources, (4) science, (5) governance and institutional constraints, (6) lack of awareness and communication, (7) attitudes, values and motivations, (8) politics, and (9) adaptation process.

Table 2: Identification of types of barriers to climate change adaptation in urban areas. Each type is represented by supporting references.

Type of barrier	References
Conflicting timescales and conflicts of interest	Long term changes in the climate system and the rate of impacts difficult to relate to dynamism of social changes and short-termism in decision-making and policies; other issues with a more pressing nature, more certain impacts or more visible short term results (Biesbroek et al., 2011)
	Short term interventions based on a long term vision, and persistent uncertainties about the nature and scale of risks and the effectiveness of adaptation (Eisenack et al., 2014)
	Different timeframes (Huggel et al., 2014)
	Adaptation competes with other interests for priority (Measham et al., 2011)
	Conflicts of use and of objectives (Mahammadzadeh et al., 2013)
	Divergent objectives, needs, scope and priorities (Huggel et al., 2014)
Leadership	Lack of or ineffective leadership (Moser & Ekstrom, 2010)
	Behavioural barriers and leadership capabilities of individuals in critical positions (Burch, 2010b)
	Local leadership (Measham et al., 2011)
	Lack of or problematic leadership, too many leaders (Ekstrom & Moser, 2014)
	Missing or dominant leadership and lack of local leadership (Eisenack et al., 2014)

Table 2 continued: Identification of types of barriers to climate change adaptation in urban areas. Each type is represented by supporting references.

Type of barrier	References
Resources	Financial means, technical resources, technology, staff expertise and time (Moser & Ekstrom, 2010)
	Context and human, financial and technical capacity (Burch, 2010b)
	Lack or inaccessibility of human, financial, physical and natural resources (Biesbroek et al., 2011)
	Lack of financial resources and of cost-benefit analysis (Mahammadzadeh et al., 2013)
	Resources and funding (Ekstrom & Moser, 2014)
Science	Lack or inaccessibility of information resources (Biesbroek et al., 2011)
	Lack of useful, credible and relevant information (Measham et al., 2011)
	Lack of information (Mahammadzadeh et al., 2013)
	Scientific understanding (Ekstrom & Moser, 2014)
	Uncertainty, and different epistemic communities and rationalities (van Stigt et al., 2015)
Governance and institutional constraints	Regulatory barriers, and structural or operational constraints (Burch, 2010b)
	Institutional void, institutional crowdedness and fragmentation (Biesbroek et al., 2011)
	Institutional constraints, missing legal basis (Measham et al., 2011)
	Administrative structure (Mahammadzadeh et al., 2013)
	Institutional governance issues (Ekstrom & Moser, 2014)
	Institutional fragmentation; adaptation strategies depend on the interaction of various sectors and policy levels (Eisenack et al., 2014)
	Different institutional settings and standards (Huggel et al., 2014)
Lack of communication and awareness	Communication and information about the problem, solutions and their implications (Moser & Ekstrom, 2010)
	Lack of social and public awareness and communication (Biesbroek et al., 2011)
	Awareness raising (Mahammadzadeh et al., 2013)
	Lack of communication or miscommunication (Ekstrom & Moser, 2014)
	Different understanding and mistrust (Huggel et al., 2014)

Table 2 continued: Identification of types of barriers to climate change adaptation in urban areas. Each type is represented by supporting references.

Type of barrier	Reference
Attitudes, values and motivations	Deeply held values and beliefs (Moser & Ekstrom, 2010)
	Behavioural barriers and personalities of individuals in critical positions (Burch, 2010b)
	Physical attitudes of cognitive decision-making processes on adaptation (Biesbroek et al., 2011)
	Attitudes, values and motivations (Ekstrom & Moser, 2014)
	Different cultural values (Huggel et al., 2014)
Politics	Strategic uncertainty due to actors' behaviour in decision-making processes (Biesbroek et al., 2011)
	Politics (Ekstrom & Moser, 2014)
Adaptation process	Adaptation options process (Ekstrom and Moser, 2014)

4.3.1. Conflicting timescales and conflicts of interest

The first cluster includes barriers related to conflicting timescales and conflicts of interests. Conflicting timescales result from the nature of climate change adaptation. Very often it is difficult to relate the long term changes in the climate system, as well as the rate of observed and expected climate change impacts, to the dynamism of societal changes and short-termism in decision-making (Bisbroek et al., 2011; Huggel et al., 2014). Short term interventions with a long term vision demand a continuous commitment by taxpayers, politicians and the private sector (Eisenack et al., 2014). However, politicians need to produce valuable outcomes in the short term, so that they do not lose their legitimacy vis-à-vis the electors. Even though adaptation is urgent, conflicting timescales make it a big challenge to incorporate climate change concerns into new and existing policy processes (Biesbroek et al., 2010). For example, in contrast to long term climate change impacts, strategic policy documents traditionally only plan for the upcoming 20 to 30 years (Biesbroek et al., 2011). At the same time, critical infrastructure needs to consider long term impacts in order to be climate-proof, and thus has critical implications for the future sustainability of cities (United Nation Environment Programme, 2013). Long term perspectives in climate change do not make it easier to stay on the political agenda either, as climate change competes with other pressing issues. Adaptation represents only one area of priority amongst other competing issues for urban government planning (Measham et al., 2011). Conflicts of interest may arise, for instance for financial and human resources with other, more immediate agendas, such as housing. In addition, the short term results of these agendas might be more visible than adaptation to long term climate change (Biesbroek et al., 2011). Finally, the importance of climate change adaptation is strongly influenced by how the issue is framed (Measham et al., 2011). Prioritization might change if adaptation is not just seen as an environmental issue, but as a comprehensive problem impacting public safety, health and the environment (Measham et al., 2011). Then, it may have greater resonance within local governments and be prioritised.

4.3.2. Leadership

Numerous authors identify leadership issues as a major barrier (Moser & Ekstrom, 2010; Burch, 2010b; Measham et al., 2011; Mozumder et al., 2011; Mahammadzadeh et al., 2013; Ekstrom & Moser, 2014). Leadership is especially important in urban areas; generating interest for adaptation, increasing awareness and pushing for institutional change to bring action (Revi et al., 2014). Burch (2010b), for instance, has found that in municipalities, leadership can contribute to novel governance mechanisms and in consequence change the decision-making context. Furthermore, leadership can be critical at all stages of the adaptation process, but is of special importance in initiating the process and sustaining momentum over time (Moser & Ekstrom, 2010). In this line, Eisenack et al. (2014) highlight the role of local leadership in overcoming the first steps and in creating the necessary action space for other actors. Leadership can be exercised not only by individuals, but also by a certain group of people or an organization (Moser & Ekstrom, 2010; Eisenack et al., 2014). On the other hand a lack of or ineffective leadership, problematic or dominant leadership, or too many leaders can disturb the adaptation process and keep others from engaging in adaptive behaviour (Moser & Ekstrom, 2010; Ekstrom & Moser, 2014; Eisenack et al., 2014). For example, individual leaders might abuse their power or undermine mutual ownership among administrative agencies, thus making the coordination of adaptation measures more difficult (e.g. by significantly slowing down the process) (Eisenack et al., 2014).

4.3.3. Resources

The third cluster compounds barriers that are related to human, financial, and technical resources. Numerous studies point out that resources are a critical factor throughout the entire process of climate change adaptation (e.g. Moser & Ekstrom, 2010; Burch, 2010b; Mozumder et al., 2011; Mahammadzadeh et al., 2013; Ekstrom & Moser, 2014). Moreover, Füssel (2007) highlights that resources are key components for building adaptive capacity. Even though resources typically include information resources as well (e.g. Moser & Ekstrom, 2010; Biesbroek et al., 2011), they are excluded in this cluster and are grouped into the science cluster, as literature often points out the importance of scientific information and understanding. Financial constraints can be linked to broader macroeconomic forces, such as economic development (e.g. global financial crises) and trends in globalization, or to small-scale financial resources, such as funding issues and financial means (e.g. an inappropriate budget) (Klein et al., 2014). In Sydney, for example, costs of investigating and responding to climate change are viewed as significant barriers to adaptation (Measham et al., 2011). Moreover, insufficient access to financial capital can have direct implications for staffing (e.g. lack of staff, of capacity among staff, or of staff expertise) or technology. For example, Moser et al. (2008) point out that technical means (e.g. building structural protections against the rising sea, developing new crop varieties) are potentially powerful options to adapt to climate change, but the availability of such technological adjustments is closely linked to financial resources. Other human resources (e.g. managerial support) and lack of time can further hinder successful adaptation (Biesbroek et al., 2011).

4.3.4. Science/scientific understanding

The role of scientific knowledge in the decision-making process about urban development has been debated intensively (van Stigt et al., 2015). Thus, the fourth cluster is dealing with scientific understanding and information. Barriers may arise from indispensable or uncertain expert knowledge; from the fact that decision-makers and scientists belong to different epistemic communities, and from the rationality and linearity of decision-making (van Stigt et al., 2015). Thus, accessibility and availability of data, credibility and legitimacy of information, but also understanding, translation and management of data are all highly important in adapting to climate change (even though these issues can also be found in other processes (e.g. management)) (Moser & Ekstrom, 2010; Ekstrom & Moser, 2014; van Stigt et al., 2015). Beside expert knowledge, local knowledge can be of equal importance and ignoring it might cause a barrier to adaptation (Huggel et al., 2014; van Stigt et al., 2015). In addition, decision-making about urban planning is a rational and non-linear process, which may lead to the disuse of available knowledge or may make it difficult to understand which knowledge is needed when in the planning process (van Stigt et al., 2015). Finally, scientists and practitioners often argue that uncertainty associated with foreseeing future climate is an impediment to climate change adaptation (Hulme et al., 2007; Ekstrom & Moser, 2014). Dessai et al. (2009) distinguish between epistemic uncertainty (uncertainty about our knowledge), natural stochastic uncertainty (uncertainty about the variability of the climate system) and human reflexive uncertainty (uncertainty about the reflexive behaviour of humans). The second type of uncertainty is inherent to model projections for instance. Concluding, expert knowledge contains an inherent level of uncertainty based on incomplete knowledge behaviour and behaviour of systems that may cause problems in the decision-making process.

4.3.5. Governance and institutional constraints

The fifth cluster is made up from barriers, which are linked to the governance structure and the institutional environment. Under institutional constraints are grouped structural and regulatory barriers. Thus, this cluster includes barriers linked to physical organisations, as well as to regulations, rules and norms that guide behaviour (Moser et al., 2008). Furthermore, Biesbroek et al. (2011) identify two very opposite types of structural barriers: institutional crowdedness and institutional voids. ‘Institutional crowdedness’ refers to a sum of institutions, which influence the decision-making process and create confusion about tasks and responsibilities conflicting aims and criteria, and divergent perceptions about problem-framing and appropriate adaptive actions in response. For example, unclear roles and responsibilities in the multi-governance system in Australia have contributed to a low priority off adaptation in urban policy agendas (Mukheibir et al., 2013; Eisenack et al., 2014). In contrast, ‘institutional voids’ refers to a lack of institutions which enable, support or stimulate adaptation. This lack of institutions leads to a scarcity of formal and informal rules, norms and values for adaptation, contributing to a lack of mechanisms and instruments (Biesbroek et al., 2011). For example, in Germany, climate change policy is considered as a voluntary task and thus, there exists no formal legislation that forces municipalities to include adaptation in their activities (Bulkeley & Kern 2006, Kern & Mol, 2013). Moreover, fragmentation is inherent to any governance process that deals with a complex policy problem (Biermann et al., 2009). Fragmentation is the consequence of lack of connection and coordination among institutions, organizations, individuals and policies, at different levels and scales (Biesbroek et al., 2011). As climate change adaption occurs across sectors and requires action at all levels of governance, fragmentation issues are very prominent. Finally, Koppenjan and Klijn (2004) identify institutional uncertainty, linked to actors, which come from different institutional backgrounds and might cause uncertainty as they may have different understandings of the problem.

4.3.6. Lack of awareness and communication

This cluster is made up by barriers related to awareness and communication, as well as public understanding of climate change. Throughout the adaptation process, it is of extreme importance to communicate the impacts of climate change, adaptation measures and their implications to the general public, as well as to other institutions and levels of governance (Moser & Ekstrom, 2010). Without communication, the public, stakeholders and other decision-makers are kept in the dark about their role and the efforts on adaptation made so far. Thus, effective communication is of extreme importance and will increase awareness and understanding, provide continuity and constructively engage all policy-makers, stakeholders, and the public (Moser & Ekstrom, 2010; Biesbroek et al., 2011). Literature on climate change adaptation explicitly stresses the importance of social and political awareness. Furthermore, the level of awareness of a society is influenced by various media, which can be both positive and negative (Biesbroek et al., 2011). Complete lack or insufficient frequency or content of communication between science, policy and society on climate change adaptation can interrupt or affect social interactions among those involved in the adaptation process and result, for instance, in a low level of awareness, scepticism, overconfidence, or denial (Moser et al., 2008; Moser & Ekstrom, 2010; Biesbroek et al., 2011). Low problem awareness in the urban context sometimes is traced back to a low priority for adaptation at higher levels of governance due to lack of communication between policy and science (Lehmann et al., 2013; Eisenack et al., 2014). Wolff et al. (2010) highlight that overconfidence in the ability of actors to manage risk has constrained adaptation in two UK cities.

4.3.7. Attitudes, values and motivations

This cluster is derived from several studies arguing that social and cultural constraints are an important issue in adapting to climate change. Burch (2010b) refers to behavioural barriers which incorporate the personalities of individuals in critical positions and the cultures of various groups within the institution and municipality. Social and cultural factors are directly linked to societal values, world views, cultural norms, beliefs, and behaviours (Klein et al., 2014). Deeply held attributes, pre-existing values, norms and beliefs have a critical influence on the decisions made in the adaptation process. These social and individual factors influence how people perceive risk, how they explain and think about climate impacts, what information and knowledge they take into consideration, what adaptation options they select and, ultimately, why actors choose to engage in adaptive behaviour and the factors that lead to, or impede, their adaptive behaviour (Hulme et al., 2007; Moser & Ekstrom, 2010; Biesbroek et al., 2011; Eisenack et al., 2014). For example, Klein et al. (2014) summarize the findings of recent research, indicating that multiple factors influence how knowledge is perceived, including the role of traditional knowledge, political affiliation, educational background, and trust placed in different information sources. Thus, cognitive filters shape the perceptions of the actors, inhibit their attitudes about adaptation measures, and thus manipulate the decision-making processes (Moser et al., 2008). For example, the motivation of decision-makers in urban areas to engage in climate change adaptation often arises from the occurrence of an extreme event (Berrang-Ford et al., 2011). Blennow and Persson (2009) have shown that the strength of belief in climate change and adaptive capacities is of extreme importance in explaining differences in adaptation among forest owners in Sweden. Finally, differences in the perception of climate risk between actors and governing institutions can also hinder adaptation (Patt & Schröter, 2008).

4.3.8. Politics

The eighth cluster of barriers groups constraints that result from politics. Erikson and Lind (2009), as well as Ekstrom and Moser (2014), stress the importance of political constraints to adaptation in developing and developed countries (e.g. Kenya and USA). Revi et al. (2014) stress that the local urban level is particularly prone to political barriers as a great number of powerful interests are concentrated in a small area. Moreover, political actors might cause strategic uncertainty due to their strategic behaviour in decision-making processes (Koppenjan and Klijn, 2004; Biesbroek et al., 2011). Hence, uncertainties about the hidden agendas of politicians or their willingness to act are two examples of political constraints.

4.3.9. Adaptation process

Last but not least, barriers can also be linked to an unclear adaptation process. Therefore, the last cluster refers to barriers which are related to the adaptation process itself. Municipalities might need guidance on where to start adaptation, or which concrete actions to take. For instance, the diversity of approaches for local adaptation does not only create opportunities, but actors can also struggle with identifying the most suitable and efficient approach when strategic long term thinking and a broad perspective are missing (Klein et al., 2014). Moreover, the transferability of adaptation measures is difficult (Cortekar et al., 2015a). Very often the adaptation process is based on best-practices, even though their actual added-value is restricted due to the highly context-specific nature of climate change adaptation. For example, limited financial means or different environmental regulations can hinder a one to one implementation of best practices (Cortekar et al., 2015a).

5. Methodology

5.1. Setting, context and selection of case studies

The study focused on urban areas in Germany. Nine cities, distributed throughout Germany, took part in the study: Aachen, Bad Liebenwerda, Essen, Jena, Karlsruhe, Nuremberg (German*: Nürnberg*), Regensburg, Saarbrucken (German*: Saarbrücken*) and Syke (Fig. 6). The cities were selected to reflect diversity in terms of their size, density, demographic profile, geographic location, urban structure and type of city (e.g. state capital or belonging to a district), socio-economic conditions, and their relative vulnerabilities to climate change impacts.

Figure 6: Map of Germany showing the location of participating cities (BMVBS, 2010).

All nine cities were part of a project on local strategies and potentials in climate change protection and adaptation at the local level ('StadtKlima – Municipal strategies and potentials in regard to climate change') within the research field 'Urban Strategies to Combat Climate Change' under the 'Experimental Housing and Urban Development' (ExWoSt) research programme of the former Federal Ministry of Transport, Building and Urban Development (BMVBS) and the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning. The project started in December 2009 with the aim of developing integrated urban adaptation strategies, taking into account adaptation and mitigation, and other pressing issues of urban development. The project ended in October 2012.

The most important criterion for choosing the cities that participated in the StadtKlima project was that a concerted adaptation effort had already been undertaken in these cities;

strategies and adaptation options had been developed and partially implemented. This was critical to make sure that something could be learned about barriers at different stages in the adaptation process. Furthermore, the selected case studies are embedded partially in different governance systems, which is important as the governance context can enable different barriers to emerge or hinder them from emerging in the adaptation process. Even though the cities have very different characteristics, as described above, they all have a similar status of adaptation due to the participation in the StadtKlima project, and have recently begun to implement adaptation options.

5.2. Methods

5.2.1. Data collection

Data collection involved interviews with key actors in climate change adaptation in the nine cities, as well as a review of publicly available documents. A preliminary public document analysis was carried out for each case in order to become familiar with the context of climate change adaptation in the relevant city. Council reports, official government documents, and media reports were identified via online research on the StadtKlima project, via the websites of the respective cities or suggested by the interviewees themselves upon initial contact. These documents were the base for the interviews and for following up after the interviews to collect more details about the current status of adaptation efforts.

One semi-structured interview with one or more decision-makers involved in urban adaptation planning was carried out for each of the nine cities. Participants were identified through a review of adaptation related documents and city websites, and invited on the basis of their active participation in the StadtKlima project and/or their direct involvement into the adaptation process; the understanding, development and implementation of climate change adaptation measures. In total, 13 participants were interviewed in nine interviews (the contacted individuals were free to choose one or two colleagues to help answer the questions) (see appendix 1). All interviewed people were leading or coordinating the adaptation process in the agency, department or unit (environmental-, urban planning-, urban development-, open spaces or climate protection agency/department/unit) within their jurisdiction. Participants were contacted via e-mail using a standardized letter of invitation, in which they were briefed about the purpose and nature of the study and why they were selected for participation. All individuals contacted for interviews participated in the study (in one case, the e-mail was forwarded to a colleague, who agreed to do the interview). The interviews followed a basic script (provided in appendix 8), according to the state of the art in the literature (Flick, 2002; Mayring, 2002; Lamnek, 2005; Schnell, 2011) and questions were derived from relevant research (e.g. Moser and Ekstrom, 2010; Biesbroek et al., 2011; Ekstrom, Moser & Torn, 2011; Measham et al., 2011; van Stigt et al., 2015). The script was used as guidance. It contained questions about the background of the participant and his work place, his or her view on climate change and adaptation, the status of adaptation in the agency, and process description and associated barriers. Thus, while capturing more general information about participants (personal views, roles, positions and experience), the interview was centred on the different phases and stages within the adaptation process. The primary interest was to find out where the city was in the adaptation process, what challenges the participants had experienced in the process, and what they had done to overcome them. Furthermore, the interviewees mentioned several aids and advantages that helped them to avoid barriers to adaptation. Even though aids and advantages were not part of the initial framework, this information was used in the study as well. All interviews were conducted in person at the office of the respondent or via telephone (due to personal preferences, health or time issues). The length of interviews ranged from 31 to 115 minutes. The interview form and length had no effects on the quality and content of the interviews. Notes were taken during and after each interview and all interviews (but one) were recorded with the permission of the participants.

5.2.2. Data analysis

The first step of the data analysis was to fully understand the adaptation process in each city based on reviewing document, as well as the insights gained from the interviews. This descriptive part of the study very briefly captures what had occurred to date in each case study (see section 5.3). Although all cities were part of the StadtKlima project, they used different pathways, focused on different sectors and, thus, results were not necessarily the same. Moreover, the actors, governance system and the systems of concern changed depending to the case studies. Last but not least, the cities adopted different approaches to climate change adaptation after the project had ended; while some were continuously engaging in climate change adaptation, others prioritized different issues.

Second, in the analytical part, for each participating city type, source and origin of barriers and ways to overcome them were examined. The interview transcripts were coded using a specific coding structure in order to identify barriers to adaptation, aids and advantages, and strategies to overcome the identified barriers (figure 7 illustrates the coding and analysis process). Standard coding software (MAXQDA, Atlas TI, or f4analysis) was found to be too time consuming and thus, an innovative approach was taken in order to extract relevant data from the transcripts without losing detail or rigor. First, all barriers that were mentioned explicitly or implicitly were identified, also taking into account those which the participants expect to encounter in the future (Fig. 7). Then, for each of the nine clusters of barriers that were previously identified from the literature review (see section 4.3), a classification scheme, which was inductively derived from the interviews, was developed (Fig. 7) (see appendix 9). This classification scheme evolved as the analysis progressed in order to take into account new information provided by participants. The typology of barriers is therefore the result of a mixture of inductive and deductive methods, and resembles a hermeneutic approach with the goal to identify and describe general and idiosyncratic patterns (Oevermann, 2002). This made sure that the interviews were guided by the state of the art in the literature (see section 5.2.1), while taking into account novel insights and context-specific properties that arose during the empiric part. The typologies of strategies and of aids and advantages, as well as the according classification schemes, were only derived inductively, as the focus of the work lay on barriers (Fig. 7) (see appendix 9). In the following steps, the sources and origins of the different barriers mentioned during the interviews were analysed, and the aids and advantages that helped avoid barriers in practice and the strategies employed to overcome the identified barriers were studied. Moreover, it is important to mention that all unique barriers were counted. Therefore, if a specific barrier (e.g. lack of staff) was mentioned more than once per stage, it was only counted once in that stage, but could be counted once in every stage, if mentioned. If a type of barrier (e.g. resources) was observed several times in a specific stage, this means that several particular barriers, falling into this cluster, were encountered (e.g. limited budget and lack of capacity among staff). The reason for this choice is driven by the methodology of the study (interviews) and the inability to interpret the frequency measures (by counting every single mention of a barrier or counting how often the same barrier was mentioned). The goal of this qualitative study is not to find out how many times a particular barrier is mentioned or what is the 'favourite' or most recent barrier in the actor's perspective, but to generally identify barriers that hinder the adaptation process

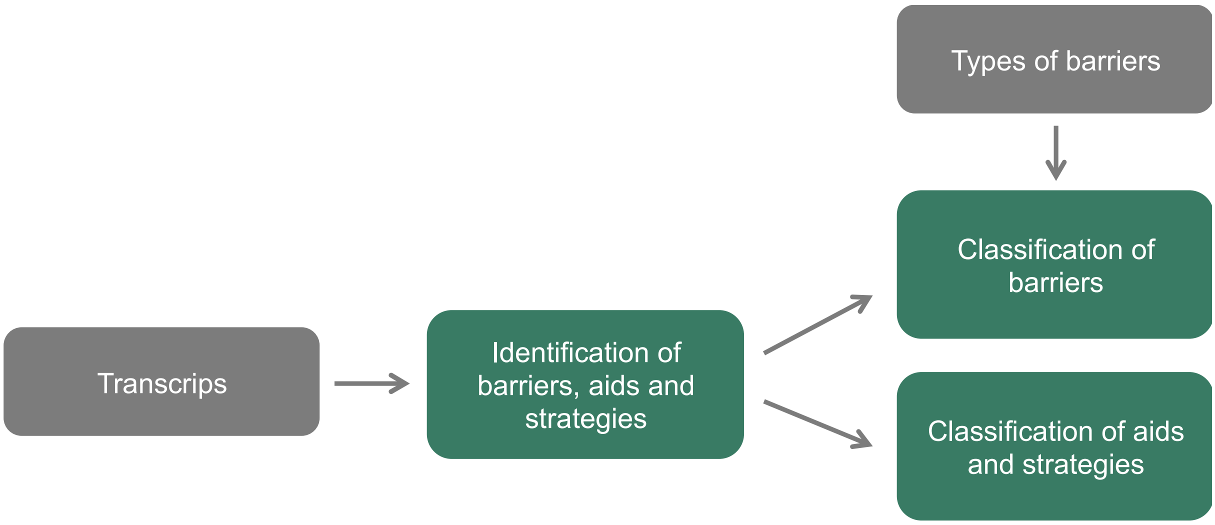

Figure 7: Analytical process

The last step of the analysis is the interpretive part of the study. The data sets were analysed and graphically displaced using Microsoft Excel spreadsheet. Patterns, such as noticeable differences and commonalities were identified across cases and across stages in the adaptation process. Moreover, the comparative case study approach allowed identifying cross-cutting issues, as well as the most dominant barriers, aids and advantages, and strategies. Finally, more general conclusions about barriers in the adaptation process were drawn.

5.3. Introduction to the cases and status of adaptation

In this section, each case study is briefly recapped with a summary of its characteristics and vulnerabilities to climate change, and it is briefly reported adaptive measures have been taken to date.

5.3.1. Karlsruhe

Karlsruhe has roughly 300,000 inhabitants and is located in the Upper Rhine Rift in Baden-Württemberg (BMVBS, 2010). The population of the city is forecasted to further increase in the future, leading to densification and soil sealing in the area (BMVBS, 2010). As often stated in literature, an extreme event triggered the adaptation process in the case of this city. In 2003, several severe heatwaves were responsible for increased death rates and made the region aware of the adaptation challenge (BBSR, 2012; Stadt Karlsruhe, 2013; Beermann et al., 2014). The area around Karlsruhe is one of the warmest areas in Germany due to its geographical and topographical situation in the Upper Rhine Rift (BMVBS, 2010). High temperatures and frequent heat waves make overheating of the urban area a serious problem (BMVBS, 2010; 2012). In the future, the average surface temperature is projected to further increase, as is the mean number of heat waves, thus leading to increased heat stress (Jacob et al., 2014; Umweltbundesamt, 2015b). Furthermore, the city has been increasingly affected by the phenomenon of the urban heat island (Beermann et al., 2014). Therefore, the StadtKlima project focused on the climate effects of overheating of urban areas during hot periods and on planning strategies for urban development (BBSR, 2012; BMVBS, 2012). Based on the results of this project, the municipality of Karlsruhe developed an urban development framework for climate change adaptation for the city (‘*Städtebaulicher Rahmenplan Klimaanpassung’*). The framework focuses on urban heat island effects and possible tangible adaptation options, thereby considering the vulnerability of different districts (Stadt Karlsruhe, 2015a; 2015b). In March 2015, the municipal council included the framework as a planning instrument in urban development planning (Stadt Karlsruhe, 2015a). Furthermore, the city has joined the Covenant of Mayors (signatories pledge to adopt an integrated approach to tackling mitigation and adaptation) in 2010 and has developed an integrated urban development concept (‘*Integriertes Stadtentwicklungskonzept’*), as well as an adaptation strategy, reiterating the long term goal to achieve climate neutrality by 2050 (Stadt Karlsruhe, 2013).

5.3.2. Aachen

The city of Aachen is located in North-Rhine Westphalia on the boarder to the Netherlands and Belgium, and has a population of roughly 250,000 people (BMVBS, 2010). The spa town has had a longstanding interest in climate change mitigation and adaptation (since early nineties). This is due to its location in a valley basin and its image of a spa town with a healthy climate (‘*Bad Aachen’*) (Stadt Aachen, 2014). However, political and public awareness of climate change adaptation only increased in the last couple of years. Owing to its location in a river valley, the spa town is especially vulnerable to heat-related and air quality issues, and flooding (BMVBS, 2010, Stadt Aachen, 2014). Based on EURO-CORDEX RCP4.5 and RCP8.5 and ENSEMBLES A1B simulations, the mean surface temperature is projected to increase and mean precipitation is projected to decrease in summer while increasing in winter by the end of the century (Jacob et al., 2014, Pfeifer et al., 2015). Beside these gradual changes, an increase in and intensification of extreme weather events (e.g. heavy precipitation) represent a considerable potential risk for the city. Especially industrial and commercial areas are often located in vulnerable areas, such as near water streams, and are characterized on the one hand by high densities of assets, infrastructure and buildings, and on the other hand by high proportions of sealed surface (BMVBS, 2010; 2011;

2012; Stadt Aachen, 2014; Umweltbundesamt, 2015b). In addition to working within the StatdKlima project, Aachen became a member of the Covenant of Mayors Initiative on Adaptation to Climate Change. Alongside this, the city has adopted an adaptation concept in 2014 in the course of the development of a new land use plan. The concept creates a strategic basis for further action and includes an analysis of current exposure to climate change impacts, a sensitivity analysis, needs for action, and adaptation actions (Stadt Aachen. 2014). Moreover, Aachen has integrated climate change mitigation and adaptation into the urban development plan (‘*Aachen 2030 Masterplan’*) (Stadt Aachen, 2012). Currently, the city is working on the development of a consecutive action plan (Stadt Aachen, 2015).

5.3.3. Essen

The city of Essen, with its more than 570,000 inhabitants, is the largest city of all cases and recorded population figures show an unexpected positive trend (BMVBS, 2010). Essen is located within the so-called *Ruhrgebiet*, a large agglomeration in the Ruhr with five million inhabitants, which is itself considered a part of the larger Rhine-Ruhr metropolitan region of more than twelve million people (BMVBS, 2010). Thus, it is not surprising that the district-free city is densely populated with 2731 people per km^2 (BMVBS, 2012). Due to its location and structure (densely built-up areas), Essen is extremely susceptible to climate change impacts and especially to extreme events (BMVBS, 2012). Already today, the city is affected by climate change; an important difference in temperature between the city centre and its surroundings is frequently being observed, and winter precipitation and heavy precipitation events are increasing, leading to higher flood risks (BMVBS, 2011; 2012, Stadt Essen, 2014a). In the future, mean near surface temperature is projected to increase (Jacob et al., 2014). Thus, it can be assumed that urban heat islands will form with increased frequency and that, in general, the city population will face a rise in bioclimatic and health burdens (Stadt Essen, 2014a; Umweltbundesamt, 2015b). Alongside this, heavy precipitation events are projected to increase for the region under EURO-CORDEX RCP4.5 and RCP8.5 and ENSEMBLES A1B simulations, as is the mean number of heat waves (especially under EURO-CORDEX RCP4.5 and RCP8.5) (Jacob et al., 2014). Thus, increased flood risks can be expected, especially in water sensible parts of the city with high proportions of sealed surface, inappropriate sewage systems or high groundwater levels (BMVBS, 2011; 2012). In 2009, the city of Essen set up an integrated energy and climate concept (‘*Integriertes Energie- und Klimakonzept*’) to contribute to sustainable urban development, and became a member of the Covenant of Mayors one year later (Stadt Essen, 2009; 2013). In the course of the StadtKlima program, the energy and climate concept which was primarily focusing on mitigation was supplemented with adaptation strategies and measures in very different fields of action in urban development (Stadt Essen, 2014a). The integrated energy and climate concept also indirectly led to the development of the so-called ‘*klima*|*werk*|*stadt*|*essen*’ (literally ‘climate|work|city|essen’). This structure concentrates competences and know-how from science, the private sector and the municipality in the realm of climate change mitigation and adaptation, and provides a work and communication platform, thereby optimizing cooperation and communication between involved actors (Stadt Essen, 2014b). Today, climate change adaptation is being integrated into ongoing processes and strategies (e.g.

strategy Essen.2030 or *Essen.Neue Wege zum Wasser*) and the city is planning on monitoring the implemented adaptation options (Stadt Essen, 2014b; 2015).

5.3.4. Saarbrucken (German: Saarbrücken)

Saarbrucken is the capital of the Saarland and has around 180,000 inhabitants with 1054 people per km^2 (city area of 167 km^2) (BMVBS, 2010; 2012). The city is located in the valley floodplain of the river Saar in western Germany (BMVBS, 2010). As for most of the cities, the susceptibility of Saarbrucken to climate change is determined on the one hand by the occurrence of extreme heat events that cause a reduction in thermal comfort and stress for residents (e.g. through urban heat islands), and on the other hand by water-related issues, such as the increase in flooding and inundation events (partly due to an increase in heavy precipitation events), or water scarcity during summer months (due to higher temperatures and less precipitation) (BMVBS, 2010; Landeshauptstadt Saarbrücken, 2012; Umweltbundesamt, 2015b*).* Already today, mean surface temperature and winter precipitation are increasing, leading to increased thermal stress in some residential areas, and flooding of the city (BMVBS, 2011; 2012; Landeshauptstadt Saarbrücken, 2012). As the capital of the Saarland has a past of mining and industry, large industrial wastelands provide great potential for open space development and hence for adaptation measures. Therefore, in the course of the StadtKlima project, Saarbrucken's open space development program (‘*Freiraumentwicklungsprogramm’*) was supplemented with adaptation measures, and open space planning is used as an instrument for climate change adaptation (BMVBS, 2010; 2012). Furthermore, measures for climate change adaptation have been integrated into the urban development concept, as well as into ongoing planning processes (e.g. ‘*Stadtmitte am Fluss*’ or ‘*Grüne Insel Kirchberg’*) (Landeshauptstadt Saarbrücken, 2009; BMVBS, 2010; Landeshauptstadt Saarbrücken, 2011a; 2011b; 2012). In addition, Saarbrucken participated in the transnational INTERREG project "C-Change - Changing Climate, Changing Lives” (Landeshauptstadt Saarbrücken, 2012). Despite these projects, no regional or city-level adaptation strategy or concept has been produced so far, as the German Adaptation Strategy was recognized as being sufficient and transferred to the local level. An integrated climate mitigation concept for the region only was developed by the regional association Saarbrucken (Regionalverband Saarbrücken, 2014). Therefore, the city aims to develop a climate protection plan (*Klimaschutzplan*), focusing on mitigation and adaptation measures (Landeshauptstadt Saarbrücken, 2012). Furthermore, it is planned to integrate climate adaptation measures into the regional development plan (‘*Landesentwicklungsplan’*) for Saarland, as well as into the landscape plan and the land-use plan (Landeshauptstadt Saarbrücken, 2012).

5.3.5. Bad Liebenwerda

Located in Brandenburg, Bad Liebenwerda is the least populated municipality participating in the study (less than 10,000 inhabitants) (BMVBS, 2012). In addition, the municipality has the lowest population density with 71 people per km^2 (BMVBS, 2012). In the future, the population is projected to further decrease (BMVBS, 2010). The city is a recognized spa and wants to enhance this image, as well as boost local tourism (BMVBS, 2010; Stadt Bad Liebenwerda, 2010). However, the spa town faces climate change impacts, and as in entire

Germany, mean surface temperature, mean winter precipitation and heavy rainfall events are projected to increase in the future (Jacob et al., 2014; Pfeifer et al., 2015). As a consequence, on the one hand, an increase in heat stress and a decrease in air quality and thermal comfort in the summer can be expected, causing health risks. On the other hand, flooding from the Black Elster and inundation from heavy precipitation put critical infrastructure in danger, and has a significant impact on the water balance and management of the city (BMVBS, 2010; 2011; Stadt Bad Liebenwerda, 2012; 2013). Therefore, the city has developed an adaptation strategy (‘*Integrationsplan Klimaanpassung*’), which has been added to the landscape plan and contributes to an integrated, climate friendly urban development (BMVBS, 2010; 2012; Stadt Bad Liebenwerda, 2012; 2013). Last but not least, the city incorporated climate change adaptation into its integrated urban development concept (‘*Integriertes Stadtentwicklungskonzept*’) and will implement climate change adaptation measures in the land-use plan during its next update (Stadt Bad Liebenwerda, 2013).

5.3.6. Nuremberg (German: Nürnberg)

Nuremberg is located in the Central Franconian Basin and with its more than 500,000 inhabitants is the second largest city in Bavaria. It currently has a positive population trend and the highest population density among all participating cities (2745 people per km^2) (BMVBS, 2010; 2012). The district-free city is characterized by an intensively developed city centre, a city structure with few fresh air corridors and, in general, high proportions of sealed surfaces (BMVBS, 2010; 2012). Thus, Nuremberg is increasingly affected by the phenomenon of urban heat islands and is facing increased heat stress as the number of summer days, hot days and dry periods have increased in the past years (BMVBS, 2010; 2011; Stadt Nürnberg, 2012a; 2014a; Umweltbundesamt, 2015b). In the future, with a projected increasing mean surface temperature and total number of heatwaves, heat stress will further increase (Jacob et al., 2014). These effects are even made more severe by the topographical position of the city which inhibits an adequate aeration of the town (BMVBS, 2010). Taking into account demographic changes, health effects are expected to be even more important in the future (Stadt Nürnberg, 2012a). In the light of the StadtKlima project, an adaptation strategy (within the handbook for climate change adaptation) was developed (Stadt Nürnberg, 2014a). In addition, the Nuremberg climate protection timetable (‘*Klimaschutzfahrplan’*) was updated and supplemented by a second part on climate change adaptation, containing the updated adaptation strategy (‘*Klimafahrplan 2010-2050*’) (Stadt Nürnberg, 2014a). Concrete adaptation options were integrated into the new timetable, as well as into other ongoing planning processes (BMVBS, 2010; 2012; Stadt Nürnberg, 2014a). In the light of another project (‘koopstadt’), the city developed integrated urban development concepts for several districts, which had been supplemented by climate change adaptation strategies (BMVBS, 2012). Furthermore, the city has become a member of the Covenant of Mayors in 2009, included climate change adaptation in the integrated urban development concept (‘*Nürnberg am Wasser’*) and in the masterplan on green and open spaces (‘*Masterplan Freiraum’*), and produced a comprehensive climate expert report for the entire city, which served as a basis for planning (Stadt Nürnberg, 2014a; 2014b). Overall, much work on climate change adaptation has been done in the last couple of years in Nuremberg and the city currently works towards including climate change adaptation into the land development plan ('*Bebauungsplanung*') (Stadt Nürnberg, 2014a).

5.3.7. Jena

The city of Jena has more than 105,000 inhabitants and is the major local centre in Thuringia (BMVBS, 2010; 2012). Against the general tendency in eastern Germany, Jena records a consistent rise in population (Stadt Jena, 2012). The district-free city has an area of 114 km^2 and an average population density of 925 people per km^2 (BMVBS, 2012). The urban climate is strongly influenced by its topographical situation. Located in a valley and surrounded by steep slopes, aeration of the city is insufficient, leading to atmospheric inversions and overheating of the urban area in certain weather situations (BMVBS, 2010). Moreover, the valley location intensifies the predominant continental dryness, so that Jena belongs to the warmest and driest cities in eastern Germany (BMVBS, 2010). Already today, Jena experiences heat stress due to a positive trend in the amount of summer and hot days, and extreme precipitation events have caused flooding in the city area in recent years (BMVBS, 2010; 2012; Stadt Jena, 2012). Due to the projected increase in mean near surface temperature, overheating of the city in summer can be expected (Stadt Jena, 2012; Jacob et al., 2014; Umweltbundesamt, 2015b). Furthermore, winter precipitation and heavy precipitation are expected to increase (Jacob et al., 2014; Pfeifer et al., 2015). Thus, the city expects to face increased base runoffs in the river Saale in winter, as well as more extreme peak runoffs due to increased heavy precipitation events (Stadt Jena, 2012). Already in 2009, the city council decided to develop a concept for climate change adaptation (Stadtrat Jena, 2009). In the course of the Stadtklima programme, the city has concentrated its commitment to climate change adaptation, has developed a handbook for a climate-friendly urban development ('*Handbuch klimawandelgerechte Stadtentwicklung für Jena'*) (containing an adaptation strategy) and has incorporated climate change adaptation into urban development processes with an integrated approach (BMVBS, 2012; Stadt Jena, 2012). Based on the results from the StadtKlima project and with the goal to deepen the knowledge on climate change adaptation, Jena joined the EU research project 'Bottom-up Climate Adaption Strategies towards a Sustainable Europe' (BASE), which supports decision-makers in sustainable climate change adaptation (Stadt Jena, 2012). Currently, according to a resolution from the city council, all agencies and divisions are working to incorporate climate change adaptation into relevant concepts and plans ('*Fachplanungen'*), such as urban development concepts, the land-use plan, the landscape plan and the binding part of urban land-use planning ('*Bauleitplanung*') (Stadt Jena, 2012; Stadtverwaltung Jena, 2013).

5.3.8. Syke

The city of Syke counts just under 25,000 inhabitants and has a very low population density (191 people per km^2) (BMVBS, 2012). Syke is a sub-regional centre, situated about 20 km south of Bremen in the Northern Lowland and characterized by the valley floodplain of the River Hache (BMVBS, 2010; 2012). As EURO-CORDEX RCP4.5 and RCP8.5 simulations project an increase in heavy precipitation, mean surface temperature, mean winter precipitation and mean number of heat waves (Jacob et al., 2014; Pfeifer et al., 2015), the small city expects to face heavy precipitation events, hot days and heat waves on a more frequent basis, leading to increased heat stress on the one hand, and to more frequent flooding around the Hache on the other hand (BMVBS, 2010; 2011; Stadt Syke, 2012a; Umweltbundesamt, 2015b). However, Syke also identified opportunities resulting from climate change (e.g. an extended summer season for tourism) and saw a chance to set up an innovative and integrative framework for its local climate policy (BMVBS, 2010; Stadt Syke, 2012a). As the outcome of the StadtKlima project, an integrated adaptation strategy was drawn up and an adaptation action plan was created (Stadt Syke, 2012a; 2012b). The strategy links urban development, climate protection and climate adaptation, and is being used to integrate climate change adaptation into ongoing processes (BMVBS, 2012).

5.3.9. Regensburg

The city of Regensburg has more than 135,000 inhabitants and shows the greatest population growth among all participating cities (BMVBS, 2010; 2012). The fourth largest city in Bavaria is located at the intersection of topographical zones and is mostly surrounded by hills, promoting the formation of inversions and making the city susceptible to fine dust pollution during the winter months (BMVBS, 2010; Buck, 2015). Furthermore, there is also a risk of flooding as a result of its location on three rivers, the Naab, the Regen and the Danube (BMVBS, 2010). Beside its exposure to the physical environment, Regensburg is characterized by a compact and structured urban form and a homogeneous settlement structure (BMVBS, 2010; Buck, 2015). In addition, the historic old city is a UNESCO World Heritage Site and more importantly, marked by a dense building structure with stone squares and alleys and almost no green areas (BMVBS, 2010; 2012; Buck, 2015). In summer, the medieval city centre heats up more quickly than its surroundings, which signifies a sharp decline in thermal comfort and results in additional energy requirements for cooling (BMVBS, 2010; 2012; Buck, 2015). In the recent past, the average surface temperature and the amount of hot days, summer days and tropical nights have already increased (BMVBS, 2011; DWD, 2012; Stadt Regensburg, 2014). With ongoing climate change, the urban heat island phenomenon is expected to be even more distinctive for the city (centre) due to the projected increase in mean near surface temperature and the mean number of heat waves (Jacob et al., 2014; Stadt Regensburg, 2014; Umweltbundesamt, 2015b). Finally, the projected increase of heavy precipitation significantly increases the risk of flooding (DWD, 2012; Jacob et al., 2014; Pfeifer et al., 2015). The StadtKlima project initiated the integration of climate change adaptation into the UNESCO world heritage management plan (‘*Welterbe-Managementplan’*) and into the urban development framework for the city centre (‘*Städtebauliche Rahmenkonzept Innenstadt 2025’*) (which still has to be acknowledged by the municipality council), and a climate expert report for the entire city was produced (Buck, 2015). Furthermore, the city of Regensburg is working on an update of the land-use plan and of the urban development plan (‘*Regensburg-Plan 2005’*) in order to fully incorporate climate change adaptation into both plans, as well as into other ongoing processes, such as into the binding part of urban land-use planning (‘*Bauleitplanung*’) (Buck, 2015).

6. Results

6.1. Overall patterns of barriers encountered across all cities

Across all cities,[1] the overall occurrence of barriers revealed the results shown in figure 8.

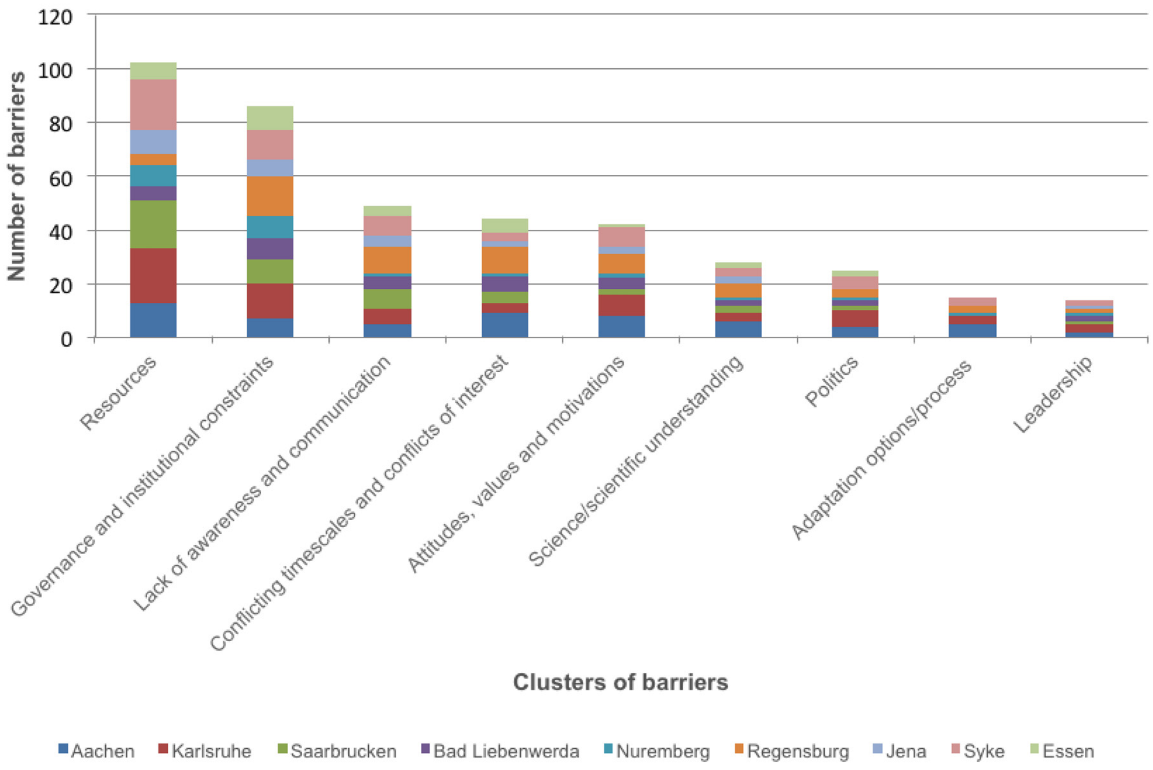

Figure 8: Frequency of different clusters of barriers encountered in the nine cities.

The most frequent clusters of barriers encountered are related to resource issues (e.g. limited budget due to high public debts, cuts with implications on staffing level and capacity). These are closely followed by governance and institutional barriers (e.g. institutional crowdedness, contradictory mandates, restricted jurisdictions or fragmentation). The third most important cluster is linked to a lack of awareness and communication (e.g. lack of awareness or scepticism, denial and miscommunication, lack of knowledge about adaptation or climate change) and is already far less common than the two aforementioned types of barriers. The third cluster is closely followed by barriers related to conflicting timescales and conflicts of interests (e.g. pressure of short term electoral cycles or prioritization of other more forward pressing issues of urban planning), and by those linked to attitudes, values and motivations (e.g. lack of concern, making no effort to understand climate related issues, inability to see common interests or to accept changes). The four remaining clusters of barriers are less frequently mentioned. However, lack of scientific understanding about climate change and information (e.g. uncertainty, lack of data or access), barriers related to politics (e.g. political ambitions and agendas, lack of political will, distrust), issues specific to the adaptation process (e.g. lack of guidance, missing guidelines), and, finally, leadership

[1] Evaluations have been carried out for each city and will be made available on request. For reasons of confidentiality, the results are only presented on an aggregated level.

(e.g. lack of) are still important even though they have been less frequently encountered in the different cities being studied.

These findings are consistent with literature in some regard, but also into some respect surprising. First, the dominance of barriers related to resources is not really surprising, as a large body of literature already identified economic and financial issues as the most important cluster of barriers. Resource issues might even have become more important in recent years, as the last economic crisis revealed the bad financial situation of many municipalities and cities, and initiated austerity measures in order to reduce budget deficits *("Haushaltsnotlagenkommune", "Haushaltssicherungskommune").* The lack of financial resources mainly results in a lack of staff or capacity among staff (while the remaining staff is distracted with other responsibilities). It leads less to a lack of money for understanding climate change adaptation, planning or implementing adaptation options. Furthermore, competition for existing funds with other issues that are considered more urgent cannot be neglected and significantly reduces available funding for climate change adaptation.

Second, the prevalence of barriers associated with governance, institutional arrangements and regulatory issues illustrates that the governance process used, the current structure of institutions and regulatory policies might not be appropriate to achieve adaptation objectives. Institutional barriers are especially linked to limited or no jurisdictions (e.g. for implementing adaptation options), to contradictory mandates (e.g. mitigation versus adaptation), to legal barriers imposed by existing law, to a lack of policies, laws and rules, and, finally, to institutional crowdedness (e.g. overlapping or opposite strategies, goals and responsibilities between urban planning and climate change adaptation).

In the cluster 'lack of awareness and communication', barriers such as lack of awareness, scepticism, overconfidence or denial of climate change and adaptation, not linking weather and climate events to climate change, and a lack of communication are most often mentioned. Interestingly, awareness related barriers, which are mainly linked to significant knowledge gaps, are more prominent than barriers linked to communication.

The cluster on conflicting timescales and conflicts of interests is considered an important barrier as well. On the one hand interviewees mentioned the difficulties in dealing with the long term nature of climate change adaptation (e.g. only knowing in the future if adaptation measures will be successful, which makes adaptation quite intangible) and short-termism in politics. On the other hand, conflicts of interests emerge on a regular basis with other pressing issues of urban development (e.g. housing and densification due to population growth) or arise from the general situation (e.g. refugee influx). What is added to these problems is that adaptation actions have not yet been implemented in legislation and are therefore, in practice, voluntary undertakings which have to compete with other non-mandatory issues.

Even though 'attitudes, values and motivations' are ranked fifth, they have almost the same importance as the third cluster. This is in accordance with the importance of these barriers identified in literature. The inability to accept chances or to think in the long term, a desire to maintain the status quo, humans not understanding or making no effort to understand climate related issues, and lack of concern and interest are the issues encountered most often in the nine cities.

Interestingly, science-related constraints have a very low importance. This is opposite to the general argumentation of many scientists and decision-makers who see lack of science as a major barrier hindering the adaptation process. Several elements can explain this difference. First, the leaders are generally well informed about climate change impacts and adaptation, due to their participation in the StadtKlima project and the existence of a large number of studies that focus on climate change in Germany. Most participants argued that trends are secure enough for initiating the adaptation process and developing and implementing adaptation options. Uncertainty is regarded as a part of their job and does not exceedingly hinder adaptation (not more than economic uncertainty e.g.). Moreover, selected adaptation options are very often no-regrets or have several co-benefits and thus do not require sophisticated data. Thus, science-related barriers are overall not as deciding. However, in some cases, they are still persistent and include a lack of small-scale data necessary to assess adaptation options. In the future, when adaptation strategies might involve more important projects, scientific barriers may become more significant.

The cluster of barriers ‘politics’ is, consistent with literature, only of minor importance. However, a lack of political will and support due to different agendas and ambitions can severely impede and slow down the adaptation process, especially in small municipalities. Moreover, the missing objectivity of politicians (“*Unterschied zwischen Anpruch und Wirklichkeit*”) on staffing capacity (on what a staff-limited administration can achieve) is mentioned as a major impediment.

Barriers linked to the adaptation process itself are predominantly related to lack of guidance. In the eyes of most interview partners, the Federal Government needs to support decision-makers with financial and regulatory (e.g. policy tools such as laws) means, and guide the cities through the adaptation process (by making it a mandatory duty).

Another unexpected result is the overall low importance of barriers related to leadership. Even though leadership is unanimously recognized as crucial to initiate the adaptation process and move adaptation forward, very few problems with ineffective, dominant or a lack of leadership are encountered. This is an indication for overall good leadership in key positions in the selected cities. The fact that the interviewees are leaders themselves in most cases can explain that they only see minor problems regarding leadership. Nevertheless, it can be assumed that in those cities that have done only little work on adaptation so far, a lack of effective leadership is certainly one important reason for missing adaptation.

6.2. Barriers in the nine cities

In the first category, the cities of Karlsruhe, Jena and Syke are grouped together, which largely follows the overall pattern of barrier occurrences (Fig. 9; individual graphics are provided in appendix 2). Limited financial and human resources dominate, followed by governance and institutional issues such as fragmentation and a lack of internal collaboration and cooperation. In the third and fourth place, attitudinal, or awareness and communication related barriers are ranked. This sequence is more or less consistent with the general pattern (acknowledging that ‘lack of awareness and communication’ and ‘attitudes, values and motivations’ are really close to each other; Fig. 8). The importance of the remaining clusters of barriers, which have been less frequently mentioned, however, changes between the three cities. In Karlsruhe, for instance, politics seem to be slightly more important and are ranked in fifth position (e.g. strategic uncertainty due to different ambitions and agendas of politicians), while barriers related to science are less important as it is argued that trends are clear and robust enough to start adapting to climate change. In Jena, on the other hand, it is noticeable that due to a strong political support and clear agendas from the very beginning, no barriers related to politics have arisen. However, in contrast to Karlsruhe, constraints related to scientific information (e.g. provision and analyses of data) have proven to be more important in Jena. Despite quite a low level of importance of ‘conflicting timescales and conflicts of interests’ (due to the integration of adaptation into daily work) in the city of Syke, no real outliers can be identified in the occurrence of barriers and the local pattern fits extremely well into the overall one.

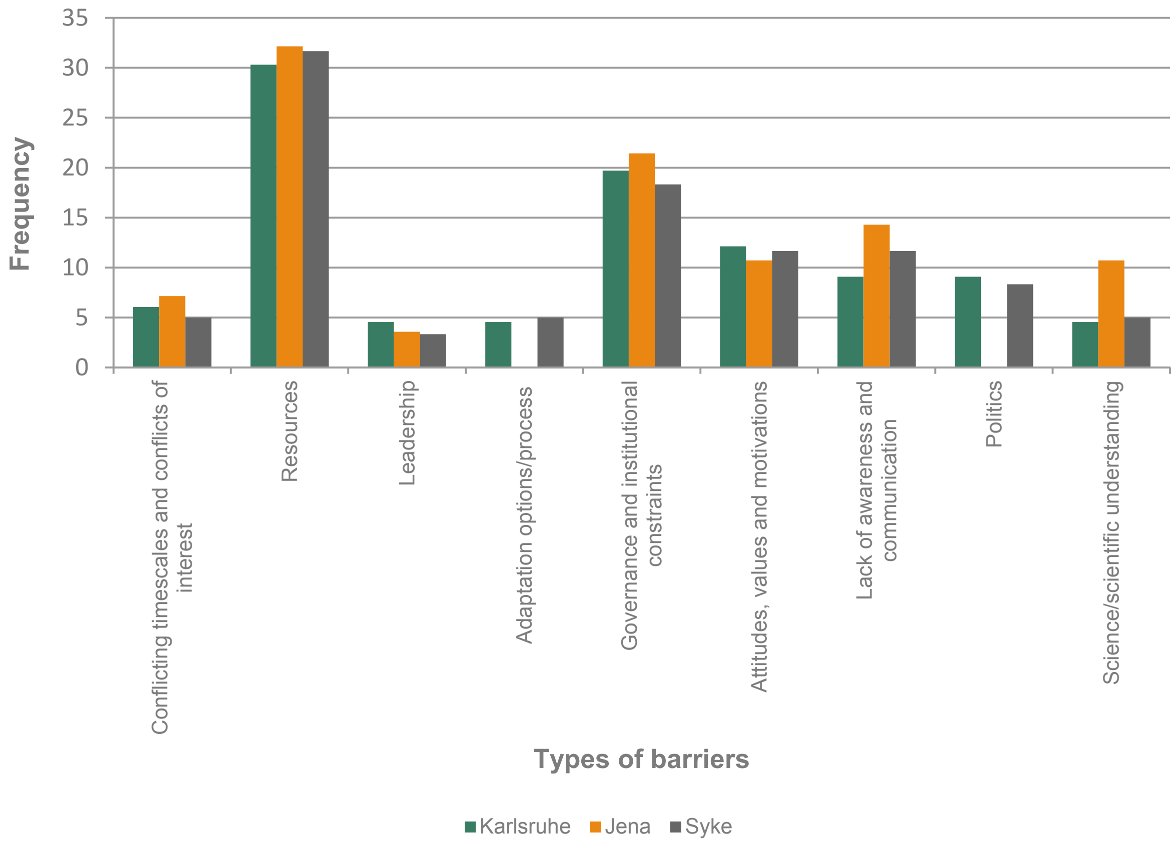

Figure 9: Barriers encountered in Karlsruhe, Jena and Syke.

Saarbrucken and Nuremberg are grouped in the second category (Fig. 10). With regards to the occurrences of barriers, both cities have something in common. They are strongly dominated by resource issues (and in the case of Nuremberg by governance and institutional constraints as well). More than one third of all barriers encountered in both cities can be attributed to a lack of human resources (staffing levels and capacity) and to la ack of financial resources for developing and implementing adaptation options. In Saarbrucken, the municipality is heaviliy indepted and has to realize important savings

(“*Haushaltsnotlagenkommune*”), making resources very scarce and hindering the adaptation process. Beside resource issues, governance and institutional barriers have been mentioned in second place and play a minor role in Saarbrucken and a major role in Nuremberg. In Nuremberg, these two clusters account for two thirds of all barriers mentioned. Thus, it is not surprising that very few additional barriers are encountered in both cities. In addition of all cities interviewed, Nuremberg mentioned the smallest number of barriers.

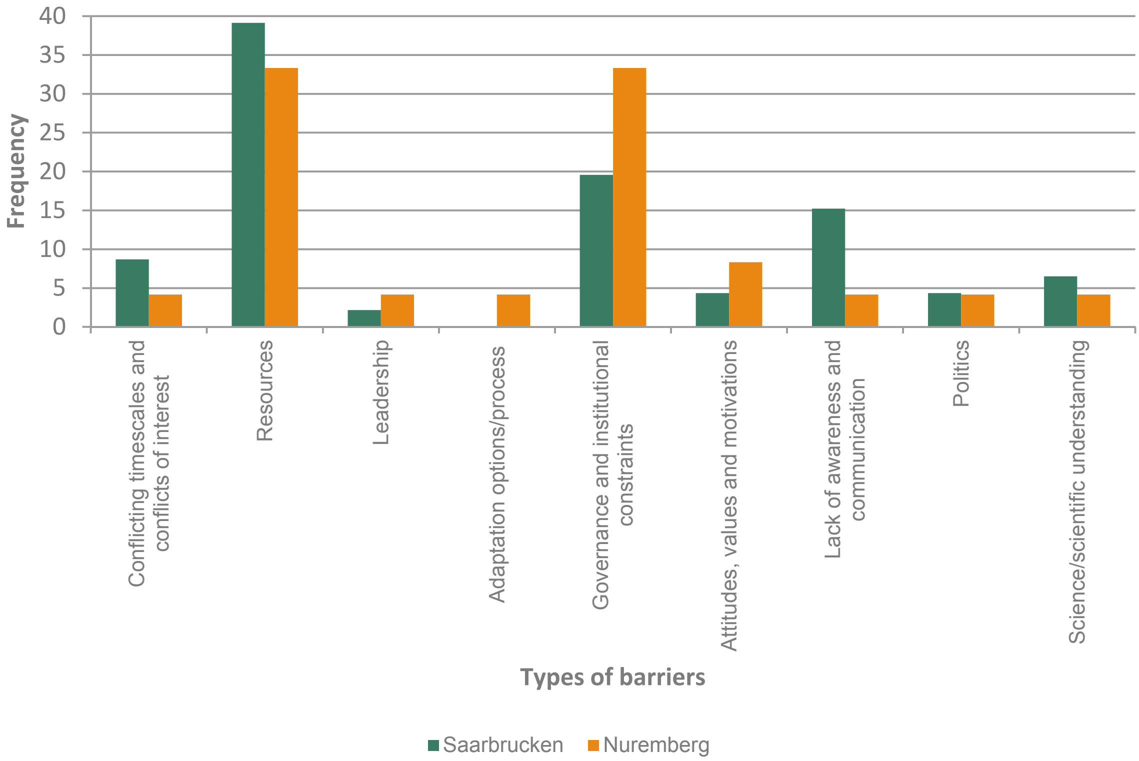

Figure 10: Barrier encountered in Saarbrucken and Nuremberg.

Even though resource barriers also dominate in Aachen, the local pattern of barrier occurrences here is very special and thus grouped in its own category (Fig. 11). In contrast to the second category, resource issues are only slightly more dominant. Contrary to the first (and the second) category, governance and institutional barriers are only ranked fourth and the entire sequence of barriers differs from the overall pattern. Beside ‘governance and institutional constraints’, barriers related to ‘lack of awareness and communication’ are also far less important (ranked sixth). The relatively low importance of institutional and communicational barriers might be due to the fact that the interviewee works within the climate protection unit (‘*Klimastabstelle’*) of the city, which has a coordinating function between the different agencies and divisions (e.g. between the environmental and urban planning agencies). This coordination makes sure that the different administrative units are communicating and coordinating their work with each other, and are following the same overarching strategy for climate change adaptation. On the other hand, barriers linked to the adaptation process, to scientific information and to ‘conflicting timescales and conflicts of interests’ are more relevant than for the study as a whole. The importance of science can be explained by climate change impacts that pose a threat to the spa town and thus the town requires a lot of scientific information (which are the source for related barriers) to understand impacts and to adapt in order to not lose its status as a healthy place.

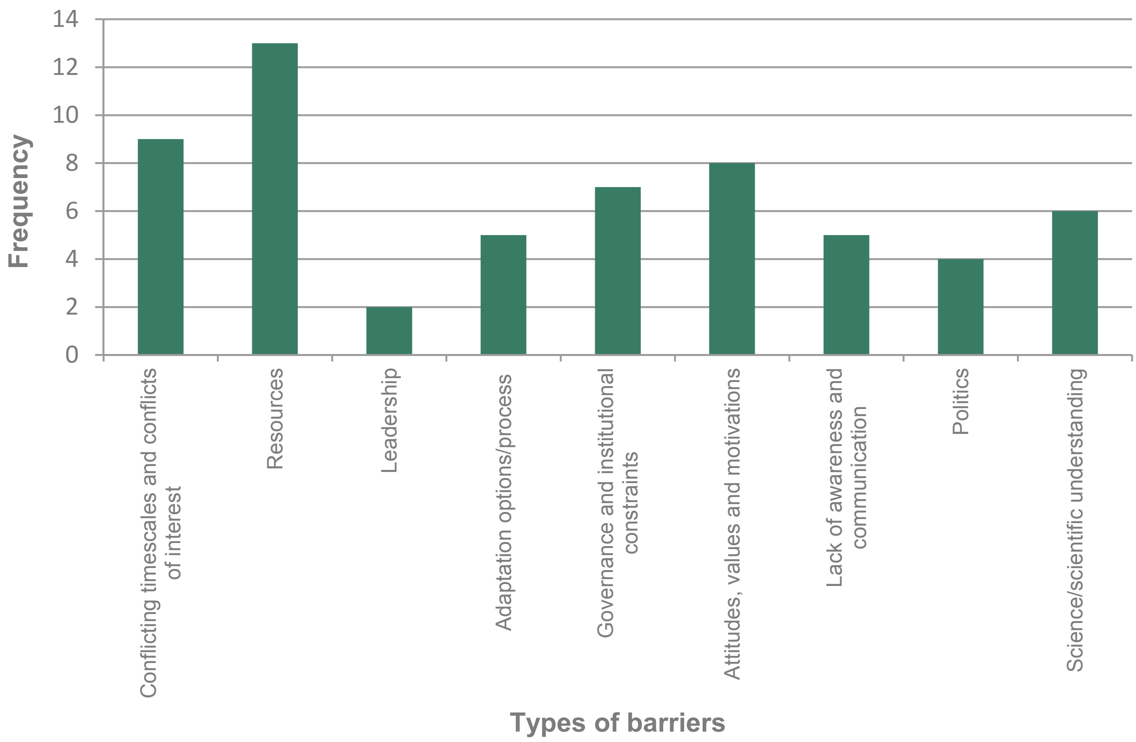

Figure 11: Barriers encountered in Aachen.

Finally, in the fourth category of barriers, those cities are grouped in which resource issues do not dominate (Fig. 12). In the cities of Regensburg, Bad Liebenwerda and Essen, institutional constraints are the most important cluster of barriers, even though they also partially have to deal with a limited budget. In Regensburg, resource related barriers are far less important and only rank in sixth position due to a relatively good financial situation. In Bad Liebenwerda, resource issues are the third and in Essen the second most important type of barrier, which is surprising as both suffer from high public debts. An explanation can be very strong personal commitment, which compensates for a lack of staff. Concerning the dominance of institutional issues, missing regulations and a lack of policy and laws on the one hand, and contradictory mandates, overlapping strategies and limited jurisdictions on the other hand, are mentioned most often. In addition, in all three cities, 'lack of awareness and communication', and 'conflicting timescales and conflicts of interests' are relatively important.

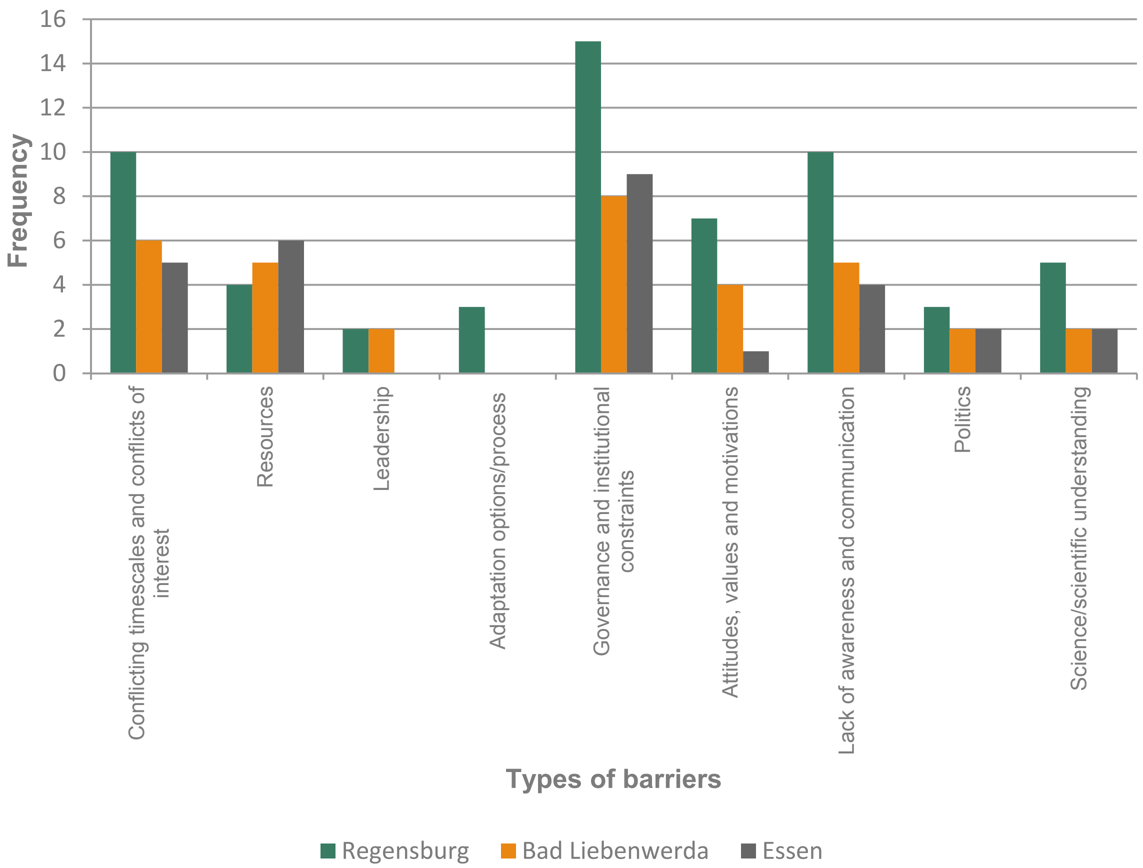

Figure 12: Barriers encountered in Regensburg, Bad Liebenwerda and Essen.

6.3. Adaptation barriers by phase and stage in the process

Breaking down the decision-making cycle into three phases and nine stages helps to identify where certain (types of) barriers occur in the adaptation process and thus allows decision-makers to be aware and prepared for those barriers, which match up with different phases and stages in distinctive trends. In this regard, some barriers are found almost exclusively in one or two phases or stages of the idealized adaptation process, while others are present in all phases and almost all stages. However, interviewees sometimes had minor difficulties categorizing barriers to certain stages, and sometimes barriers were implicitly associated with specific stages. In consequence, when associating barriers with stages, the context of the interview has to be considered.

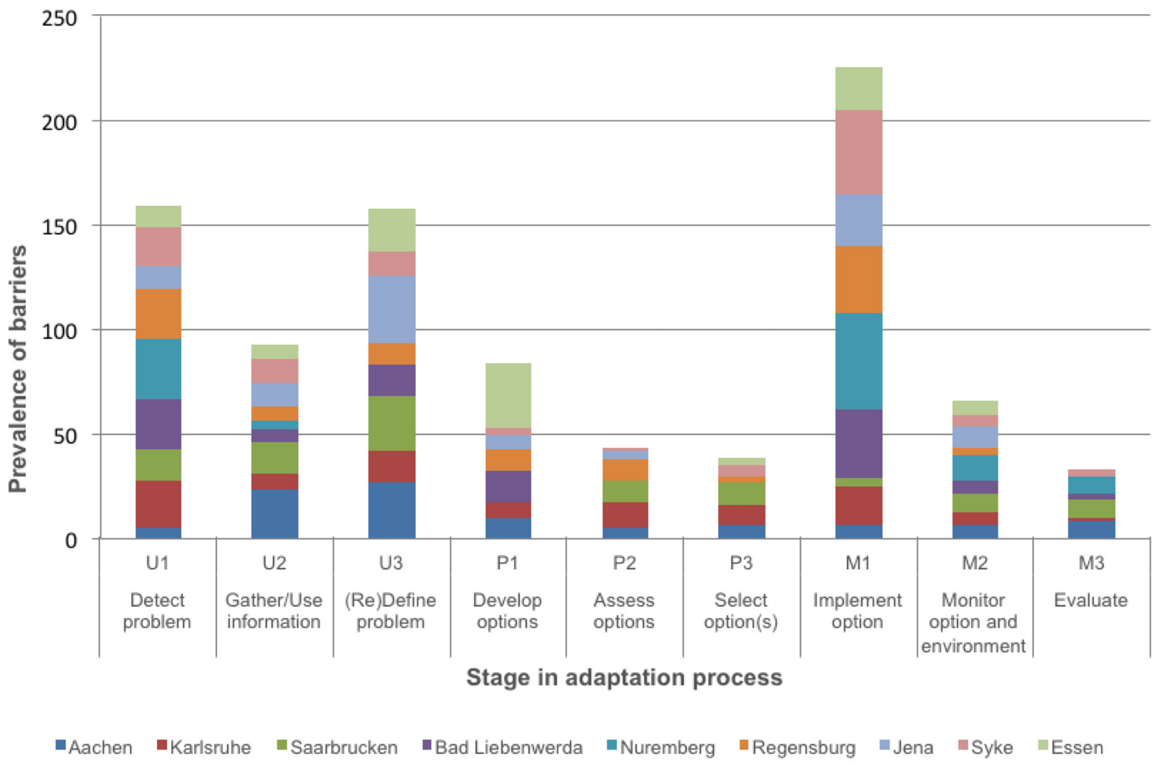

Figure 13: Prevalence of barriers by stage in the adaptation process as determined across all nine cities.

As can be seen in figure 13 (numbers of barriers are normalized by the total number of barriers per case in order to enable comparison), barriers are not equally distributed among the nine stages, but the distribution changes greatly (the prevalence of barriers by phase for each city is provided in appendix 3). Decision-makers come across most barriers in the understanding phase, fewer barriers in the managing phase, and least barriers occur in the planning phase. A second look at the data across all cases reveals that most barriers are encountered in the first and third understanding stages (U1-Problem detection and U3-(Re)Define problem), as well as in the first managing stage (M1-Implementation of selected options). These results sound reasonable. First, in the understanding phase, the initiation of the process is most difficult as climate change impacts must rise above a certain threshold of concern to initiate (U1) or reframe (U3) the problem, and above the threshold of response need and feasibility to initiate (U1) or reframe (U3) the response. In addition, consensus among the decision-makers is needed. To this are added problems with scientific data in the second stage (even though of minor importance, which is consistent with the low importance of science), resulting in numerous activities which focus on understanding climate change adaptation. Nevertheless, the greatest number of barriers occurs in the implementation stage. Since the end of the StadtKlima project in 2012 (so only very recently), most cities have started implementing adaptation options and are facing relatively severe problems. The dominance of barriers in this stage is related to the large amount of institutional constraints on the one hand, and to barriers which reappear during implementation on the other hand (such as conflicts of interests or attitudinal constraints) and are a sign that those barriers were not fully overcome in a first phase. The latter stages of monitoring and evaluation have not really taken place yet and thus reflect anticipated barriers. These indications are, once more, a sign for the early nature of the adaptation process. Having a closer look at the underlying data allows us to discuss these patterns for each phase and stage in more detail in the following.

6.3.1. Barriers to climate change adaptation in the understanding phase

As mentioned above, most barriers are found in the understanding phase, as cities have spent most time in this phase to understand the problem in detail. The predominant types of barriers change between the stages and are highlighted for each stage below.

Problem detection (U1): Barriers related to attitudes and to awareness are repeatedly observed in the first stage. Common barriers include:

- Lack of awareness, denial and scepticism within the administration (climate change is not seen as a problem and thus very little attention is given to adaptation);
- Lack of knowledge about climate change and/or adaptation (climate signals are not recognized in consequence);
- Lack of or insufficient concern, not making any efforts to understand climate change and/or adaptation (no clear indication of local changes);
- Inability to think in the long term, to accept changes and desire to maintain status quo;
- Missing leadership to initiate the process and to put adaptation on top of the priority list;
- Strong focus on climate change mitigation with the promotion of the maxim of inner-development before outer-development (‘*Innenentwicklung vor Außenentwicklung*’);
- Other, more urgent priorities and mandatory duties are preventing people from engaging into climate change adaptation and distract staff;
- Institutional void: missing policies, laws and rules which would give incentives to the executive authority and support the initiation of climate change adaptation;
- Lack of political will and support due to the pressure of short term electoral cycles and the long term nature of climate change adaptation.

Information gathering (U2): In the second stage, scientific barriers, and especially those elements which would promote the production and analysis of scientific data, dominate:

- Availability of data and lack of significant, credible, accessible and comprehensible science (lack of small-scale data with a high resolution, diversity of information leading to confusion, uncertainty due to different model projections, data not practically relevant);

- Lack of appropriate staff capacity on climate related issues (vulnerability assessments, expertise on climate change);
- Lack of financial resources to generate, collect, process and analyse scientific information;
- Lack of internal and external collaboration (to collect information);
- Lack of knowledge about climate change related issues (data was recorded, but no link was made to climate change);
- Lack of guidance (missing guidelines how to use scientific information).

Redefinition/Reframing of problem (U3): In the last stage of the understanding phase, barriers from all nine clusters emerge. Not surprisingly, some barriers identified in this stage are similar to those encountered in the first stage. However, some interviewees had problems understanding why an additional reframing of the problem was necessary and thus it was difficult to delimit this stage from the previous ones. This might explain why all types of barriers are mentioned at least several times, even though institutional and resource related barriers clearly dominate:

- Inability to find a level of agreement (lack of governance structure, institutional crowdedness, fragmentation, lack of collaboration and cooperation among different players, not everyone involved in the discourse);
- Inability to convey the need for climate change adaptation to staff or the public (limited vision and a narrow perspective, lack of capacity among staff);
- Lack of interest in, familiarity with and efforts to explore other types of information in order to understand climate related issues;
- Lack of awareness among decision-makers and no or insufficient communication among agencies, divisions and with higher levels of government (lack of knowledge about adaptation, difficulties to mobilize actors, lack of a clear message, inability to think in the long term);
- Lack of, or ineffective, leadership;
- More pressing current problems and competition between agencies for different prioritization keep the focus away from climate change adaptation;
- Lack of capacity (lack of time, lack of staff).

6.3.2. Barriers to climate change adaptation in the planning phase

The low prevalence of barriers in the planning phase is surprising at first. This pattern can be explained by the participation of the cities in the StadtKlima project. During this project, all cities had been attributed a local research assistance team that provided them with both scientific and organizational support. The teams also helped to develop, assess and select adaptation options and thus guaranteed a relatively smooth planning process. For example, barriers related to the multiplicity of actors and levels of government were far less important than in the managing phase. Moreover, in some cases, the assessment of developed options has been skipped. The majority of barriers encountered in the planning phase are related to a lack of human resources on the one hand, and governance and institutional constraints on the other hand. Even though some participants mentioned that strong regulations would make adaptation more difficult and reduce the ability to plan and act autonomously, the majority claimed that missing policies and laws are the reason why cities tend to lag behind climate change adaptation. Furthermore, over all three stages, lack of guidance is repeatedly observed.

Development of options (P1): As for the entire phase, barriers related to governance and to limited human resources are commonly encountered. In two cities, no barriers are observed in this stage.

- Lack of funds for starting planning process (limited budget, lack of staff);
- Institutional fragmentation;
- Lack of governance (restricted jurisdictions, contradictory mandates, lack of policies and laws, missing regulations);
- More pressing current problems are preventing people from getting into adaptation planning.

Assessment of options (P2): In this stage, as in the other planning stages, very little consistency is found, due to the low number of barriers mentioned. Only barriers related to resources emerge more or less in six of the nine cities (no barriers arose in the three remaining cities).

- Lack of funds to assess options in detail;
- Lack of time or staff (competing priorities, distraction with other responsibilities, lack of capacity among staff).

Selection of options (P3): In this stage, the fewest barriers overall are encountered due to the attribution of a local research assistance team in each city during the StadtKlima project. Again, no barriers emerge in three cities and low consistency is found.

- Lack of money for planning (e.g. to buy land serving as a retention area);
- Lack of staff (e.g. to update urban development plans);
- More pressing current problems (e.g. the housing of refugees) are preventing decision-makers from selecting options;

Lack of communication and coordination among the administration (lack of agreements on options; contradictory mandates).

6.3.3. Barriers to climate change adaptation in the managing phase

The majority of barriers observed in the managing phase (and in the entire decision-making cycle) arises in the first stage during the implementation of adaptation options. Decision-makers stress that the implementation process is the most difficult step, as the process involves a range of actors from different agencies and levels of government, making implementation very tough, complex and long-lasting. Besides scientific barriers, constraints from eight of the nine clusters are repeatedly mentioned, even though governance and institutional issues clearly dominate.

Implementing options (M1): In the first stage of the managing phase, barriers are primarily related to governance and institutional constraints, followed by a lack of resources and funding, and by conflicts of interests. Common barriers encountered include:

- Institutional crowdedness and fragmentation of governance structure (overlapping strategies, goals and responsibilities within and between agencies, lack of coordination with higher levels of governance, limited or no jurisdictions, lack of guidance);
- Legal barriers (contradictory or no mandates, bureaucracy, barriers from existing law);
- No implementation of existing policy, lack of policies, laws and rules, missing regulations;
- Lack of funds for implementation (budget cuts and debt reduction, revenue declines, lack of financial support and incentives from the Federal Government, competition for existing funds with other priorities);
- Lack of staff for implementing adaptation options;
- Resistance from affected parties and missing acceptance for adaptation options (property rights problems, lack of power, ignorance and lack of concern/desire for status quo);
- Predominantly other, more urgent priorities, such as mandatory duties (e.g. create nursery places) and current problems (e.g. population growth) lead to conflicts of interest and impede the implementation process;
- Lack of political will and support (different political agendas and ambitions, fear of opposition).

Monitoring options and environment (M2): In the second stage, significantly fewer barriers are mentioned. Almost all barriers have to be anticipated, as most cities have only recently started implementing adaptive options and have not made monitoring a priority yet. In addition, monitoring the effectiveness and impacts is only possible for some of the implemented options. Resource related barriers are predominant and include:

- Financial concerns (limited budget);
- Lack of capacity among staff and know-how to do an appropriate monitoring;
- Lack of time (distraction with other responsibilities, lack of staff);
- Lack of political will.

Evaluation (M3): As in case of the second stage in the managing phase, evaluation has barely begun to date. Nevertheless, most actors have recognized the need for evaluating options and emphasized that they have plans to do so in the future. Resources are almost the only anticipated barriers:

- Lack of funding (limited budget);
- Lack of time and staff.

6.4. Sources of barriers

The second step in the analysis includes finding out how the structural elements contribute to the barriers. As it was depicted in section 5.2.2, each barrier, which was mentioned during the interviews was put in its context in order to identify its source. To recall, the structural component of the framework helps to identify the causes of each barrier (described in detail in section 4.2). The three fundamental sources of barriers are (1) the actors participating in the adaptation process, (2) the larger context in which they act, and (3) the object upon which they act (called the system of concern). In figure 14, results for all cases are summarized and give an overall view on the different sources of barriers encountered.

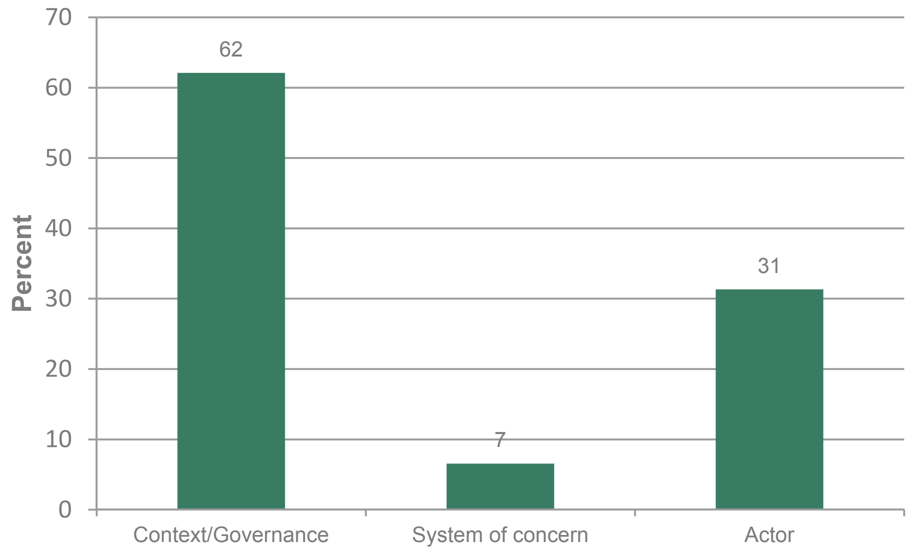

Figure 14: Summary of the sources of adaptation barriers across all cases.

As can be seen from figure 14, the dominant source of anticipated and observed barriers is ‘context/governance’, whereas ‘system of concern’ is by far the least important and the ‘actor’ the most variable source. These results are true for each individual case and all cases actually show very similar patterns (see appendix 4). The overall prevalence of context related sources (62%) is in accordance with previous results on the overall occurrence of barriers and the dominance of resource related and institutional barriers, which predominantly stem from the larger context and governance. Second, 31 percent of barriers stem from the actors themselves. This source accounts for the biggest difference between the individual cases (ranging from 25-41%), which makes sense, as actors have different societal values and beliefs, motivations and world views. Approximately one third of actor-related barriers correspond to the medium importance of attitudinal and communicational types of constraints in the overall occurrence of barriers. Third, the very low importance of barriers that come from the system of concern (7%) is mainly due to the fact that decision-makers are selecting and implementing adaptation options which have several benefits, are not specific to climate change adaptation (or to any system of concern) and thus do not take future states of systems into account. Moreover, at present, systems have not changed so much and are still understood by the decision-makers, making it easy to manage them with an unchanged routine. In addition, it is notable that the relative unimportance of barriers that relate to the system of concern again corresponds to the result of few scientific barriers. The fact that the monitoring phase has not yet begun also contributes to few barriers with a ‘system of concern’ source. In the future, the source ‘system of concern’ will become more important, once climate change impacts on the states of systems will be more severe, which will require specific adaptation actions and the need for more than just superficial knowledge.

6.5. Origins of barriers

The final component of the diagnostic framework is the simple matrix that helps to locate the origin of the barrier relative to the actor’s influence and position over it. Thus, it can be a first indication as to where to intervene in a system to overcome identified constraints. The temporal and the spatial/jurisdictional axis locate the origins of barriers and thus the locus of control over them. Concerning the classification, it is crucial to always position the origin of the barrier vis-à-vis to the actor. However, locating the origin is not always easy. In fact, sometimes there is an overlap between legacy/remote barriers and contemporary/proximate barriers, respectively. For instance, when it is not clear whether there is a local or federal law inhibiting the adaptation process and thus, whether the barrier has a proximate or remote origin. On the temporal axes, the origin of a barrier (e.g. lack of financial resources) may be located in the past but can be still of relevance today. In such cases both categories on the spatial (first example), and, respectively, temporal axes (second example) have been considered. Beside the explicit explanations by the decision-makers, the interviews have also been considered in their respective context, which makes it possible to classify more than 90 percent of all barriers uniquely as falling only into one of the four categories (the remaining barriers have been categorized twice).

		Temporal	
		Contemporary	Legacy
Spatial / Jurisdictional	Proximate	25%	38%
	Remote	10%	27%

Figure 15: Summary of the origins of barriers across all cases.

Figure 15 provides a summary and combines results for all cases (the individual cases are displayed in appendix 5). First, most barriers have a proximate origin (63%) and are close to the actor's control, whereas the minority of barriers (37%) have remote origins. In contrast to barriers, which are far from the actor's point of influence, barriers, which are local in origin can be more easily overcome in theory. Second, the domination of legacy barriers (65%) (from previously made decisions) over contemporary ones (35%) (barriers created at present) is even more important. This predominance of legacy barriers reveals the importance of past decisions, which can still largely influence the adaptation process several years after they had been made. Third, when considering all four categories, the matrix shows that the majority are proximate/legacy barriers (38%). They are followed by remote/legacy (27%) and proximate/contemporary barriers (25%), which are almost of equal importance. The minority of barriers have a remote/contemporary origin (10%). In the following, a closer look at the underlying data will reveal further information.

The dominating proximate/legacy barriers (38%) relate on the one hand to the actors, such as attitudes, motivations and a lack of capacity to think outside the box, leadership, and a lack of communication and cooperation. On the other hand, barriers stem from the local context and governance system, including institutional crowdedness and fragmentation (leading to overlapping strategies/goals/responsibilities and contradictory mandates), political dynamics (lack of political will and support), conflicts of interests and lack of resources (from lack of local funding to lack of staff). Even though these barriers are close to the actor's sphere of influence, without support they can be very hard to overcome if the actors are local ones as legacy barriers are very persistent. Attitudinal barriers, for instance, are rooted in long-lasting societal values, beliefs and cultural norms and are very difficult to change. Institutional barriers, such as conflicting strategies, can prevent a local official from taking a certain adaptation action. The official has control over these strategies and can initiate changes. However, the situation can be too challenging sometimes and effective leadership at the local level might not be enough to overcome persistent legacy barriers. Therefore, federal or regional incentives, research projects, and other interventions by higher levels of governance (e.g. encouraging or enforcing adaptive action, providing resources) can overcome these types of barriers by influencing personal values and behaviours, and by changing dynamics inside and outside the administration.

The remote/legacy barriers, which are the second most important variety of barriers, are predominantly related to the general context. The underlying data shows that for this variety, two dominant types of barriers emerge: economic and financial issues (including economic crises, budget cuts, high levels of debt), and institutional barriers (such as lack of governance structures capable of addressing the adaptation challenge, institutional crowdedness, restricted or no jurisdictions, lack of policies, laws and regulations or legal barriers from existing law). As these barriers stem from decisions made in the past and are far from the locus of control, they are most difficult to overcome. Institutions for instance were built in the past in order to support and consolidate societal procedures, making it difficult to adapt to changes now. Here, the initiation of changes is outside the control of a local actor, as structural and policy changes are needed, which can only be decided at higher levels of governance (e.g. by making climate change adaptation a mandatory task). Therefore, local actors can only intervene with compensating strategies in order to make the best of the situation e.g. by weighing possible outcomes of different measures.

The remote/legacy barriers are closely followed by the proximate/contemporary variety (25%). A closer look at the underlying data shows that the barriers are primarily related to the actors, and to a lesser extent to the governance/context. On the actor’s side, barriers linked to attitudes and motivations (such as the inability to see common interests and think long term), and to a lack of awareness and communication (including a lack of understanding of climate change and adaptation) are most often mentioned here. On the context side, most barriers are resulting from competing priorities (such as prioritization of climate change mitigation). Proximate/contemporary barriers are those barriers, which can be most easily surmounted by the actors, as they are near the actor’s point of influence and are created at present. They can be addressed ‘here and now’ through awareness raising (e.g. education and training), coordination (e.g. bringing everyone to the table) communication (e.g. strategic framing of climate change adaptation, emphasizing opportunities) and cooperation (across jurisdictions and scales).

Finally, the minority of barriers (10%) stems from decisions made in the present, but far away from the sphere of influence of the actor. These remote/contemporary barriers mostly have to do with lack of national guidance and missing regulations, the political landscape (uncertainties about the agendas of politicians and the missing willingness to make adaptation to climate change a policy priority) and missing financial incentives from the Federal Government. Beside these barriers, which are related to the actors and the local context, those that stem from the system of concern (such as the availability and accessibility of data) are frequently observed as well. As the locus of control is not in the hands of the local actor, intervention from non-local actors is needed, (e.g. through the allocation of mandates, non-financial incentives and funding). Furthermore, taking the initiative and lobbying in politics and in higher levels of administration can initiate a change in thinking among political and administrative leaders.

6.6. Aids and advantages to avoid barriers

During the interviews, participants frequently mentioned aids and advantages, which help them to avoid certain barriers in the first place or to overcome them faster. Thus, all relevant aids and advantages have also been classified, even though they are not included in the framework to identify barriers. These aids range from human assets (such as extraordinary qualities of individuals, leadership, communication) over circumstantial factors (availability of scientific knowledge, municipality size, existing awareness, political support) to institutional and economic advantages (such as relevant policies, effective cooperation and collaboration, present governance structure, good economic situation). A graphic summary of the normalized prevalence of aids and advantages, categorized into 14 distinct types, for all nine cities is provided in figure 16. In summary, five types of aids and advantages dominate, even though 'relevant policies' are the most important aid or advantage.

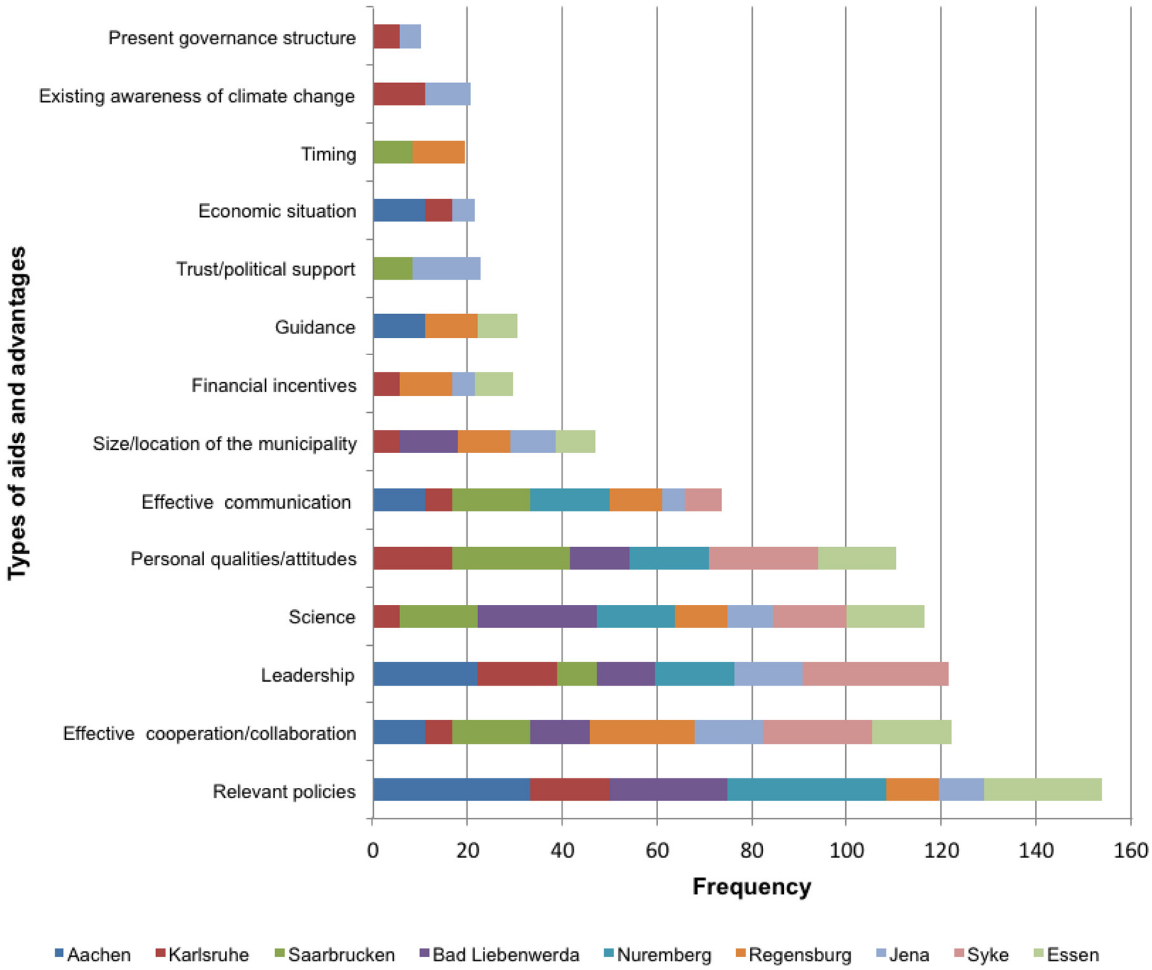

Figure 16: Aids and advantages that helped avoid barriers.

First, relevant local, state and federal policies and laws support integration of climate change adaptation. On the national scale, the existence of an adaptation strategy and an action plan is useful, as it helps to frame climate change adaptation. Furthermore, the update of the Federal Building Code has created a legal basis for the integration of climate change adaptation into urban planning. In addition, regional plans (adaptation plan by the state, land-use plan) and local policies and plans (various city council resolutions promoting adaptation, adaptation strategies) have facilitated the integration of climate change adaptation into urban processes. Second, the adaptation process is also supported by effective cooperation and collaboration across jurisdictions, scales and agencies. Here, early consultations with all involved actors have proven to be especially successful to avoid certain barriers. Third, leadership in key positions among different agencies is regarded as an important advantage, moving adaptation forward. In all cities, several individual leaders (or a group taking the lead) are identified and help to place adaptation in relevant processes. Fourth, the availability of relevant knowledge (external partners doing relevant research, collecting and analysing scientific data, vulnerability assessment) has proved to be extremely helpful in all cities to overcome barriers in the understanding phase and start developing and assessing adaptation options. Finally, people with certain personal qualities are indispensable and help to avoid (and overcome) several types of barriers. Passionate and visionary actors with strategic thinking are of crucial importance to advance adaptation. In almost all cases, such committed individuals are crucial to compensate insufficient staffing levels and capacity. Moreover, for these leaders, the participation in the StadtKlima project has been an important aid as it resulted in growing interest in climate change adaptation among staff, the public, and agency and political leaders, which has facilitated their task. All other types of aids and advantages are mentioned less frequently, which does not necessarily mean that they are less important. In fact, these aids and advantages are less important in the study as a whole, but are of strong relevance in one or a few cities (see appendix 6); e.g. existing economic wealth is an advantage in Karlsruhe and Aachen, trust and political support is an important aid in Jena, and the small size of the municipality of Bad Liebenwerda leads to a very low occurrence of barriers, as the same person is in charge for the environmental, urban planning and building sectors in the city. Further aids and advantages that are less important overall are: effective communication, financial incentives, guidance, timing, existing awareness of climate change and the present governance structure. Interestingly, experience with extreme events does not always lead to more adaptation as these events are not necessarily understood as climate change impacts. Also, other municipalities with less experience with extreme weather events have implemented the same amount of adaptation measures. Thus, existing awareness of climate change is not playing a strong role and is only one factor among others affecting climate change adaptation.

Concluding this section, the results reveal that aids and advantages are often linked to people (personal qualities of individuals, leadership, and effective communication) and institutions (relevant policies and laws, effective cooperation and collaboration). Thus, people with their attitudes and motivations, and institutions with their physical structures cannot only create barriers to adaptation, but also guide structure and enable on-going activities, which help to avoid and overcome barriers.

6.7. Strategies used to overcome barriers

In the final step of the analysis, the focus lies on strategies, which actors use to overcome barriers to adaptation. These strategies depend not only on the context, but also on the set of barriers encountered in each case. Figure 17 provides a graphic summary of the normalized prevalence of different strategies, categorized into 13 distinct types, for the study as a whole and for each of the case studies.

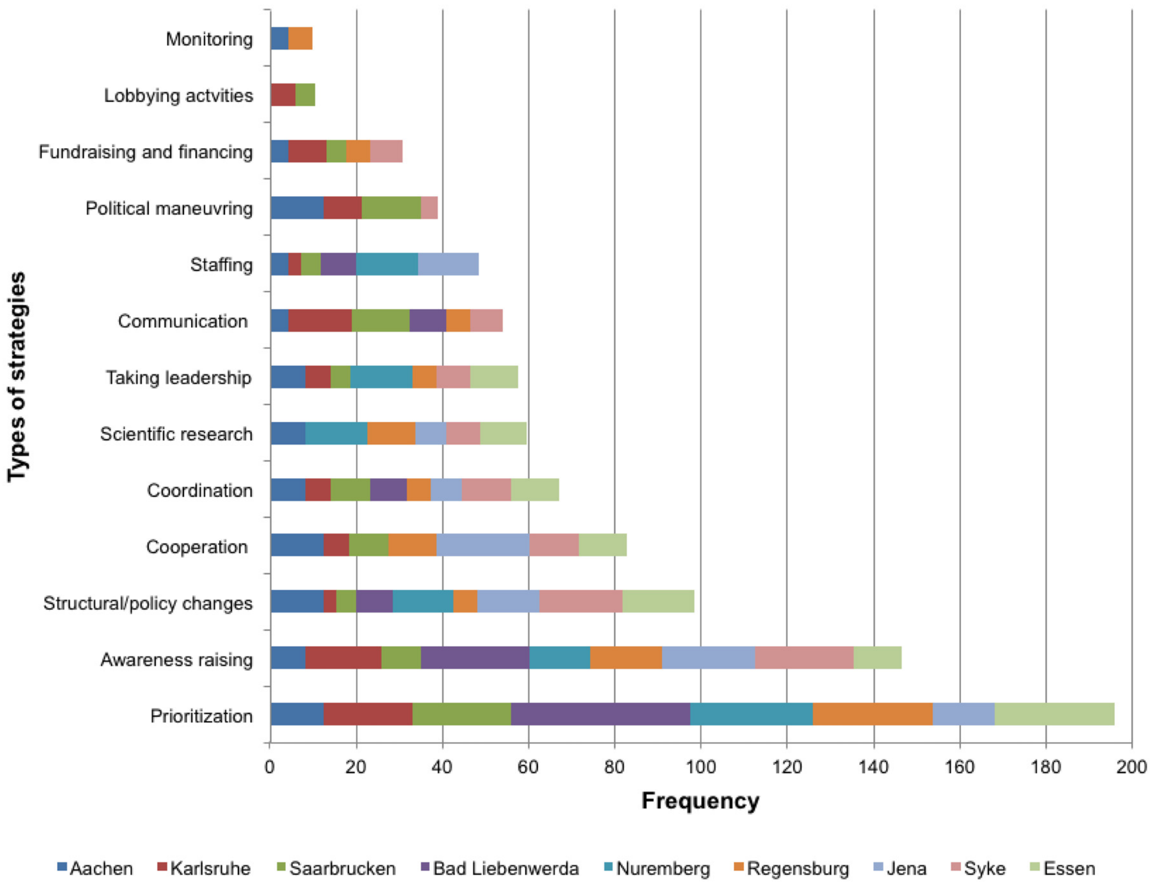

Figure 17: Strategies used to overcome barriers.

As can be seen in figure 17, the two types of strategies that dominate overall ('prioritization' and 'awareness raising') are very important in most individual cases. Behind these two types, the set of prevailing strategies changes from case to case, depending on a different set of actors, conditions and goals in each case (for more information on individual cases, see appendix 7). For example, an actor will face different problems when producing a climate expert report than when trying to initiate changes in a local law.

First, prioritizing strategies that have co-benefits and are politically feasible, or incorporate no-regret options, help to circumvent or overcome different types of barriers. While no-regret strategies help to circumvent barriers related to scientific information (as such options provide benefits even in the absence of climate change), strategies that are politically feasible are in general of smaller nature and have several benefits, which increase public acceptance and political support, reduce costs (as shared between agencies) and conflicts of interests. In fact, most of the implemented options are weighed up against more urgent problems (e.g. urban renewal) or coupled with other pressing issues of urban development (e.g. well-being), and are not only focusing on climate change adaptation. For example, large green areas are not only important for urban climate or storm water management; they also provide benefits for the preservation of biodiversity or recreation. Ultimately, such strategies help to overcome barriers related to contradictory mandates or overlapping goals, such as adapting and developing the city at the same time. Thus, prioritization of certain strategies helps to overcome a multitude of barriers (related to attitudes, lack of awareness, science, conflicts of interests, resources, institutions and politics). In this context, it is interesting to note that several measures (e.g. bright road surfaces for monument conservation or preservation of green areas for biodiversity and recreational reasons) also have an adaptation function, even though the reason for implementation is not climate change adaptation.

Second, awareness raising among the public, staff, agency leaders and politics through workshops, training, public panels and events is the second most important strategy overall. This type of strategy increases knowledge about climate change and adaptation, and thus helps to make people aware of the need to start adapting now. Moreover, by continuously addressing such strategies, actors make sure that climate change adaptation is not forgotten in the current workload, while increasing the support and acceptance for adaptation. Furthermore, the participation in research programmes (such as the StadtKlima project) (described as 'catalysts' for climate change adaptation) is seen as an important strategy to raise awareness among staff, public and politicians. Not surprisingly, such strategies help to overcome barriers related to lack of awareness and attitudes.

The third most important strategy to overcome barriers to adaptation includes structural and policy changes. The integration of climate change adaptation into on-going processes, activities and networks is important to overcome several institutional barriers. In this category, the context is especially important as the difference between minor (e.g. new standards, resolutions) and far reaching (e.g. reorganization of unit) changes is important (see appendix 7).

The next most frequent types of strategies involve cooperative arrangements and networking on the one hand, and strategies related to effective coordination on the other hand. Informal relationship-building, cooperation (across jurisdictions and scales) and coordination (such as timing, bringing everyone to the table in so-called '*Klima-Tische*' (literally 'climate-desks')) have their major interest in overcoming governance and institutional barriers. Here, again, it is recognised by interviewees that research programmes on climate change adaptation are generally encouraging integrated approaches, and thus present a unique opportunity to involve everyone in the process, from inside and outside the administration, which increases cooperation, learning outcomes and helps to position climate change adaptation on top of the priority list.

The following four types of strategies are of similar importance ('scientific research', 'taking leadership', 'communication' and 'staffing'). They have in common that the proposed intervention strategies are the solution that counterpoints the identified barriers. Additional research is conducted to obtain more detailed information on changes in the local climate, and thus counterpoints the identified scientific barrier (lack of high resolution data). Taking the lead or putting pressure on those in positions of power helps to overcome missing or insufficient leadership and governance barriers. Furthermore, existing staff members going beyond the call of duty is an important strategy to compensate for lack of staff. Finally, strategic framing of climate change adaptation (linking global problems to personal interests, emphasizing chances and opportunities of adaptation, appealing to the self-responsibility of people) surmounts communicational barriers, whereas hiring new staff would allow the actors to put more efforts into adaptation.

The remaining types of strategies are not playing crucial roles. Political manoeuvring and lobbying at higher levels of governance in order to make sure that politicians are incorporated into the adaptation process, only is of major importance in a few cases. Even though, applying to funding programmes and competing for grants is mentioned as a common practice in the majority of cases, these strategies have only a weak importance overall, which is partly due to the additional workload off writing applications.

To conclude this section, it has to be recognized that most strategies employed to date by decision-makers are the solutions that counterpoint the identified barriers. For example, when there is lack of awareness of climate change in the public or among the staff, public events and workshops are organized to increase awareness. Similarly, when there is a local law that prevents taking a certain adaptation action, policy changes (e.g. a new resolution) can address this barrier, or when relevant actors are missing in the process from the very beginning, the actor can invite additional people for the next discussion round.

7. Discussion

7.1. Frequency of types of barriers

First, the results show that resource related and institutional barriers dominate. This was to be expected, as adaptation literature highlights the importance of both types of barriers (Measham et al., 2011; Moser & Ekstrom, 2010; 2012; Mahammadzadeh et al., 2013; Eisenack et al., 2014). Moser and Ekstrom (2010) for instance have found that inadequate resources are often the first response local actors give when confronted with questions regarding why they have not engaged into adaptation planning or management yet. Moreover, in German municipalities, the amount and quality of public service provisions (which includes climate change adaptation) depend on their economic performance. However, the economic crisis has revealed the bad financial situation of many municipalities and initiated deep budget cuts. For example, in highly indebted cities, resource barriers have been extraordinarily important, in contrast to other cities with a relatively good financial situation. As adaptation measures have not yet been implemented in legislation, they are in practice voluntary undertakings and have to compete with other non-mandatory problems for the remaining funds. According to some actors, these long term budget cuts reinforce other types of barriers, such as inappropriate coordination between agencies. This is a clear indication for the interdependency of different barriers to adaptation. However, it is not exclusive to resource related barriers. For example, Biesbroek et al. (2011) found that scientific uncertainty is reinforced by conflicting timescales (long term impacts of climate change), and Rudberg et al. (2012) argue that uncertainty and lack of awareness can interact in both directions. Interestingly, Burch (2010b) emphasizes that in theory financial or human resources are not necessarily needed when existing ones are used more efficiently. This is only partly supported by the results; human resources are clearly missing, whereas institutional structures and policy-making procedures sometimes hinder the effective use of resources (which suggests once more interdependency between, and mutual strengthening of, different barriers to adaptation). Last but not least, while certain barriers seem to be about missing financial means at first glance, the roots of financial issues are often institutional or attitudinal (Adger et al. 2008). This is leading over to governance and institutional barriers, which are the most frequently reported barriers in the majority of studies (Biesbroek et al., 2013).

Moser and Ekstrom (2014) argue that the inflexible nature of public institutions, which aim to stabilize societal procedures inevitably hinders change. In addition, the results suggest that complex governance networks and institutional arrangements hinder effective collaboration and cooperation, which leads to contradictory mandates and limited jurisdictions vis-à-vis the Federal Government, the state or district. Especially the smaller cities (e.g. Syke), which are part of a district and are not independent, face many institutional barriers, such as limited jurisdictions and lack of authority. This is supported by the findings of Dannevig et al. (2012), who point out that larger urban municipalities are more strongly connected to the central level of government through various (scientific) networks. Thus, the larger cities tend to participate and benefit on a more frequent base from research programmes than smaller cities. Furthermore, the results suggest that institutional fragmentation is of particular interest, as the development and implementation of many adaptation options depend on the interaction of various sectors, which is supported by Biesbroek et al. (2011) and Eisenack et al. (2014). Again, the fact that implementation of adaptation options is not legally binding is seen as a major impediment. This is consistent with the work of Mahammadzadeh et al. (2013), who argue that municipalities in Germany see a stronger regulation of climate change adaptation (e.g. by making it a mandatory duty) as a chance, as this would also allow the allocation of new financial resources through the principle of related actions (*Konnexitätsprinzip*).

Knowledge deficits are recognized as the most important barrier contributing to a 'lack of awareness and communication'. However, recent literature suggests that addressing knowledge deficits might not necessarily lead to adaptive responses (Klein et al. 2014). This is closely related to the attitudes of decision-makers. They might be aware of climate change and its impacts, but remain passive as they are 'unable' to think long term, to accept changes, and desire maintaining the status quo. The occurrence of behavioural and attitudinal barriers confirms the role of norms and values in understanding barriers (Hulme et al., 2007; Adger et al., 2008; Moser & Ekstrom 2010). Compared to other studies, 'attitudes, values and motivations' have already been ranked higher (Moser and Ekstrom, 2014) and lower (Biesbroek et al. 2011) than in this case study. Even though the importance of different norms, values and motives is recognized in the results of this study, some explanation for the difference to the other studies and the relatively moderate importance of attitudinal barriers will be given here. Both the participation in the StadtKlima project and the work on climate change mitigation in previous years contributed to changing attitudes and values of decision-makers regarding climate change, and have thus resulted in a decreasing importance of 'attitudes, values and motivations'. For this type of barriers, it is notable that those cities, which claim to be little concerned with climate change impacts (namely Bad Liebenwerda and Nuremberg) overall have the lowest prevalence of barriers to adaptation. Furthermore, a lack of awareness is a smaller challenge in those cities which are especially concerned about climate change impacts (e.g. Karlsruhe, Jena) and located in river valleys or surrounded by mountains as they have in the recent past suffered from extreme weather events and impacts that have continuously raised awareness already.

The cluster on conflicting timescales and conflicts of interests is considered an important barrier as well. Biesbroek et al. (2011) have found that conflicting timescales, which are typical for adaptation (and especially the clash between long term impacts of climate change and short-termism in politics), are the most important barrier for actors in the Netherlands. This can only be partly confirmed here. Nevertheless, conflicts of interest have proven to be more important. A city faces several challenges; structural and demographic changes, climate change, and other, more new challenges (e.g. housing). Thus, adaptation can only be considered when weighing all these issues and may not be on top of the priority list. These findings are supported by Mahammadzadeh et al. (2013) and Measham et al. (2011). The latter highlight that whether climate adaptation is on top of the priority list or not of a city administration is largely influenced by how the issue is framed: if it is only seen as an environmental or public safety issue or as a crosscutting problem.

In the previous section (6.1), the relatively low importance of scientific barriers has already been explained; leaders are in general well informed about impacts, numerous studies have been focussing on climate change and its impacts on Germany, uncertainty is part of urban planning (not just relevant in science) and most adaptation options are no-regrets. Moser and

Ekstrom (2014) have found similar results for California. However, numerous studies still emphasize the importance of scientific information and uncertainty in decision-making (Measham et al., 2011; Biesbroek et al. 2013; Klein et al., 2014; Huggel et al., 2014; van Stigt et al., 2015).

Barriers related to politics and to the adaptation process are neglected in most studies (Biesbroek et al., 2013). Also in this study, they have proven to be relatively unimportant, even though most interviewees have missed guidance from the Federal Government. In contrast, problematic, ineffective or missing leadership is generally of major importance (Moser & Ekstrom, 2010; 2014; Eisenack et al., 2014). While missing or dominant leadership can lead to a lack of appropriate decision-making procedures, a lack of local leadership is often explained by missing support from higher levels of governance (Burch, 2010b; Measham et al., 2011; Eisenack et al., 2014). This is contradicted to some extent by the findings of this study. Even though a lack of guidance and support result in a lack of leadership in all nine cities, missing leadership is only of minor importance. The reason could be that people interviewed play important roles in moving adaptation forward, they are leaders themselves and thus do only see minor problems regarding this type of barrier.

7.2. Barriers encountered per stage

Breaking down the decision-making process into three phases and nine stages has proved to be very useful, and several specific barriers could be attributed to certain phases or stages. Moreover, in some cases, very similar barriers are identified in two subsequent phases or stages, and some barriers have been explicitly mentioned in a stage one would not expect them in (e.g. scientific uncertainty during implementation of selected options). These are clear indications that some barriers have not been overcome at first and carried on through the process, while other barriers are only noticed at a later stage in the adaptation process.

As already stated earlier, few barriers are recorded in the planning phase due to the specific guidance, which was given to all nine cities when developing, assessing and selecting adaptation options (BMVBS, 2010; 2011; 2012). Thus, expected types of barriers are not encountered in specific phases (e.g. scientific barriers in stage P2-Assessment of options), as the research assistance teams provided excellent scientific and organizational support. Also, the monitoring and evaluation stage have barely begun and thus no conclusions can be drawn here (beside the anticipated barriers of a lack of funding and staff). However, in the future it will be critical to define practice-oriented and easy-to-use indicators to optimize monitoring activities, and to implement tools for monitoring and evaluating urban adaptation actions to justify investments (Revi et al., 2014; Cortekar et al., 2015b).

From all barriers mentioned in the different stages, one can distinguish between those barriers, which arise in multiple phases and stages, and those which match up with only one phase or a few stages. On the one hand, resources proved to be important in almost every stage, but mostly in the planning and managing phases, as well as in the science-heavy understanding phase (stage U2). This is supported by the literature review of Moser and Ekstrom (2010). Furthermore, governance and institutional barriers span all three phases and almost all stages. However, they are most dominant and therefore of special importance during the implementation of adaptation options. On the other hand, several barriers are very specific to a certain phase or stage(s). Lack of leadership matches up with the first and third stage of the understanding phase, and proves to be especially important in initiating the process and to overcome the thresholds of concern and response. This finding is supported by the literature (Moser & Ekstrom, 2010; Measham et al., 2011; Eisenack et al., 2014). Lacks of awareness and communication align in characteristic ways with the understanding phase. A lack of knowledge about climate related issues, a lack of awareness, denial or miscommunication occur in all three stages of the understanding phase and are thus critical in understanding and framing adaptation. A similar pattern can be observed for attitudinal barriers. Such barriers match up with the first and third stages of the understanding phase, and can impede on the initiation of the adaptation process (threshold of concern) or contribute to the inability to find level of agreements. In addition, deeply held values and beliefs reappear in the implementation stage, when it is required to put theory into practice. Political support and will is especially important in the beginning to foster the initiation of the process (stage U1) and to put developed and selected options into concrete action during implementation (stage M1). Barriers related to scientific information emerge in characteristic ways in the science-heavy understanding phase (stage U2), which could be expected (Moser & Ekstrom, 2010; 2014). Competing priorities and conflicts of interests are encountered throughout all three phases (U1; U3; P3; M3), but are of special importance in the first phase, when other, more urgent priorities and mandatory duties keep the focus away from climate change adaptation and are preventing people from engaging with it. Furthermore, when it comes to the implementation of adaptation options, conflicts of interest reoccur. To sum up, this stage-specific breakdown provides practitioners with valuable insights into the adaptation process and may warn them to take preventive measures or better manage the challenges as they proceed through the adaptation process.

7.3. Sources and origins of barriers

The results suggest that the majority of barriers can be easily overcome as they are of local origin. The proximate/contemporary barriers stem primarily from the actors involved and as they are local in origin and stem from decisions made in the present, can be overcome ‘here and now’ by local actors through awareness raising, coordination, communication and cooperation. Proximate/legacy barriers are related to the actors and to the local context and governance system. Such barriers are already more difficult to overcome and local intervention might not be enough. Similar to these findings, Bulkeley and Kern (2006) suggest that there is a need to provide more political support and guidance to local actors. This way, they would be enabled to use traditional forms of authority, and to provide resources and incentives to collaborate with other actors so that local government can play a key role in climate change related issues. Biesbroek et al. (2011) further highlight the importance of outside intervention, and that national governments could create incentives for action, take strategic decisions to address climate change, and enforce or encourage adaptation practices in order to contribute to more successful adaptation at the local level. The same is true for remote/contemporary barriers, which make up the smallest category of barrier origins. For example, Burch (2010b) stresses that climate change adaptation must be part of the job descriptions, rather than being additional work that is pursued if time and budget allow for it. The second most important category of origins of barriers is the one of remote/legacy barriers, which are predominantly related to the general context and more precisely to economic and financial issues, and to institutional barriers. These are most difficult to surmount. Such barriers (but also those which have only one ‘remote’ or one ’legacy’ origin) need outside intervention from higher levels of government through funding, policy or structural changes, incentives, mandates or other similar interventions. For example, Kern et al. (2005) suggest that in order to overcome inertia within the administration, it is necessary to establish a department, which exclusively focuses on climate change and can ensure the issues stay on the political agenda. These results fit to the findings of Moser and Ekstrom (2014), who applied the same matrix on coastal urban areas in California. Finally, the importance of legacy barriers (vis-à-vis contemporary ones) is a clear indication of how persistent and influential past decisions are. Thus, it is of crucial interest to avoid creating future legacy barriers.

7.4. Aids and advantages to avoid barriers

All cities and communities have aids, assets and advantages that help them to avoid certain barriers and to countervail challenges that impede the adaption process. This is supported by the literature (e.g. Klein et al., 2014; Moser and Ekstrom, 2014). The most important aid or advantage is related to having relevant policies, plans and laws which guarantee a smooth integration of climate change adaptation into urban processes and strategies. Such legal and regulatory responsibilities are critical in facilitating adaptation (Klein et al., 2014). Biesbroek et al. (2010) emphasize that the success of implementation of climate change related policies is strongly related to the integration of such policies with other directives, whereas the basis for integration with other policies is a good government cooperation and collaboration (de Oliveira, 2008). This is supported by the results as effective cooperation and collaboration are the second most important type of aid or advantage. In addition, recent literature suggests that active participation of civil society and integration among the different levels of government to deal with climate change can enable and incentivize adaptation measures (de Oliveira, 2008; Biesbroek et al., 2010; Eisenack et al., 2014). Beside, these two rather institutional types of aids and advantages (‘relevant policies’ and ‘effective cooperation and collaboration’), the next types in frequency are almost of the same importance, but related to people (namely ‘leadership’ and ‘personal qualities and attitudes’). Progressive leadership in key positions and committed individuals, which are forward thinking, ready to take on challenges and compensate for a lack of staff and time, are critical to avoid barriers to adaptation. Dannevig et al. (2012) stress that in the absence of national adaptation policies, the efforts made by individuals within the municipal organization are among other factors of crucial importance (use of external expertise and municipal size) for the successful implementation of adaptation at the local level. In this line, Burch (2010b) highlights that leadership and organizational culture are deeply linked and can be important enablers of action. ‘Science’ completes the quintet of the most important aids and advantages. The significance of the use of external expertise and existing scientific data is also recognized in other studies (Dannevig et al., 2012; Huggel et al., 2014; van Stigt et al., 2015). Last but not least, even though ‘guidance’ is not identified by the interviewees as being of special importance, the fact that the least amount of barriers occurred in the planning phase (the phase in which the cities received the strongest assistance during the StadtKlima project) is a clear indication that guidance through the adaptation process (from the Federal

Government or/and expert teams) is crucial to avoid barriers to adaptation. Overall, Moser and Ekstrom (2014) found similar results; people and institutions dominate, even though the order is different, compared to the findings here.

7.5. Strategies used to overcome barriers

The results of this study suggest that no blueprint or 'one-size-fits-all' solutions exist, as local actors face a particular set of barriers depending on the local conditions and envisaged goals. In general, it is not possible to find a universal adaptation strategy as local needs have to be identified in order to tailor measures to the respective purpose (Bender et al., 2015, Cortekar et al., 2015b). This can also explain the different set of dominant strategies found by Moser and Ekstrom (2014). To overcome or circumvent barriers to adaptation, several strategies have been developed. The most important strategies employed involve prioritization of no-regrets and of strategies, which have co-benefits and are politically feasible. Such strategies help to overcome a multitude of barriers (related to attitudes, lack of awareness, science, conflicts of interests, resources, institutions and politics). These results suggest that adaptation takes place in response to multiple stimuli and not just climate, which is in accordance with the literature on climate adaptation (Berrang-Ford et al., 2011; Carter, 2011). Interestingly, in Bad Liebenwerda, adaptation co-benefits are especially emphasized, and the need for adaptation should be used as a location factor to ensure that the local spa development, tourism, health and infrastructure can derive particular benefits from the implemented options. This could be an indication that especially smaller municipalities (with decreasing population figures) could benefit from adaptation, if they prioritize options that provide co-benefits, as they do not have multiple pillars to generate income (in contrast to big cities). The second most important strategy includes awareness raising among staff, public, agency leaders and politics. Education and training, as well as workshops and public events help to overcome barriers related to a lack of awareness and attitudes. Furthermore, participation in the research programme has been a decisive strategy to raise awareness and promote cooperation among divisions and agencies. Structural and policy changes, cooperation and coordination, scientific research, taking leadership and communication are critical complementary strategies to overcome a wide range of barriers. Moreover, the results suggest that most strategies are actually solutions that counterpoint the identified barriers, which is consistent with the literature (Brown & Farrelly, 2009; Moser & Ekstrom, 2014). Although most studies recommend interventions to overcome barriers (e.g. Eisenack et al., 2014), empirical studies on interventions are scarce. Burch (2010b) is an exception and provides five steps to overcome barriers by transforming them into enablers of adaptive action, but does not categorize strategies to overcome the barriers. Eisenack et al. (2014) suggest that the limitations of our current knowledge on overcoming barriers are linked to the limited state of the art in systematically explaining barriers. Therefore, this study provides a first step towards identifying, analysing and explaining barriers to adaptation and mapping associated strategies, which help to circumvent or overcome these barriers.

8. Conclusion

In this study, barriers to adaptation in urban areas in Germany have been identified, organized and analysed. In addition, the nine cities examined in this study offer insights on how to avoid and overcome these barriers, and several types of aids, advantages and strategies have been identified. One can conclude that institutions and people make the biggest difference, whether it is about constraining or enabling adaptation activities. On the one hand, institutions and governance structures shape, guide, enable or constrain ongoing processes, and can thus help or hinder human actions. On the other hand, individual people are the primary agents of change and all efforts to climate change depend upon them. Cognitive filters affect human perception, influence attitudes about climate change adaptation and manipulate the decision-making process. Overall, adaptation is proceeding incrementally, often in response to climate change trends and impacts, or as a logical extension of work on climate change mitigation. In order to be successful, adaptation has to be recognised as a crosscutting topic and strategies need to be integrated across sectors and within multiple governmental scales.

Based on the literature relevant to this topic, nine clusters of barriers have been proposed for the classification of barriers in urban areas. The framework used for analysis served its purpose and produced a more systematic understanding of barriers, which can explain the persistent adaptation deficit. Even though the dynamic and structural components are not reflective of the real world dynamics of understanding, planning and managing processes, most easily located their problems within it. Moreover, the different elements of the diagnostic framework have been very useful and allowed to generate a much richer understanding of barriers. Furthermore, this study has increased the reliability of, and confidence in, the diagnostic framework and the substantive findings established in the study of Moser and Ekstrom (2014).

In the future, as adaptation advances, it would be interesting to explore how the dominance of certain types of barriers or strategies change over time, and whether new types of barriers or strategies emerge or not. Furthermore, it would be valuable to identify the difficulty with which specific barriers can be overcome, and to come up with recommendations on how to avoid creating barriers, as already stated by Moser and Ekstrom (2014). Moreover, the diagnostic framework could be refined in order to learn something about the possible connections between its different elements; e.g. to find out whether a specific origin of barriers is more or less dominant in a specific phase or stage. In addition, further research in this area might focus on barriers to adaptation in different institutions within one city (as adaptation is not limited to the field of work of only one agency) or at different levels of government. Knowing that scales of governance matter in understanding the barriers to adaptation (Biesbroek et al., 2011), this would allow drawing larger conclusions (e.g. on how the dominance of barriers alters with levels of governance).

In addition, due to the selection of cities with varying characteristics, the results, which were found here, can possibly be transferred to other cities in Germany, in Europe or in polycentric structured Western countries. Nevertheless, it has to be taken into account that the participating cities have strongly benefited from their participation in the StadtKlima project, and thus, generally more barriers (especially in the planning phase, but also in the understanding phase) can be expected in other cities without previous knowledge or work on climate change adaptation. In such cities, the last phase of the adaptation process, the management of the implementation of the selected options, might have hardly begun.

In conclusion, the observations from this study provide a useful input into the emerging discussion on barriers to adaptation, which is still in its infancy, and serve the scientific understanding of adaptation. At the same time, the overarching findings on the nature, source and origin of barriers provide practitioners on the ground with valuable insights into the adaptation process and may warn them to take preventive measures or better manage the challenges as they proceed through the adaptation process. Finally, the findings of the study on which clusters of barriers, sets of aids and advantages, and types of strategies are most important, can be informative to local governments in their adaptation process and climate service providers that have the power and capacity to support local communities.

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Appendix

A1 Basic information on interviews

Table 3: Basic information concerning the date, the interviewee's work place, the type of interview, and the number of interviewed people.

City	Date	Affiliation	Type of interview	People per interview
Aachen	17.12.2015	*Stabstelle Klimaschutz*	Telephone	One
Bad Liebenwerda	14.01.2016	*Bauamt*	Telephone	One
Essen	27.01.2016	*Umweltamt*	In person*	One
Jena	21.01.2016	*Dezernat Stadtentwicklung*	In person*	Two
Karlsruhe	21.12.2015	*Stadtplanungsamt*	In person*	One
Nuremberg	18.01.2016	*Umweltamt*	Telephone	One
Regensburg	19.01.2016	*Stadtplanungsamt, Umweltamt, Gartenamt*	In person*	Four
Saarbrucken	13.01.2016	*Amt für Stadtgrün und Friedhöfe*	In person*	One
Syke	26.01.2016	*FB4 Bau, Umwelt, Planung*	In person*	One

(* All interviews, which were conducted in person, took place at the participant's office.)

A2 Interview script

The interview script, which was sent out to the participants so that they could prepare accordingly for the interviews, is provided below (although in German language). However, interviews were handled more as conservation and did not follow the script (and the questions) step by step. However, the script ensured that the main aspects were all addressed during each interview. In order to provide maximum transparency, the script is reproduced below.

Leitfaden für die Experteninterviews

Es handelt sich um ein semi-strukturiertes Leitfadeninterview mit wesentlichen Aspekten, welche im Verlauf des Interviews angesprochen werden. Im Folgenden erläutere ich die verschiedenen Teilbereiche des Interviews und formuliere für jeden Punkt ein paar Beispielfragen.

1. Persönlicher Hintergrund und Wissensstand zum Klimawandel: Zunächst würde ich gerne etwas zu Ihrer Person erfahren, was Ihre Auffassung von Klimawandel ist und wie Sie den Wissensstand Ihrer Behörde zum lokalen Klimawandel einschätzen würden.

    - Was ist Ihre Aufgabe, seit wann sind Sie bereits in dieser Position und wie oft sind Sie mit Anpassung und Barrieren in Ihrer täglichen Arbeit konfrontiert?
    - Was verstehen Sie unter Anpassung? Was sind die Vor- und Nachteile der Anpassung?
    - Sind die Folgen bereits heute sichtbar oder aber erst in Zukunft?
    - Wie würden Sie den Wissensstand der Behörde/Kommune bezüglich sozioökonomischen und ökologischen Folgewirkungen, Anpassungsmaßnahmen, langfristigen Klimaveränderungen und verändertem Auftreten von Extremereignissen einschätzen?

2. Hintergrund der Arbeitsstelle und der interviewten Person: Nun würde ich gerne etwas über die Arbeit Ihrer Behörde erfahren.

    - Hat Ihre Behörde/Stadt die Zuständigkeit, um Entscheidungen zu treffen?
    - Was sind die derzeitigen Prioritäten der Arbeitsstelle? Machen Sie einen Unterschied zwischen Klimaschutz und Anpassung?
    - Welche Rolle spielen lokale Dienststellen in der Anpassung an den Klimawandel?
    - Wird Anpassung in Zukunft eine höhere Bedeutung in Ihrer Behörde zukommen und welche Rolle sollten lokale Behörden generell bei der Anpassung spielen?

3. Status im Anpassungsprozess: Hier würde ich gerne erfahren, welche Anstrengungen Ihre Behörde bis jetzt unternommen hat.

    - Wo befinden Sie sich im Anpassungsprozess?
    - Haben Sie bereits eine entsprechende Anpassungsstrategie entwickelt?
    - War die bisherige Anpassung ein Erfolg?

4. Hemmnisse im idealtypischen Adaptationsprozess: Dieser Punkt stellt den Hauptteil der Befragung dar. Ich komme auf die einzelnen Phasen im Adaptationsprozess zu sprechen, sodass ich den Prozess welchen Sie durchlaufen mussten, sowie mögliche Hemmnisse besser verstehe (siehe Abbildung 1).

- Verständnis: Erkennung des Klimasignals
    - Wann und wie wurden Sie auf die Klimafolge aufmerksam?
    - Wurden die Signale ernst genommen und weiter verfolgt oder nicht?
- Verständnis: Datengewinnung
    - Welche Informationen wurden gesammelt? Von wem? Haben Sie sich auf einen Sektor oder Bereich fokussiert?
    - Welche Informationen würden Sie weiter brauchen (Klimamodelle, Vulnerabilitätsanalysen…)?
    - Haben Sie alle Informationen bekommen, welche Sie brauchten?
- Verständnis: Problemdefinierung (siehe a. Erkennung des Klimasignals)
    - Hat sich Ihre Sichtweise auf die Auswirkungen des Klimawandels nach der Datengewinnung verändert?
    - Gibt es eine bestimmte Person/Gruppe welche eine Führungsrolle eingenommen hat?
    - Gibt es Gesetze oder Strategien, welche dazu beitragen das Problem ernst zu nehmen?
    - Gibt es eine Übereinstimmung mit anderen Behörden darüber was das Problem eigentlich ist?
- Planung: Maßnahmen entwickeln
    - Wurden Maßnahmen entwickelt?
    - Fügen sich die Maßnahmen in die bereits existierende Agenda ein? Verfolgen die Maßnahmen ein allumfassendes Ziel?

    - Gab es genügend Ressourcen?

- Planung: Maßnahmen bewerten
    - Gab es eine Bewertung darüber, welche Maßnahmen gewählt wurden?
    - Gab es bestimmte Kriterien oder Ziele, welche die Auswahl bestimmten?
    - Wie viel Zeit wurde für die Bewertung eingeplant? Gab es sonstige Zeitprobleme?
- Planung: Maßnahmen auswählen
    - Wurden eine oder mehrere Strategien ausgewählt?
    - Sind die ausgewählten Maßnahmen bereit umgesetzt zu werden? Genießen sie den Rückhalt in der Bevölkerung und Politik?
- Verwalten: Umsetzung
    - Wurden Maßnahmen bereits umgesetzt?
    - Wird die Umsetzung von Maßnahmen von der Politik, Gesetzen, Bevölkerung unterstützt?
    - Besitzt die Behörde die Befugnis über die Implementierung einer Maßnahme zu entscheiden?
    - Gibt es Überschneidungen oder Gegensätze mit anderen Strategien (z.B. dem Klimaschutz)?
- Verwalten: Monitoring
    - Gibt es einen Monitoringplan?
    - Gibt es Übereinstimmung zwischen den Behörden was und wie kontrolliert werden soll?
- Verwalten: Evaluation
    - Gibt es periodische Evaluierungen?
    - Wurde bereits evaluiert?
    - Werden die Ergebnisse irgendwo eingebracht?

5. Zusammenfassung

- Was sind die 3 wichtigsten Hemmnisse? Was sind die drei wichtigsten Strategien um Barrieren zu überwinden?

- Wird Ihre Behörde in Zukunft mehr mit Anpassung zu tun haben? Welche Rolle müsste die Behörde einnehmen, um Anpassung noch mehr voranzutreiben?

A3 Typologies of barriers, strategies, and aids and advantages

The typologies below have been employed to categorize and code barriers, strategies, and aids and advantages. The clusters of barriers (nine in total) were derived from a literature review, while the different obstacles falling under each cluster have been identified inductively from the interview transcripts. Typologies for strategies, and aids and advantages were inductively generated. There are 13 types of strategies and 14 types of aids and advantages.

Barriers

1. Conflicting timescales and conflicts of interest
    a) Conflicting time scales
        - Pressure of short term electoral cycles
        - Long term climate change impacts/adaptation
        - Intangible nature of climate change adaptation

    b) Competing priorities
        - Prioritization (general)
        - Reprioritization
        - Different priorities within and between agencies
        - Image of the city
        - Monitoring and evaluation are no priorities yet
        - Focus on mitigation
2. Leadership
    a) Problematic/dominant leadership

    b) Lack of or ineffective leadership
3. Resources
    a) Financial resources
        - Lack of financial resources
        - Economic crisis
        - Funding inaccessible

- Missing incentives
- Limited budget
- Competition for existing funds
- Lack of money for understanding (science)
- Lack of money for planning
- Lack of money for managing (implementing)

b) Human resources

- Lack of human resources
- Lack of staff
- Lack of capacity among staff
- Distraction with other responsibilities
- Lack of time
- Lack of expertise

c) Physical resources

- Lack of technical resources

4. Science/scientific understanding

a) Uncertainty (about climate and social change)

b) Lack of credible data/wrong data/meaningful data

c) No significant outcomes of model results

d) Accessibility/provision of data/not finding data

e) Availability of data/lack of data

f) Confusion (which data is needed)

g) Data available but not practically relevant

h) Data not delivered

i) Two different communities (scientists versus practitioners)

5. Lack of awareness and communication
    a) Lack of awareness, scepticism, overconfidence and denial
    b) Signal not detected/not aware of
    c) Not making the link between weather and climate events and climate change
    d) Lack of knowledge about adaptation
    e) Lack of communication
    f) Lack of a clear message
    g) Unclear social costs and benefits
    h) Cost justification
    i) Lack of public acceptance
6. Governance and institutional constraints
    a) Lack of collaboration or cooperation (internal/external)
    b) Lack of flexibility or rigid institutions/arrangements
    c) Stove-piped organization
    d) Bureaucracy
    e) Restricted/no jurisdiction
    f) Fragmentation
    g) Lack of governance structure
    h) Not everyone at the table
    i) No implementation of existing policy
    j) Lack of mandate, contradictory mandates
    k) Institutional crowdedness
        - Lack of agreements on goals/options/purpose/priorities
        - Overlapping strategies and goals
    l) Institutional void
        - Lack of an institution

- Lack of policy/law/rules

m) Legal barriers from existing law

n) Missing regulations

o) Institutional/governance changes

7. Attitudes, values and motivations

a) Lack of concern

b) Lack of interest

c) Lack of motivation

d) ‘Lack of a mail box’ problem

e) Greed/selfishness

f) People not understanding or making no effort to understand climate related issues

g) Inability to accept changes

h) Inability to think long term

i) Inability to see common interest

j) Desire to maintain status quo

k) Passive attitude

l) Inability to see the necessity for climate change adaptation

8. Politics

a) Lack of political will/awareness

b) Political ambitions and agendas/strategic uncertainty

c) Distrust

d) Fear of opposition

e) Political obstacles

9. Adaptation options/process

a) Lack of guidance

b) Lack of (feasible) options/too many options

c) Limited vision

d) Bounded perspective

e) Vague strategies/measures

f) Missing guidelines

Strategies

1. Scientific research

   a) On climate change impacts/adaptation

   b) Assess vulnerabilities/risks/local climate

2. Staffing

   a) Employing new staff/adding capacity

   b) Assigning staff to climate change

3. Structural and policy changes

   a) Reorganization of agencies/restructuring purposes

   b) Development of an adaptation concept

   c) Development of integrated approaches

   d) New standards

   e) Resolutions/laws

   f) Enforcing authority

4. Cooperation and networking

   a) Cooperation among divisions/agencies/units (internal)

   b) Cooperation among cities/across jurisdictions and scales (external)

   c) Networking (informal relationship-building)

   d) Setting up a bridging institution

   e) Coalitions among agencies

5. Coordination
    a) Bringing everyone to the table
    b) Involving everyone in the process and giving them the possibility to contribute
    c) Timing
6. Funding and financing
    a) Cost-sharing
    b) Applying for funding programmes (writing and competing for grants)
7. Leadership
    a) Taking the leadership
    b) Identification with his/her work
    c) Going beyond the call of duty
8. Communication
    a) Strategic framing of climate change adaptation (linking global change to existing priorities, combining global problems to local interests, presenting chances of adaptation)
    b) Translation of scientific data into understandable language (for planners)
9. Prioritization
    a) Setting policy priorities
    b) Focus on options which are politically feasible
    c) Focus on strategies that provide added-value/that have adaptation co-benefits
    d) Focus on no-regrets
    e) Focus on synergies
    f) Focus on win-win strategies
    g) Focus on strategies within own jurisdiction
10. Monitoring
    a) Monitoring climate change options

11. Awareness raising (political, public and among staff)
    a) Organizing public events
    b) Information campaign
    c) Direct involvement of the public
    d) Workshops
    e) Education
    f) Showing successful results and showcases
    g) Projects (e.g. StadtKlima)
12. Political manoeuvring
    a) Showing possible opportunities, chances of adaptation
    b) Breaking big problems into smaller ones to convince politicians for greater support and resources
    c) Attract political support
13. Lobbying activities
    a) For resources
    b) At the municipal level for adaptation options

Aids and advantages

1. Effective cooperation and collaboration
    a) Across jurisdictions, scales and agencies
    b) Early consultation with all involved actors/agencies
2. Effective communication between agencies
    a) Clear message/political profiling
3. Personal qualities/attitudes/motivations
    a) Passionate
    b) Progressive leadership
    c) Strategic thinking (to put forward the advantages of climate change adaptation)

    d) Commitment

4. Leadership

    a) Leadership in several agencies/positions and in working groups, capable of taking the lead

    b) Among staff in the administration and agency leaders

    c) In key positions

    d) A coordinating agency, capable of taking the lead

    e) Political will

5. Financial incentives

    a) Funding or federal/EU grants

6. Policies

    a) Federal and regional policies, laws and mandates (e.g. DAS, APA, adaptation concepts, *BauGB*)

    b) Local policies, laws and mandates (e.g. local adaptation strategies)

    c) Providing clear messages with tangible actions gives strong support to local actors

7. Science

    a) Research is done by external partners (universities, private business)

    b) Use of existing data

    c) Vulnerability assessment

    d) IPCC report

8. Economic situation

    a) Economic wealth

    b) Jurisdiction over budget

9. Existing awareness of climate change

    a) One of the warmest regions

    b) Extreme events

10. Present governance structure

    a) Formal

11. Guidance

    a) From federal entity

    b) Rewards

12. Timing

13. Trust/political support

14. Size of the municipality/location

Statement of Originality

I, Philippe Weyrich, declare that I have developed and written the enclosed Master Thesis completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. The Master Thesis was not used in the same or in a similar version to achieve an academic grading.

15.04.2016, Luxembourg

Philippe Weyrich

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