HUMBOLDT-UNIVERSITÄT ZU BERLIN

Lebenswissenschaftliche Fakultät

Albrecht Daniel Thaer-Institut für Agrar- und Gartenbauwissenschaften

Masterarbeit

zum Erwerb des akademischen Grades Master of Science

Barriers to urban climate change adaptation planning – Applying fuzzy-set QCA to identify constraining conditions to climate change adaptation for cities in Germany

vorgelegt von

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Acknowledgements

This thesis marks the final step of my university career and I would like to take the opportunity and thank certain people without whom I believe this thesis had not been possible. First of all I would like to thank my supervisors Prof. Dr. Eisenack and Dr. Matteo Roggero for their guidance and patience. Especially Matteo was a constant source of helpful advice and support in navigating through the wonders of *R* and *QCA*.

Furthermore, I want to express special thanks to Dr. Diana Reckien who was so kind to share here dataset on European cities with us which was of fundamental help for the conceptualisation of this work.

Also, I want to show my gratitude to my fellow "Masterand*innen", John and Magdalena in particular, for our mutual knowledge sharing and "cross-fertilization".

Lastly, I want thank my family, girlfriend and friends for their relentless motivational support and love during the past year.

Finn Hingst

Neukirchen, 26.04.2020

Abstract

In the face of an ever-increasing climate change, which is also increasingly tangible in Germany, comprehensive adaptation strategies will be of fundamental importance for the continued existence of societies on our planet. Due to the increasing concentration of human activities in urban areas, cities will play a central role in the development of appropriate strategies. However, adaptation strategies are commonly less present than mitigation strategies and a better understanding of the factors that prevent cities from developing adaptation strategies is needed. Moreover, existing studies on the topic are often very site-specific and consider constraining factors mostly individually and thereby neglect possible interactions between factors.

Therefore, the aim of this study is to conduct a *Qualitative Comparative Analysis (QCA)* to determine the extent to which commonly reported barriers as well as combinations of barriers hamper the development of adaptation strategies in German cities.

The results show that the barriers frequently cited in the literature also have an impeding influence on the development of adaptation strategies in Germany while the personnel situation of a city in particular is of particular importance. With regard to the interaction of individual conditions, it is shown that extensive planning at higher political levels can prevent planning at the local level if cities also have limited financial resources and lacking political will and thus rely on superior levels to engage in adaptation planning. It is also determined that government initiatives that support cities in the development of adaptation strategies are highly effective in overcoming barriers.
However, the results only apply to the development of adaptation strategies and not to any barriers that may arise in the implementation process of adaptation measures. It is also likely that other factors complicate the development of adaptation strategies that are not covered by the present analysis.

Zusammenfassung

Im Angesicht eines sich immer weiter verstärkenden Klimawandels, der auch in Deutschland zunehmend spürbar ist, werden umfangreiche Anpassungsstrategien von elementarer Bedeutung für das Fortbestehen von Gesellschaften auf unserem Planeten sein. Aufgrund der fortschreitenden Ballung von menschlicher Aktivität in urbanen Räumen, wird Städten bei der Entwicklung entsprechender Strategien eine zentrale Rolle zuteil. Allerdings sind Anpassungsstrategien deutlich seltener anzutreffen als Mitigationsstrategien und es bedarf daher einer besseren Erforschung der Faktoren, welche Städte an der Ausarbeitung von Anpassungsstrategien hindern. Außerdem sind vorhandene Studien häufig sehr kontextspezifisch und betrachten Hürden zumeist individuell und vernachlässigen somit etwaige Wechselwirkungen zwischen Faktoren.

Ziel dieser Studie ist es daher, mittels einer *Qualititative Comparative Analysis (QCA)* sowohl zu bestimmen inwiefern individuelle Faktoren als auch Kombinationen von Bedingungen die Entwicklung von Anpassungsstrategien in deutschen Städten erschweren.

Die Ergebnisse zeigen, dass die in der Fachliteratur häufig genannten Hürden auch in Deutschland einen behindernden Einfluss auf die Erarbeitung von Anpassungsstrategien haben, wobei vor allem die personelle Situation einer Stadt von entscheidender Wichtigkeit ist. Bezüglich des Wechselwirkungen einzelner Bedingungen zeigt sich, dass eine umfangreiche Planung auf höheren politischen Ebenen eine eigene Planung auf lokaler Ebene verhindern kann, wenn Städte zusätzlich über limitierte finanzielle Ressourcen verfügen. Auch zeigt sich, dass staatliche Initiativen, welche Städte bei der Erarbeitung von Anpassungsstrategien unterstützen, eine hohe Effektivität bezüglich der Überwindung von Hürden aufweisen.

Die Ergebnisse gelten allerdings lediglich für die Entwicklung von Anpassungsstrategien und nicht für etwaige Barrieren, welche im Implementierungsprozess von Anpassungsmaßnahmen auftreten. Auch ist es wahrscheinlich, dass weitere Faktoren die Ausarbeitung von Anpassungsstrategien erschweren, welche von der vorliegenden Analyse nicht abgedeckt werden.

Table of contents

List of abbreviations

AfD	Alternative für Deutschland
BPB	Bundeszentrale für politische Bildung
DAS	Deutsche Anpassungsstrategie an den Klimawandel
DWD	Deutscher Wetterdienst
EPA	Environmental Protection Agency
fsQCA	Fuzzy-set Qualitative Comparative Analysis
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
ISCED	International Standard Classification of Education
ITDP	Institute for Transportation and Development Policy
OECD	Organization for Economic Cooperation and Development
QCA	Qualitative Comparative Analysis
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN DESA	United Nations Department of Economic and Social Affairs
UKCIP	United Kingdom Climate Impact Programme

List of figures

List of tables

1. Introduction

1.1 Background

1.1.1 The adaptation imperative

The 2015 Paris Agreement marked a milestone in the global coordination on climate adaptation and mitigation. For the first time, the global community commonly agreed upon measures to limit the rise in global mean surface temperature to 2°C (preferably 1.5°C) compared to preindustrial times (UNFCCC 2020a). Despite the fact that it was commonly regarded as a historical step in the fight against climate change, the derivation of its spirit into ambitious climate policies and thus a significant reduction in global carbon emissions turns out to be challenging as the currently made commitments are insufficient to avert a rise in global mean temperature above 2.0°C, let alone 1.5°C.

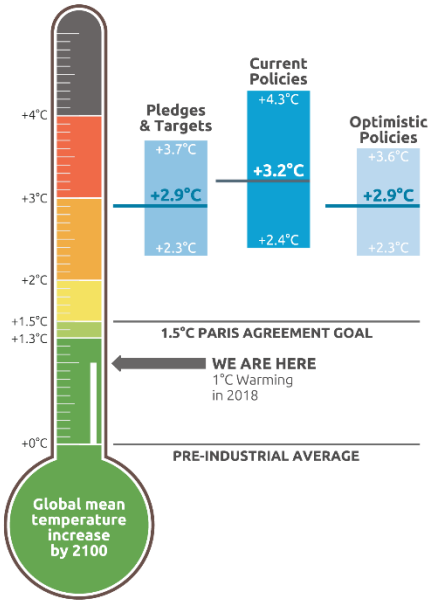

Figure 1: Projections of global temperature rise by 2100, Source: Climate Action Tracker (2019)

As can be depicted from Figure 1, current projections foresee a temperature rise between 2.3°C and 3.7°C if all pledges and targets of the Paris Agreement are met by 2100. In case the Paris agreement will not be put into action and current policies will be maintained the rise will be between 2.4°C and 4.3°C. Recent political developments such as the election of climate change sceptics like Javier Bolsonaro in Brazil or Donald Trump in the United States additionally endanger reaching the targets of the Paris Agreement. In 2018, global carbon emissions reached an all-time high and current estimates indicate that emissions amounted to 36.6 billion tons in 2019, which would mean a 0.6% rise compared to the record year of 2018 (Mooney and Dennis 2019).

In the light of these figures, it is questionable whether the global community will be able to master the massive collective action problem which comes along with climate change and to agree upon climate policies which align with the Paris Agreement. As a result, a significant increase in global mean temperature by the end of the current century seems highly unlikely.

The potential impacts of any rise in global mean surface temperature over 1.5°C are outlined in the *Special Report: Global Warming of 1.5°C* by the Intergovernmental Panel on Climate Change (IPCC). It states that impacts from climate change are already occurring and will be significantly more severe already at a warming of 2°C than previously assumed "including warming of extreme temperatures in many regions (high confidence), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (high confidence), and an increase in intensity or frequency of droughts in some regions (medium confidence). (IPCC 2018, p. 7)"

Furthermore, the risk of triggering potentially irreversible climatic tipping points is significantly increased at a warming of 2°C instead of 1.5°C (IPCC 2018). Assuming the global warming projections of *Climate Action Tracker* described earlier (up to 3-4°C by 2100), the impacts of climate change will be severe on global social, economic and ecological systems.

Thus, governments need to elaborate effective strategies to be prepared for future challenges. Despite the need to adapt, ambitious mitigation policies will continue to be crucial since the more successful these policies are, the less adaptation efforts will be needed. As social and ecological systems are limited in their capacity to adapt, mitigation action is necessary in some places to make adaptation possible after all and reduce their costs (Dow et al. 2013).

However, if global warming cannot be limited to 1.5°C the associated consequences require very sophisticated adaptation strategies in order to maintain human systems around the globe.

1.2.1 The role of cities in climate change adaptation

In 2018, 55% of the world´s population lived in urban areas. Due to increasing migration from rural into urban areas combined with the general growth of the world´s population, this figure is expected to rise to 68% by 2050, meaning that an additional number of 60-70 million people will move to cities each year (UN DESA 2018). These migration movements do not only increase the number of inhabitants of urban areas but also lead, in the light of the ongoing tertiarization of economies, to a bundling of innovation activity in cities. As a consequence, the capacity of cities to challenge national government taking the forerunner role in addressing future challenges increases significantly (Carter et al. 2015). Therefore, cities will stand in the front row in the battle against climate change as

their actions will affect the livelihood and wellbeing of two thirds of the world´s population and most of its built structures and economic activities.

Also, for adaptation efforts, cities are considered to play a crucial role as their bureaucratic structures are less complex than those of national governments allowing a more efficient and faster implementation of policies. Furthermore, they are best aware of their specifics and hence able to design policies which accurately meet the specific local needs (Reckien et al. 2015). Consequently, as national governments struggle to agree on common climate action, cities will become increasingly prominent in international climate debates. The way they succeed in tackling the challenges that come along with climate change will be crucial for the livelihood of billions of people around the globe.

1.2.2 Adaptation in Germany

When talking about the climate change adaption, the focus commonly rests on developing countries. Due to the high severity of expected impacts combined with the often low adaptive capacity of human system in developing countries, this is undoubtedly justified. Nevertheless, climatic events such as the extraordinary dry summer in Germany in 2018 or the devastating wild fires in Australia in early 2020 highlight the importance of adaptation action also in developed countries and question their capability to adapt to climate change (Moser and Ekstrom 2010).

According to the "Climate-Risk-Index"[1], Germany was among the three countries in the world that were affected the most by extreme weather events in 2018. This was caused mainly by the exceptionally hot and dry summer which featured the highest number of "hot days"[2], since the beginning of weather recording (Germanwatch 2020; Umweltbundesamt 2019b).

Current projections for Germany indicate that, analogously to global developments, comparable years will become increasingly frequent in the future leading to higher probabilities of extreme weather events such as droughts, storms and heavy rains (Brasseur et al. 2017). Hence the impact of climate change is already tangible in Germany and expected to aggravate in the future.

While the global urbanisation rate is not expected to exceed 70% before 2050,

[1] The "Climate Risk Index" is issued annually by the German NGO *Germanwatch* on the basis of data from Munich Re and IMF and analyses to what extent countries are affected by extreme weather events such as floods, storm, droughts. For more information visit https://germanwatch.org/en/16046

[2] A "hot day" denotes a day when the countrywide average peak temperature exceeds 30°C.

in Germany this number has already been surpassed as in 2015 approximately 75% of all Germans were living in cities (LBBW 2015). Bearing in mind the expected climate change impacts in combination with the high degree of urbanisation, it will be of crucial importance for adaptation efforts in Germany to what extent cities will be able to develop effective adaptation strategies.

1.2 Problem statement

As outlined in the previous section, effective adaptation measures are essential for coping with future impacts of climate change – especially on the city level. This both requires and calls for a thorough understanding of the dynamics behind urban climate action, enabling local governments to formulate effective strategies for the best possible degree of resilience towards climate change.

A relatively large body of knowledge is available on potential physical measures to adapt to climate change. However, it is still not fully understood under which conditions cities become active in climate change adaptation and what hindering factors they face. While a growing number of cities have developed comprehensive mitigation plans and targets, adaptation action is often lacking behind. For instance, a recent study by (Reckien et al. 2018) compared the climate action of 800 European cities and revealed that not more than approximately 11% of the considered cities possessed an adaptation plan.[3]

Climate protection measures are, with a time lag, decisive for the extent of climate change and thus also for the required adaptation, whereas the costs and potentials of adaptation can be essential for climate protection efforts. They also compete for similar resources and are linked by synergies and trade-offs (Klein et al. 2007; Moser 2012). Often, both groups of measures are treated as substitutes, but this runs the risk of ignoring important interactions as well as possible limits to adaptation. To reduce the costs and risks of climate change, a coordinated mix of ambitious climate protection goals and sustainable adaptation measures is important.

In Germany the number of cities with an adaptation plan is significantly higher than on the European average. Yet, also here a large number of cities does not possess a distinctive adaptation strategy (Reckien et al. 2018). Previous studies indicate that a city's vulnerability to projected climate impacts does not seem to correlate with the existence

[3] This figure relates to only 612 of the cities as those cities were excluded from the analysis that are obligated by national legislation to have a local climate plan (UK, France, Denmark, Slovakia).

of adaptation plans: one should not expect that the more cities need to adapt, the likelier they are to have an adaptation plan and vice versa (Reckien et al. 2015).

The dynamics and factors which act as barriers (and drivers) for adaptation are complex and yet to be understood thoroughly. This assessment was confirmed by the IPCC as in its 4th Assessment Report it is stated that "there are significant outstanding research challenges in understanding the processes by which adaptation is occurring and will occur in the future … (Adger et al. 2007)". As research on barriers to adaptation was initially mainly focused on national states, this is even more valid for barriers to adaptation planning in urban areas (Rosenzweig et al. 2010). Furthermore, Biesbroek et al. (2013) demand a better conceptualisation of the characteristics of barriers as this will be crucial to fully understand the dynamics of climate change adaptation and assess adaptation measures and policies.

Despite the need for a clear understanding of barriers occurring in the adaptation process, they state that "the existing literature on barriers to adaptation is highly fragmented and often very context specific, which complicates any progress on fully understanding their nature (Biesbroek et al. 2013, p. 1120)".

The determination of barriers to adaptation planning and the resulting elaboration of policy measures to dismantle them is essential for raising the resilience towards climate change of German cities and thus for most of the German population. Hence, the purpose of this study is to analyse institutional, attitudinal and socio-economic factors which influence the development of urban adaptation planning in Germany and thereby identify conditions which prevent cities from elaborating adaptations strategies.

1.3 State of the art

In the light of rapidly advancing climate change and therefore an increased focus on potential adaptation options, the issue of barriers to adaptation has become increasingly present in scientific research. The need to adapt is widely affirmed and current debates range around the questions of how the adaptation measures can be elaborated and how possible constraints to adaptation can be identified.

There is a plethora of studies (Eisenack et al. 2014; Eisenack and Stecker 2010; Biesbroek et al. 2013; Lehmann et al. 2013; Moser and Ekstrom 2010; Reckien et al. 2015) which deal with the issue of barriers to adaptation. Commonly, these analyse small numbers of cases and tend to be descriptive rather than comparative. Also, arguably due to the small

n in these studies and their high context specificity, their results vary widely and the list of potential barriers seems endless. This makes it difficult to determine general overlaying patterns.

By conducting a review of existing literature on the topic, Eisenack et al. (2014) outline commonly reported barriers to climate change adaptation and potential ways of overcoming them. While they are able to identify certain barriers, which were reportedly frequently by researchers, they indicate the existence of conflicting results and the need to analyse eventual interdependencies and conjunctions among barriers and encourage more research on the latter.

Reckien et al. (2015) intend to identify more general patterns than in those studies with a small number of analysed cases by comparing the climate action of over 200 European cities. They succeed in identifying several hindering factors but acknowledge that the certain determination of barriers to adaptation proves to be challenging. Furthermore, as they compare cities from different countries the specific vertical influence might be very relevant for the analysis but does not find representation in the study.

Studies with an explicit focus on barriers to adaptation planning in German cities are scarce. Lehmann et al. (2013) provide anecdotal evidence about barriers to adaptation planning in Germany and Peru by applying a self-elaborated framework but also recommend further research which involves more quantitative methods.

In general, it can be stated that previous studies succeeded in determining an extensive set of potential barriers to climate change adaptation. However, these are commonly highly site specific and the influence of institutional, attitudinal and socio-economic factors on adaptation are not well understood yet (Engle 2011). Additionally, the understanding needs to be advanced of whether factors are independent from each other or if conjunctions exist among them and how these would influence their impact on adaptation efforts (Eisenack et al. 2014). This section only intends to provide the reader with a brief impression of the current state of the art of research on barriers to climate change adaptation.

A more detailed assessment of the available literature including a stockpile of commonly reported barriers is conducted in chapter 2.

1.4 Research question

Resulting from the problem statement described earlier and from the status quo briefly sketched in the previous section, the overall aim of this research is to advance an understanding of which conditions hinder the existence of adaptation plans in Germany. Since most previous studies had a comparably narrow regional focus and therefore identified barriers, that might be highly site specific, this thesis aims to identify rather general patterns. The current literature on the topic commonly does not indicate whether the mentioned barriers occur during the planning process of adaptation strategies or during the implementation process of elaborated strategies.

Against this background, this study aims at answering the question of under which conditions cities develop adaptation plans. For this purpose, it is assumed in the following that reported barriers from the literature are, to a large extent, transferable to barriers to adaptation planning, even if they are not explicitly marked as being barriers to planning. Thus, the overarching research question of this study is:

How do commonly reported constraining conditions hamper the development of climate change adaptation plans in German cities?

In addition to the main research question, certain sub-research questions emerge. It will be of interest to determine whether certain conditions are individually sufficient to prevent cities from elaborating adaptation plans. Furthermore, as encouraged by previous researchers (Eisenack et al. 2014), this study intends to analyse eventual conjunctions and interdependencies among barriers. Lastly it is investigated whether the absence of barriers ultimately leads to the development of adaptation strategies. Consequently, the three sub-research questions of this study are:

Are there conditions that are individually sufficient to prevent German cities from having adaptation plans?

How do eventual conjunctions among conditions influence their impact on the outcome?

Does the absence of the barriers lead to adaptation?

1.5 Summary of the chapter

In order to address the future implications of climate change in the best possible way, cities, both in developing as well as in industrialized countries, need to develop comprehensive adaptation strategies. Despite this undeniable need, adaptation action is commonly still in its early stages and lacking behind mitigation efforts. This thesis shall improve the knowledge about constraining conditions which impede the development of adaptation strategies in Germany. Furthermore, it is analysed whether barriers exist interpedently from each other or if there exist certain conjunctions among them.

It should be noted that the focus of this study resides on barriers to the development of urban adaptation strategies but not on their implementation. It is crucial to gain holistic knowledge about the dynamics behind urban climate change adaption in order to be able to initiate the necessary policies which support the removal of barriers to adaptation and thus ensure the resilience of urban areas in the future.

2. Theoretical framework

2.1 Objectives of this chapter

The goal of this chapter is to provide an overview of the theoretical principles of urban climate change adaptation and barriers to it and link the research question to the current state of the art of research on the topic. First, the special importance and specifics of urban areas in the adaptation context are highlighted to gain a thorough understanding of the matter. Thereinafter, certain core principles for urban climate change adaptation are outlined. However, the core part of this chapter is a comprehensive literature assessment in order to develop a robust theoretical framework on the barriers to climate change adaptation which are used for the analysis of barriers to adaptation planning in German cities in the further course of this study.

2.2 Climate change adaptation in urban areas

As outlined in the introduction, cities play a key role in the efforts to adapt to climate change. They are called upon to reduce their vulnerability to the effects of climate change and increase their resilience. However, urban climate policy is a long-term transformation process based on broad participation, which affects both the built environment and the actions of urban society (Brasseur et al. 2017). As the number of inhabitants of cities increases they are increasingly becoming the core hubs of innovation and challenge the dominance of national governments (Carter et al. 2015). Furthermore, the effects of climate change will vary locally and due to their knowledge about the local circumstances, cities possess higher capacities for elaborating tailored adaptation plans which meet the local needs than national governments.

In the adaptation context certain terms are crucial and their definitions shall be briefly outlined here. To ensure broad applicability, the definitions provided by the IPCC are used for this study.

Adaptation: “In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate. (IPCC 2012, p. 556)”

Adaptive Capacity: “The combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial

opportunities. (IPCC 2012, p. 556)"

Resilience: "The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions. (IPCC 2012, p. 563)"

Vulnerability: "The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2012, p. 564) "

2.2.1 Cities and climate change risk

Due to their physical structure, cities are already subject to certain microclimatic effects which are independent of climate change. During the day, urban areas absorb heat more easily than the surrounding areas and heat up distinctively faster respectively cool down slower than the hinterland. In a city with over 1 million inhabitants, the annual mean temperature of the city centre can be between 1-3 °C higher than in the vicinity. This figure significantly increases in the evening when the temperature difference can be as high as 12°. The reason for this phenomena, which is called "Heat Island Effect", resides mainly in the mass of building structures which are agglomerated in a city (EPA 2019).

Furthermore, the large amount of sealed soils and the resulting low infiltration rate raises the threat of flooding in case of heavy rains (Carter et al. 2015) while the limited ventilation of heavily built-up urban areas and the often dense traffic negatively impact air quality.

Depending on the actual experienced change in climate, these effects are likely to intensify in the future due to the expected higher frequency of extreme weather events which comes along with climate change. As annual mean temperatures are rising all around the globe, the "Heat Island Effect" will exacerbate and heavily impact living conditions in cities. Especially in inland cities the effects will be severe raising the risk of heat-related fatalities most notably among vulnerable groups such as the elderly, chronically ill or infants (Åström et al. 2016).

Correlating with the "Heat Island Effect", the deterioration of air quality in urban areas increases with rising mean air temperature causing potential negative effects on human health (The World Bank 2011).

In cities in coastal and mountainous regions and on riverbanks, heavy rain events are expected to become more frequent and intense in the future. Due to the previously described large extent of surface sealing in urban areas, the risk of flooding and thus the danger of damages on physical structures, disruptions of fresh water supply and economic activities as well as human illnesses and deaths is expected to become more prevailing (ibid). Coastal cities have to bear the additional risk of rising sea levels as, according to the IPCC, the rise in global mean sea level will constitute between 0.43m and 0.84m by 2100 (Oppenheimer and Glavovic 2019) resulting in more frequent and intense storm surges (Revi and Satterthwaite 2014).

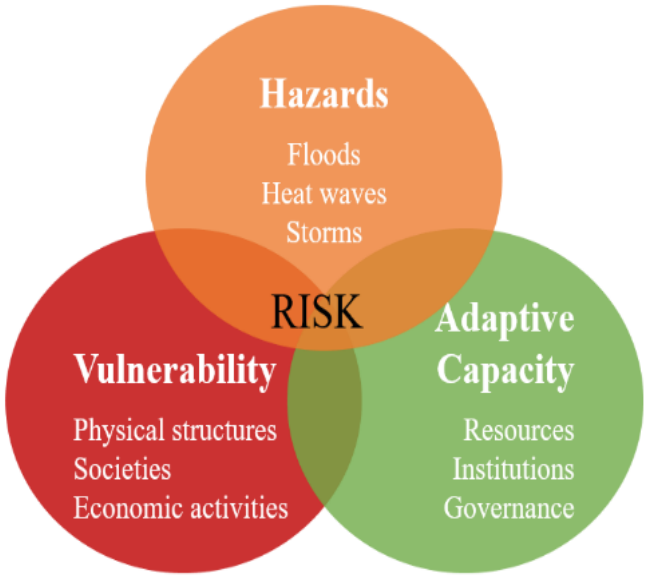

Figure 2 Urban climate change vulnerability and risk assessment framework, own elaboration based on Rosenzweig (2011)

The degree to which cities are put at risk by climate change depends on the actual climate hazards and the vulnerability of its structures. This relationship can be depicted from figure 2. A third element in this interaction represents the adaptive capacity of the city. The interplay of these three factors defines the degree of climate risk, since, if the adaptive capacity is high, meaning that sufficient social and financial resources are available and institutions and governmental structures are performing well, the climate change risk can be reduced.

To summarize, the climate change risk for cities depends on the severity of climate hazards, the vulnerability of its structures and the design and adaptive capacity of systems to confront these hazards (Rosenzweig 2011). In this context, comprehensive adaptation measures are commonly the product of a high adaptive capacity and aim at reducing the vulnerability of human systems and physical structures.

Therefore, it is of crucial importance for cities to implement strategies that improve their adaptive capacity in order to be able to develop effective adaptation measures that reduce

their vulnerability and the level of climate change related risk (Carter et al. 2015).

2.2.2 Principles of urban climate adaptation strategies

In order to lessen the severity of climate change related impacts and maintain the living quality of their inhabitants, cities need to deploy cross-sectoral measures as the climate change effects a wide range of urban sectors and city planners need to carefully integrate adaptation measures into development plans of key urban sectors. It is important to ensure that potential measurers fit their purpose, even though the actual benefit of a measures can usually only determined after being implemented (Climate Adapt 2020).

In order to guarantee the highest degree of effectiveness, certain guiding principles can be followed. It should be noted that when addressing the issue of climate change adaptation, the existing literature rarely distinguishes between adaptation in cities and adaptation in general. [4]The listed principles are to a great extent based on the principles and success factors given out by the *European Climate Adaptation Platform Climate-ADAPT*.

Broad stakeholder engagement

The elaboration of adequate adaptation measures requires a comprehensive understanding of the local needs and characteristics as cities differ in design, geographic location, climate and administrative structure resulting in a high degree of site specificity of the measures to be employed (Climate Adapt 2020). It is therefore considered to be crucial to engage all relevant stakeholders in a process of mutual knowledge sharing to guarantee that elaborated measures are based on a diversified set of opinions and expertise leading to the highest degree of quality in decision-making in the adaptation process (UKCIP 2007).

The value of an extensive stakeholder involvement is visualized in figure 3. It guarantees that eventual adaptation responses are backed by all affected entities, erases the risk of conflicting strategies and gives room for the identification of alternative options in case measures are feared to have constraining effects on other actions and policies (UKCIP 2007).

[4] Please note that the principles are of organisational, ecological or administrative nature. To get an overview of potential physical measures visit http://www.climateapp.org/

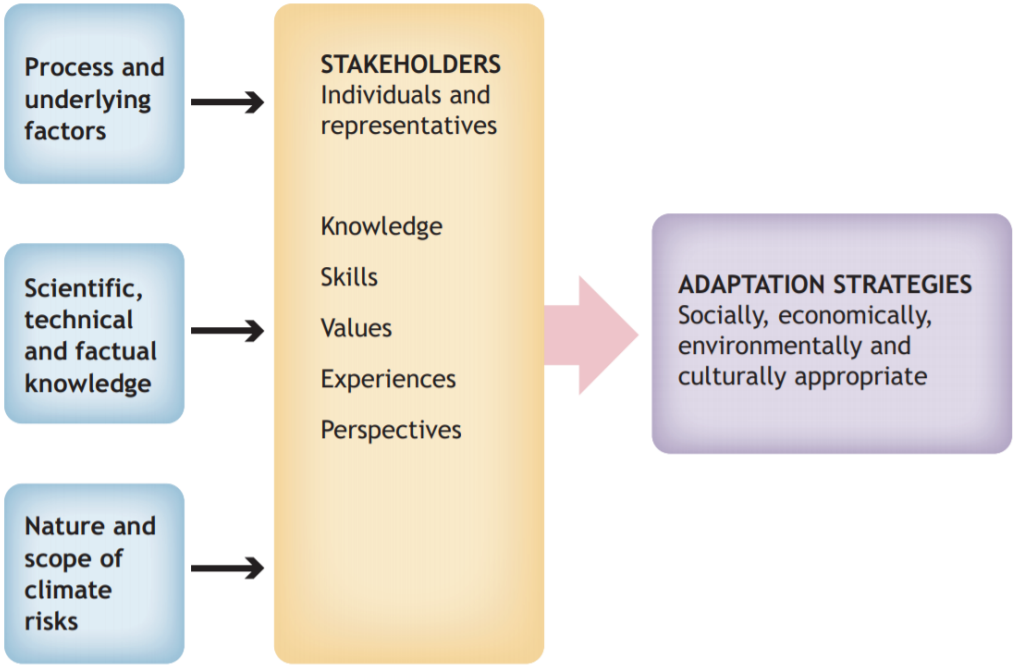

Figure 3 Stakeholder involvement in the adaptation process, Source: UKCIP (2007)

Addressing uncertainty

When deciding on adaptation measures, city planners have to bear the risk of implementing potentially expensive interventions while accepting a certain degree of uncertainty about the actual extent of climate change on the local level as existing climate models are commonly not downscaled to city level (Revi and Satterthwaite 2014). It has therefore been noted that "the complexities and uncertainties associated with climate change pose by far the greatest challenges that planners have ever been asked to handle" (Susskind 2010). It is evident that the formulation of comprehensive adaptation actions proves to be challenging when the actual extent of climate change impact and hence the adequate degree of adaptation is uncertain. For example, if the experienced impact will be less severe than projected, cities risk financial and image-related damages due to over-adaptation (UKCIP 2007).

In order to avoid inefficient adaptation action, it is advisable to implement so called "no or low regret options". These target the improvement of resilience towards a broad set of possible climate scenarios while simultaneously benefitting other relevant political goals (Brasseur et al. 2017). No regret options are cost-effective and useful irrespective of the

actual extent of climate change impact. Examples for no regret strategies include avoiding the construction of buildings in instable areas (e.g. flood plains) or designing buildings in a way that prevents overheating in summer months (UKCIP 2007). Low regret strategies on the other hand feature a certain degree of financial risk but their potential benefits are comparably large and thus justify their implementation. An example for a low regret strategy is the expansion of urban green spaces (ibid.).

Ensuring sustainability

There is a direct link between climate change mitigation and adaption as the more successful mitigation actions are, the less extensive adaptation actions need to be. It is therefore crucial that potential adaptation measures do not counteract mitigation policies through increased emissions. Likewise, a holistic approach of adaptation should be followed to avoid that adaptation measures of one sector negatively influence the adaptive capacity of another (Climate Adapt 2020).

Tailored to local situations

In order to optimally address the specific local need of adaption, adaptation measures should be tailored to the local circumstances as no "one-size-fits-all" solution exists (UNFCCC 2020b). For this reason, projected climate risks and vulnerabilities should be assessed carefully in order to develop strategies which incorporate the local specifics. Also, it is advisable to conduct a feasibility study of the intended adaptation measures by examining the available (social and financial) resources as well as the administrative set up (Climate Adapt 2020).

2.3 Barriers to climate change adaptation

2.3.1 Definition of barriers in the adaptation context

When talking about barriers, it is advisable to be certain of how barriers are defined in the adaptation context. While there is no universal one, several different scholars and institutions provide firm definitions (Adger et al. 2009; Amundsen et al. 2010; Moser and Ekstrom 2010). In their 5th Assessment Report, the IPCC (Klein et al. 2014) provides a broad definition and states that "an adaptation constraint represents a factor or process that makes adaptation planning and implementation more difficult."[5] This definition allows both internal factors (e.g. institutional capacity, financial resources) and external factors (e.g. environmental or locational factors) to be regarded as barriers to adaptation.

There exists an ongoing debate on whether external and hence mostly unalterable factors should be regarded as barriers or as limits (Preston and Stafford-Smith 2009) and since barriers to adaptation are mostly reported to be socio-economic, institutional or attitudinal factors (Biesbroek et al. 2013), locational factors will not be part of the further analysis in this study.

It is important to state that the occurrence of barriers does not make adaptation impossible but that they can be overcome via a sound mix of political effort, social support and sufficient resources (Adger et al. 2009). Limits to adaptation only exist when there are no feasible adaptation options that can be carried out over a certain time horizon and thus the affected system may not sustain under advancing climate change and hence will be altered (Klein et al. 2014). Likewise, the absence of certain barriers cannot be regarded as a sufficient condition for cities to engage in adaptation planning (Araos et al. 2016).

2.3.2 Barriers to urban climate change adaptation

As mentioned in the previous chapter, a multitude of different barriers to adaptation has been identified by earlier studies. These are often derived from small-n analyses or case studies and as a consequence, their universal significance is disputable, as they are highly actor and site specific (Eisenack et al. 2014). Furthermore, the categorization of barriers proved to be challenging and no clear indicators exist to analyse them (Biesbroek et al. 2013). Moser and Ekstrom (2010) difference between institutional, attitudinal, financial and political barriers while Biesbroek et al. (2011) provide a more thorough categorization and divide barriers into 7 types: (1) conflicting timescales, (2) substantive,

[5] In adaptation literature, the terms *obstacle*, *constraint* and *barrier* are commonly used as synonyms.

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. As the latter already defines actual barriers instead of super categories, the division by Moser and Ekstrom is employed in a slightly modified form (attitudinal and political factors are listed jointly) in the following in order to provide a comprehensive stockpile of the current knowledge about barriers to adaptation.

It should be noted, that a clear identification of barriers to adaptation is additionally aggravated by the fact that reported barriers commonly do not relate exclusively to climate change adaptation but generally constrain effective policy making (Eisenack et al. 2014). The amount of adaptation specific barriers is considered to be small. For example, Klein and Juhola (2014) name conflicting time scales to be an adaptation specific barrier as they require the willingness of the current generation to invest in measure which will benefit future ones. . However, it is out of the scope of this research to determine, whether barriers are unique to adaptation or also appear in other contexts.

2.3.2.1 Institutional capacity and organizational structure

"Institutions are the prescriptions that humans use to organize all forms of repetitive and structured interactions including those within families, neighbourhoods, markets, firms, sports leagues, churches, private associations, and governments at all scales" (Ostrom 2005, p. 3). Well working institutions are considered to be crucial for the successful development and implementation of adaptation policies. Likewise, low institutional capacity can have constraining effects on adaptation action and increase the vulnerability towards the impact of climate change (Oberlack 2017) as they are crucial to translate other factors such as financial resources or political will into effective measures and policies.

Despite the broad consensus on the importance of institutions in the scientific community, which aspects of institutional capacity are especially important is still under discussion (Klein et al. 2014). The identification of institutional barriers is an own field of research and requires thorough analyses. Frequently institutional capacity is assessed by pointing out qualitative attributes of the institutional capacity. For example, Oberlack (2017) conducted a meta-analysis on 52 case studies of public climate change adaptation in Europe in order to identify barriers and opportunities to adaptation. One of the results was

a new taxonomy of institutional aspects which are relevant for adaptation which can be depicted from figure 3. It shows, that the listed attributes are mostly of qualitative or organizational nature.

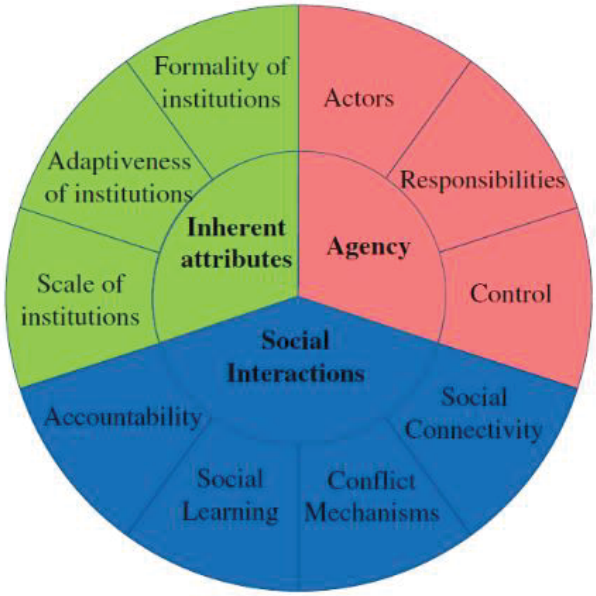

Figure 4 Taxonomy of institutional attributes in climate adaptation, Source: (Oberlack 2017)

The importance of efficient and clearly defined organizational structures is also highlighted by Amundsen et al. (2010) as they state that unclear responsibilities can substantially constrain adaptation processes as actors consider the responsibility to develop adaptation measures to reside on superior decision levels resulting in the absence of a coordinated adaptation process. This problem of unclear responsibilities is further confirmed by Rotter et al. (2016) as well as Brasseur et al. (2017).

Besides unclear roles in the adaptation process, lacking expertise on the local level has been frequently reported to constrain adaptation since local actors are overchallenged with the planning process due to missing qualification of employees (Massey et al. 2014). While the information and skill level of staff can be enhanced via the employment of targeted measures, certain limits exist regarding the availability of information on the local level. As adaptation measures need to be tailored to local needs in order to ensure maximum fit and effectiveness, the actual extent of climate change impact on the local level is often unknown. This observation was reported by Amundsen et al. (2010) who surveyed mayors in Norway regarding adaptation planning in their municipalities and 93% of the mayors stated that they would need better information on the actual climate change impact in their region in order to decide on adequate measures.

Hence, the development of comprehensive strategies is challenging if the actual target and thus the needed degree of adaptation is unsure (Brasseur et al. 2017). As a potential option to increase the capacity on the local level to cope with the administrative challenges, Ekstrom and Moser (2014) as well as Lehmann (2013) recommend to raise the number of employees in local authorities. The issue of insufficient human resources

is also picked up by Eisenack and Stecker (2010), who argue that adaptation might be constrained if the necessary means (both capacity and budget) for the adaptation process are not available. In addition, Eisenack et al. (2014) mention that the insufficient capacity of local actors to cope with the challenges of climate change adaptation results from lacking top-down support. If superior actors provided solid support for adaptation action, the capacity of local structures would be improved. Likewise, they add for consideration that excessive involvement from higher levels might have discouraging effects on leadership on the local level.

2.3.2.2 Financial Resources

Adaptation to climate change requires the investment into measures, whose exact benefit is uncertain and will mostly be experienced by future generations. If financial resources are scarce, adaptation processes might be delayed as actors want to avoid malinvestments and do not allocate sufficient budgets for adaptation action (Amundsen et al. 2010).

This assessment is supported by Eisenack and Stecker (2010) who, argue that adaptation might not happen in case that necessary means are not available due to budgetary constraints even though actors are well aware of the need to adapt.

While the absence of financial resources is especially relevant for developing countries, this also might be the case for certain cities in industrialized countries. Nevertheless, in this case it is likely that the financial constraint is occurring not due to a complete absence of financial resources but rather due to a disadvantageous allocation of available budgets for adaptation action (Eisenack et al. 2014). Furthermore, budgetary constraints might not only be caused by the individual financial situation of a city but due to a general extensive financial crisis (ibid.).

The actual importance of financial resources in developed countries for adaptation planning respectively which aspects of the financial situation of a city play a key role is still under debate. For example, Reckien et al. (2015) articulate that high public costs constrain adaptation planning on the local level in Norway and Australia but does not seem to affect adaptation action in the US, where aggregated personal income and poverty rates are more substantial impediments than the financial situation of the city.

2.3.2.3 Attitude and political will

In their paper on an action theory of adaptation, Eisenack and Stecker state that in some situations "there is no operator due to complete ignorance of impacts. In this case, not even the necessary means for adaptation are known(Eisenack and Stecker 2010, p. 8)." Hence, adaptation might not happen if the responsible decision makers lack the necessary degree of problem awareness even though the necessary budgetary or capacity means are available. One explanation for lacking problem awareness can be, as described earlier, an insufficient knowledge of local actors about climate change impacts and potential measures due to missing top-down support (Eisenack et al. 2014; Ekstrom and Moser 2014).

Nevertheless, the cause of the missing expertise can be diverse. On the one side, there are certain limits to the degree of knowledge local decision makers can have on climate change impact and applicable adaptation measures. On the other side, adaptation might be constrained if actors deliberately ignore the problem of climate change due to political agendas or social habits (Eisenack and Stecker 2010).

Another factor which can have potentially negative implications for the attitude of actors towards adaptation action are conflicting time scales. As mentioned before, adaptation measures can sometimes incur high costs today, but their benefits will only become apparent in the future. For those affected and decision-makers, the question therefore arises as to when in the future the benefits will become noticeable or how far these measures can be postponed. Private investors, politicians, public administrations and households may weigh up these issues differently.

In general, the question is one of economic or political incentives for forward-looking adaptation action (Brasseur et al. 2017). The importance of an adequate attitude among decision makers is also affirmed by Reckien et al. (2018) who compared climate action among over 800 European cities and identified lacking political will as a factor which constrains adaptation efforts.

2.3.3 Interdependencies among constraining conditions

One of the goals of this study is not only to determine how individual factors hamper the development of adaptation plans in Germany but also to investigate whether there exist any possible conjunctions among barriers. As previously mentioned, hardly any

literature exists on this issue but scholars recommend more research on the topic making the formulation of theoretical expectations regarding conjunctions challenging.

Nevertheless, certain interdependencies among the constraining conditions presented in chapter 2.3.2 can be determined by analysing general theoretical assumptions about the included factors.

Firstly, it is commonly reported that a connection between a low institutional capacity and low economic performance/unfavourable financial situation exists since poorly governed entities tend to lack efficiency and are consequently characterized by hampered economic development (UNDP 2011). It is likely that affluent cities rather have the resources to employ designated experts and create targeted working groups which can adequately address the issue of climate change adaptation and thus increase their adaptive capacity better than comparably poor cities (Thathsarani and Gunaratne 2018).While this mainly refers to the quality of institutions, it also seems conclusive that wealthy cities are able to employ more staff. As a result, the assumption could be made that the barriers of lacking institutional capacity and lacking financial resources commonly occur in conjunction.

Furthermore, a certain interdependence between the income level of people and their electoral decision can be determined. The analysis of the electoral behaviour of the German population shows that voters of the *Green Party* tend to have an income level above the national average (BPB 2018b). Assuming that voters of the *Green Party* have a generally positive attitude towards climate policies, it is likely that a positive correlation between a high economic performance (high GDP) and a positive attitude exist. Likewise, voters of climate sceptical parties such as *AfD* generally have lower income levels than the national average. Therefore a low economic performance is likely to coincide with a comparably negative attitude of the population towards climate policies (BPB 2018a).

Summarizing the above it can be stated that certain interdependencies between the affluence of a city and its institutional capacity as well as the attitude of its inhabitants towards climate policies are likely. Their importance for this research is further evaluated during the hypothesis formulation in chapter 4.6.

2.4 Summary of the chapter

Due to the "Heat-Island Effect" and the high degree of sealing, urban areas are particularly vulnerable to increased heat and heavy rains. Due to these specifics, it is crucial for the livelihood of its inhabitants that cities develop holistic, integrative and sustainable adaptation strategies. Nevertheless, as outlined by a multitude of researchers, numerous potential barriers exist on the way to achieving successful adaptation planning.

Cities might not possess the necessary institutional capacity to combine political will and available resource into comprehensive strategies.

In addition, unclear responsibilities in the adaptation process or insufficient support from higher governance levels can hamper the development of strategies.

In case a city is in a challenging financial situation, adaptation measures might be delayed since they are potentially expensive, and the scarce financial resources could be allocated for other fields of action.

Lastly, even when financial and institutional barriers do not occur, it is essential that decision makers feature the needed degree of attitude in order to initiate the required steps for developing adaption strategies.

Some of these barriers are also likely to occur in conjunction since an unfavourable economic environment is commonly associated with a lower institutional capacity and rather negative attitude towards climate policies.

The retrieved barriers from literature form the basis for formulating the conditions that are integrated in the later analysis in order to determine barriers to urban climate change adaptation planning in Germany.

3. Case description

3.1 Objectives of this chapter

The goal of this chapter is to provide the necessary contextual information on the present case which is climate change adaptation in Germany. Therefore, the most recent climate change predictions for Germany are outlined in order to comprehend the need to develop adaptation strategies in Germany. Thereinafter, the adaptation efforts on the federal, *Länder* and municipal level are explained while lastly, the characteristics of the 40 cities which were selected for the analysis are presented according to their number of inhabitants, GDP per capita, share of student, employees in the city administration and if they possess an adaptation strategy or not.

3.2 Climate change in Germany

3.2.1 Air temperature

Analogously to the global development, the average temperature in Germany has risen significantly over the past decades. Figure 5 depicts the deviation of individual years from the long-term mean (1961-1990). Since 1985 all years, apart from two exceptions, deviated significantly positive from the long-term mean (1961-1999). The linear trend of this development indicates that between 1881-2019 the average temperature in Germany has risen by 1.6 °C. This is a notable observation because Germany is heating up distinctly faster than the global average, where temperature has risen by approximately 1 °C since 1881 (NASA 2020) .

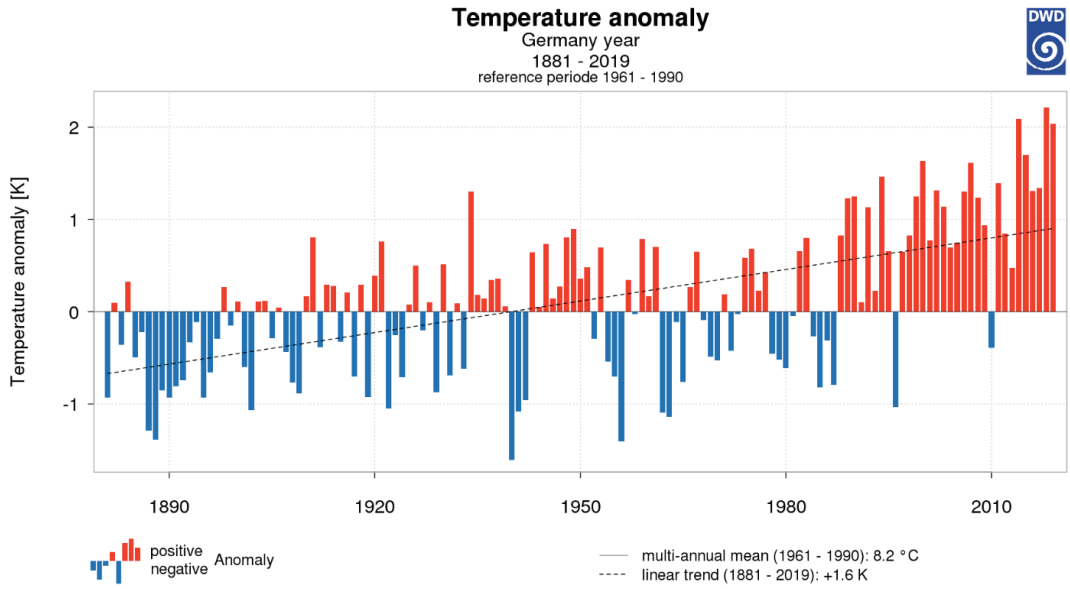

Figure 5 Temperature anomalies in Germany for the period 1881 to 2019, Source: DWD (2020b)

With an average temperature of 10.3 °C, 2019 was the second warmest year in Germany (warmest year: 2018, 10.5°C) since the beginning of systematic climate observation in 1881. Furthermore, 9 of the 10 warmest years since 1881 were within the last 20 years (Kaspar and Friedrich 2020). Alongside this development, also the number of so called "hot days" has been rising constantly. While from 1961-1990 the average number of hot days per year accounted between 0 and 14 (depending on the region), the number rose up to 27 in 2019. In the record year of 2018, some region of Germany even recorded up to 43 hot days (DWD 2020a).

The regional differences of temperature anomalies from the long-term mean in 2019 within Germany can be observed in figure 6. It shows that especially the Eastern and South-Eastern parts were significantly warmer in 2019 than the rest of the country and that temperatures were at a minimum 1.3 °C and at a maximum 4.5 °C higher than the long-term mean. The long-term linear trend of the annual mean temperature (which is not depicted by an extra figure here) however reveals that the Southern and Western Federal States recorded the highest warming while the Northern Federal states as well as Berlin and Brandenburg are warming at the lowest speed.

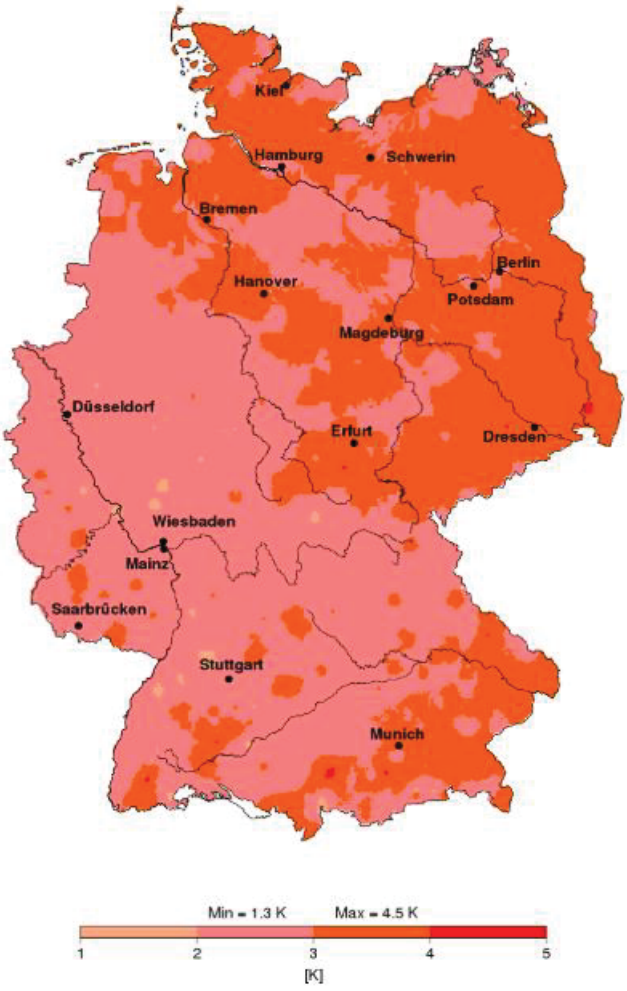

Figure 6 Temperature anomalies in Germany in 2019 with respect to the 1961-1990 normals, Source: (DWD 2020)

Regional differences in warming are relatively small as they span from 1.3 °C to 1.6°C (Umweltbundesamt 2019a). In principle, this also applies to the different meteorological seasons. Only in spring (March to May) does the value deviate slightly from the different seasons with an area average of 1.6°C, while for the rest of the year the average is 1.5°C (Kaspar and Friedrich 2020).

To summarize briefly, climate change has already significantly changed the air temperature in Germany. The further development of the German mean air temperature will depend on how successful international mitigation policies will be implemented. Between 1961 and 1990 the average temperature in Germany was 8.2°C. Figure 7 displays the potential future development of temperature averages in Germany. The different coloured lines represent different climate scenarios which are applied by the German Weather Service (DWD).

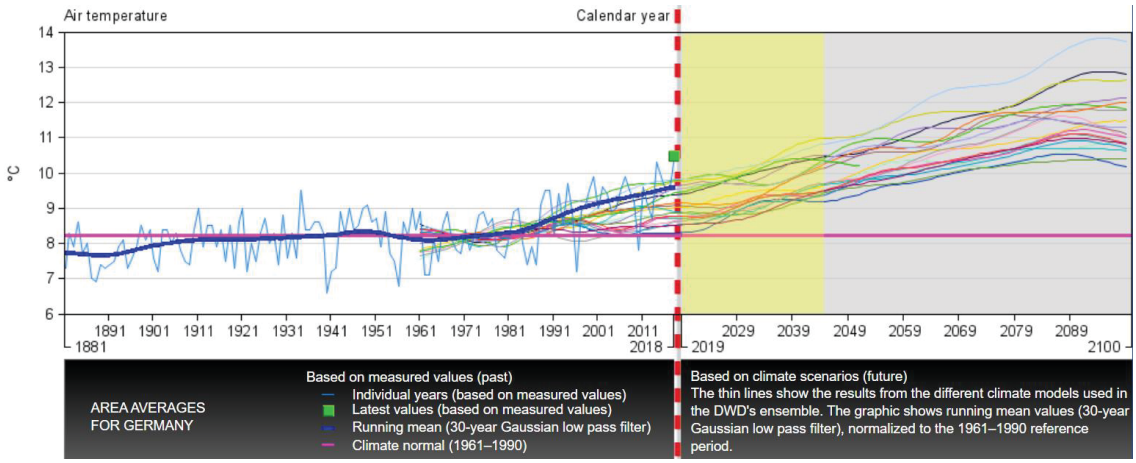

Figure 7 Temperature development in Germany according to DWD climate scenarios, Source: DWD (2020a)

The scenarios predict a rise to slightly over 10°C (~1.8°C rise compared to 1961-1990 levels) up until almost 14°C (~5.8°C rise compared to 1961-1990 levels) by 2010. It should be emphasized that these temperature increases relate to temperature averages of the period between 1961 and 1990 and not to the commonly used “preindustrial times” when referring to changes in global mean temperatures.

3.2.2 Precipitation

The development of precipitation in Germany since 1881 is depicted in figure 8. The linear development has been slightly positive over the past decade and the average annual precipitation per year has risen by 66.1 mm or 8.7% between 1881 and 2019. While the regional and seasonal differences in mean air temperature rise are minor, there are distinct regional and seasonal differences for the development of annual precipitation in Germany. For the summer months, rainfall has been slightly decreasing since 1881 (linear trend: - 9.1mm or – 3.8%) whereas the winter months have gotten significantly wetter

(linear trend: + 45.3 mm or + 25%) (Umweltbundesamt 2019a).

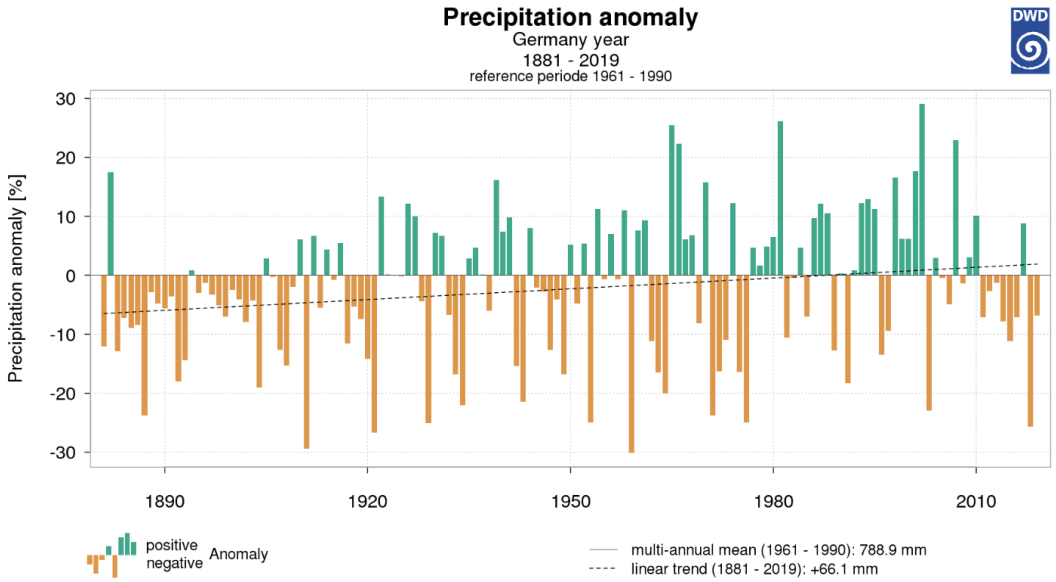

Figure 8 Precipitation anomalies in Germany for the period 1881 to 2019, Source: DWD (2020b)

The changes in rainfall also vary among the different regions of Germany as the Northern states experience an distinct increase in annual rainfall (linear tend for Schleswig-Holstein: +16%), the precipitation rate in Mecklenburg-Western Pomerania, Thuringia and Saxony-Anhalt rose by less than 10% and Saxony even experienced a slight decrease in rainfall (Ibid.).

Despite the general trends of increasing rainfall in Germany, the years 2018 and 2019 were extraordinary dry. 2018 for instance only reached 74.3% of the multi-year mean precipitation sums of 1961-1990, which was 202.6 mm too dry compared to this reference period. As the fourth driest year since 1881, it is classified as an extremely dry year in the climate time series (Umweltbundesamt 2019c).

As for temperature, there are also different climate models which are employed by DWD in order to predict the future development of precipitation patterns in Germany. As can be seen in figure 9, the general trend of increasing rainfall is likely to increase until 2100. However, it is likely that, analogously to the historic development, there will be significant local and seasonal differences in the development of rainfall which are not represented in the climate models.

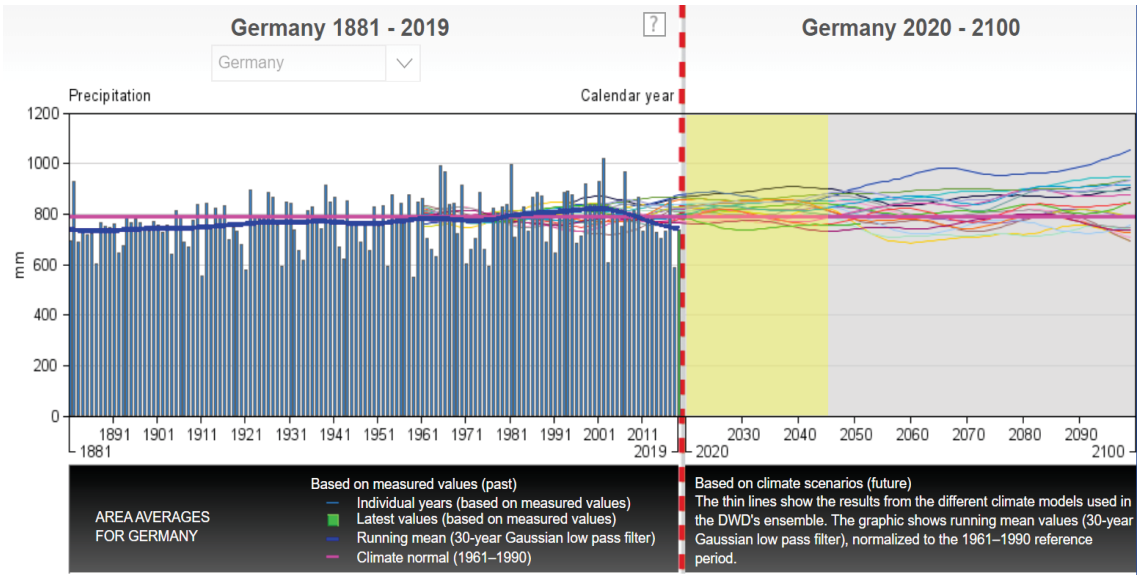

Figure 9 Precipitation projections for Germany according to DWD climate scenarios, Source: DWD (2020a)

3.2.3 Implications

The projected climate changes in Germany will have implications for all kinds of human and environmental systems. In the urban context, one of the key results of the expected rise in mean temperature and number of "hot days" will be an amplification of the previously described "heat-island effect" leading to an increased risk of heat related casualties in urban areas (Kneist 2019). In addition, the frequency of heart waves, where the average daily maximum temperature exceeds 30°C for 14 consecutive days, will rise in the future. The more southern a city is located in Germany, the higher the risk of facing frequent heat waves. Nevertheless, also northern German cities are likely to face more heat waves, as Hamburg for instance did not experience any heat wave until 1994 but already five since then(Umweltbundesamt 2019a).

As mentioned in chapter 1, in 2018 Germany was among the three countries in the world that recorded the highest insured losses due to extreme weather events (Germanwatch 2020). While 2018 was without a doubt an extreme year, the DWD predicts that extreme weather events such as storms and heavy rain will occur more frequently in the future as the air can absorb 7% more water per degree of warming (BR 2019). As a consequence, precipitation patterns in Germany will become less consistent but instead more scattered and intense.

3.3 Adaptation planning in Germany

3.3.1.1 Federal level

Germany adopted a national climate change adaptation strategy ("Deutsche Anpassungsstrategie an den Klimawandel-DAS") in 2008, which represents the fundamental document for adaptation in Germany. In it, the long-term impact of climate change on Germany is projected and necessary steps are mentioned to implement adaptation measures timely and prescient. It highlights the implications for a range of action fields and provides potential courses of action. Furthermore, the *DAS* promotes the "mainstreaming" of adaptation, hence the consideration of adaptation aspects in decision making processes of all relevant fields of action.

The DAS also emphasises the principle of subsidiarity, which refers to the shared responsibilities between the federal, *Länder* and local authorities. The federal system places special governance requirements on the vertical integration of adaptation policy. To ensure an efficient coordination between the different governance levels, a standing committee on climate change adaptation was set up (Brasseur et al. 2017).

The implementation of the DAS takes places by reference to four fields of activity (Umweltbundesamt 2018):

1. **Implementation of adaptation measures:** By adopting the "action plan adaptation" the German government backs up the targets and courses of action defined in the DAS with specific activities of the federal government and the *Länder*. The action plan also provides financial support for adaptation measures.
2. **Dialogue and participation processes:** In order to secure ownership and transparency, an extensive and interdisciplinary dialogue and participation process was initiated as early as the strategy development phase.
3. **Pooling of knowledge:** In order to be able to provide administration, businesses and citizens with information and decision-making aids, as much knowledge as possible about climate change and its consequences is necessary.
4. **Evaluation of strategy and measures:** After the first adaptation measures to climate change have been implemented, the adaptation strategy and adaptation in the individual fields of action will be evaluated on the basis of indicators.

Apart from the overarching adaptation strategy, the national government provides a set of tools which shall facilitate climate change adaptation in Germany. As a central hub for

adaptation action functions the competence centre for climate impact and adaptation ("KomPass"). It provides an online directory ("Klimalotse") which shall support cities and municipalities with the development or simple or comprehensive adaptation strategies[6], a collection of best practice examples ("Tatenbank") which shall provide decision makers with ideas for effective adaptation measures[7] as well as a search engine for adaptation related literature (Umweltbundesamt 2019d). In addition to these tools, 2 monitoring reports on the implementation of the DAS were issued so far which evaluate the progress in adaptation regarding the relevant fields of action in the adaptation context (Umweltbundesamt 2019a).

3.3.2 *Länder* level

While the adaptation efforts on federal focus on the provision of guidance, funding and information, the *Länder* are responsible for outlining priorities and forming the regulatory framework in which adaptation takes place (Massey et al. 2015). Due to the regional difference in extent of climate impact and the resulting high site specificity of adaptation measures, states are required to individually elaborate comprehensive adaptation strategies which are tailored to the specific local and regional circumstances (Bundesregierung 2008; Umweltbundesamt 2011). The extent of adaptation action in Germany is therefore highly dependent on the specific policies and targets of the respective *Länder* (Lorenz et al. 2017).

Table 1 depicts the extent of adaptation strategies on the *Länder* level in Germany. As can be seen, there are significant differences as some *Länder* feature long and comprehensive strategies (e.g. Bavaria, Berlin, Bremen, Thuringia) while others are comparably simple (Hamburg, Brandenburg) and 4 federal states (Mecklenburg Western Pomerania, Rhineland Palatinate, Saarland and Saxony) have not developed an integrative adaptation strategy yet[8]. However, even though some states do not possess a distinct adaptation strategy, they still might be active in certain regional or sectoral contexts. For example, Mecklenburg Western Pomerania developed an adaptation strategy for forests[9] while Rhineland Palatinate set up a competence centre for climate

[6] „Klimalotse" Website: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse#Einf%C3%BChrung
[7] „Tatenbank" Website: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/tatenbank
[8] As of November 2019
[9] https://www.regierung-mv.de/Publikationen/?processor=veroeff&id=2890

impacts.[10] Furthermore it can be seen, that most strategies were developed comparably recently between 2015 and 2019 and that older strategies tend to be less extensive than recent ones.

Table 1 Adaptation strategies of federal states in Germany, Source: Appendix I

State	Name of adaptation strategy	Number of pages	Fields of action	Year
Baden Wurttemberg	Strategie zur Anpassung an den Klimawandel in Baden-Württemberg	166	9	2015
Bavaria	Bayerische Klima-Anpassungsstrategie (BayKLAS)	205	15	2016
Berlin	Anpassung an die Folgen des Klimawandels in Berlin	190	9	2016
Brandenburg	Maßnahmenkatalog zum Klimaschutz und zur Anpassung an die Folgen des Klimawandels	7[11]	-	2008
Bremen	Klimaanpassungsstrategie Bremen und Bremerhaven	135	12	2018
Hamburg	Aktionsplan Anpassung an den Klimawandel	13	9	2013
Hessen	Strategie zur Anpassung an den Klimawandel in Hessen	67	13	2012
Lower Saxony	Klimapolitische Umsetzungsstrategie Niedersachsen	60[12]	16	2013
Mecklenburg Western Pomerania	***No integrative adaptation strategy***	-	-	-
North Rhine Westphalia	Klimaschutzplan Nordrhein-Westfalen Klimaschutz und Klimafolgenanpassung	54[13]	16	2015
Rhineland Palatinate	***No integrative adaptation strategy***	-	-	-
Saarland	***No integrative adaptation strategy***	-	-	-
Saxony	***No integrative adaptation strategy***	-	-	-
Saxony Anhalt	Strategie des Landes zur Anpassung an den Klimawandel	121	18	2019
Schleswig-Holstein	Anpassung an den Klimawandel Fahrplan für Schleswig-Holstein	57	8	2017
Thuringia	Integriertes Maßnahmenprogramm zur Anpassung an die Folgen des Klimawandels im Freistaat Thüringen	168	12	2019

[10] http://www.klimawandel-rlp.de/de/start/
[11] The whole consists extent of 24 pages but only 7 deal with adaptation and the rest with mitigation.
[12] The whole strategy consists of 90 pages but only 60 deal with adaptation and the rest with mitigation.
[13] The whole strategy consists of 311 pages but only 55 deal with adaptation and the rest with mitigation.

3.3.3 Municipal level

While adaptation efforts on the national and *Länder* level intend to create a supportive environment, the municipalities are responsible to ensure the actual implementation of practical adaptation measures. As there is no legal obligation to elaborate adaptation strategies, this calls for a high degree of personal initiative and a regional focus (Bardt 2005). Consequently, municipalities in particular are considered to be central actors in adapting to climate change, since on the one hand they are particularly affected but on the other hand, due to their many competences and their proximity to citizens, they also bear a special responsibility in dealing with climate change and its consequences (Brasseur et al. 2017)

In comparison to other European cities, Germany is considered one of the top runners in terms of adaptation to climate change (Massey et al. 2015). When analysing local climate action in Europe, Reckien et al. (2018) determined that among the German cities which were included in the study (n=125), 24.8% had developed an adaptation plan. Among the other countries, where the elaboration of adaptation plans is not required for cities by national law, only Finland featured a higher share of cities with adaptation plans.[14] Also the samples for France, the UK and Sweden featured higher shares of cities with adaptation plans but in these countries national legislation requires cities to elaborate mitigation and adaptation plans.

3.4 Characteristics of the selected cities

In the course of this study, a sample of 40 German cities is analysed. They were carefully selected in order to create a diversified image of the German urban landscape. The sample includes mostly large and medium-sized cities from every federal state. The following part outlines their main characteristics which are relevant for the subsequent analysis.

3.4.1 Population

Figure 10 depicts the distribution of cities according to their number of inhabitants. The included cities are medium-sized and large cities whose number of inhabitants ranges from approximately 60,000 (Frankfurt an der Oder) to around 3.5 million (Berlin) while the median is 261,800. Combined, the cities represent 18.2 million or approximately 22% of the German population.

[14] It should be noted that only 7 Finish cities were included in the analysis.

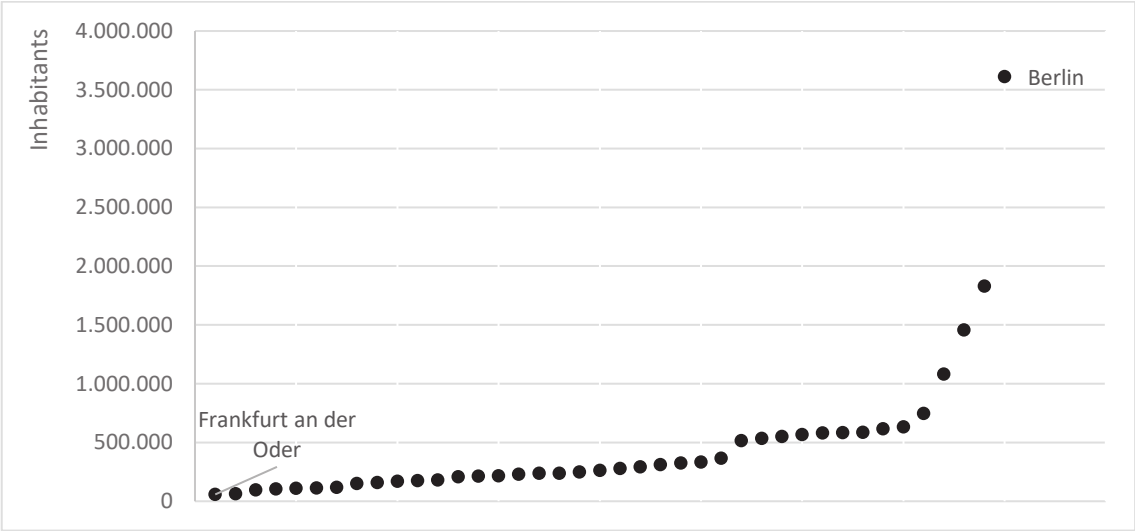

Figure 10 Number of inhabitants of selected cities, Source: Appendix I

3.4.2 Economy

As can be seen in figure 11, the average GDP per capita (2007-2009) varies widely among the selected cities since values in the cities with the highest GDP per capita (Düsseldorf, Regensburg and Frankfurt am Main) are more than three times higher than in the cities with the lowest GDP (Moenchengladbach, Weimar). The values range from around €20,000 (Moenchengladbach) to over €75,000 (Frankfurt am Main), while the median value is €35,400 and the mean €38,330. Thus, the GDP per capita in the selected cities is higher than the national average which was €30,926 per capita between 2007 and 2009 (Statista 2020b). This can be explained by the fact that there is a strong correlation between number of inhabitants and GDP per capita since most of the economic activities takes place in medium-sized and large cities.

In 2015, German cities with more than 500.000 inhabitants had on average a 70% higher GDP per capita than the national average while cities with more than 100.000 inhabitants still featured a 55% higher GDP than the national average (IWD 2017). As the sample of selected cities is mostly compromised of cities with over 100.000 inhabitants, unsurprisingly their GDP per capita is higher than the German average.

Furthermore, a discrepancy between western and eastern Germany cities can be observed as 7 of the 10 cities with the lowest GDP are located in the former GDR and the average GDP per capita of Western German cities in the sample (€ 42,675) is approximately 55% higher than the average GDP per capita in their Eastern German counterparts (€ 27,518).

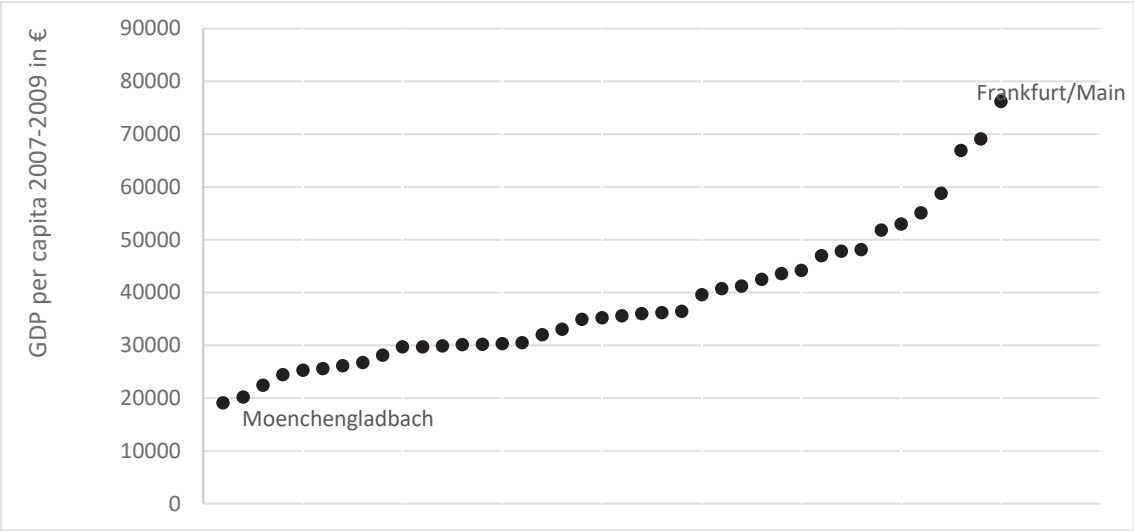

Figure 11 GDP per capita of selected cities, Source: Appendix I

3.4.3 Education

As displayed in figure 12, most of the selected cities are university cities. Only Schwerin does not have a public university or university of applied sciences ("Fachhochschule"), whereas in cities like Göttingen or Darmstadt, students account for almost 30% of the whole city population. On average, the selected cities (excluding Schwerin) have a share of students of 11% while the median value is 9%.

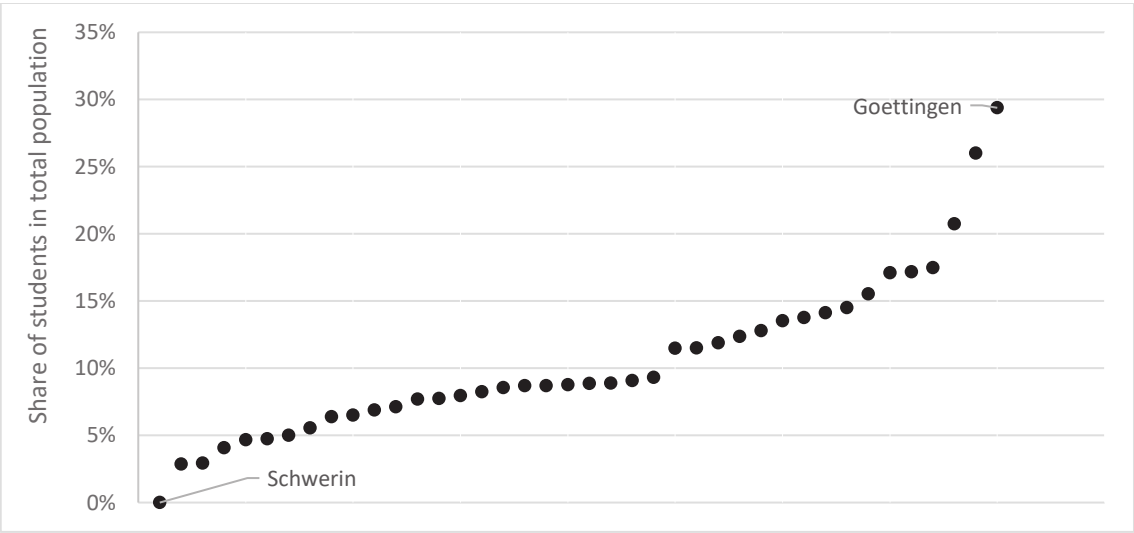

Figure 12 Share of students in total population of selected cities, Source: Appendix I

3.4.4 Politics

Figure 13 depicts the strength of the green party in 2014 per city. Since the dates for municipal elections vary among federal states in Germany, it only provides a snapshot of how strong the green party was represented in city governments in 2014 while the election might have happened earlier. As can be seen, the green party is least represented in

Frankfurt/Oder (6%, 2014 election) while it received its strongest result in Darmstadt (33 %, 2011 election). Among the 40 cities, the average is 15.6% while the median is 15.25%. Thus, on average the green party is almost twice as strong among the selected cities than in the federal election in 2013 (8.4%) (Tagesschau 2013).

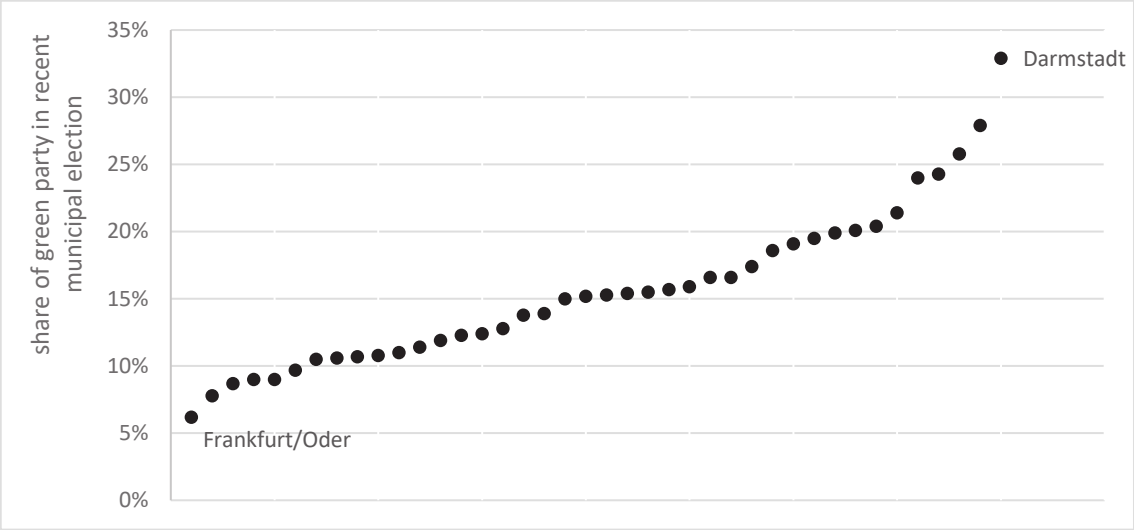

Figure 13 Share of green party in city government in 2014, Source: Appendix I

3.4.5 City administration

Figure 14 depicts the ratio between employees in the city administration and the number of inhabitants of the specific city. The higher the value, the more inhabitants there are for an employee in the city administration. As can be seen, there exist significant differences among the selected as, in relation to its population, Bremen employs over 5 times more staff in its city administration than Magdeburg. On average, the ratio between inhabitants and employees in the city administration among the selected cities is 54:1 while the median is 55:1.

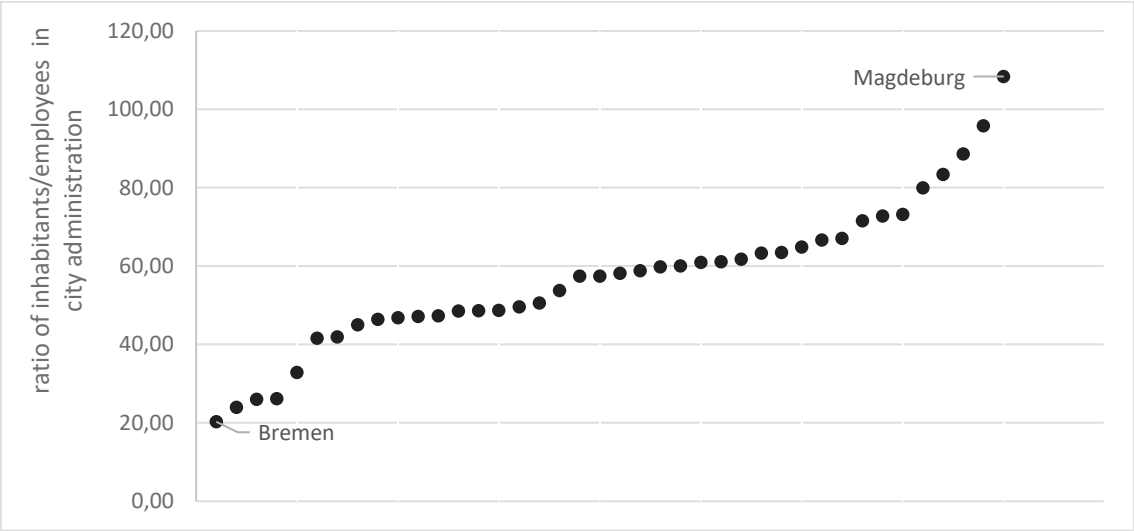

Figure 14 Ratio of inhabitants of a city/employees in city administration, Source: Appendix I

3.4.6 Adaptation strategies

As outlined earlier, in Germany there is no legal obligation for cities to elaborate adaptation strategies but cities are encouraged to autonomously develop the necessary adaptation measures. Table 2 shows that 20 out of the 40 cities from the sample have an adaptation plan.[15] The 20 cities while are listed here under "no adaptation plan" might still address the topic of climate change adaptation but did not yet elaborate a distinctive adaptation strategy which includes concrete practical measures (the reader can find more information on how documents were retrieved in Chapter 4 and in the Appendix).

Out of the 20 documents, 16 were adopted between 2012-2016. Likewise, the oldest documents originate from 2012 (Nuremberg, Dresden, Saarbruecken, Stuttgart, Bochum) while the newest document is from 2019 (Freiburg). The issue year of an adaptation strategy however cannot be equated with the first year cities addressed the issue of climate change adaptation as the current documents might be extension of preceding strategies. For example, the city of Karlsruhe already released an adaptation strategy in 2008 but revised this document and adopted its current strategy in 2013.

The extent of the adaptation strategies also varies distinctly among the selected cities. While the documents of the adaptation plans of cities like Bochum, Potsdam and Dresden have more than 200 pages, those of Göttingen (25), Frankfurt/Main (19) and Hamburg (13) are comparably brief. However, a large number of pages does not necessarily indicate a detailed adaptation strategy, as, for example, the adaptation plan of the city of Freiburg

[15] As of November 2019

comprises almost 200 pages but merely deals with the issues of heat while the strategy of Stuttgart only has half the number of pages but provides an extensive cross-sectoral overview about climate change implications and advised practical measures.

Table 2 Presence of adaptation strategies on city level, Source Appendix I

Adaptation strategy	Year	Pages	Fields of action	No adaptation strategy
Berlin	2016	191	7	Augsburg
Bochum	2012	214	3	Bielefeld
Bremen	2018	140	5	Bonn
Cologne	2013	148	7	Darmstadt
Dresden	2012	281	6	Dortmund
Dusseldorf	2017	132	11	Erfurt
Essen	2014	173	5	Frankfurt/Oder
Frankfurt/Main	2014	19	6	Halle/Saale
Freiburg im Breisgau	2019	196	1	Kiel
Goettingen	2015	25	2	Koblenz
Hamburg	2013	13	9	Magdeburg
Hannover	2018	117	4	Mainz
Karlsruhe	2013	224	15	Moenchenglabdach
Leipzig	2016	36	5	Moers
Munich	2016	144	5	Muelheim an der Ruhr
Nuremberg	2012	93	3	Regensburg
Potsdam	2015	281	10	Rostock
Saarbruecken	2012	130	2	Trier
Schwerin	2016	200	3	Weimar
Stuttgart	2012	75	10	Wiesbaden

3.5 Summary of the chapter

As shown in this chapter, climate change will also have severe implication for Germany due to the projected rise in mean surface temperature and a higher frequency of heavy rain events and storms. The federal government is aware of this problem and provides a wide range of different tools and instruments which shall enhance the development of local adaptation plans. Nevertheless, cities are not required by law to develop adaptation strategies and among the selected 40 cities 20 do not possess a comprehensive adaptation strategy and four federal states even lack an integrated adaptation plan.

4. Materials and methods

4.1 Objectives of this chapter

To identify barriers to urban adaptation planning in Germany, the method "Fuzzy-Set Qualitative Comparative Analysis (QCA)" is employed in this study. The following section outlines its core principles and explains, why this method was considered suitable for the intended research approach. Thereinafter, it is explained how the available data and case knowledge is used in order to come up with the conditions and measures for the *QCA* and how the data collection was conducted. Lastly, the calibration process of the sets for *QCA* is defined and subsequently it is intended to formulate a hypothesis based on the theoretical knowledge from chapter 2 and the case knowledge from chapter 3.

4.2 Qualitative Comparative Analysis

4.2.1 The principles of QCA

The *QCA* method was first introduced by Charles Ragin in 1987 and represents a technique of data analysis which aims at revealing all logical conclusion a set of variables upholds (Ragin 1987). It can be both a research approach and a technique for data analysis. In their book on set-theoretic methods in social science, (Schneider and Wagemann 2012a, p. 13) state that "the plausibility of findings from a *QCA* as a technique much depends on the quality of the work done before and after the analysis, i.e., QCA as a research approach".

After initially being mostly applied in macro sociology it has been successfully established in a wide range of economic, social and environmental sciences and employed by a growing number of researchers in recent years ((Short et al. 2019; Mondal et al. 2019; Pagliarin et al. 2019; Ma et al. 2019).[16] *QCA* is not a fixed static method but there exist a variety of different approaches and variants. Consequently, several scholar dedicated themselves to investigating its adequate implementation resulting in a large number of books and journal articles that circle around this issue (Schneider and Wagemann 2012b, 2012a; Berg-Schlosser et al. 2009; Basurto and Speer 2012). Especially Schneider and Wagemann have published a multitude of studies and manuals on *QCA* and in the following sections, their publications are frequently used to outline the principles of *QCA*.

[16] The COMPASS group library at Zotero.org lists wide selection of papers which employed QCA. For more information visit https://www.zotero.org/groups/510780/compasss/library

As the name indicates, *QCA* acknowledges the importance of qualitative research and case studies but gives room for comparability by allowing a certain degree of theorization and generalization. It can be seen as a middle way between qualitative and quantitative research as it combines features of both approaches (Sehring et al. 2013). It permits the investigation of complex causality, numerous conjunctural causation (=Combinations of conditions produce an, equifinality (an outcome can be explained by more than one combination), asymmetry (Presence of a condition for Y does not imply absence of that condition for ~Y), and can render substantial outcomes utilizing smaller samples than different techniques (Verhoeven 2016).

4.2.2 Set calibration

Assigning membership scores is crucial for every set-theoretic method and thus also for implementing QCA. In order to be able to properly assign adequate membership scores, empirical information on the case are collected and analysed (Blatter et al. 2007).

There are two major ways of determining membership scores: crisp sets and fuzzy sets. In crisp sets, membership can only be either completely in (1) or completely out (0). This dichotomization allows a comparably easy analysis but lacks rigor since, while certain real-world problems might be truly dichotomous, many are not.

Fuzzy sets on the other hand take up the problems which come with the dichotomization in crisp sets and assign a certain degree of membership, meaning a case could be for example “definitely in (1)”, “more in than out (0.66)”, “more out than in (0.33)” and “definitely out (0)”.

The two different approaches of assigning set membership also give name to the two major variants of QCA: Crisp-Set QCA and Fuzzy-Set QCA. Since the dichotomization of numeric socio-economic data, which is used later in the analysis, could lead to an oversimplification and potentially meaningless results, this thesis employs fuzzy-set *QCA*.Despite differing in their approach towards set calibration, they still equal in their fundamental principle of trying to determine qualitative differences between case that are (rather) out of the set and those that a (rather) in (Schneider and Wagemann 2012a).

4.2.3 Set operations and set relations

For the previously described calibration of sets, a careful selection of conditions needs to be conducted whose impact on the outcome is tested. When selecting conditions certain principles should be kept. Firstly, the number of conditions should be moderate as the

number of possible combinations of conditions rises by the function 2^k , where *k* is the number of conditions. For example, if four conditions are chosen, the number of possible combinations is 2^4=16. As a rule of thumb it can be stated, that the number of possible combinations should not exceed the number of selected cases (Schneider and Wagemann 2010). Once conditions and cases are calibrated, one can conduct the analysis determining whether there are certain conditions which alone are sufficient or necessary for the outcome.

Necessary conditions

A condition is regarded as necessary, if whenever a certain outcome is present, the condition is also present or, in other words, whenever there is Y, there is X (Y->X) (Schneider and Wagemann 2012a). For example, being able to swim is a necessary condition for being a whale yet the ability to swim does not immediately include being a whale since also other animals have the same ability.

Sufficient conditions

A condition is regarded as sufficient, if whenever it is present, the outcome is also present or, in other words, whenever here is X, there is Y (X->Y). For example, being a whale is a sufficient condition for being able to swim since all whales can swim. The difference between necessary and sufficient conditions is visualized in figure 15. Apart from single conditions, also combinations of conditions can be tested for sufficiency as one of the underlying assumptions of QCA is equifinality, meaning that several different combinations of conditions might be sufficient for the presence of an outcome (Schneider and Wagemann 2010).

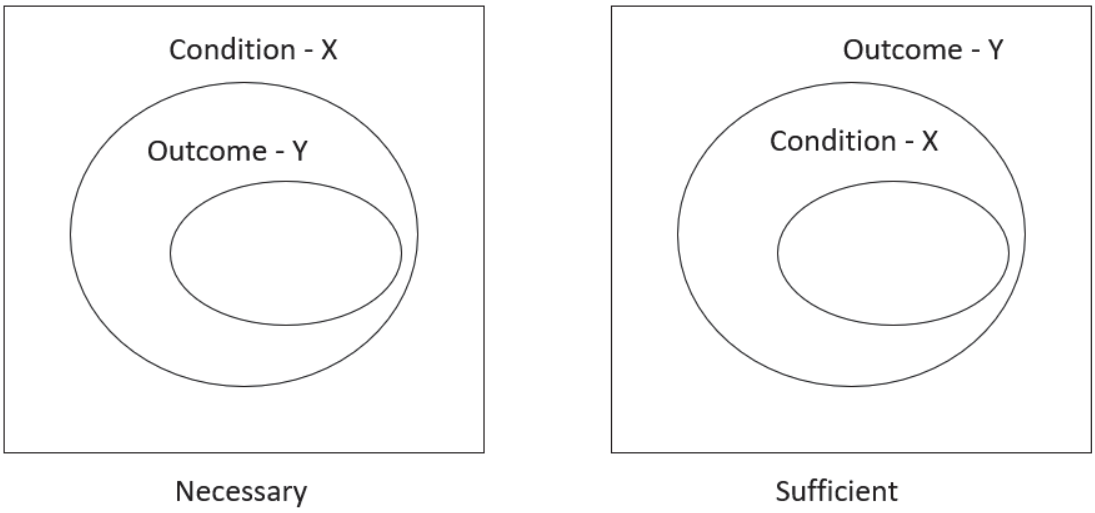

Figure 15 The difference between necessary and sufficient conditions, Source: Own elaboration based on Schneider and Wagemann (2012a).

4.2.4 The truth table

The truth table analysis forms the core element of *QCA*. In its raw form, a truth table combines all logically possible combinations of conditions (number of combinations is 2^k). Thereby, each row of the truth table ending with the outcome value of 1 can be considered as sufficient conditions as these rows comprise those conditions and combinations of conditions that lead to the outcome (Schneider and Wagemann 2012a). Since there might exist a large number of combinations which are sufficient for the outcome, in a next step these combinations are "logically minimized" by looking for logical communalities among them in order to come up with the most precise solution formula(s) possible.

For example, if row 1 of the truth table equals *abc* while row 2 equals *abC* and the linked outcome value in both cases in 1, the two rows can be summarized to *ab* by applying Boolean algebra since it is irrelevant for the outcome, whether C is present or not.[17] This process can be deployed for the whole truth table either manually or by employing tailored software for this purpose to determine the fully logically minimized solution formula. It should be noted that due to the assumption of equifinality, the logical minimization of the truth table leads to more than one solution formula which is sufficient for the outcome (Schneider and Wagemann 2012a).

Once the solution formula(s) have been determined, there are two parameters of fit which support the interpretation of the result. The *consistency* score expresses the extent to which empirical evidence supports the assertion that there is a set-theoretical relation while the *coverage* score expresses "the way the respective terms of the minimal formulas 'cover' observed cases" (Ragin and Rihoux 2009). These scores are helpful for the further interpretation of the result as they allow the analysis necessity and sufficiency for the solution formula.

As a last step of the analysis, one needs to validate the results that came up from the statistical analysis by going back to the cases and supporting them with anecdotal evidence and also relate them back to theoretical expectations (Schneider and Wagemann 2010).

[17] Capital letters indicate the presence of a condition, small letters the absence.

4.2.5 Justification of employing *QCA* for this research

Applying *QCA* enables the analysis of the given subject in a thorough manner due to multiple reasons. Firstly, it allows the determination of whether there exist certain conditions in Germany which alone prevent cities in Germany from adaptation planning by the included analysis of sufficiency. As stated earlier, the attempt of this paper however is not only to analyse single conditions but also potential interdependencies among them and *QCA* allows the analysis of patterns which results from the integration of diversified conditions. Due to the equifinality of *QCA*, it further enables researchers to explain the outcome, which is missing adaptation planning, by a (potential) multitude of solution pathways. Both of these features tackle the issue that it is questionable that lacking adaptation planning is caused by mono-causal coherences (Reckien et al. 2015). The employment of *QCA* to explore the conjunctions among barriers was furthermore encouraged by authors of previous research on the topic (Eisenack et al. 2014).

The actual *QCA* implementation can be either done manually or by employing specialized software which facilitates the analysis. For this study, the analysis is conducted by making use of the *QCA* and *Set Theoretic Methods* packages in *R (R Core Team 2019)*.

4.3 Operationalization of the construct

After having set out the theoretical principles of barriers to adaptation in chapter 2 and characterized the selected cases in chapter 3, the theory and the selected cases need to be combined in order to lay out the conditions included in the QCA.

4.3.1 Outcome

The underlying research question of this thesis is the determination of barriers to urban climate change adaptation planning in German cities. As a result, for the analysis of constraining factors for adaptation planning, the targeted outcome is “no adaptation plan/strategy”. However, since a fuzzy-set *QCA* is employed, a simple dichotomization of the outcome (“adaptation plan”, “no adaptation plan”) is not possible. Also, it would only allow statements on whether any kind of adaptation strategy exists or not and neglect that existing strategies differ in their extent. Instead, the present analysis focuses on the presence vs. absence of detailed, encompassing adaptation plans. How detailed and encompassing a certain adaptation strategy is, is proxied by the numbers of pages of the respective strategy documents and the number of field of actions covered therein. Doing so prevents that simple, brief documents are rated equally to long, comprehensive ones and allows a more thorough analysis of the subject.

4.3.2 Conditions

For the *QCA* implementation, the theoretical framework from chapter 2 needs to be translated into certain conditions whose impact on the outcome is assessed. In chapter 2, barriers are categorized into institutional/organizational, financial and attitudinal constraints. These categories are transformed into conditions for the analysis with the alteration that institutional and organizational constraints are considered as two separate conditions leading to a total of four conditions that are included in the analysis. The following section outlines these conditions and explains, which indicators are employed to measure them.

Lacking institutional capacity

As outlined by several researchers (Amundsen et al. 2010; Massey et al. 2015; Oberlack 2017) on the topic, institutional capacity is commonly reported to play a crucial role in establishing adaptation efforts as it forms the basis for an institution to define and achieve social, political and economic targets (ITDP 2016). Likewise, low institutional capacity is considered to constrain the administrative performance of an actor. Consequently, as first condition "lacking institutional capacity" is included in the analysis.

However, measuring institutional capacity is very challenging and there are no universally applicable methods to do so. Both Lehmann et al. (2013) and Moser and Ekstrom (2010) highlight the possibility to raise the capacity of the responsible institutions for developing adaptation strategies by employing more staff. Therefore, the present analysis assesses institutional capacity based on the number of people working in the city administration in relation to the total population. A high ratio (larger number of inhabitants per single employee in city administration) indicates lower institutional capacity. The necessary data was retrieved by looking for population data of the sample cities (e.g. Eurostat) and by assessing the websites of cities. In case the needed information is not available, they were inquired via email.

Lacking top-down support

Another commonly reported barriers to climate change adaptation are unclear responsibilities. This owes to the fact that adaptation efforts might be delayed in case lower level actors in a multilevel governance system rely on guidance from higher levels (Amundsen et al. 2010; Rotter et al. 2016; Brasseur et al. 2017). In the case of Germany however, the responsibilities among the federal, *Länder* and municipal level are comparably well determined as had been outlined in chapter 3.2. Thus it is of more

interest to analyse the impact of how well cities are supported from higher levels, as missing top-down support has likewise been reported to constrain adaptation on the municipal level (Eisenack et al. 2014). Since the available support from the federal level in form of knowledge and financial assistance can be considered to be relatively equal among cases, the *Länder* level becomes the centre of attention. As mentioned by Massey (2015) the *Länder* are responsible for outlining priorities and forming the regulatory framework in which adaptation takes place. However, as described in chapter 3.3, the extent of adaptation strategies of the German federal states varies distinctly as, while certain federal states have long and comprehensive adaptation strategies (e.g. Bavaria), others completely lack an integrative strategy (e.g. Sachsen). Therefore, for the following analysis the assumption is made that support from the *Länder* level for cities is low in those states which have no or very basic adaptation strategies. To measure the degree to which the extent of *Länder* adaptation strategies vary, both their number of pages and the number of fields of action covered is assessed.

Lacking financial resources

The importance of financial aspects in the implementation of adaptation measures and policies in general has been highlighted frequently in literature (Eisenack et al. 2014; Ekstrom and Moser 2014). Since adaptation measures are potentially expensive and their actual benefit is uncertain, it is conceivable that cities that lack financial resources do not allocate sufficient funds for adaptation planning and thereby delay the development of adaptation strategies (Brasseur et al. 2017). However, since an in-depth analysis of the financial resources and their allocation for each of the sample is out of the scope of this analysis, the financial situation of a city is measured according its GDP per capita. It is be assumed that cities with a high GDP per capita tend to be in a more favourable financial situation than those with a low GDP and that hence adaptation in cities with a low GDP per capita might be constrained due to lacking financial resources.

Lacking attitude

In order to ensure adequate adaptation planning, it is important that decision makers on the local level have a high degree of problem awareness and political will to induce the necessary measures that trigger the development of adaptation strategies. In case an adequate attitude is missing, adaptation planning can be constrained. (Eisenack and Stecker 2010). Therefore, as fourth and last condition “lacking attitude” is included in

the analysis. It is out of the scope of this study to be able to gain detailed information about the attitude of the responsible actors for adaptation planning and thus certain simplifying assumptions need to be made. It is assumed, that in cities whose population has a generally positive attitude towards environmental and climate policies, adaptation plans are more likely to be developed and vice versa. In order to determine the attitude of a city´s inhabitants, the share of students among the total population (assuming that a low share of students indicates a lower degree of problem awareness and comparably negative attitude towards climate policies) and the representation of the green party in the city government (assuming that cities with a low representation of the green party are less likely to initiate adaptation planning).

Table 3 summarises the included conditions and the outcome plus their respective measures.

Table 3 Conditions and outcome for QCA

Conditions	**Measures**
Lacking institutional capacity	Ratio of employees in city administration and total population of the city
Lacking top-down support	Extent of adaptation strategy on *Länder* level
Lacking financial resources	GDP per capita
Lacking attitude	Representation of green party in city government and share of students among total population
Outcome	
No/marginal adaptation planning	Extent of adaptation strategies of included cities

4.4 Data collection

4.4.1 Outcome

In order to compile a comprehensive list of adaptation strategy documents of the sample cities, a desk research was conducted focusing on official documents retrieved through internet search. Only those documents were regarded as adaptation strategies which included both a projection of climate change impacts on the city plus a list of adequate measures of adaptation. Likewise, only strategy documents were added to list while other projects focussing on adaptation were not listed. For example, the city of Kiel initiated a project focussing on the potential impact of climate change on the city but has not elaborated an adaptation strategy yet.

4.4.2 Conditions

Lacking institutional capacity

As mentioned before, for the purpose of this study the institutional capacity is measured by the ratio between employees of the administration and the total population of a city. The necessary population data was retrieved from the *Urban Audit* of the European statistics platform *Eurostat.* [18] The number of employees in the respective city administrations was retrieved either from the websites of the cities or, in case the number as not stated on the website, requested via Email. Subsequently, the total population per city was divided by the number of employees in the city administration to come up with the ratio for the analysis. At it, a high ratio indicates a low number of employees of the city administration and thus assumed low institutional capacity and vice versa.

Lacking top-down support

The top-down support is measured by the extent of the adaptation strategies of the respective federal states. Similar to the data collection for the cities, the list of strategy documents was compiled by conducting a desk research. Only integrative cross-sectoral documents were accepted as adaptation strategy. For example, Mecklenburg Western-Pomerania only has an adaptation strategy for forestry and agriculture. As this strategy is likely to be irrelevant for cities, it was not included in the list of adaptation strategies on *Länder* level.

Lacking financial resources

The financial situation of a city is measured by the GDP per capita of the respective city. The data was retrieved from the online data base of the *OECD*.[19]

Lacking attitude

The attitude towards climate policies is measured by the representation of the Green Party in the city government and the share of students in the total population. The number of students (ISCED level 5-8) was retrieved from the *Urban Audit* platform while the degree of representation of the green party was determined by researching the

[18] https://ec.europa.eu/eurostat/web/cities/data/database

[19] In an earlier version of this study, the GDP data was taken from the study by Reckien et al. (2015) who graciously agreed to share their dataset. Therefore, the data taken from the WTO will be of the same years (2007-2009) as in the that study and not the most up to date one.

results of the municipal elections in 2014 or the most recent before that year. The year 2014 was selected as several federal states had municipal elections in that year.[20]

4.5 Calibration

For the purpose of this study, a four-value fuzzy set *QCA* is employed. In the following section, the calibration process leading to this table is outlined. The calibrated data matrix is presented at the end of this chapter

4.5.1 Outcome

After the collection process was finished, the strategy documents were rated according to their number of pages and number of fields of action from 1 (low number of pages/fields of action) to 3 (high number of pages/fields of action). Subsequently, the sum of these two values was again rated from 1-3 (1,2=1;3,4=2;5,6=3) in order to end up with scores of 0 (for those cities without an adaptation strategy) to 3 to facilitate the calibration of the outcome.[21]

When rating the adaptation strategies only those documents were given a lower ranking that featured a particularly low number of pages (e.g. Hamburg)/fields of action (e.g. Freiburg). Also, the number of pages was considered to be more important in case of a large asymmetry between pages numbers and fields of action. For example, the adaptation strategy of Hamburg was rated with 1 even though it covers 9 fields of action since the whole document compromises only 13 pages and thus should be rated as rather basic.

The city of Cologne does not possess a document which is explicitly labelled to be an adaptation strategy but conducted a comprehensive scientific analysis which includes certain recommendations for action. It is therefore rated with a value of only 1, despite the document being comparably extensive.

Since the analysis is focused on determining barriers to adaptation, a score of 0 is calibrated to 1, a score of 1 to 0.66, a score of 2 to 0.33 and a score of 3 to 0. As a result, cases that are not member of the set (that is, cases with a membership score lower

[20] Since municipal elections are conducted every 5 years in Germany, the respective federal states also had municipal elections in 2019. However, the time period between the election date and this study was considered insufficiently long to have an influence on the elaboration of adaptation strategies.
[21] For a detailed description of the conducted data manipulations, see Annex III

than 0.5) are not only cases without an adaptation strategy, but also cases with a very basic adaptation strategy (that is: few pages and few fields of action).

A detailed table explaining the rating process can be found under Appendix III.

4.5.2 Conditions

Lacking institutional capacity

When calibrating sets it should be considered "that calibration must also make use of criteria for set membership that are external to the data (Schneider and Wagemann 2012a, p. 33)." However, the applied ratio between employees in the city administration and the total population of a city is unique to this study and making the integration of "external data" challenging. In case the calibration cannot be achieved via the employment of external consideration, one can analyse the distribution of the included data in order to determine natural gaps. When looking at the graph in section 3.4.5, it can be seen that cities with a ratio higher than 70 and lower than 40 are scattered distinctly different from the rest of the cases. Hence, it is assumed that all cases above 70 are definitely "in" (1) and all cases below 30 are definitely out (0). The cases between these two values are ordered in two groups ranging from 41.6 to 53.78 and 57.4 to 67.02. Thus, the cases from the first group are regraded to be rather out (0.33) while cases of the second group are regarded as rather in (0.66).
For the analysis, the condition is abbreviated with **LOW_InstCap**.

Lacking top-down support

After the adaptation strategies of the *Länder* level were collected, a rating process (identical to the city adaptation strategies) was executed in order to come up with ratings of 0 to 3. As for the outcome, the values were thereinafter translated into fuzzy logic meaning 0=1, 1=0.66, 2=0.33 and 3=0.

A detailed data table explaining the conducted rating process can be found under Appendix III.
For the analysis, the condition is abbreviated with **LOW_TopSupp**

Lacking financial resources

The GDP per capita in Germany between 2007 and 2009 was approximately € 30,000 (Statista 2020a). As the GDP per capita is commonly higher in cities than in rural areas, every case with a GDP per capita lower than €30,000 is considered to have a low GDP, hence being definitely in the set of LOW_GDP (1). Likewise, all cases with values over

€50,000 is considered as definitely out (0), since those city with a GDP per capita over €50,000 can unquestionably be regarded as wealthy. For the remaining cases, the threshold is drawn between Freiburg and Saarbruecken, with Freiburg being the first city to be regarded as rather wealthy (0.33) and Saarbruecken the last city to be regarded as rather poor (0.66) as Freiburg being commonly regarded to be comparably wealthy and therefore all cities with a higher GDP per capita than Freiburg are be rated as such. For the analysis, the condition is abbreviated with **LOW_FinRes**.

Lacking attitude

After the data collection process was finished, a rating process was executed by rating the values for each city with numbers from 0 (very low share of students/representation of the *Green Party*) to 3 (very high share of students/representation of *Green Party*). Again, the resulting scores were added together and rated again (0,1=0; 2,3=1; 4,5=2; 6=3). For a detailed overview of the rating process, see Appendix III.

Unlike for the outcome and for the condition "lacking top-down support" also cases with a cumulated sum of 1 were rated with a final score of 0 since in no city there is a complete absence of students and the Green Party and otherwise the number of 0 rated cases would be insignificant.

Furthermore, a notable positive correlation between the two indicators was determined, arguably because the Green Party is commonly stronger among students (Frankfurter Rundschau 2017).

Similar to the condition "lacking institutional capacity" the scores were subsequently translated into fuzzy logic with 0=1, 1=0.66, 2=0.33 and 3=0.

For the analysis, the condition is abbreviated with **LOW_Att**.

The complete calibrated table can be seen below.

Table 4 Calibrated data matrix

City	LOW_FinRes	LOW_TopSupp	LOW_InstCap	LOW_Att	OUTCOME
Augsburg	0.33	0	0.33	0.66	1
Berlin	1	0	0	0.66	0
Bielefeld	0.66	0.33	0.66	0.33	1
Bochum	0.66	0.33	0.66	0.33	0.33
Bonn	0.33	0.33	0.33	0.33	1
Bremen	0.33	0	0	0.66	0.33
Cologne	0.33	0.33	0.66	0.33	0.66

Darmstadt	0	0.33	0.66	0	1
Dortmund	1	0.33	0.66	0.66	1
Dresden	1	1	0	0.66	0
Duesseldorf	0	0.33	0.66	0.66	0
Erfurt	1	0	0.33	1	1
Essen	0.66	0.33	0.66	0.33	0
Frankfurt/Main	0	0.33	0.66	0.33	0.66
Frankfurt/Oder	1	1	0.66	0.66	1
Freiburg im Breisgau	0.33	0	0.66	0	0.33
Goettingen	1	0.33	0.66	0	0.66
Halle an der Saale	1	0	1	1	1
Hamburg	0.33	0.66	0	1	0.66
Hannover	0.66	0.33	0.33	0.33	0.33
Karlsruhe	0.33	0	0	0	0
Kiel	0.33	0.33	0.33	0.33	1
Koblenz	0	1	0.33	0.66	1
Leipzig	1	1	1	0.66	0.66
Magdeburg	1	0	1	0.66	1
Mainz	0.33	1	0.33	0	1
Moenchen-gladbach	1	0.33	0.33	1	1
Moers	1	0.33	1	1	1
Muelheim an der Ruhr	0.66	0.33	0.66	1	1
Munich	0	0	0.33	0.66	0.33
Nuremberg	0.33	0	0.33	1	0.33
Potsdam	0.66	1	1	0.33	0
Regensburg	0	0	0.33	0.33	1
Rostock	0.66	1	1	0.66	1
Saarbruecken	0.66	1	0.66	0.33	0.33
Schwerin	0.66	1	1	1	0
Stuttgart	0	0	0.33	0.33	0
Trier	0.33	1	0.66	0.33	1
Weimar	1	0	1	0.66	1
Wiesbaden	0.33	0	0.33	0.66	1

4.6 Hypothesis formulation

The study at hand follows a perspective approach meaning that the conditions included were selected regarding theoretical expectations from literature. Since the included conditions are commonly reported to constrain adaptation, it seems plausible that each condition plays a significant role in constraining adaptation planning. The conditions “lacking financial resources” and “lacking institutional capacity” have a direct impact on the institutional performance of a city and thus are likely to exhibit a clear impact while the conditions “lacking attitude” and “lacking top-down support” rather refer to

the surrounding conditions cities act in and making their influence at this point more difficult to predict.

As pointed out in chapter 2.3.3, an unfavourable economic situation and an indifferent attitude towards climate issues as well as an unfavourable economic situation and a low institutional capacity often occur in conjunction . Since these conditions are included in the present analysis, they are likely to appear in presence of each other.

For “lacking top-down support” it is challenging to formulate expectations based on theoretical knowledge as a strong influence from higher levels is considered to potentially have both a positive as well as constraining effect on the development of adaptation measures on the local level (Amundsen et al. 2010; Eisenack et al. 2014).

The included conditions aim at covering the mayor factors which are commonly mentioned in scientific literature to act as barriers for adaptation. However, it is likely that there are other factors which impact adaptation planning which are not included in this analysis. Therefore, an absence of the included conditions is unlikely to be sufficient for the existence of adaptation strategies.

4.7 Summary of the chapter

For the purpose of this study, a four-value fuzzy set *QCA* is conducted. The *QCA* method fits well the specific needs of this research as it allows the analysis of both the influence of individual conditions and of combinations of conditions on urban adaptation planning in Germany. Based on the scientific literature, the conditions “lacking institutional capacity”, “lack top-down support”, “lacking financial resources” and “lacking attitude” are included in the analysis.

The necessary data for their respective measures was retrieved via a desk research from online databanks, governmental and municipal websites as well as per personal inquiry. After the successful data collection, the data was calibrated into fuzzy-set logic via the employment of external criteria, qualitative judgements and distributional considerations.

At this point of the paper, it is hard to predict the exact influence the individual conditions might have but it seem plausible that both “lacking institutional capacity” and “lacking financial support” will have a clear containing impact on adaptation planning while the impact of the remaining two conditions is much more unclear. Based on theoretical expectation, it seems likely that the conditions “lacking financial

resources" and "lacking institutional capacity" as well as "lacking financial resources" and "lacking attitude" will frequently occur in conjunction.

This chapter outlined the specific of the employed methods and informed about the conducted steps which were conducted in order to translate the theoretical foundations from chapter 2 and the case specifics from chapter 3 into conditions which are analysed regarding their impact on urban adaptation planning in Germany. In the following chapter, the results from the *fsQCA* are outlined and further discussed.

5. Results

5.1 Objectives of this chapter

The objective of this chapter is to outline the findings of the *fsQCA* described in chapter 4. The analysis included 40 German cities, and aimed at gaining an understanding under which constraining conditions (institutional, organizational, financial, attitudinal) adaptation planning is hampered in Germany. In the following, the individual steps of the analysis are explained. For the practical implementation of the *fsQCA*, the free programming language *R* was used (R Core Team 2019).

5.2 Analysis of necessity

After having calibrated the raw data matrix into a four-value fuzzy set matrix by following the steps outlined in chapter 4.5, the analysis of necessity represents the first step of the analysis. It is conducted since it is of interest to examine whether there exists a certain condition (or conditions) which always has to be present in case adaptation is hampered. To accept a condition to be necessary for the outcome, Emmenegger (2011) proposes to use a consistency score of at least 0.9. As can be seen in table 4, none of the four conditions or their compliment (~) have a higher consistency score than 0.9 and consequently none of the conditions is necessary for the outcome. However, it is noteworthy to find that ~LOW_TopSupp exhibits a higher consistency score than LOW_TopSupp thus comprehensive adaptation strategies on the *Länder* level seem to be of higher importance in constraining adaptation planning than comparably brief ones. The values were determined by using the *QCAfit* function from the *SetMethods* package in *R* (Oana and Schneider 2018).[22]

Table 5: Analysis of necessity for individual conditions

Condition	Cons.Nec	Cov.Nec	RoN
LOW_FinRes	0.622	0.727	0.752
LOW_TopSupp	0.440	0.707	0.837
LOW_InstCap	0.646	0.769	0.788
LOW_Att	0.620	0.738	0.766
~LOW_FinRes	0.481	0.681	0.791
~ LOW_TopSupp	0.651	0.683	0.669
~LOW_InstCap	0.471	0.653	0.771
~LOW_Att	0.483	0.67	0.779

[22] The complete code used in *R* is outlined in appendix IV.

5.3 Analysis of sufficiency

5.3.1 Individual conditions

After having determined that there exist no necessary conditions for the outcome, the next step is to examine whether any conditions are individually sufficient for the outcome meaning that whenever they are present, also the outcome is present. The analysis of sufficiency is conducted in two steps.

First, a formal analysis of sufficiency for the induvial conditions is performed, again by employing the *QCAfit* function of the *SetMethods* package in *R*. The results of the formal analysis can be depicted from table 5. Schneider and Wagemann (2012a) argue, that a minimum consistency cut-off value of 0.75 should be used as lower scores lack enough consistency and could lead to potentially meaningless conclusions. As can be seen, the condition "lacking institutional capacity" has a consistency score of 0.769 and is formally sufficient. It is also notable that all other conditions have comparably high consistency scores close to 0.75. Also, none of the complements (~) of the conditions qualifies do be sufficient for the outcome and the complement scores, as for necessity, are consistently lower than the scores for the presence of the conditions.

Table 6 Analysis of sufficiency for individual conditions

Condition	Cons.Suf	Cov.Suf	PRI	Cons.Suf(H)
LOW_FinRes	0.727	0.622	0.678	0.698
LOW_TopSupp	0.707	0.427	0.639	0.684
LOW_InstCap	0.769	0.646	0.726	0.746
LOW_Att	0.738	0.620	0.690	0.716
~LOW_FinRes	0.682	0.481	0.609	0.642
~ LOW_TopSupp	0.692	0.651	0.643	0.663
~LOW_InstCap	0.653	0.471	0.567	0.621
~LOW	0.67	0.483	0.597	0.634

Since the formal analysis resulted in determining one sufficient condition, it is advisable to analyse the sufficiency relation visually in order to verify that "low institutional capacity" is indeed throughout sufficient for the outcome. The sufficiency relation

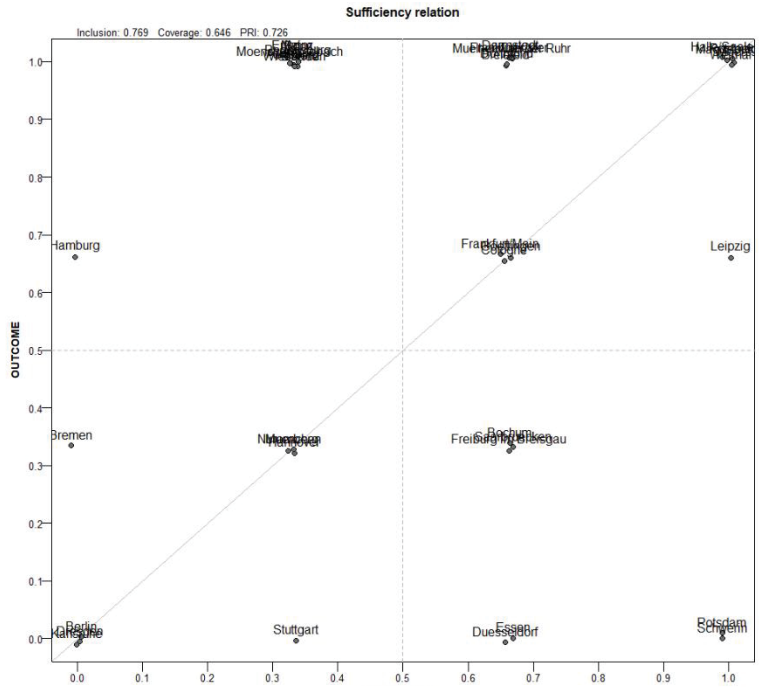

Figure 16 Sufficiency relation between condition "low institutional capacity" and outcome

between "low institutional capacity" and the outcome is visualized in figure 16. In order to be truly sufficient, cases should almost exclusively be listed above the diagonal axis. As can be seen, despite the fact that the majority of cases is indeed listed above the diagonal, a significant number of cases is listed below justifying the judgement that "lacking institutional capacity" should not be regarded as sufficient for the outcome due to the high number of cases in the bottom-right quadrant. These are cities that do have adaptation strategies despite having an assumed low institutional capacity, contradicting the sufficiency claim.

5.3.2 Combinations of conditions

One of the research questions of this study is to examine whether there exists any conjunction among barriers that enable combinations of certain conditions to be sufficient for the outcome. As outlined in chapter 4, via *QCA* this can be achieved by conducting a truth table analysis. The truth table contains all theoretically possible combinations of conditions (2^k). Each row is assigned with the cases that are characterised by the specific combination of conditions of the row and it is determined, whether the row is consistent for the outcome, not consistent or a logical remainder (logically possible cases which are not observed in the sample) (Schneider and Wagemann 2012a). Table 7, which was constructed with the *truth Table* function of the *QCA* package in *R* (Dusa 2019), depicts the resulting truth table from the calibrated fuzzy data matrix which was erected according to the calibration principles outlined in chapter 4.5.

As can be seen, there exist a multitude of combinations which can be deemed to be sufficient to hamper adaptation planning in German cities with Low_FinRes*low_topsupp*LOW_INSTCAP*LOW_ATT being classified with the

highest score (0.96). Keeping in mind the high consistency score of each individual condition, this does not come as a surprise. Also here the ambiguous impact of an extensive adaptation strategy on *Länder* level on municipal adaptation planning can be observed, as row 12, where all barriers are occurring apart from Low_TopSupp, exhibits a distinctly higher inclusion score than row 16 which depicts the combination of all 4 barriers. Likewise, the high impact of the institutional capacity can be abstracted from row 3.

In general, it becomes evident that already the occurrence of one barrier might be enough to constrain adaptation and that every combination of at least two barriers is sufficient for the outcome. In order to streamline these results and be able to make reliable judgements on the nature of barriers to urban adaptation planning in Germany, in the following step these combinations are logically minimized.

In order to prevent misleading conclusion and guarantee an adequate degree of empirical evidence, all combinations which are observed less than two times are regarded as logical remainders and not be included in the further analysis as in the course of this study logical remainders are omitted.

Table 7 Truth table

Row No.	LOW_ FINRES	LOW_ FEDSUPP	LOW_ INSTCAP	LOW_ ATT	OUT	n	incl	PRI
12	1	0	1	1	1	6	0.960	0.953
6	0	1	0	1	1	2	0.875	0.799
10	1	0	0	1	1	3	0.851	0.788
11	1	0	1	0	1	4	0.834	0.770
16	1	1	1	1	1	4	0.818	0.764
3	0	0	1	0	1	4	0.797	0.709
15	1	1	1	0	1	2	0.779	0.668
2	0	0	0	1	0	5	0.738	0.598
1	0	0	0	0	0	5	0.734	0.619
5	0	1	0	0	?	1	0.866	0.799
7	0	1	1	0	?	1	0.821	0.747
14	1	1	0	1	?	1	0.813	0.728
4	0	0	1	1	?	1	0.765	0.637
9	1	0	0	0	?	1	0.747	0.597
8	0	1	1	1	?	0	0.000	0.000
13	1	1	0	0	?	0	0.000	0.000

5.4 Logical minimization

In the previous section it was determined that 7 different combinations of conditions could be formally determined as being sufficient for the outcome. However, since the logical interpretation of 7 different paths is very challenging, as the last step of the analysis, the paths are logically minimized by applying Boolean Algebra in order to get rid of logically redundant conditions and come up with the most concise solution formula possible. While this process can also be done manually, for the purpose of this research the *minimize* function of the *QCA* package in *R* was employed. The logically minimized truth table is depicted in table 7. Applying the previously used cut-off consistency score of 0.75, it can be seen that 4 paths exist which are formally sufficient for the outcome with LOW_FINRES*low_topsupp*LOW_ATT having the highest consistency score.

Table 8 Logically minimized truth table

n OUT = 1/0/C: 25/10/0
Total : 35
Number of multiple-covered cases: 10

M1:
LOW_FINRES*LOW_INSTCAP +
LOW_FINRES*low_topsupp*LOW_ATT +
low_topsupp*LOW_INSTCAP*low_att +
low_finres*LOW_TOPSUPP*low_instcap*LOW_ATT
=> OUTCOME

		incls	PRI	covS	covU
1	LOW_FINRES*LOW_INSTCAP	0.816	0.78	0.517	0.13
2	LOW_FINRES*low_topsupp*LOW_ATT	0.907	0.885	0.375	0.039
3	low_topsupp*LOW_INSTCAP*low_att	0.786	0.713	0.285	0.077
4	low_finres*LOW_TOPSUPP*low_instcap*LOW_ATT	0.875	0.799	0.18	0.039
	M1	0.797	0.754	0.711	

	Cases
1	Bielefeld, Bochum, Essen, Goettingen, Dortmund, Halle/Saale, Magdeburg, Moers, Muelheim an der Ruhr, Weimar, Potsdam, Saarbruecken, Frankfurt/Oder, Leipzig, Rostock, Schwerin
2	Berlin, Erfurt, Moenchengladbach, Dortmund, Halle/Saale, Magdeburg, Moers, Muelheim an der Ruhr, Weimar
3	Cologne, Darmstadt, Frankfurt/Main, Freiburg im Breisgau, Bielefeld, Bochum, Essen, Goettingen
4	Hamburg, Koblenz

5.5 Solution formula

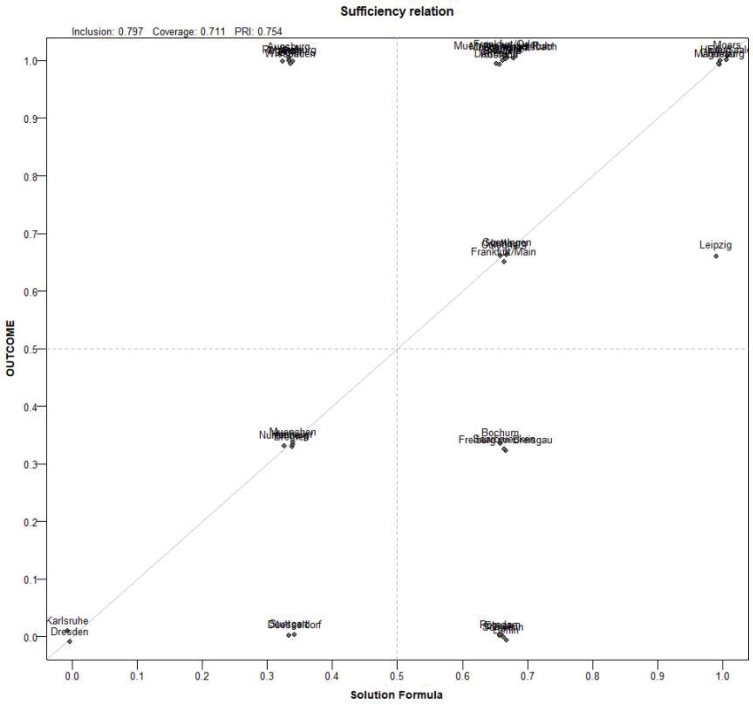

Figure 17 Plot of the solution formula

The solution formula is depicted by figure 17. In the previous section it was determined that it consists of 4 different paths which are formally sufficient to prevent adaptation strategies in German cities when applying the previously used cut-off value of 0.75.

The 4 sufficient combinations of conditions which were determined via the *fsQCA* are:

*LOW_FINRES*LOW_INSTCAP +*

*LOW_FINRES*low_topsupp*LOW_ATT +*

*low_topsupp*LOW_INSTCAP*low_att +*

*low_finres*LOW_TOPSUPP* low_instcap*LOW_ATT*

In order to further assess this outcome, in the following the 4 prime implicants of the solution formula are analysed according to their coverage/consistency scores and to the degree to which they can be linked to theoretical expectations and/or anecdotal evidence.

5.5.1 LOW_FINRES*LOW_INSTCAP

The first prime implicant of the solution formula indicates that adaptation is hampered in Germany, if a city features a low GDP per capita AND a high number of inhabitants per employee of the city administration and thus an assumed low institutional capacity. By looking at the plot of the sufficiency relation, which is depicted by figure 18, certain observations can be made. First, it can be seen that in total there are 6 cities which contradict the path, since they do have an adaptation strategy despite having a low institutional capacity and GDP per capita (Essen, Schwerin, Potsdam, Saarbruecken, Bochum and Leipzig) and hence lower the consistency score. Especially Essen, Schwerin and Potsdam have a comprehensive adaptation strategy (0 membership in the outcome)

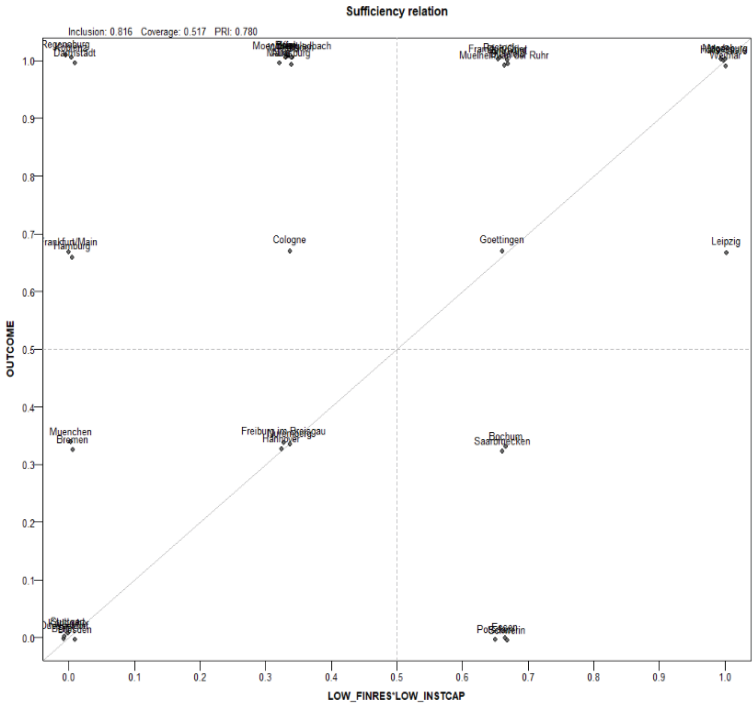

Figure 18 Sufficient path LOW_FINRES*LOW_INSTCAP

despite having a membership score of 0.66 in the present sufficient path. It is worth noting that Schwerin and Potsdam are capitals of Federal states so the assumption could be made, that this circumstance caused the development of an adaptation strategy. However, by looking at the other cases this assumption can be falsified as several other federal capitals (Kiel, Mainz, Wiesbaden, Erfurt, Magdeburg) lack comprehensive adaptation plans and thus the nature of being the capital of a federal state does not automatically lead to the development of adaptation plans.

When analysing the genesis of the adaptation strategies of Essen, Potsdam and Schwerin, it is noteworthy to find that all were developed with support of national climate initiatives. Both Schwerin and Potsdam were supported by the *National Climate Initiative* which is funded by the *Federal Ministry of the Environment, Nature Conservation and Nuclear Safety* and promotes climate action in municipalities throughout Germany[23] while Essen was part of the model project *StadtKlima* which was funded by the *Federal Ministry of Transport and Digital Infrastructure* and focussed on the development of comprehensive adaptation strategies for 9 model cities.[24] Also the cities of Bochum and Saarbruecken, which feature a similar institutional capacity and GDP per capita like Essen, Potsdam and Schwerin but possess comparably less comprehensive adaptation strategies, were explicitly supported by federal initiatives in the development of their adaptation plans as Saarbruecken was also part of the *StadtKlima* project while the adaptation strategy of

[23] For more information, see: https://www.klimaschutz.de/en/promoting-climate-action
[24] For more information, see: https://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/ExWoSt/39/exwost39_3.pdf?__blob=publicationFile&v=2

Bochum was developed with support of an earlier version of the *National Climate Initiative*. Hence it is likely that the availability of national support programmes helped cities to develop adaptation strategies despite having an unfavourable institutional or financial environment.

Furthermore, it can be seen that there exists no case which has a perfect membership in the present path and zero membership in the outcome as only Leipzig has a comparably brief strategy while all other cities with a perfect membership score (Magdeburg, Halle, Moers) do not have an adaptation strategy at all.

Out of the 6 cases which formally contradict the solution formula, Leipzig is the only city that developed an adaptation strategy without the explicit support of national support programmes (even though it is distinctively less comprehensive that those developed with support of national climate initiatives). The fact that Leipzig still managed to develop an adaptation strategy could be explained by the fact that there seems to exist a strong correlation between the population size of a city and the likeliness to have an adaptation strategy. The sample includes 14 cities with a population size of over 500,00 and only two of these (Köln, Dortmund) do not have an adaptation strategy. Likewise, among the 11 cities with less than 200,000 inhabitants only 4 (Saabruecken, Schwerin, Goettingen, Potsdam) have an adaptation strategy.

Apart from analysing the consistency score of the statement of sufficiency it is of interest to determine its coverage in order to assess whether the present path is supported with empirical evidence. As can be abstracted from table 7, the present path LOW_FINRES*LOW_INSTCAP has both the highest *raw coverage* and *unique coverage*[25] indicating that among the implicants of the solution formula, it is supported with the highest degree of empirical evidence. As can be seen in figure 17, indeed there are multiple cases located in the upper right quarter above the bisecting line.

Furthermore, it can be observed that also multiple cases are located in the upper left corner which have no or low membership in the path but still perfect or high membership in the outcome (especially Regensburg, Koblenz and Darmstadt have no membership in the implicant but full membership in the outcome). Keeping in mind the equifinality of QCA, it is likely that for these cases the membership in the outcome was caused by other

[25] The difference between these two measures is that *raw coverage* indicates the degree to which the outcome is covered by a path while *unique coverage* indicates how much of the outcome is covered by a specific path only (Schneider and Wagemann 2012a.)

sufficient paths (Schneider and Wagemann 2012a). By looking at table 7 it can be seen that indeed Koblenz and Darmstadt are covered by other paths (2,4) while Regensburg is not covered by any of the 4 sufficient paths of the solution formula and remains unexplained by the solution term.

Besides the analysis of consistency, raw coverage and unique coverage, Schneider and Wagemann (2012a) recommend the determination of cases which are uniquely covered by the specific solution terms in order to further assess the empirical importance of paths. As can be seen in table 8, the present path LOW_FINRES*LOW_INSTCAP (P1) features the highest number of uniquely covered cases and thus the highest degree of empirical importance.

Table 9 Cases uniquely covered by specific implicants of the solution formula

P1	P2	P3	P4
Potsdam	Berlin	Cologne	Hamburg
Saarbruecken	Erfurt	Darmstadt	Koblenz
Frankfurt/Oder	Moenchengladbach	Frankfurt/Main	
Leipzig		Freiburg im Breisgau	
Rostock			
Schwerin			

In addition to having the highest coverage among the 4 implicants of the solution formula, LOW_FINRES*LOW_INSTCAP also meets theoretical expectations. As outlined in chapter 2, insufficient financial resources (assumed to be the case if GDP is low) and a low institutional capacity are commonly reported to constrain the development of adaptation strategies. Since these two barriers commonly occur in conjunction, the present sufficient path confirms the theoretical assumptions from chapter 2.3.3 as well as the hypothesis formulated in chapter 4.6. The sufficiency analysis of individual conditions performed in chapter 5.3.1 showed that both conditions alone already feature significant consistency scores and LOW_INSTCAP was even deemed to be formally sufficient but also exhibited a notable number of offenders below the bisecting line. The present implicant shows, that when they occur in conjunction their consistency scores rise slightly while the offenders are less severe and can be explained with empirical evidence by analysing the genesis of the adaptation strategies of those cities that contradict the sufficiency relation.

Summarising it can be stated that the present sufficient path can be considered to be both formally sufficient and to be backed with a significant degree of empirical evidence as it features the highest coverage among the 4 implicants of the solution formula. However, the analysis provided 3 further paths which are formally sufficient to prevent adaptation planning in German cities. In the following, these are be further analysed according to the same measures as the present path.

5.5.2 LOW_FINRES*low_topsupp*LOW_ATT

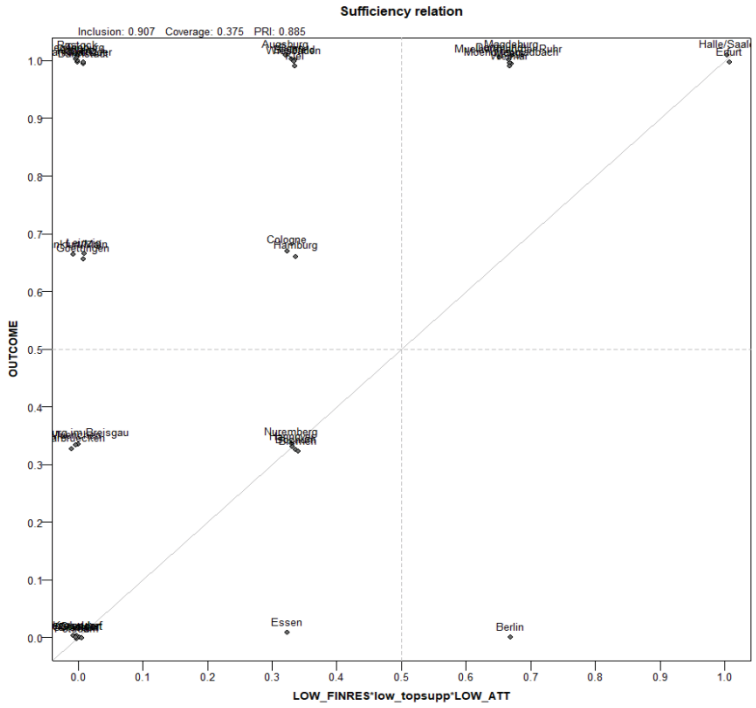

Figure 19 Sufficient path LOW_FINRES*low_topsupp*LOW_ATT

The second prime implicant of the solution formula is depicted by figure 19. It claims that adaptation planning is constrained in case cities feature a low GDP per capita and less favourable attitude towards climate policies while the adaption strategy of the respective federal state is extensive. As can be seen, the number of offenders contradicting the path is very low leading to the high consistency score of 0.907, the highest score of all 4 sufficient paths. Even more, the significance of Berlin for this path is questionable since the path includes the condition “low_topsupp” and due to its nature of being a federal city state, the municipal and federal adaptation strategy are identical. For Essen, the reasons that lead to the development of an adaptation strategy were already outlined in the previous part. Thus, the present statement of sufficiency is almost completely in line with the empirical evidence at hand.

Furthermore, figure 18 shows that a significant number of cases is located in the upper right corner of the plot indicating that the present statement of sufficiency is backed by a

reasonable degree of empirical evidence (9 cases[26]) despite exhibiting a lower coverage than the first implicant of the solution formula (16 cases). Especially the unique coverage of the present path is low as only 3 cases are uniquely covered (see table 9). Among the 9 which confirm the path cases it is challenging to identify patterns. However, the present path seems to be more relevant for small and medium-sized cities as 7 out of the 8 cities which empirically support the statement of sufficiency have less than 250.000 inhabitants.

The proposition that extensive adaption efforts on higher governmental layers hampers adaptation on the municipal level is deeply interesting though, since it confirms the assumption made by Amundsen et al. (2010) who that state a high degree of effort on higher governmental levels might discourage adaptation action on the municipal level. It also aligns well with the statement of Rotter et al. (2016) and Brasseur et al. (2017) who argue that unclear responsibilities regarding adaptation efforts are a common barriers for the development of measures. According to the present sufficiency statement, this is particularly the case if cities lack sufficient financial resources combined with a rather indifferent attitude towards climate polices leasing to the assumption that in these cases cities rely on adaptation to be planned on higher governmental levels and delaying own actions. The current path also confirms the potential conjunction between an unfavourable economic situation and an indifferent position towards climate policies which was assumed in chapter 2.3.3.

5.5.3 low_topsupp*LOW_INSTCAP*low_att

The third statement of sufficiency from the solution formula is displayed by figure 19. It claims that an extensive adaptation strategy on *Länder* level combined with a low institutional capacity and a positive attitude towards climate polices is formally sufficient to constrain the development of adaptation strategies in Germany.

The formal analysis though reveals certain aspects that question the validity of the present statement of sufficiency. As can be seen in figure 19, there are 5 cases which formally contradict the statement leading to the comparably low consistency score of 0.786, the lowest among the 4 implicants of the solution formula.

[26] 8 of these cases are located in the upper right quarter above the bisecting line while Berlin is still represented in the coverage function despite being an offender for the statement of sufficiency.

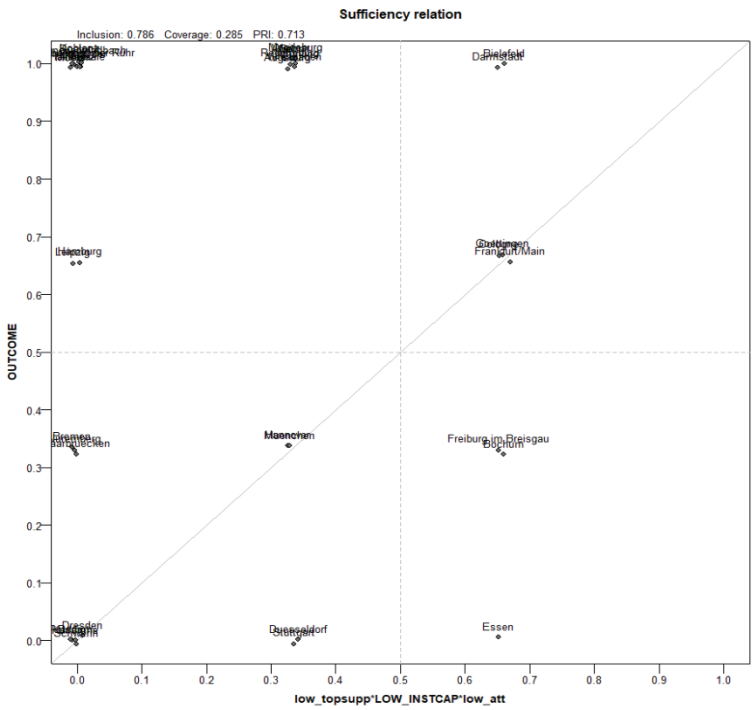

Figure 20 Sufficient path low_topsupp*LOW_INSTCAP*low_att

Some researchers Ragin and Rihoux (2009) even recommend a threshold of at least 0.8 to deem a condition to be sufficient which would exclude the present path from the further analysis. However, as outlined earlier, for this study a cut-off value of 0.75 is applied and making the present path formally sufficient.

In addition to the low consistency score, it can be seen that there are only 4 cases which are located above the bisecting line in the upper right quarter of the plot and none of these cases has a full membership the present implicant. Thus, the degree of empirical evidence for the present statement of sufficiency is much lower than for the first two implicants of the solution formula. Having low coverage score does not necessarily make results less significant as they still might be of high theoretical importance (Schneider and Wagemann 2012a). Interestingly, all cities that cover the path (above and below the bisecting line) are located in Western Germany. Arguably, the high importance of the condition "low institutional capacity" has a strong influence on the present path while attitude and "top-down support" are rather irrelevant as the consistency score of the path is only slightly higher than the one of low institutional capacity alone.

However, it shows that adaptation is constrained in case the institutional capacity is insufficient even though the attitude and support from higher governmental levels is given. This finding aligns with the findings of Eisenack and Stecker (2010) who argue that adaptation might be constrained in case of capacity (or budget) limitations despite no lack of problem awareness. A closer examination of the two cases (Bielefeld, Darmstadt) that have a full membership in the outcome and a high membership in the present path shows, that Darmstadt indeed exhibits a strongly positive attitude towards climate issues

as among the 40 cities of the sample, the city has the highest share of voters for the Green Party and the second highest share of students in relation to the number of inhabitants. Thus, it is a good example to demonstrate the high constraining effect of insufficient institutional capacities. This is even more noteworthy sine the financial situation of Darmstadt can be considered to be very favourable as its GDP per capita is among the 10 highest values of the sample cities.

The city of Bielefeld features a slightly better institutional capacity than Darmstadt but distinctly lower ratings according to attitude and GDP per capita. Despite not having an adaptation strategy yet, the city started to implement a research process which aims at developing an adaptation strategy.[27]

5.5.4 low_finres*LOW_TOPSUPP*low_instcap*LOW_ATT

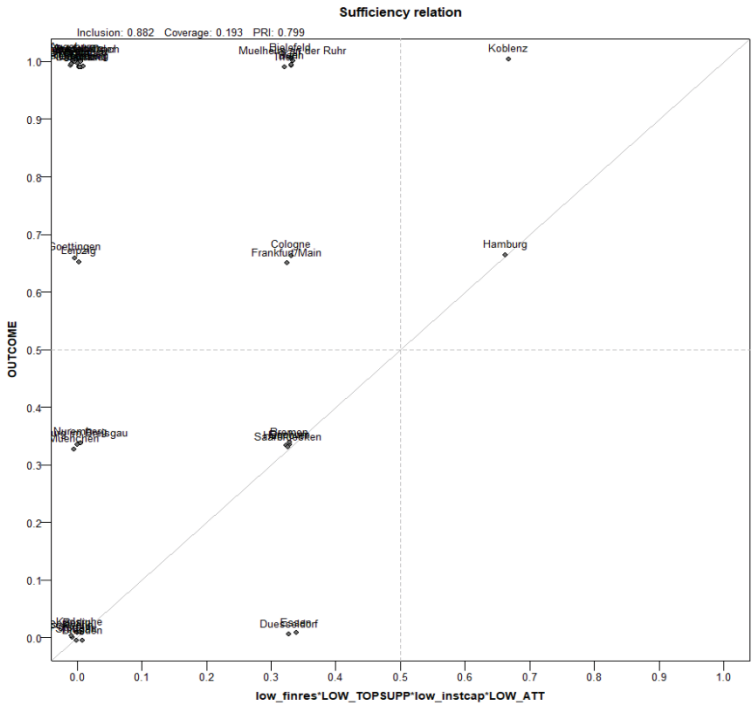

Figure 21 Sufficient path low_finres*LOW_TOPSUPP_low_instcap*LOW_ATT

The last sufficient path which was determined by the fsQCA analysis indicates that adaption planning is hampered in cities which are located in federal states that feature a low degree of adaption planning, exhibit a comparably good institutional capacity and GDP per capita plus their inhabitants have a positive attitude towards . The sufficiency relation is plotted in figure 20. As can be seen, there are only two offenders below the bisectional line, explaining the high consistency score of 0.875. Only the cities of Essen and Duesseldorf contradict the path as they both possess comprehensive adaption strategies (0 membership in the outcome) but a moderate membership in the present path (0.33). Likewise, it can be seen that the majority of the cases are located in the upper left quarter of the plot while only 2 cases are located in the upper right quarter. Thus, there are hardly

[27] For more information, see: https://www.bielefeld.de/de/un/stkl/stra/

any cases which provide empirical evidence for the present path leading to the low raw coverage score of 0.180 . Like Berlin in section 5.5.1., the validity of Hamburg in this case is questionable since there is no difference between municipal and federal adaptation strategies. Hence, the present path is only covered by the city of Koblenz and judgements based on the present path should be treated with care. According to the applied logic in chapter 5.3.2 to regard every combination which is covered by less than two cases a logical remainder, the current path should be even excluded from further analysis. A closer examination of Koblenz also reveals that a dialogue process between the city administration and students of the local university in order to develop an adaptation strategy for the city[28]. Therefore, the finding that affluent and well-staffed cities fail to develop adaptation strategies in case their inhabitants are rather indifferent towards climate policies and the adaptation strategy on *Länder* level is brief should not be overinterpreted.

5.6 Summary

For the summary of the findings, the chapter 6.1.

[28] For more information, see: https://www.hs-koblenz.de/hochschule/organisation/pressebereich/aktuelles/detail/_n/eine-strategie-zur-klimaanpassung-fuer-koblenz-studierende-der-hochschule-koblenz-im-dialog-mit-ve

6. Discussion

6.1 Summary of the findings and objectives for this chapter

The *fsQCA* analysis revealed a multitude of noteworthy results which are further discussed in this chapter.

The analysis of necessity showed that of the 4 included conditions, none is individually necessary for the outcome to occur. Interestingly, the condition "Low_TopSupp" had a distinctly lower consistency score than its negation indicating that extensive adaptation on higher governmental layers potentially discourages adaptation on the municipal level.

The analysis of sufficiency for individual conditions showed that all 4 conditions have high consistency score with "Low_TopSupp" having the lowest scores while "Low_InstCap" is formally sufficient but exhibits a relatively large number of offenders which question the validity of the statement of sufficiency.

The high consistency score of the individual conditions lead to a large amount of combinations of barriers which can be considered sufficient for the outcome, expressed via the truth table in section 5.3.2. In order to streamline result and address the issue of limited diversity, all combinations with a coverage of < n=2 were considered logical remainders. Thus, for the following logical minimization 7 combinations were included. As a result, 4 different paths were identified which are formally sufficient to constraining urban adaptation planning in Germany.

The first implicant of the solution formula (LOW_FINRES*LOW_INSTCAP) exhibits the degree of highest empirical evidence and a reasonable degree of consistency. Interestingly, all "offending" cases could be explained by the fact that these cities took part in governmentally funded initiatives which support municipalities in developing adaptation strategies. The findings align well with theoretical expectation also regarding the occurrence in conjunction of these two barriers.

The second implicant of the solution formula (LOW_FINRES*low_topsupp* LOW_ATT) features the highest consistency score among the four implicants of the solution formula and a good amount of empirical evidence. The statement, that extensive adaptation strategies on the *Länder* level potentially constrains adaptation on the municipal level confirms the previously made assumptions and can be linked back to theoretical expectations. Apparently especially small and medium sized cities rely on

higher governmental level to engage in adaptation planning in case they lack the necessary financial means and political will.

The third implicant of the solution formula (low_topsupp*LOW_INSTCAP* low_att) exhibits a comparably high number of offenders and only a small amount of empirical evidence. The finding though highlights the BIG constraining impact of a low institutional capacity on adaptation planning since the example of Darmstadt reveals that even in case cities are in a favorable economic situation, have a very positive attitude towards climate issues, cities can fail in developing adaptation strategies.

The last implicant of the solution formula (low_finres*LOW_TOPSUPP* low_instcap*LOW_ATT) features a high consistency score but hardly any empirical evidence. Due to the questionable validity of the 2 cases which cover the path, the combination is regarded a logical remainder and not be further included in the analysis.

In chapter 1.5 it was stated that one of the research questions of this study is to investigate whether the absence of barriers leads to adaptation. However, since the selected individual conditions exhibits a very strong negative influence on the existence of adaptation plans, one barrier can be enough to hinder cities from adapting. This assessment is supported by the analysis of ~Outcome, which can be observed in table 10. As can be seen, even in case all 4 barriers are not occurring, the consistency inclusion score is not high enough to be deemed sufficient to cause adaptation planning. It is probable that even in case the 4 constraining conditions are not affecting a city, adaptation might be constrained by other barriers or factor that cause the nonexistence of adaptation strategies. Hence, a separate study would be needed which explicitly focusses on the drivers for adaptation in German cities.

After having outlined the results of the *fsQCA*, the objectives of this chapter is to list all factors that might have negatively influenced the validity of this analysis. Once this is done, recommendations for future research on the topic are given. Lastly, the findings are further discussed by putting them in the political context of adaptation planning in Germany.

Table 10 Analysis of ~Outcome

Row No.	LOW_ FINRES	LOW_ FEDSUPP	LOW_ INSTCAP	LOW_ ATT	OUT	n	incl	PRI
2	0	0	0	1	0	5	0.609	0.402
1	0	0	0	0	0	5	0.566	0.381
15	1	1	1	0	0	2	0.554	0.332
3	0	0	1	0	0	4	0.505	0.291
6	0	1	0	1	0	2	0.502	0.201
10	1	0	0	1	0	3	0.447	0.212
11	1	0	1	0	0	4	0.444	0.230
16	1	1	1	1	0	4	0.410	0.236
12	1	0	1	1	0	6	0.200	0.047
9	1	0	0	0	?	1	0.625	0.403
4	0	0	1	1	?	1	0.587	0.363
14	1	1	0	1	?	1	0.499	0.272
7	0	1	1	0	?	1	0.472	0.253
5	0	1	0	0	?	1	0.465	0.201
8	0	1	1	1	?	0	0.000	0.000
13	1	1	0	0	?	0	0.000	0.000

6.2 Validity limitations

For the purpose of this study, certain assumptions and simplifications were made which are outlined in the following in order to provide a maximum degree of transparency and applicability.

Firstly, the conducted *fsQCA* analysis is a static comparison which lacks a proper uncovering of dynamics and processes. It was assessed whether cities had adaptation strategies in November 2019 or not but in the analysis, it is not reflected whether there exist already certain efforts to a strategy. Reference to such eventual dynamics was only made when individual cases were more closely analysed in the results chapter.

For this study, a four-value fuzzy set *QCA* was conducted. When calibrating sets, a certain degree of simplification has to be done since cases are either completely in, more in than out, more out than in or completely out. As the used data was often numerical, this potentially leads to the effect that differences among cases is increased or decreased (depending on the set they assigned to) and as a result, the empirical image is altered.

The applied approach when selecting conditions to be included in the *fsQCA* is a perspective approach, meaning that conditions were selected based on theoretical expectations depicted from empirical literature. However, this bears the risk of neglecting factors which were not listed in the compiled literature but potentially constrain

adaptation planning. Furthermore, as outlined in chapter 2, literature commonly does not differentiate between barriers to adaptation planning and barriers to the implementation of adaptation measures. In this study it was assumed that barriers from literature are relevant for adaptation planning even though they might not be explicitly mentioned to be it.

After having outlined 4 main types of barriers in chapter 2, certain measures were used in order to translate these into conditions for the subsequent *QCA*. The first condition, "lacking institutional capacity", was measured by the ratio between the number inhabitants of a city and the number of people working in the city administration. While this ratio informs on how well cities are staffed in general, it does not reflect how the staff is distributed among the respective departments. Some cities may have a well-staffed environmental office despite having a comparably low total amount of people working in the city administration and vice versa. Also, the ratio only provides quantitative information regarding the institutional capacity but neglects qualitative information.

The second condition, "lacking top-down support", was measured by the degree of adaptation on the *Länder* level since support from the national level is identical among all cases. This was done by assessing the extent of adaptation strategies the *Länder* level regarding their number of pages and fields of action. However, the actual degree of support cities receive is not reflected but only assumed that where extensive adaptation strategies exist, the issue is regarded to be important and thus cities are provided with a high degree of support.

The third condition, "lacking financial resources", was measured by GDP per capita. While this surely provides a valid statement about the general economic situation of a city it does not reflect how funds an allocated among the departments. Similar to staff, some cities might allocate more financial resources for climate related issues than other which exhibit a higher GDP per capita.

The last condition, lacking attitude, was measured by the strength of the Green Party and the share of students among the total population. It was assumed, that cities with a weak Green Party and a low share of students have a generally less positive attitude towards climate issues and are less likely to develop adaptation strategies. However, this measure only represents the attitude of the population of a city and the attitude of political decision makers and authorities might differ. Moreover, having a low share of voters of the Green

Party does not necessarily indicate a low importance of climate issues since also other parties picked up climate political measures in their agendas.

The outcome, which was to be assessed by this study, is whether cities have adaptation strategies or not. In order to reflect the differing degree of adaptation, existing strategies were rated according to their pages numbers and fields of action. It is likely that this ratification inhibits some flaws as a complete judgement of the extent of adaptation based on only these two measures bears the risk of oversimplification. Furthermore, this studies only analyses urban adaptation regarding the existence of adaptation strategies. However, cities still might become active in adaptation despite not having elaborated an explicit adaptation strategy. As an example, the city of Kiel does not have an adaptation strategy but initiated the programme "KUR-Klimaanpassung in urbanen Räumen[29]" in 2018, which focuses on the analysis of climate change impacts for the city and potential measures to cope with them.

6.3 Implications for research

As the first study of its kind this study provides a comprehensive image of the extent of urban adaptation planning in Germany and presents general patterns and sufficient paths which constrain adaptation planning. It provides empirical evidence for the list of barriers which were commonly reported in the scientific literature and does not only reflect on the impact of single barriers but reveals potential interactions among them, as demanded by previous studies on the topic (Eisenack et al. 2014). Hence, it avoids the commonly highly context-specific nature of adaptation research (Biesbroek et al. 2013) and uncovers general dynamics behind urban adaptation planning.

The gathered knowledge can be used by researchers who intend to dig deeper into the exact dynamics that prevent a single city from adapting as it would be of high interest to determine whether the results of this study align with the perceptions of decision makers on the municipal level. Furthermore, the applied methodology could be used in order to determine constraining factors in other countries where adaptation strategies are so far less present than in Germany.

The conducted analysis showed that governmental support schemes for the developing of adaptation strategies are a vital tool for overcoming barriers. Future research could be

[29] English: „climate adaptation in urban areas", for more information see: https://www.kur.uni-kiel.de/kur/index.php/startseite.html

therefore focusing on the determination of factors that hamper cities from taking part in these programmers as they are available for all but still a reasonable number of cities does not engage in them.

Also, this study only revealed conditions which hamper the development of adaptation strategies but does not inform about potential barriers which might occur during the implementation of adaptation measures. Cities are likely to face additional challenges after they successfully developed an adaptation plan and seek to implement the agreed upon measures. Additional research is needed to investigate how successful cities are in implementing measures and which challenges they face.

6.4 Implications for policy

The present study provides political decision makers a comprehensive overview of the current state of adaptation planning in German cities. It shows, under which circumstances cities are likely to fail in developing adaptation strategies and thus enables a targeted support mechanism which aims at overcoming the identified barriers.

It has been shown, how crucial a well-staffed city administration is for the development of adaptation strategies and hence the resilience of a city towards climate change. Due to budgetary constraints, a simple raise in employees of the city administration is likely to be unrealistic but municipalities should be supported in the best possible way in developing strategies. It shows, that national initiatives are a very effective tool for the development of local adaptation strategies and allows also cities with an unfavorable financial and institutional capacity to develop comprehensive adaptation plan. While there already exist a wide range of different tools (see chapter 3.3.1), the communication of these tools should be improved in order to engage a maximum number of cities. As mentioned in the previous section, a targeted study would be of help to identify factors that hinder cities in taking parts of these programs.

Furthermore, it has been shown that especially small and medium-sized cities are at risk of not developing an adaptation strategy in case the adaptation strategy on the *Länder* level is comprehensive. Therefore, the responsibilities between municipal and *Länder* level regarding adaptation planning should be improved in order to avoid that cities rely on superior government level to deal with adaptation and lack own strategies.

The findings of this study could be also used by decision makers in other European countries in order to raise the number of cities with adaptation plans.

7. Conclusion

In the face of an ever more perceptible and intensifying climate change, successful adaptation strategies to these very changes will be of fundamental importance for the maintenance of human life on our planet. It is essential to act early in order to be able to face future challenges adequately.

Due to the increasing concentration of knowledge, economic activity and population, cities play a crucial role in this context. In Germany, too, the consequences of climate change are already being felt and will continue to intensify in the coming decades. In global comparison, warming in Germany is actually progressing particularly rapidly and thus requires comprehensive and effective strategies to prepare German cities for the expected challenges. While, compared to other European countries, German cities exhibit a comparably high number of adaptation strategies, it turns out that adaptation strategies are far less common than mitigation strategies. It was therefore the aim of this thesis to determine which factors hinder the development of adaptation strategies and to what extent these factors influence each other. A maximum understanding of barriers to adaptation strategies is crucial to address them effectively and to create a political and regulatory framework that offers the best possible degree of support for the development of adaptation strategies for German cities.

The review of the available literature shows that there are a multitude of possible barriers to climate change adaptation. These were categorized under 4 over-categories in the course of this work, which form the theoretical foundation for the subsequent analysis. During the selection process of measures for the picked conditions, a certain degree of simplification cannot be avoided and this work does not claim to cover all potential hurdles. Nevertheless, the applied method allowed to examine the integrated conditions both regarding their individual influence on the development of adaptation strategies and potential interactions between conditions. Furthermore, due to the inherent principle of equifinality in QCA, the present analysis avoids linear noncausality and determines a large number of combined conditions that are sufficient for the absence of adaptation strategies in German cities.

The results of the analysis show that all 4 integrated conditions have a significant impact on adaptation planning in German cities. Especially the high importance of the respective institutional capacity is clearly visible, which can sometimes prevent the development of adaptation plans even if a high degree of political will and financial resources is available.

The influence of higher political levels, however, is more difficult to determine, since a high level of adaptation activity can also have a slowing effect on local efforts if necessary financial resources and a positive attitude towards climate-related issues are not given. It is therefore of central importance that responsibilities are clearly communicated between the different administrative levels. At the same time, it has been shown that government support programmes that specifically aim to develop adaptation strategies can be a key element in overcoming barriers. It needs to be further investigated to what extent a higher participation of cities in such programmes can be achieved. The analysis of ~Outcome has also shown that even a complete absence of the 4 included conditions does not ultimately result in the existence of an adaptation strategy. This shows that it is very likely that, in addition to the conditions included in the study, there are a number of factors that prevent cities from developing adaptation strategies.

The present study is the first of its kind to provide a detailed picture of the current status of climate change adaptation in German cities and the factors hampering the development of adaptation strategies. It provides valuable insights into the general empirical significance and patterns of barriers outside of small-scale case studies and revealed how certain barriers influence each other. Likewise, its analytical focus resides on barriers to urban adaptation planning and not on the implementation of actual measures. Additional research is needed to determine potential pitfalls in the implementation process of adaptation measures. Also, a closer examination on potential barriers for the participation in governmental support programmes for the development of adaptation plans is encouraged as these proved to be very effective in elevating barriers.

The collected findings can be used both by researchers to further develop this field of knowledge and policy makers in Germany and abroad to increase the number of cities with comprehensive adaptation strategies and thus contribute to the best possible increase in the resilience of our societies to climate change.

Declaration

I hereby declare that this thesis is the result of my own work and that I have indicated all sources, including online sources, which have been cited without changes or in modified form, especially sources of texts, graphics, tables and pictures. I confirm that I have not submitted this thesis for any other examination. I am aware that in case of any breach of these rules procedures concerning plagiarism or attempted plagiarism will be taken in accordance with the subject-specific examination regulations and/or the Allgemeine Satzung zur Regelung von Zulassung, Studium und Prüfung der Humboldt-Universität zu Berlin (ZSP-HU).

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Neukirchen, 27.04.2020

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Appendix I Raw data matrix

(starts on next page)

City	GP_14	Source	POP	Source	Fed_adapt	Source
Augsburg	12.4%	https://de.wikipedia	292851	https://ec.europa.eu	Bayerische Klima-Anpassungsstrategie 2016	https://www.be
Berlin	15.2%	https://de.wikipedia	3613495	https://ec.europa.eu	Anpassung an die Folgen des Klimawandels in Berlin	http://www.pik
Bielefeld	15.9%	https://de.wikipedia	332552	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Bochum	12.8%	https://de.wikipedia	365529	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Bonn	18.6%	https://de.wikipedia	325490	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Bremen	17.4%	https://de.wikipedia	568006	https://ec.europa.eu	Klimaanpassungsstrategie Bremen Bremerhaven	http://www.kli
Cologne	19.5%	https://de.wikipedia	1080394	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Darmstadt	32.9%	https://de.wikipedia	158254	https://ec.europa.eu	Strategie zur Anpassung an den Klimawandel in Hessen	https://www.hl
Dortmund	15.4%	https://de.wikipedia	586600	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Dresden	15.7%	https://de.wikipedia	551072	https://ec.europa.eu	No integrative strategy	
Duesseldorf	13.8%	https://de.wikipedia	617280	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Erfurt	9.7%	https://de.wikipedia	212988	https://ec.europa.eu	Integriertes Maßnahmenprogramm zur Anpassung an die Folgen des Klimawandels im Freistaat Thüringen	https://umwelt.
Essen	25.8%	https://de.wikipedia	583393	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Frankfurt/Mair	15.3%	https://de.wikipedia	746878	https://ec.europa.eu	Strategie zur Anpassung an den Klimawandel in Hessen	https://ww
Frankfurt/Oder	6.2%	https://de.wikipedia	58237	https://ec.europa.eu	No integrative strategy, only few pages on adaptation in general climate concept	
Freiburg im Br	24.3%	https://de.wikipedia	229636	https://ec.europa.eu	Strategie zur Anpassung an die Folgen des Klimawandels in Baden-Württemberg	https://um.bade
Goettingen	27.9%	https://de.wikipedia	119529	https://ec.europa.eu	Klimapolitische Umsetzungsstrategie Niedersachsen	https://www.ur
Halle/Saale	8.7%	https://de.wikipedia	239173	https://ec.europa.eu	Strategie des Landes zur Anpassung an den Klimawandel	https://mule.sa
Hamburg	12.3%	https://de.wikipedia	1830584	https://ec.europa.eu	Aktionsplan Anpassung an den Klimawandel	https://www.ha
Hannover	21.4%	https://de.wikipedia	535061	https://ec.europa.eu	Klimapolitische Umsetzungsstrategie Niedersachsen	https://www.ur
Karlsruhe	19.9%	https://de.wikipedia	311919	https://ec.europa.eu	Strategie zur Anpassung an die Folgen des Klimawandels in Baden-Württemberg	https://um.bade
Kiel	20.4%	https://de.wikipedia	247943	https://ec.europa.eu	Anpassung an den Klimawandel - Fahrplan für Schleswig-Holstein	https://www.sc
Koblenz	13.9%	https://de.wikipedia	113844	https://ec.europa.eu	No integrative strategy	
Leipzig	15.0%	https://de.wikipedia	581980	https://ec.europa.eu	No integrative strategy	
Magdeburg	10.6%	https://de.wikipedia	238478	https://ec.europa.eu	Strategie des Landes zur Anpassung an den Klimawandel	https://mule.sa
Mainz	20.1%	https://de.wikipedia	215110	https://ec.europa.eu	No integrative strategy	
Moenchengladl	10.7%	https://de.wikipedia	262188	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Moers	9.0%	https://de.wikipedia	103949	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Muelheim an d	11.0%	https://de.wikipedia	171265	https://ec.europa.eu	Klimaschutzplan Nordrhein-Westfalen - Klimaschutz und Klimafolgenanpassung	https://www.kl
Muenchen	16.6%	https://de.wikipedia	1456039	https://ec.europa.eu	Bayerische Klima-Anpassungsstrategie 2016	https://www.be
Nuremberg	9.0%	https://de.wikipedia	515201	https://ec.europa.eu	Bayerische Klima-Anpassungsstrategie 2016	https://www.be
Potsdam	11.9%	https://de.wikipedia	175710	https://ec.europa.eu	No integrative strategy, only few pages on adaptation in general climate concept	
Regensburg	10.5%	https://de.wikipedia	150894	https://ec.europa.eu	Bayerische Klima-Anpassungsstrategie 2016	https://www.be
Rostock	11.4%	https://de.wikipedia	208409	https://ec.europa.eu	Adaptation strategy only for forestry and agriculture	
Saarbruecken	10.8%	https://de.wikipedia	180966	https://ec.europa.eu	No integrative strategy	
Schwerin	7.8%	https://de.wikipedia	95797	https://ec.europa.eu	Adaptation strategy only for forestry and agriculture	
Stuttgart	24.0%	https://de.wikipedia	632743	https://ec.europa.eu	Strategie zur Anpassung an die Folgen des Klimawandels in Baden-Württemberg	https://um.bade
Trier	16.6%	https://de.wikipedia	110013	https://ec.europa.eu	No inegrative strategy	
Weimar	15.5%	https://de.wikipedia	64426	https://ec.europa.eu	Integriertes Maßnahmenprogramm zur Anpassung an die Folgen des Klimawandels im Freistaat Thüringen	https://umwelt.
Wiesbaden	19.1%	https://de.wikipedia	278654	https://ec.europa.eu	Strategie zur Anpassung an die Folgen des Klimawandels in Baden-Württemberg	https://um.bade

Pages_fed_adapt	Foa_fed_adapt	Year_fed_adapt	GDP_07-09	Source	Empl_admin	Source	Ratio_inhab_empl	Stud_abs	Source	Stud_share	Is_Adapt
205	15	2016	42500	https://www.re	6500	https://www.aug	45.054	26051	https://appsso.e	10%	0
190	9	2016	24400	https://www.re	110000	https://www.berl	32.84995455	180582	https://appsso.e	5%	1
54	16	2015	30500	https://www.re	5716	https://www.biel	58.17914626	38180	https://appsso.e	11%	0
54	16	2015	30300	https://www.re	6000	https://www.bocl	60.9215	56730	https://appsso.e	16%	1
54	16	2015	40700	https://www.re	6900	https://www.bon	47.17246377	38665	https://appsso.e	12%	0
135	12	2018	41200	https://www.re	28000	https://www.fina	20.28592857	36334	https://appsso.e	6%	1
54	16	2015	43600	https://www.re	18000	https://www.stad	60.02188889	100541	https://appsso.e	10%	1
67	13	2012	51800	https://www.re	2500	https://www.darr	63.3016	41163	https://appsso.e	26%	0
54	16	2015	29700	https://www.re	9500	https://rathaus.dc	61.74736842	53312	https://appsso.e	9%	0
0			29700	https://www.re	23000	https://www.dres	23.95965217	42624	https://appsso.e	8%	1
54	16	2015	66900	https://www.re	10500	https://www.dues	58.78857143	52831	https://appsso.e	9%	1
168	12	2019	29900	https://www.re	4500	https://www.erfu	47.33066667	9953	https://appsso.e	5%	0
54	16	2015	35200	https://www.re	9000	https://www.esse	64.82144444	72062	https://appsso.e	12%	1
67	13	2012	76200	https://www.re	13000	https://www.fran	57.45215385	65504	https://appsso.e	10%	1
7		2008	28100	https://www.re	874	https://www.fran	66.63272311	6700	https://appsso.e	12%	0
166	9	2015	36000	https://www.re	4000	https://www.beru	57.409	33288	https://appsso.e	15%	1
60	15	2013	25600	https://www.re	2000	https://www.goet	59.7645	35119	https://appsso.e	29%	0
121	18	2019	22400	https://www.re	2700	https://m.halle.de	88.58259259	20822	https://appsso.e	9%	0
13	9	2013	47800	https://www.re	70000	https://www.xing	26.1512	101660	https://appsso.e	6%	1
60	15	2013	33000	https://www.re	11000	https://www.han	48.64190909	46548	https://appsso.e	9%	1
166	9	2015	47000	https://www.re	12000	https://web3.karl	25.99325	42213	https://appsso.e	15%	1
57	8	2017	36200	https://www.re	5000	https://www.kiel.	49.5886	34107	https://appsso.e	14%	0
0			53000	https://www.re	2250	https://www.kobl	50.59733333	14559	https://appsso.e	13%	0
0			26100	https://www.re	8000	https://www.leip	72.7475	37878	https://appsso.e	7%	1
121	18	2019	26700	https://www.re	2200	https://www.mag	108.3990909	18352	https://appsso.e	8%	0
0			39600	https://www.re	4000	https://www.mai	53.7775	37620	https://appsso.e	17%	0
54	16	2015	19100	https://www.re	5400	https://www.moe	48.55333333	7700	https://magazir	3%	0
54	16	2015	25300	https://www.re	1300	https://jobsnieder	79.96076923	8277	https://appsso.e	8%	0
54	16	2015	32000	https://www.re	2700	http://www.mbi-	63.43148148	4915	https://appsso.e	3%	0
205	15	2016	55100	https://www.re	35000	https://www.mue	41.60111429	119954	https://appsso.e	8%	1
205	15	2016	44200	https://www.re	11000	https://www.nuer	46.83645455	24414	https://appsso.e	5%	1
7		2008	30200	https://www.re	2400	https://www.pots	73.2125	24810	https://appsso.e	16%	1
205	15	2016	69100	https://www.re	3600	https://www.rege	41.915	31307	https://appsso.e	21%	0
0			34900	https://www.re	2500	https://rathaus.ro	83.3636	14376	https://appsso.e	7%	0
0			35600	https://www.re	2700	https://www.saar	67.02444444	31093	https://appsso.e	17%	1
0			30100	https://www.re	1000	requested via em	95.797	0	https://appsso.e	0%	1
166	9	2015	58800	https://www.re	13000	https://www.stutt	48.67253846	56046	https://appsso.e	10%	1
0			36400	https://www.re	1800	https://www.trier	61.11833333	18814	https://appsso.e	17%	0
168	12	2019	20200	https://www.re	900	https://stadt.wein	71.58444444	4591	https://appsso.e	7%	0
166	9	2015	48100	https://www.re	6000	https://www.wies	46.44233333	11346	https://appsso.e	4%	0

Name_Adapt	Source	Pages_adapt	Foa_adapt	Year_adapt
n.a.				
Konzept zur Anpassung an die Folgen des Klimawandels	http://www.pik	191	7	2016
n.a.				
Klimaanpassungskonzept Bochum	https://geodate	214	2	2012
n.a.				
Klimaanpassungsstrategie für Bremen und Bremerhaven	https://klimast	140	5	2018
Klimagerechte Metropole Köln	https://www.la	143	7	2013
n.a.				
n.a.				
Regionales Klimaanpassungsprogramm (IRKAP)	http://www.reg	281	6	2012
Klimaanpassungsprogramm für die Landeshaupstadt Düsseldorf	https://opendat	132	11	2017
n.a.				
Stadt begegnet Klimawandel	https://media.e	173	5	2014
Frankfurter Anpassungsstrategie an den Klimawandel	https://www.en	19	6	2014
n.a.				
Klimaanpassungskonzept Stadt Freiburg	https://www.fre	196	1	2019
Klimaplan Stadtentwicklung	https://www.go	25	2	2015
n.a.				
Aktionsplan Anpassung an den Klimawandel	https://www.ha	13	9	2013
Klimaanpassungskonzept für die Region Hannover 117	https://www.ha	117	4	2018
Bestandsaufnahme und Strategie für die Stadt Karlsruhe	https://www.ka	224	15	2013
n.a.				
n.a.				
Klimawandel Anpassungsstrategien für Leipzig	https://static.lei	36	5	2016
n.a.				
n.a.				
n.a.				
n.a.				
n.a.				
Konzept zur Anpassung an die Folgen des Klimawandels in der Landeshauptstadt München	https://www.m	144	5	2016
Handbuch Klimaanpassung	https://www.nu	93	3	2012
Klimaschutzteilkonzept Anpassung an den Klimawandel in der Landeshauptstadt Potsdam	https://www.po	281	10	2015
n.a.				
n.a.				
Städtische Freiraumplanung als Handlungsfeld für Adaptionsmaßnahmen	https://www.sa	130	2	2012
Klimaanpassungskonzept der Landeshauptstadt Schwerin	https://brs-schw	200	3	2016
Klimaanpassungskonzept Stuttgart KLIMAKS	https://www.st	75	10	2012
n.a.				
n.a.				
n.a.				

Legend of raw data table

City	Name of the respective city
GP_14	Share of the green party in city government in 2014
POP	Population of the respective city
Fed_adapt	Name of the adaptation strategy of the respective federal state
Pages_fed_adapt	Number of pages of adaptation strategy of federal state
Foa_fed_adapt	Fields of action of adaptation strategy of federal state
Year_fed_adapt	Issue year of adaptation strategy of federal state
GDP_07-09	GDP per capita 2007-2009
Empl_admin	Number of employees of administration of respective city
Ratio_inhab_empl	Ratio between inhabitants and employees in city administration
Stud_abs	Total number of students
Stud_share	Share of students in total population of city
Is_Adapt	Presene of an adaptation strategy
Name_Adapt	Name of the adaptation strategy of the respective city
Pages_adapt	Number of pages of adaptation strategy of city
Foa_adapt	Fields of action of adaptation strategy of city
Year_adapt	Issue year of adaptation strategy of city

Appendix II Data table used for *QCA*

City	GDP	Federal_adaptation	Administration	Attitude	Extent_adaptation
Augsburg	42500	3	45	1	0
Berlin	24400	3	33	1	3
Bielefeld	30500	2	58	2	0
Bochum	30300	2	61	2	2
Bonn	40700	2	47	2	0
Bremen	41200	2	20	1	2
Cologne	43600	2	60	2	1
Darmstadt	51800	2	63	3	0
Dortmund	29700	2	62	1	0
Dresden	29700	0	24	1	3
Duesseldorf	66900	2	59	1	3
Erfurt	29900	3	47	0	0
Essen	35200	2	65	2	3
Frankfurt/Main	76200	2	57	2	1
Frankfurt/Oder	28100	0	67	1	0
Freiburg im Breisgau	36000	3	57	3	2
Goettingen	25600	2	60	3	1
Halle/Saale	22400	3	89	0	0
Hamburg	47800	1	26	0	1
Hannover	33000	2	49	2	2
Karlsruhe	47000	3	26	3	3
Kiel	36200	2	50	2	0
Koblenz	53000	0	51	1	0
Leipzig	26100	0	73	1	1
Magdeburg	26700	3	108	1	0
Mainz	39600	0	54	3	0
Moenchengladbach	19100	2	49	0	0
Moers	25300	2	80	0	0
Muelheim an der Ruhr	32000	2	63	0	0
Munich	55100	3	42	1	2
Nuremberg	44200	3	47	0	2
Potsdam	30200	0	73	2	3
Regensburg	69100	3	42	2	0
Rostock	34900	0	83	1	0
Saarbruecken	35600	0	67	2	2
Schwerin	30100	0	96	0	3
Stuttgart	58800	3	49	2	3
Trier	36400	0	61	2	0
Weimar	20200	3	72	1	0
Wiesbaden	48100	3	46	1	0

Appendix III Rating process of adaptation documents and conditions

Outcome

City	Pages_doc	Rating_pages	FOA_doc	Rating_FOA	SUM	Rating_final
Berlin	191	3	7	3	6	3
Bochum	214	3	2	1	4	2
Bremen	140	2	5	2	4	2
Cologne	143	2	7	3	5	1
Dresden	281	3	6	3	6	3
Duesseldorf	132	2	11	3	5	3
Essen	173	3	5	2	5	3
Frankfurt/Main	19	1	6	3	4	1
Freiburg im Breisgau	196	3	1	1	4	2
Goettingen	25	1	2	1	2	1
Hamburg	13	1	9	3	4	1
Hannover	117	2	4	2	4	2
Karlsruhe	224	3	15	3	6	3
Leipzig	36	1	5	2	3	1
Munich	144	2	5	2	4	2
Nuremberg	93	2	3	2	4	2
Potsdam	281	3	10	3	6	3
Saarbruecken	130	2	2	1	3	2
Schwerin	200	3	3	2	5	3
Stuttgart	75	2	10	3	5	3

Comments:

- Rating of page numbers: < 50->**1**, < 150->**2**, > 150->**3**
- Rating of fields of action: < 3->**1**, < 6->**2**, > 5->**3**
- Rating of sum: 1,2->**1**, 3,4->**2**, 5,6->**3**
- The setting of threshold was mostly done according to distributional attributes of the data.
- Apart from the formal analysis certain qualitative judgements were made:
    - The sum for the city of Saarbruecken resulted in 2 which would have in a final rating of 1 but due to the high number of pages, the final rating was raised to 2.
    - Despite exhibiting a reasonable number of fields of action, the adaptation documents of Hamburg, Frankfurt/Main and Leipzig are very short and lack clearly defined measures. Thus, all 3 documents were rated with a final rating of 1.
    - As outlined in the main text, the adaptation of Cologne was rated with a final rating of 1 as it is rather an scientific research the potential impact of climate change in Cologne.

Condition “lacking top-down support”

City	Pages_Fed	Rating_pages	FOA_Fed	Rating_FOA	Sum	Rating_final
Baden Wurttemberg	166	3	9	1	4	3
Bavaria	205	3	15	2	5	3
Berlin	190	3	9	1	4	3
Brandenburg	7	1	0	0	1	0
Bremen	135	3	12	2	5	2
Hamburg	13	1	9	1	2	1
Hessen	67	2	13	2	4	2
Lower Saxony	60	2	15	2	4	2
Mecklenburg-Western Pomerania	0	0	0	0	0	0
North Rhine-Westphalia	54	2	16	3	5	2
Rhineland-Palatinate	0	0	0	0	0	0
Saarland	0	0	0	0	0	0
Saxony	0	0	0	0	0	0
Saxony Anhalt	121	3	18	3	6	3
Schleswig-Holstein	57	2	8	1	3	2
Thuringia	168	3	12	2	5	3

Comments:

- Rating of page numbers: < 50->**1**, < 100->**2**, > 100->**3**
- Rating of fields of action: < 10->**1**, < 15->**1**, > 15->**3**
- Rating of sum: 1,2->**1**, 3,4->**2**, 5,6->**3**
- Please note that the thresholds applied for *Länder* strategies differ from those applied for city strategies due to distributional reasons. The adaptation strategies of the *Länder* often exhibit distinctly more field of action and thus the same setting of thresholds as for city documents would have led to a disproportionately large set of “2” and “3”.
- Apart from the formal analysis certain qualitative judgements were made:
    - The adaptation strategy of North Rhine-Westphalia is formally rated as 3 but due to the low number of pages and the fact that it is not an individual strategy (part of the general climate concept) the final given score is 2.
    - Likewise, the strategy of Baden Wurttemberg was rated with a final rating if 3 due to its high number of pages despite receiving a formal final score of 2.
    - The document of Schleswig-Holstein was given a final rating of 2 instead of 1 since the environmental ministry has been lead for years by the current leader of the Green Party Robert Habeck. Thus it can be assumed that adaptation is a

more important issue in the federal state that the formal analysis of the adaptation document indicates.

- For the 3 city states Hamburg, Bremen and Berlin, the final rating was aligned with the final rating for the city documents as these documents are identical.

Condition "lacking attitude"

City	GP14	Rating_GP	Share_Stud	Rating_Stud	Sum	Rating_Final
Augsburg	12.4	1	10%	2	3	1
Berlin	15.2	2	5%	0	2	1
Bielefeld	15.9	2	11%	2	4	2
Bochum	12.8	1	16%	3	4	2
Bonn	18.6	3	12%	2	5	2
Bremen	17.4	2	6%	0	2	1
Cologne	19.5	3	10%	2	5	2
Darmstadt	32.9	3	26%	3	6	3
Dortmund	15.4	2	9%	1	3	1
Dresden	15.7	2	8%	1	3	1
Duesseldorf	13.8	1	9%	1	2	1
Erfurt	9.7	0	5%	0	0	0
Essen	25.8	3	12%	2	5	2
Frankfurt/Main	15.3	2	10%	2	4	2
Frankfurt/Oder	6.2	0	12%	2	2	1
Freiburg im Breisgau	24.3	3	15%	3	6	3
Goettingen	27.9	3	29%	3	6	3
Halle/Saale	8.7	0	9%	1	1	0
Hamburg	12.3	1	6%	0	1	0
Hannover	21.4	3	9%	1	4	2
Karlsruhe	19.9	3	15%	3	6	3
Kiel	20.4	3	14%	2	5	2
Koblenz	13.9	1	13%	2	3	1
Leipzig	15	2	7%	1	3	1
Magdeburg	10.6	1	8%	1	2	1
Mainz	20.1	3	17%	3	6	3
Moenchengladbach	10.7	1	3%	0	1	0
Moers	9.01	0	8%	1	1	0
Muelheim an der Ruhr	11	1	3%	0	1	0
Munich	16.6	2	8%	1	3	1
Nuremberg	9	0	5%	0	0	0
Potsdam	11.9	1	16%	3	4	2
Regensburg	10.5	1	21%	3	4	2
Rostock	11.4	1	7%	1	2	1
Saarbruecken	10.8	1	17%	3	4	2
Schwerin	7.8	0	0%	0	0	0
Stuttgart	24	3	10%	2	5	2
Trier	16.6	2	17%	3	5	2

Weimar	15.5	2	6%	0	2	1
Wiesbaden	19.1	3	4%	0	3	1

Comments:

- Rating of share of Green Party: < 10%->**0**, < 15%->**1,** < 18%->**2,** >18%->**3**
- Rating of share of students: < 7%->**0**, < 10%->**1**, < 15%->**2,** >15%->**3**
- Rating of sum: 0,1->**0**, 2,3->**1**, 4,5->2, 6->**3**
- The rating was mostly conducted according to distributional attributes of the data.

Appendix IV R- Script

```
rm(list=ls())
library(QCA)
library(SetMethods)
setwd("C:/Users/finnh/Desktop/Organisation/Studium/Master_INRM/5.+6. Semester/Masterarbeit/Data")
##Import dataset "Data_QCA"
read.csv("Data_QCA.csv",
         sep = ";",
         header = TRUE,
         stringsAsFactors = default.stringsAsFactors(),
         row.names = 1) -> Data_QCA
#recoding data and calibration
myRecode <- function(data_input,
                     cuts,
                     values)
{
  data_output = data_input
    for (i in 1:length(data_input))
  {
    data_output[i] = NA
  }
    data_output[data_input < cuts[1]] = values[1]
  data_output[data_input >= cuts[1] & data_input<cuts[2]] = values[2]
  data_output[data_input>=cuts[2] & data_input<cuts[3]] = values[3]
  data_output[data_input>cuts[3]] = values[4]
    return(data_output)
  }

##Calibration of condition "LOW_GDP"
myRecode(Data_QCA$GDP, cuts = c(30000, 36000, 50000), values = c(1, 0.66, 0.33, 0)) -> LOW_FinRes
plot(Data_QCA$GDP, LOW_FinRes)

## calibration of condition "missing Top-Down Support"## Note that calibration is done according to assumption that low top down
support=1, high =0
plot(sort(Data_QCA$Federal_adaptation))
myRecode(Data_QCA$Federal_adaptation, cuts = c(0, 1, 2)+0.5, values = c(1, 0.66, 0.33, 0)) -> LOW_TopSupp
plot(jitter(Data_QCA$Federal_adaptation), jitter(LOW_TopSupp))

## calibration of condition "low institutional capacity"
```

```
plot(sort(Data_QCA$Administration))
myRecode(Data_QCA$Administration, cuts = c(40,55,70), values = c(0, 0.33, 0.66, 1)) -> LOW_InstCap
plot(jitter(Data_QCA$Administration), jitter(LOW_InstCap))

## calibration of condition "lacking attitude"##
plot(sort(Data_QCA$Attitude))
myRecode(Data_QCA$Attitude, cuts = c(0,1,2)+0.5, values = c(1, 0.66, 0.33, 0)) -> LOW_Att
plot(jitter(Data_QCA$Attitude), jitter(LOW_Att))

## calibration of outcome
plot(sort(Data_QCA$Extent_adaptation))
myRecode(Data_QCA$Extent_adaptation, cuts = c(0, 1, 2)+0.5, values = c(1, 0.66, 0.33, 0)) -> OUTCOME
plot(jitter(Data_QCA$Extent_adaptation), jitter(OUTCOME))

## Putting the sets together
BarriersQCA = data.frame(cbind(LOW_FinRes, LOW_TopSupp, LOW_InstCap, LOW_Att, OUTCOME))
rownames(BarriersQCA) = rownames(Data_QCA)
BarriersQCA
cbind(Data_QCA, BarriersQCA)[, c(1, 1+5, 2, 2+5, 3, 3+5, 4, 4+5, 5, 5+5)]   # Comparing the datasets

## Testing for necessity
QCAfit(BarriersQCA[, 1:4], OUTCOME, necessity = TRUE)
# No condition is individually necessary for OUTCOME

## Testing for sufficiency
## Individual conditions
QCAfit(BarriersQCA[, 1:4], OUTCOME, necessity = FALSE)

## visual inspection
XYplot(LOW_TopSupp,
      OUTCOME,
      relation = "sufficiency",
      jitter = TRUE,
      clabels=rownames(BarriersQCA))

XYplot(LOW_FinRes,
      OUTCOME,
      relation = "sufficiency",
      jitter = TRUE)
```

```
XYplot(LOW_InstCap,
      OUTCOME,
      relation = "sufficiency",
      jitter = TRUE, cex=1,cex.lab=2,
      clabels = rownames(BarriersQCA))

XYplot(LOW_Att,
      OUTCOME,
      relation = "sufficiency",
      jitter = TRUE)

## Truth table analysis

BarriersTT<-truthTable(BarriersQCA,
                  outcome = "OUTCOME",
                  incl.cut = 0.75,
                  n.cut = 1,
                  complete = TRUE,
                  show.cases = TRUE,
                  sort.by = "incl",
                  neg.out = FALSE)

BarriersTT
BarriersTT$tt[BarriersTT$tt$n == 1, "cases"]

# Raise n.cut to 2
BarriersTT<-truthTable(BarriersQCA,
                  outcome = "OUTCOME",
                  incl.cut = 0.75,
                  n.cut = 2,
                  complete = TRUE,
                  show.cases = TRUE,
                  sort.by = "incl",
                  neg.out = FALSE)
BarriersTT

## Complex solution
#BarriersSC<-minimize(BarriersTT, details = TRUE, show.cases=TRUE, pi.cons = 0.75)
BarriersSC<-minimize(BarriersTT, details = TRUE, show.cases=TRUE)
BarriersSC
```

```
this_prime_implicant = 1
XYplot(data.frame(BarriersSC$pims[this_prime_implicant],
                  OUTCOME),
       jitter = TRUE,
       clabels = rownames(BarriersSC$tt$minmat),
       xlab = colnames(BarriersSC$pims)[this_prime_implicant],
       ylab = "OUTCOME")

this_prime_implicant = 2
XYplot(data.frame(BarriersSC$pims[this_prime_implicant],
                  OUTCOME),
       jitter = TRUE,
       clabels = rownames(BarriersSC$tt$minmat),
       xlab = colnames(BarriersSC$pims)[this_prime_implicant],
       ylab = "OUTCOME")

this_prime_implicant = 3
XYplot(data.frame(BarriersSC$pims[this_prime_implicant],
                  OUTCOME),
       jitter = TRUE,
       clabels = rownames(BarriersSC$tt$minmat),
       xlab = colnames(BarriersSC$pims)[this_prime_implicant],
       ylab = "OUTCOME")

this_prime_implicant = 4
XYplot(data.frame(BarriersSC$pims[this_prime_implicant],
                  OUTCOME),
       jitter = TRUE,
       clabels = rownames(BarriersSC$tt$minmat),
       xlab = colnames(BarriersSC$pims)[this_prime_implicant],
       ylab = "OUTCOME")

## Compare with LOW_IstCap alone
XYplot(apply(BarriersSC$pims, 1, max),
       OUTCOME,
       jitter = TRUE,
       clabels = rownames(BarriersSC$tt$minmat),
       xlab = "Solution Formula",
       ylab = "OUTCOME")
```

```
XYplot(LOW_InstCap,
      OUTCOME,
      relation = "sufficiency",
      jitter = TRUE,
      clabels = rownames(BarriersQCA))

# Analysis of ~OUTCOME
BarriersTT<-truthTable(BarriersQCA,
                  outcome = "OUTCOME",
                  incl.cut = 0.75,
                  n.cut = 2,
                  complete = TRUE,
                  show.cases = TRUE,
                  sort.by = "incl",
                  neg.out = TRUE)

BarriersTT
```