Climate Governance Transitions

A Case Study of Climate Adaptation, Governance, and Climate-Resilience in Cologne, Germany

TITLE PAGE

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STUDENT REPORT

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This thesis is the outcome of my two year´s Master Programme in Sustainable Cities at Aalborg University. Furthermore, this is the last student paper of my higher education while being the first paper (of such a great extent) which I am writing alone. Therefore I feel that my learning outcome of this writing process was immense which I am so grateful about.

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ABSTRACT

Human induced climate change and increased urbanisation are challenging cities' development. While climate change needs to be mitigated in order to keep the impacts at a minimum, there are already some effects which are irreversible. This requires cities to conduct efficient and successful climate adaptation. Unpredictable extreme weather events such as heavy precipitation events and extended drought periods are affecting cities across the globe, including the chosen case area Cologne, Germany. These impacts require adaptive climate governance to perform Sustainable Urban Water Management (SUWM) and enhance climate-resilience. Therefore this report is identifying the main challenges Cologne is facing and how climate adaptation is currently governed in Cologne. The organisational culture of the municipality is still to a large extent characterised by silos with insufficient coordination in between. This report is exploring how the current regime in Cologne can be transitioned. The shift can be triggered by niche innovations as well as incumbent regime actors. The presentation of four reference projects allows for international insights to provide inspiration for Cologne's regime. Additionally, synergies, co-benefits, and added value of the reference projects are highlighted to emphasise the importance of synergies for successful climate adaptation. The *Principles for Water Wise Cities* (PWCC) framework can thereby support Cologne to perform water sensitive urban design by utilising synergies and therefore enhance climate-resilience. Lastly, this report finishes with a discussion about different scales of adaptation measures, the fact of location-based adaptation, the dilemma of policy levels, and the role of academia to prevent trained incapacity in climate governance.

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V ABBREVIATIONS

APA	Aktionsplan Anpassung (Action Plan Adaptation)
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
CO_2	Carbon Dioxide
DAS	Deutsche Anpassungsstrategie (German Adaptation Strategy)
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IWA	International Water Association
UHI	Urban Heat Island
LANUV	Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (State Office for Nature, Environment, and Consumer Protection)
MKULNV	Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz (Ministry of Climate Mitigation, Environment, Agriculture, Nature, and Consumer Protection)
MULNV	Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen (Ministry of Environment, Agriculture, Nature, and Consumer Protection of the State NRW)
NbS	Nature-based Solutions
NRW	Nordrhein-Westfalen
PWCC	Principles for Water-Wise Cities
StEB	Stadtentwässerungsbetriebe Köln (Water Utility Cologne)
SUWM	Sustainable Urban Water Management
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
VertiKKA	Vertikale Klimakläranlage (Vertical Climate Treatment Plant)

GLOSSARY

VI

Anpassungsstrategie	Adaptation Strategy
Bauleitplanung	Urban Land Use Plans
Grünflächenamt	Parks and Recreation Office
Hitzeaktionsplan	Heat Action Plan
Klimaanpassungsgesetz	Climate Adaptation Law
Klimaschutzgesetz	Climate Mitigation Law
Klimaschutzplan	Climate Protection Plan
Klimawandelgerechte Metropole Köln	Climate Change Appropriate Metropolis Cologne
Klimawandelvorsorgestrategie	Climate Change Precaution Strategy
Koordinationsstelle Klimaschutz	Coordination Department Climate Mitigation
Rheinische Tiefebene	Rhine-lowlands
Stadt Köln	Municipality of Cologne
Stadtentwässerungsbetriebe Köln	StEB - Water Utility Cologne
Trennerlass	Separation Decree
Umwelt- und Verbraucherschutzamt	Environmental and Consumer Protection Office - further referred to as Umweltamt
Vertikale Klimakläranlage	Vertical Climate Treatment Plant

Chapter 1
Introduction

1

Anthropogenic activities are continuously affecting planet Earth. Scholars have defined nine planetary boundaries in which it is safe to operate. Once planetary boundaries are exceeded, the future of those processes become unpredictable. Already in 2015, four of these nine boundaries were exceeded. One of the crossed boundaries is atmospheric carbon dioxide which is an indicator and main driver for climate change (European Commission, 2015).

Unpredictable events related to climate change such as droughts and floods are occurring all over the globe. The awareness about anthropogenic climate change, which at this point has some impacts that are unavoidable and irreversible, is shifting the question from whether climate is changing to how we can adapt to its effects. This requires action for both mitigating and adapting to the climate. Scholars argue that change usually happens when problems occur but as has been seen in an increase in extreme weather events globally, problems are already appearing. Cities have to transform now to be able to respond to climate change although considering the uncertainty of *"exact nature, magnitude, and timing of climate changes"* (Bierbaum et al., 2013, pp. 362–363).

The latest Assessment Report on climate change put forth by the Intergovernmental Panel on Climate Change (IPCC) illustrates the importance of accelerated action in adapting to climate change to secure sustainable development. The IPCC emphasises the role of policy design and governance to enable synergies and prevent trade-offs when conducting climate adaptation. Additionally, the cross-sectoral approach is highlighted in order to perform successful climate adaptation (IPCC, 2022).

Furthermore, the effects of climate change in cities exacerbates with increased urbanisation. By 2050, the urban population is estimated to reach up to 70% of the world's population, compared to approximately 50% today (United Nations et al., 2019). These uncontested challenges call for efficient resource management, including sustainable urban water management (SUWM). In combination with increasing extreme weather events due to climate change, urban planning regimes have to shift their planning paradigm in order to successfully respond to these multifaceted problems and sustain crises. This new paradigm is able to identify synergies and unlock co-benefits between adaptation measures and is working with cross-sectoral teams to achieve climate-resilience.

Climate change and urbanisation are global phenomena and therefore also affect Germany. Cologne is a city in West Germany which is suffering from climatic impacts and an already dense urban design. After a dramatic storm in the summer of 2021, Cologne had to face challenges related to urban flooding. On the other hand, the city is struggling with extended heat periods during summer resulting in droughts which calls for SUWM (LANUV, 2013). Therefore, the present report is analysing the climate adaptation governance in the city of Cologne, Germany as a case in order to understand how the regime in Cologne is responding to climate change. Furthermore, it will be determined how the current planning regime can be challenged to perform SUWM and therefore move towards climate-resilience. Ultimately, this report aims to draw a picture of the importance of successful climate governance to create resilient cities that are utilising synergies, co-benefits, and added value.

Chapter 2

The Need for Climate Governance and Resilience

Human induced greenhouse gas (GHG) emissions in combination with land use change are disrupting the global carbon cycle resulting in a changing climate (Bierbaum et al., 2013). The challenges coming with climate change are multi-faceted and complex to approach. This calls for a successful climate governance which can lead to urban climate-resilience.

2.1 Climate Change and Water

Climate change is affecting one of the main components of the planetary system which is rudimentary for life on planet Earth - the water cycle, also known as the hydraulic cycle. The water cycle is the occurrence of sequential processes of movement of water on earth. Water thereby changes its state between liquid, vapour, and solid form. As the name indicates, it is a circular system where there is no beginning or end to the processes. Simply put, water from the oceans evaporates into the atmosphere where it condenses into clouds. From there, the water vapour falls back on earth in the form of precipitation. The runoff of the precipitation as well as snowmelt runoff ultimately infiltrates into the groundwater to recharge the groundwater storage or flows into surface water such as rivers, lakes, and oceans. This is a very simplistic description of the water cycle. In fact, there are many more components that affect the water cycle such as evapotranspiration from plants and soil, the sun heating up the water for evaporation, and air currents which can further be seen in figure 1 (USGS, n.d.). The water cycle regulates the human, animal, and plant life on Earth and is furthermore fundamental to other nutrient cycles on our planet such as the carbon cycle. Its stability is therefore crucial for sustaining entire ecosystems (Kundzewicz, 2008; Sohoulande et al., 2016). Climate change is affecting every stage and component of the water cycle. However, these effects vary from one location to another as well as in magnitude and resulting challenges - it is a dynamic change (Sohoulande et al., 2016).

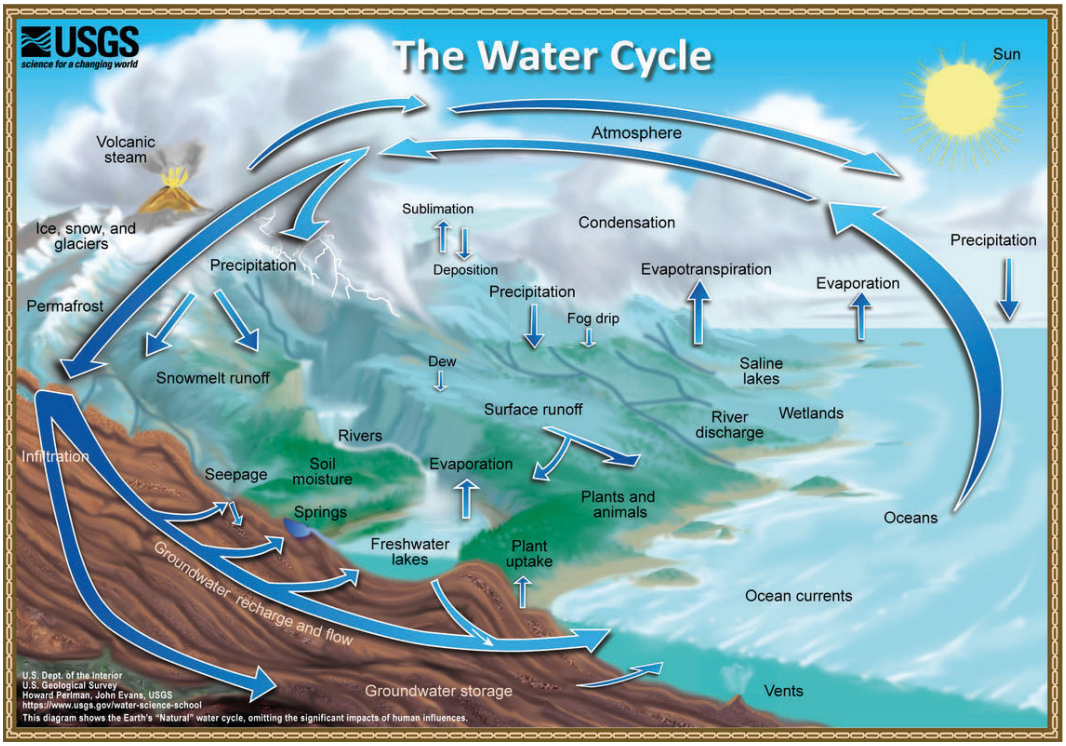

Figure 1: The Water Cycle (USGS, n.d.).

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The impact of climate change on precipitation is linked to increased temperatures. Scientists agree that the increased moisture in the air is the result of a higher oceanic evaporation rate consequential to increased water surface temperature. Identified changes in precipitation patterns are mainly the repeated occurrence of unexpected extreme weather events. Said events result in societal impacts such as interference with agriculture yields and endangering groundwater in terms of *"quality, quantity, and functionality"* (Sohoulande et al., 2016, p. 41). Groundwater levels and quality is dependent on precipitation patterns and therefore endangered by the previously mentioned disturbances. The longer drought periods in between precipitation events lead to depletion of groundwater resources but also affect the soil's ability to let the water infiltrate (Sohoulande et al., 2016). Droughts can affect the soil's infiltration capacity and subsequently lead to increased runoff from the crusted soil (UNDRR, 2021). The water cycle's stability is therefore incremental for sustainable communities and ecosystems (Sohoulande et al., 2016).

2.2 Current Challenges for Cities

Cities all over the world encounter severe challenges in the face of climate change. But not only is climate change pressuring cities' development regimes, but megatrends such as urbanisation are also demanding cities to adapt to new circumstances. Moreover, the world population is growing while the trend of moving into cities is simultaneously increasing (Koop & van Leeuwen, 2017). While currently more than 50% of the world's population lives in cities, it is projected to reach up to 70% in 2050 (United Nations et al., 2019). Additionally, cities are responsible for the majority of the world's energy consumption and GHG emissions (70% and 75% respectively) while covering just 2% of land surface (Koop & van Leeuwen, 2017).

With these uncontested challenges ahead, cities have to ultimately find a way to become more sustainable and resilient to climatic hazards. This requires a large-scale transition of the societal system through structural change of the current regimes with future generations in mind (Koop & van Leeuwen, 2017). The new planning regime has to plan and prepare for an unpredictable future, preventing catastrophic impacts of climate change on economies, society, and ecosystems. Effects of climate change on nature can be self-aggravating and consequently cause a chain reaction of negative effects. For instance, warmer temperatures lead to defrosting permafrost which releases more GHG emissions which amplify climate change and global warming (Garrelts & Lange, 2011). This is just one example of the unpredictabilities of climatic impacts in a complex and interconnected ecosystem. Ultimately, this report is focusing on the handling of stormwater in cities. Stormwater in this context is understood as all surface water which results from heavy rain.

2.3 Climate Mitigation and Adaptation

As already emphasised in the sections before, climate change is impacting cities and ecosystems. There are two ways to fight these effects, which are climate mitigation and climate adaptation. Mitigating climate change means reducing or even avoiding the impacts that affect the climate and therefore reducing the impacts. The main strategy here is to mitigate the release of GHGs into the atmosphere. Adaptation to climate change, on the other hand, is targeting the already occurring and to some extent non reversible effects of climate change and is adjusting infrastructures, other structures, and processes to the changed and ever-changing climate. Thereby, damages related to climate change can be mitigated or even avoided. The

United Nations Framework Convention on Climate Change (UNFCCC) defines climate adaptation as follows:

"Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solutions and implement action to respond to the impacts of climate change that are already happening, as well as prepare for future impacts."
(UNFCCC, n.d.)

2.3.1 Challenges of Climate Adaptation and Urban Water Management

From a historical view, cities tended to locate and develop close to water sources since water is rudimentary to life and regulating ecosystems. Therefore most big cities today are crossed or immediately connected to a water source of some kind (Sohoulande et al., 2016). This ultimately requires cities and municipalities to manage the water. With the effects that climate change has on the water cycle, in combination with increasing urbanisation, municipalities are facing challenges to create robust and sustainable systems. Ironically, the accessibility of water together with emerging engineering technologies related to water has allowed urban and demographic growth which resulted in increasing urbanisation and its challenges originating (Sohoulande et al., 2016).

In the article *"The challenges of water, waste and climate change in cities"*, Koop and Van Leuween (2017) point out the urgency to address sustainable urban water management (SUWM). Cities are running out of time in the fight against water scarcity, groundwater depletion, heavier and more precipitation in connection with extended drought periods leading to pluvial floods - all of which affect society's stability and cause economic stress. Nonetheless, the authors mention the power of such external stresses to raise awareness and ultimately stimulate a regime shift. They argue, however, that adaptation measures that are reactive to crises are usually ineffective and expensive. Therefore, they see the global challenge in moving from reactive measures to proactive transitions which require many actors and stakeholders to be involved (Koop & van Leeuwen, 2017).

It has become apparent that the effects of climate change are complex and affect many different entities. Governments thereby must lay the ground for interdisciplinary planning across sectors and interest groups by developing adaptation policies (Garrelts & Lange, 2011). Water management has to be integrated and combined with other urban developments to meet the complexity and mitigate trade-offs (Sharifi, 2020).

2.3.2 Climate Adaptation Measures

There are generally different approaches towards climate adaptation and stormwater management in cities. On the one hand, there is the traditional grey infrastructure which focuses on handling the stormwater with engineering measures such as large scale pumps, draining pipes, but also dams and treatment plants. However, when talking about resilience and sustainable solutions, these monofunctional measures are not feasible and reasonable (Voskamp & Van de Ven, 2015; Zölch et al., 2018). On the other hand, green infrastructure refers to Nature-based Solutions (NbS) that provide ecosystem services, aiming to increase urban resilience (Zölch et al., 2018). Blue-green measures are NbS, combining green infrastructure with blue infrastructure (related to water) and using an ecosystem approach and natural processes to adapt to the changing climate (Voskamp & Van de Ven, 2015).

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The following sections elaborate on blue-green NbS and the benefits thereof. Additionally, the engineered stone wool innovation Rockflow as a blue solution is presented and its attempt to create resilient cities.

Nature-based Solutions

The idea of blue-green NbS is to combine urban greenery with stormwater management to save fresh water use and adapt to the changing climate at the same time. The concept is to collect and store stormwater instead of discharging it into the sewer system and utilise the surplus water in drought periods. This approach brings added value since it can both handle stormwater of heavy precipitation events, enhance cooling via evapotranspiration to avoid heat stress, relieve pressure from the sewer infrastructure, and recharge groundwater. The type of value added by a blue-green NbS depends on the specific measure. Examples of such solutions are water storage and harvesting, retention, detention, infiltration, and cooling through evapotranspiration. Thereby, NbS is capitalising synergies between ecosystems to ultimately enhance urban climate-resilience. Voskamp & Van de Ven (2015) emphasise the importance of combining green with blue infrastructure since *"green depends on the availability of water in times of drought and extreme heat"* (Voskamp & Van de Ven, 2015, p. 160). Figure 2 and 3 show two examples of NbS; an infiltration ditch and a rain garden.

The complexity of implementing such NbS in combination with a knowledge gap on how to integrate these measures in urban planning identified by the Intergovernmental Panel on Climate Change (IPCC) explain why NbS are not (yet) the norm in urban climate adaptation regimes (IPCC, 2022; Voskamp & Van de Ven, 2015). However, considering the climatic and demographic challenges cities are facing, enhancing climate-resilience seems to be of utmost importance. Therefore, *"[a]n integrated and interdisciplinary approach is essential in order to strategically plan for this increased resilience"* (Voskamp & Van de Ven, 2015, p. 160).

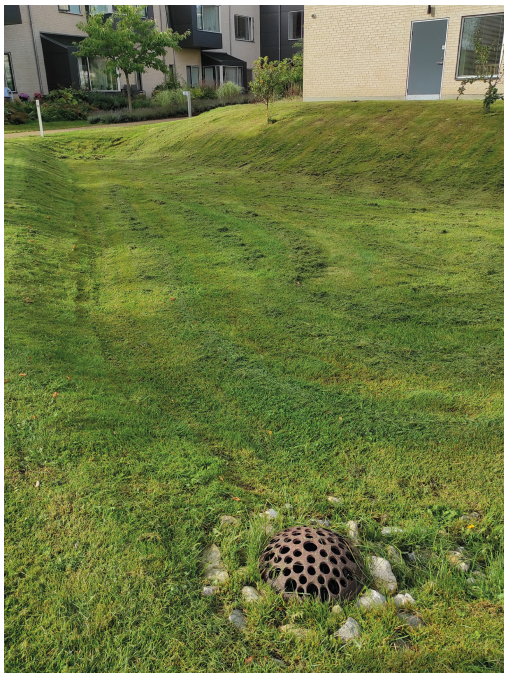

Figure 2: Infiltration ditch, fed with roof runoff (own figure).

Figure 3: Rain garden, fed with roof runoff (own figure).

Rockflow by ROCKWOOL

This section is exploring another niche innovation to handle stormwater locally. It is the stone wool product Rockflow, developed from the Danish building insulation manufacturer ROCKWOOL. Rockflow is made from stone wool (which is claimed to be fully circular) to be used by municipalities to adapt to the changing climate. Mentioned climate challenges are more and intensified precipitation patterns, extended drought periods as well as consequences such as heat stress from rising temperatures. With more and heavier rainfalls the sewer systems are stressed at times which results in sewer overflow which has negative impacts itself (health issues, flooding of roads resulting in failing infrastructure, ponding and pluvial flooding, damages to houses and other infrastructures). At the same time societies are facing water scarcity due to higher temperatures and longer drought periods. Considering said challenges there is an interest to keep the water in the city rather than discharging it into the sewer system. This product can capture, retain, and infiltrate stormwater and prevent said challenges locally. It therefore provides a *"natural delay of rainwater"* (ROCKWOOL, n.d.).

The product comes in panels of manufactured stone wool. Figure 4 shows Rockflow during its installation process in an urban area. It is installed underground and creates cloudburst reservoirs to delay stormwater filling in the sewer system. It may also infiltrate into the groundwater and subsequently be used for urban green spaces. Solutions using Rockflow entail line infiltration, central buffer, swales, urban greenspaces, and sport areas. Rockflow has high drainage and buffer capacity, it can absorb up to 95% of its own volume in water. Especially in the face of limited space in cities, sufficient capacity is important. Rockflow has a high load-bearing capacity due to the strong structure of stone fibres which makes it ideal for installation below roads, public squares, buildings, and parks. The Rockflow panels are easily adaptable to complex underground systems from pipes, cables, and other obstacles. The high flexibility does not reduce the system functionality. The product contains mainly recycled materials

Figure 4: Rockflow installation in an urban area (ROCKWOOL, n.d.).

which are complemented by basalt rock, which is an inexhaustible raw material. The product itself is fully recyclable. It is a *"versatile product with a wide range of applications"* (ROCKWOOL, n.d.).

2.4 Resilience and Added Value

If cities make use of adaptation measures, whether it is grey, green, or a combination of both, they are able to enhance their climate-resilience. Resilient cities can react to and recover from crises and go back to a pre-equilibrium or even an improved equilibrium prior to the crisis (Wong & Brown, 2009). This idea implies that there is never a maximum of resilience since it is a concept of constantly adapting and recovering to ever-changing preconditions and disturbances. Resilience can be understood as the opposite of vulnerability (Wilson, 2014).

Climate hazards and natural disasters caused by climate change can, and eventually will, stress assets, infrastructures, and economies (Koop & van Leeuwen, 2017). For example, the floods in Germany in July 2021 have caused damage worth $40 billion where infrastructure and assets were severely damaged and people killed. To date, this was the most expensive natural disaster in the country (Deutsche Welle, 2022). Despite the knowledge of high costs related to environmental hazards, scholars argue that the research both on costs for inaction (as in no adaptation measures at all) and costs for adaptation measures are scarce. However, preliminary estimates give the impression that the benefits of multifunctional adaptation measures will outweigh the costs (Koop & van Leeuwen, 2017). Multifunctional solutions can thereby create added value and provide ecosystem services (Voskamp & Van de Ven, 2015). As an example, the city of Copenhagen did calculate the costs of environmental hazards related to climate change in relation to costs for climate adaptation measures. They concluded in future savings from €2.6-3.2 billion (Koop & van Leeuwen, 2017).

As previously mentioned, many scholars argue that NbS strengthen urban resilience and contribute to urban planning through co-benefits. Such benefits are not only related to infrastructure and handling stormwater in a sustainable way but also have societal impacts. Besides already mentioned added value, NbS enhance biodiversity, provide recreational space, and additionally contribute to climate mitigation. To achieve said societal and environmental benefits, a participatory approach is encouraged since it involves many different stakeholders (Zölch et al., 2018). Such processes can be very time and resource-intensive (World Meteorological Organisation, 2015).

2.5 Governing Climate Adaptation

Climate adaptation is location-based, there is no one-size-fits-all solution (Bierbaum et al., 2013). It is very much dependent on the effects the climate has on the specific country, region, city, or even urban area (Difu, 2015). Even though there are global goals on climate adaptation e.g. in the Paris Agreement, it is not legally binding. Scholars argue that adaptation is a local and private good, since benefits are mainly felt locally where measures are implemented. This creates little incentives for regulating on an international level (Hall & Persson, 2018).

The dependency on the context as well as the unpredictability of the events make the planning and implementation of climate adaptation more complex compared to mitigation measures (World Meteorological Organisation, 2015). Furthermore, it seems more difficult to adopt nationwide regulations for a topic which is highly dependent on the regional context (Sharifi, 2020). A study

about the climate adaptation efforts in the United States identified that the current adjustments are mainly incremental, *"not the transformational changes that may be needed in certain cases to adapt to significant changes in climate"* (Bierbaum et al., 2013, p. 361).

The *Deutsches Institut für Urbanistik* (Difu - German Institute for Urbanism) reports that climate adaptation is less commonly implemented in German cities compared to climate mitigation measures. This might be due to the prioritisation of tasks and finances as well as the unpredictability of future climatic patterns. Additionally, implementing climate adaptation measures requires knowledge about climatic patterns and a cross-disciplinary approach (Difu, 2015).

The common practice is to look at climate mitigation and adaptation separately (Sharifi, 2020). Traditionally, this leads to conflicts of interests since some of the measures are working contradictorily at first sight or even result in trade-offs (IPCC, 2022). For instance, a loose urban development with low density and a high proportion of green, open space is beneficial for climate adaptation. This principle is working against the fundamentals of mitigating GHG emissions with energy and resource-efficient neighbourhoods consisting of high density and compact settlement structures. Despite the conflicts of interests, mitigation and adaptation have the ability to work together and benefit from each other. Multifunctionality of space is crucial and it requires prioritisation of climate matters over e.g. fossil fuel-based mobility (Sharifi, 2020). As an example, Copenhagen is currently rebuilding streets in the inner city that once have been car-dominated to close them completely or partly for cars, make space for pedestrians, bikes, and urban greenery. Vendersgade, in the centre of the city, is currently being redesigned for soft traffic having pedestrians and cyclists in the focus and at the same time adapting to climate challenges as well as creating added value for users (Gottlieb Paludan Architects, 2021). This requires a large-scale regime shift and rethinking of the entire urban development.

2.6 Case Study for Analysing Climate Adaptation Governance

The unpredictability and severity of climatic hazards in connection with heavy precipitation can be observed by looking at the storms occurring in Germany in the summer of 2021. In the period of July 12th to July 15th the country but especially the North-Western part around the federal state of Nordrhein-Westfalen (NRW - Figure 5 locates NRW in the German context) suffered from severe floods as a result from ongoing heavy precipitation. Consequences from these floods were failure of basic infrastructure such as electricity and drinking water supply, damaged properties and infrastructure, and even fatalities (Junghänel et al., 2021).

Figure 5: NRW in West Germany (own figure, downloaded and adapted from AdobeStock).

Based on this dramatic outcome of extreme weather events especially in NRW, the author decided to take a closer look at challenges in NRW and the city of Cologne specifically. NRW is the densest populated state in Germany with every second inhabitant living in an urban context (LANUV, 2013). It entails an agglomeration of several medium-sized and large cities with Cologne being the largest city in that area. Therefore, Cologne has been chosen as the case area since it is the largest metropolis in NRW with approximately one million inhabitants with an upward trend as it is still a growing city (Stadt Köln, 2019). Subject to the present paper is the analysis of current challenges within the city of Cologne and identifying organisational structures to determine development hurdles.

2.7 Problem Statement and Research Question

Climate change is already and will continuously affect life on earth, especially in cities. The pressure on cities is already high with heavier precipitation, extended drought periods, and heatwaves challenging municipalities with urban development (Koop & van Leeuwen, 2017). While mitigating is a very important and urgently necessary step in the fight against climate change, cities also have to adapt to the changes that are already irreversible and constantly causing damage; both economically, socially, and environmentally. The complexity of climate change and the interdependency and multicausality of its effects make it difficult to adapt (Conradie, 2020). Globally, climate adaptation appears to be still rather slow compared to the fact that it is a race against time and its effects are unpredictable in terms of date of appearance and extent (Koop & van Leeuwen, 2017). Water scarcity, floods, and heat stress are only some causes that have to be planned for. Conventional grey infrastructures such as pipe systems have been shown to be insufficient, especially in the face of water scarcity and heat stress where the urban stormwater is needed in the city instead of transporting it outside via pipe systems. Nature-based Solutions (NbS) or solutions that endeavour multifunctionality and local stormwater management can be a vital tool to these challenges (Voskamp & Van de Ven, 2015). Along with this, integrated solutions have to be developed which include synergies and added value to create climate-resilient cities. This planning discipline is complex and involves several stakeholders to discuss and ultimately make the most sustainable decisions. However, traditional organisations of municipalities are used to operating in silos with little or not sufficient cooperation and coordination (Aylett, 2011). This organisational trajectory is opposed to the aspiration of having integrated urban water management resulting in successful climate adaptation.

In order to examine the presented problem, it was chosen to analyse the city of Cologne, Germany and the local climate governance. Cologne has experienced a dramatic heavy precipitation event in the summer of 2021 which resulted in property and infrastructure damages and fatalities (Junghänel et al., 2021). To prevent a traumatic event such as this one from happening, Cologne needs to transition to a climate-resilient city which is managing stormwater sustainably and is resilient to climatic changes. Therefore, the following research question has been developed to support the research process:

How is climate adaptation in Cologne organised and how can the current regime be challenged to move towards climate-resilience and water sensitivity?

This question is supported by the three subquestions, that will assist in answering the main question:

- How is Cologne navigating the complexity of climate change as a wicked problem and how is climate adaptation currently governed?
- What solutions can contribute to a regime shift where climate adaptation and sustainable urban water management are the focus?
- How can synergies be used to contribute to creating climate-resilient cities and push for water sensitivity and water wise cities?

2.8 Project Design

The present project provides an overview of climate challenges in the case area of Cologne, Germany followed by a thorough analysis of the organisational structure of climate adaptation. It furthermore examines how different climate adaptation solutions can contribute to climate-resilient cities and ultimately support overcoming traditional development trajectories for climate adaptation and stormwater management. Additionally, the use of synergies will be explored in relation to climate-resilient cities. Based on the presented research question, the objectives of the report is threefold:
Identify the main climate challenges in Cologne and investigate the organisational culture of climate adaptation in Cologne.
Determine the current climate adaptation regime in Cologne and explore different solutions for climate adaptation by looking at reference projects and how to implement them in the case area of Cologne. The focus is on multifunctional Nature-based Solutions and the stone wool product Rockflow.
Highlight synergies, co-benefits, and added value in the presented reference projects and how they can contribute to climate-resilience. Explore Cologne's way to become climate-resilient by making use of the Principles for Water Wise Cities (PWCC) framework.

In order to answer the preliminary research question, several analyses were conducted which are built upon each other and feed into each other's contents. The analyses are framed by theoretical consideration and a diversity of empirical tools to collect relevant data. The results of the multifold analyses are discussed before this report concludes by answering the constructed research question and reflects upon the findings. The research design of the present report is visualised in figure 6.

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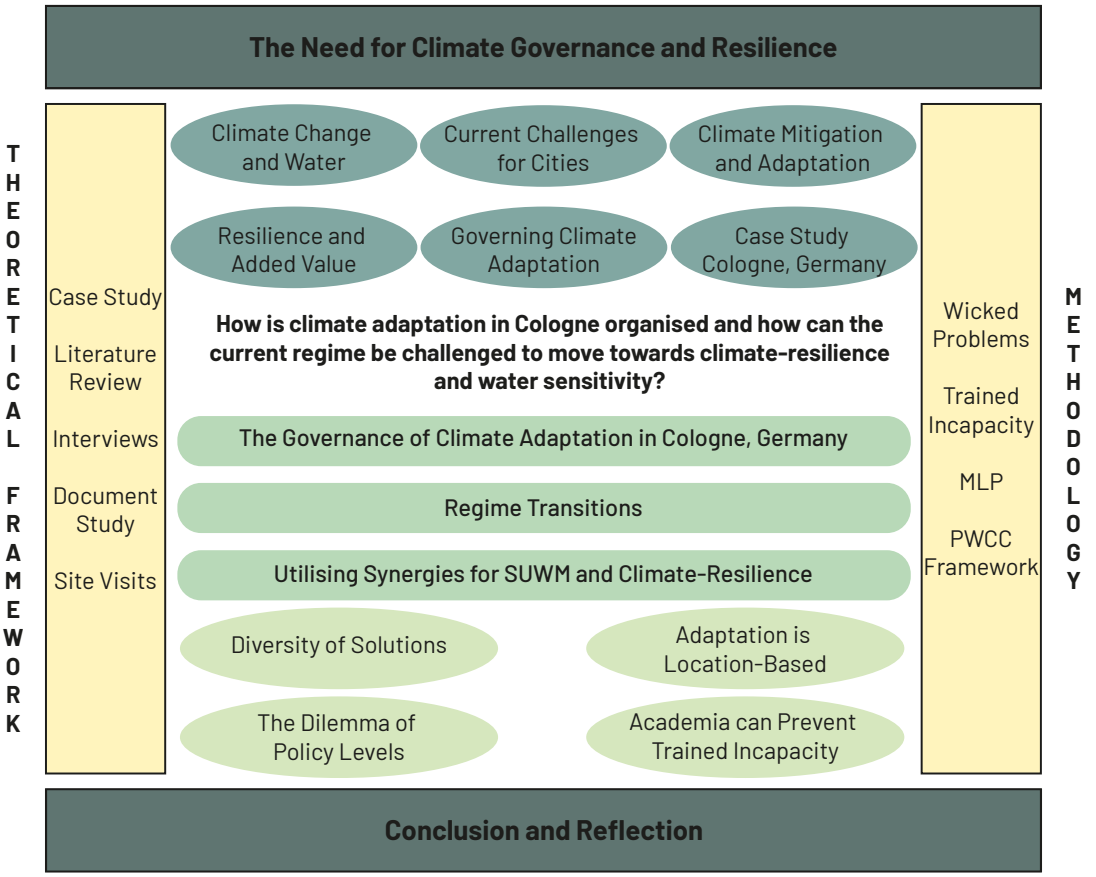

Figure 6: Project Design (own figure).

Chapter 3
Theoretical Framework

3

This chapter is describing the theoretical consideration and framework applied in the present report. The framework is the foundation for the following analyses. Therefore, the next sections are dedicated to elaborate on the theoretical considerations and the application of those in the scope of this report.

3.1 Wicked Problems

The present report is identifying climate change and connectedly climate adaptation as a wicked problem. Therefore this section is dealing with the concepts of wicked problems and the challenges planners face when dealing with those.

Wicked problems are in general complex problems. Scientists argue that wicked problems are in fact never really solved but resolved over time (Conradie, 2020; Rittel & Webber, 1973). The definition of wicked problems does not have a fixed frame but is depending on the proposed solution for those. Additionally, the messiness of a wicked problem can be understood when picturing a wicked problem as singular problems which are interacting. By solving one problem usually, new and unforeseen problems occur. Therefore, *"the solution to a mess cannot be to solve each of the problems of which it is composed independently"* (Conradie, 2020, p. 229). In contrast, solving singular problems of a wicked problem only seems to exacerbate the messiness. In his article *Why, Exactly, Is Climate Change a Wicked Problem?* Conradie (2020) refers to Ackoff (1974) who identified planning as a key to approaching wicked problems. He describes planning thereby as *"participative, coordinated, integrated, continuous, and prospective"* (Conradie, 2020, p. 230). Creative solutions are required to tackle wicked problems since currently available methods are not sufficient (Conradie, 2020).

Literature is addressing wicked problems and the challenge for planners to deal with these. Planners, unlike scientists and engineers, are dealing with societal problems which are not as well defined and separable as scientific problems. According to Rittel & Webber (1973) *"planning problems are inherently wicked"* and most often concern various public policy issues (Rittel & Webber, 1973, p. 160). Planners encounter challenges when attempting to untangle the messiness of such problems. While theoretical framing in research helps to conceptualise these wicked problems and how to approach transformative change, the practice performed by planners in a so-called learning approach is not as straightforward as theories might communicate. Furthermore, some authors argue that research and social science tend to solely be theoretical with few practical recommendations on how to address transformative change and therefore moved away from *"practical usefulness"* (Jensen & Quitzau, 2017, p. 254). Planners often stumble upon conflicting dynamics and processes that have to be overcome in a trial and error based process. Some authors argue, however, that trial and error is not possible in urban planning since implementations always have long term implications (Conradie, 2020). Implemented solutions to wicked problems are therefore always consequential (Jensen & Quitzau, 2017; Rittel & Webber, 1973).

Wicked problems are essentially unique - meaning that even though the problems might have a lot of similarities there are still distinguishing properties that might overwrite the similarities. This implies that there is no one-size-fits-all solution. Solutions can not simply be copied and implemented in other places without considering the uniqueness of societal circumstances and place-specific conditions (Rittel & Webber, 1973).

Jensen and Quitzau (2017) also explore the effects of the social practices of planners on transformations and interventions.

Thereby they argue that the dynamics of social practices might provoke interventions and challenge conventional policymaking (Jensen & Quitzau, 2017). The study of social practices will not be highlighted nor further analysed in this present paper. However, the idea of the planner´s practices as influence or inspiration for interventions will be further elaborated when talking about regime transitions. This ultimately leads to a discussion about trained incapacity and path dependency which will be elaborated on in the following sections.

3.1.1 Climate Change as a Wicked Problem

Climate change can be seen as a textbook example of a wicked problem. This section is dedicated to describing the difficulties in addressing climate change, bearing in mind the understanding of a wicked problem from the previous section. Conradie (2020) claims that the *"circular nature of the interplay between modernity, military conquest, slavery, capitalism, science, technology, industrialization, carbon emissions, and global warming"* portrays why climate change is considered a wicked problem (Conradie, 2020, p. 232). Climate change as well as other wicked problems are characterised by interdependencies and multicausality. Additionally, it is a race against time where it gets more difficult to address the problem the longer it takes. Related to climate change it is apparent that with every year that global carbon emissions are not drastically reduced, the consequences are catastrophic. The main drivers of wicked problems are also the ones with the best position to address the problem. Ironically, those are also the ones with the least incentives to do so. The main drivers of climate change are, unfortunately, not the ones suffering from it the most (Conradie, 2020).

Another argument for climate change as a wicked problem is the lack of institutional guidance through frameworks on how to develop, implement, and maintain regulations addressing climate change. The United Nations Framework Convention on Climate Change is the only internationally acting central authority and therefore the international guidance is considered insufficient. As a result, and yet another argument for the complexity of climate change, policy responses seem to irrationally neglect the future (Conradie, 2020).

Even though climate change is a global phenomenon, adaptation is usually conducted locally, since effects differ from one place to the other. Therefore, the present report is applying the concept of wicked problems to Cologne´s climate adaptation strategy and organisation in order to determine planning specific hurdles in Cologne´s climate adaptation regime. Thereby different policy levels are analysed to identify guidelines, frameworks, regulations, and relevant actors.

3.2 Trained Incapacity

Trained incapacity in this paper is understood as defined by the economist Thorstein Veblen in the late 19th century and further used by the researcher Alex Aylett (2011) in his chapter *Municipal Bureaucracies & Integrated Urban Transitions to a Low Carbon Future* from the book *Urban Transitions /Technological Transitions: Cities and Low Carbon Transitions*. The term refers to the idea that professionals are being trained throughout their education and professionalisation to use specific tools and concepts. This idea argues that this training incapacitates professionals for certain problems which fall outside of their training´s scope (Aylett, 2011). Aylett (2011) simply describes trained incapacity in the following:

"The more expert one becomes, the less able one is to respond to, or even perceive, issues that fall outside one's area of expertise."
(Aylett, 2011, p. 145)

This results in lock-ins of the current planning regime since planners within the regime are locked-in their area of expertise (Quitzau et al., 2013). The following sections are dedicated to describing how trained incapacity influences planning by looking at the organisational culture of a municipality. Consequently, the aim is to identify how climate change is governed in consideration of the phenomenon of trained incapacity.

3.2.1 Organisational Culture

The standard organisational structure of a municipality is individual entities that operate in silos and are in a hierarchical order. This does not necessarily promote trained incapacity but it often does since it somewhat gives stability and predictability to large organisations through shared rules and systems. This makes it difficult for individuals to influence and steer the direction of the entire organisation and creates a barrier for collaboration within the entities but also beyond the organisation with actors outside of this organisation. Breaking out of this standardised pattern allows for a more open and integrated but still hierarchical model. Communication and exchange between the entities are encouraged while enabling individuals to take part in forming the overall objective of the organisation. Ultimately, Aylett (2011) is arguing that this allows *"to identify synergies and shared interests with other actors both inside and outside the organisation"* (Aylett, 2011, p. 153).

3.2.2 Governing Climate Change

In order to understand how cities respond to climate change, it is crucial to understand how cities function firsthand. A city consists of an accumulation of different entities, each pursuing its own different interests. Therefore "the city" cannot be understood as one singular actor but rather a complex sociotechnical system. According to Aylett (2011), *"successful responses to climate change will involve broad networks of governance that link multiple actors"* (Aylett, 2011, p. 142). Furthermore, he argues for establishing independent institutional homes for complex issues such as climate change. The reasoning is the complexity of the problems which in the course of developing and implementing solutions have to involve several stakeholders and are affecting multiple municipal institutions across already established sectors. In fact, since climate change can not be seen as a new steady-state that cities have to adapt to but rather a constantly changing and unstable period of ever-changing circumstances, organisations must not just shift focus but rethink the entire organisational regime. This new regime ought to be an adaptive and resilient system that can sustain upcoming challenges. To reach this new regime, new organisational cultures have to be established which promote risk-taking and various opinions from a diversity of stakeholders. That way, traditional trajectories and path dependencies can be interrupted (Aylett, 2011).

After the thorough analysis of Cologne's climate adaptation as a wicked problem, the concept of trained incapacity is applied to the adaptation regime in Cologne. Therefore, the organisational culture in Cologne will be analysed followed by an elaboration on how trained incapacity is steering Cologne's climate adaptation trajectory.

3.3 Multi-Level Perspective

To understand what the current regime and development trajectory looks like and how it is embedded in a society, the Multi-Level Perspective (MLP) has been researched and will be elaborated on in the following section. Here, the MLP

aims to draw a picture of the barriers to a transition by pointing out current path dependencies and trajectories.

The MLP is describing society as operating on three levels which are embedded in each other in a nested hierarchy and therefore ultimately connected. The three levels are socio-technical landscape, socio-technical regime, and niche innovations (Geels & Schot, 2007).

3.3.1 Landscape

The landscape is the superordinate level where technological trajectories are situated. It is an external structure that consists of external factors and is therefore slow in changing. The landscape can also be understood as the *"context for interactions of actors"* (Geels, 2002, p. 1260).

3.3.2 Regime

The regime is at a stable socio-technical level. It is characterised by trajectories and path dependencies which are informed by the landscape and based on shared norms, routines, and rules which creates stability. When the superordinate landscape changes and thereby puts pressure on the regime, these stable trajectories and path dependencies can be broken or steered in another direction. This is where niche innovations can break through and change or emerge into the new establishing regime (Geels, 2002).

3.3.3 Niche

This is the hierarchically lowest level which is protected by the market of the current regime and therefore acts as an incubation room for radical innovations. Radical niche innovations which emerge at the niche level develop through appearing problems in the current regime and hope to rearrange or influence the regime. Niche innovations are therefore drivers to break out of existing path dependencies, trajectories, and lock-ins. Furthermore, niches are providing the space for learning approaches where innovations can be tested (Geels, 2002).

3.3.4 Transitions

As previously indicated, transitions of regimes or changes within existing regimes occur when the landscape slowly changes and therefore exerts pressure on the regime. The embedded regime has to adapt to the changing landscape and is therefore loosening up and becoming unstable, creating a window of opportunity. The niche innovations have the opportunity to break through this window and nest in the regime where the stability has cracked under the pressure of the landscape. However, niche innovations might also fail in the process and never emerge into the regime (Geels, 2002). Figure 7 shows the dynamics of transitions from a multi-level perspective, the arrows are indicating the dynamics of the different levels.

However, there are scholars that argue that change can also happen from within the existing regime by incumbent actors that gradually adjust the existing regime to the new challenges emerging from external pressures (Quitzau et al., 2013). The organisational culture of the regime with its shared values and practices makes it particularly difficult to change the course of direction and is therefore easily locked-in. Since the regime is generally stable, individuals within the regime are usually shaped by the established rules and routines and therefore easily victims of trained incapacity (Aylett, 2013).

In the course of this paper the case of climate adaptation actors in Cologne will be analysed regarding their trained incapacity and what hinders the incumbent actors to adjust the current regime. This is the foundation for identifying barriers of change and how to push for transitions in the climate adaptation regime in Cologne. This analysis is complemented by the presentation of four reference

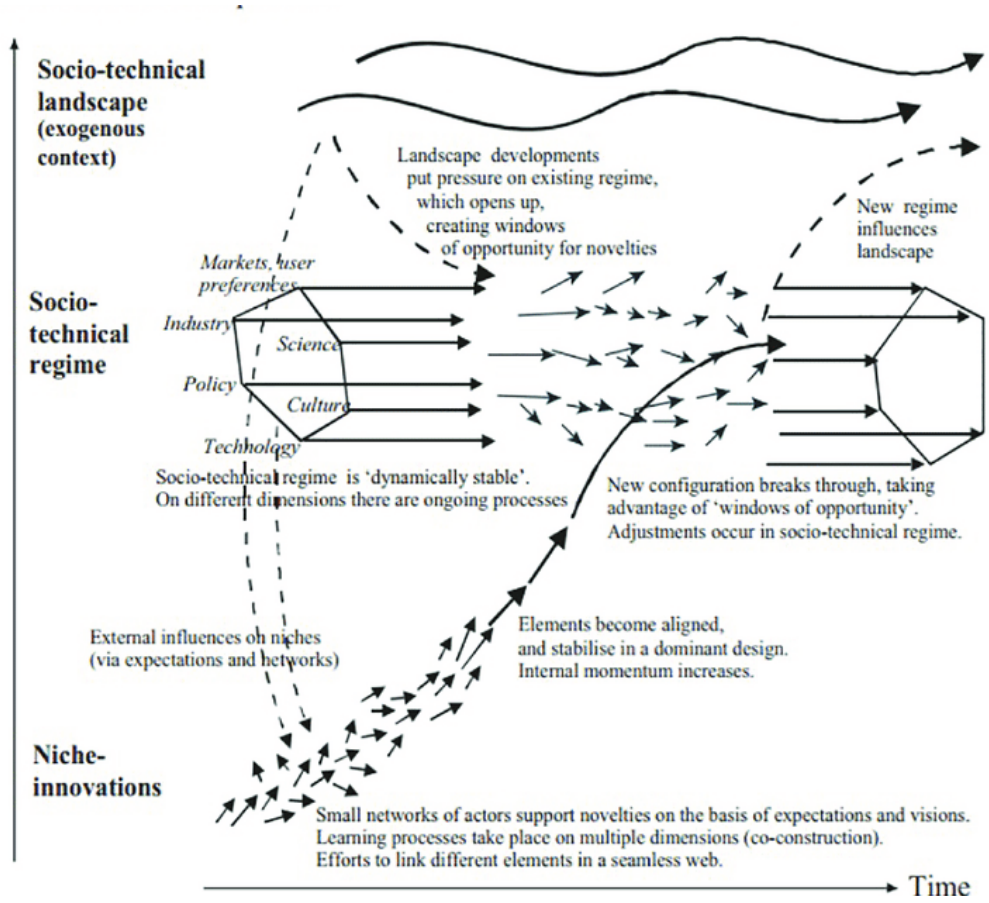

Figure 7: A Multi-Level Perspective on transitions (Geels & Schot, 2007).

projects located in the niche that could inspire Cologne's adaptation regime and change the regime's current development trajectory to have sustainable urban water management in focus.

3.4 Sustainable Urban Water Management to Create Climate-Resilience

In the face of climate change, cities have to adapt to effects and crises resulting from the changing climate and become resilient. Brown et al. (2009) talk about stages of urban water management that cities transition through to ultimately end up with *"sustainable urban water conditions"* in a water sensitive city state (Brown et al., 2009, p. 847). They thereby address the hydro-social contracts, which is a term to describe the agreement between communities, governments, and businesses on how the water should be regulated. These actors have different interests and priorities, therefore it is relevant to discuss what is a sustainable solution and how to prioritise ending up as sustainable as possible. The authors have defined six city states, which cities can develop through time and space. The Urban Water Management Transition Framework describes the six city states as a *"nested continuum"* where each city state is building upon the hydro-social contract of the state before (Brown et al., 2009, p. 851). Therefore, it is a complex system which is not as linear as depicted in figure 8. Furthermore, it is possible to jump city stages in the process. The water cycle state thereby describes the point of situation where the water reaches limits as a resource and needs to be managed sustainably. Therefore, co-management between the stakeholders, communities, governments, and businesses is

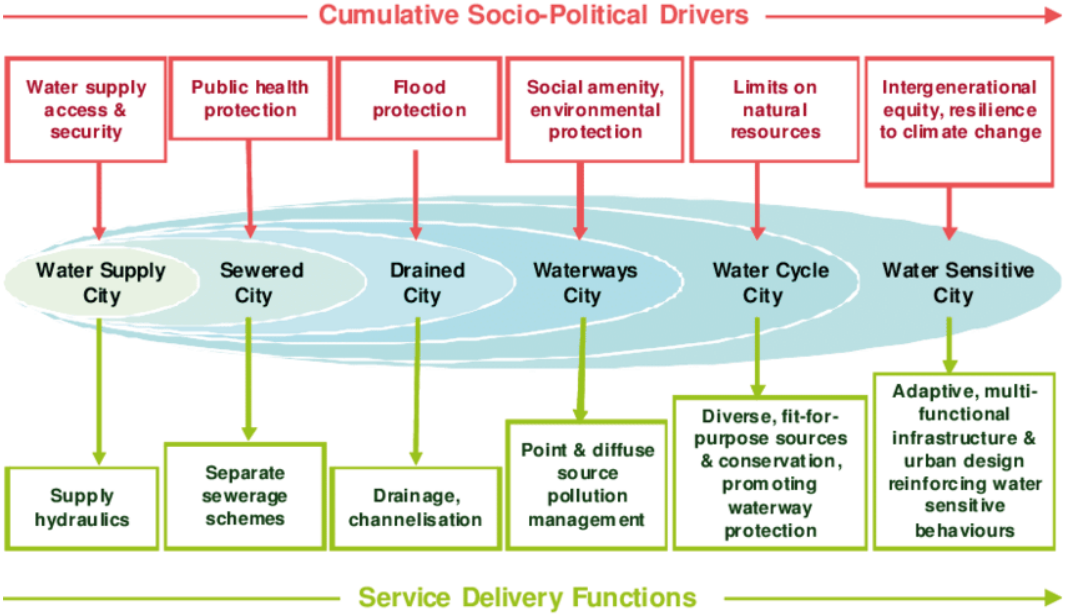

Figure 8: Six states of the Urban Water Management Transition Framework (Brown et al., 2009).

necessary. Followed by this state is the water sensitive city which up until now does not have a best practice example of an entire city. However, there are examples of water sensitive water management all over the world. The water sensitive city describes a city which *"would integrate the normative values of environmental repair and protection, supply security, flood control, public health, amenity, liveability and economic stability, amongst other"* (Brown et al., 2009, p. 854). Additionally, the water sensitive city is sought to be resilient to climate change (Brown et al., 2009).

Sustainable Urban Water Management (SUWM) is an inevitable topic when talking about climate change, climate adaptation, and climate-resilience. Water is becoming increasingly scarce and sustainably handling already stressed (urban) water resources is required. Furthermore, cities have to prepare for future uncertainties within water resources. The water sensitive city is characterised by socio-technical resilience to major system disturbances and is able to overcome vulnerabilities. A resilient system can develop new trajectories which are more sustainable and adaptive than the previous regime. Furthermore, Wong and Brown (2009) interpret a resilient system as: *"(i) the amount of disturbance the system can absorb and still remain within the same state; (ii) the degree to which the system is capable of self organisation (versus lack of organisation, or organisation forced by external factors); and (iii) the degree to which the system can build and increase the capacity for learning and adaptation"* (Wong & Brown, 2009, p. 675). Therefore resilience is not only about robustness but also about how disturbances can create windows of opportunities to change current trajectories and therefore challenge or adapt the current regime (Wong & Brown, 2009).

Bearing SUWM and water sensitivity in mind, the International Water Association (IWA) developed 17 interrelated principles split into four levels of action for water-wise cities which are displayed in figure 9. *"[T]he principles are to assist leaders to develop and implement their vision for sustainable urban water"* and therefore a vital guideline for municipalities or water management stakeholders to pursue resilient planning and design (Fu & Wang, 2021, p. 38).

The Four Levels of Action

1 Regenerative Water Services
- Replenish Waterbodies and their Ecosystems
- Reduce the Amount of Water and Energy Used
- Reuse, Recover, Recycle
- Use a Systemic Approach Integrated with Other Services
- Increase the Modularity of Systems and Ensure Multiple Options

2 Water Sensitive Urban Design
- Enable Regenerative Water Services
- Design Urban Spaces to Reduce Flood Risks
- Enhance Liveability with Visible Water
- Modify and Adapt Urban Materials to Minimise Environmental Impact

3 Basin Connected Cities
- Plan to Secure Water Resources and Mitigate Drought
- Protect the Ecological Health of Water Resources
- Prepare for Extreme Events

4 Water-Wise Communities
- Empowered Citizens
- Professionals Aware of Water Co-benefits
- Transdisciplinary Planning Teams
- Policy Makers Enabling Water-Wise Action
- Leaders that Engage and Engender Trust

Figure 9: *Four Levels of Action* and 17 Principles of the PWWC framework (own figure, adapted from Fu & Wang (2021)).

"The ultimate goal of these Principles is to encourage collaborative action, underpinned by a shared vision, so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions for managing all waters of the city."
(Fu & Wang, 2021, p. 38)

Fu & Wang (2021) emphasise the necessary paradigm shift from conventional urban water management, dominated by engineered grey structures, to new urban water systems, defined by green engineering in nature. This paradigm shift requires a new set of tools such as specific knowledge production and adaptive governance which are defined as the *Five Building Blocks* and the *Four Levels of Action* that have to be taken to successfully build water-wise cities. Figure 10 shows the *Principles for Water Wise Cities* (PWWC) framework and how the 17 Principles are founded on the *Five Building Blocks* and the *Four Levels of Action* (Fu & Wang, 2021).

In order to achieve this paradigm shift the PWWC framework highlights synergies across sectors as a potential to maximise benefits of water in the city. Besides synergies there are also dependencies

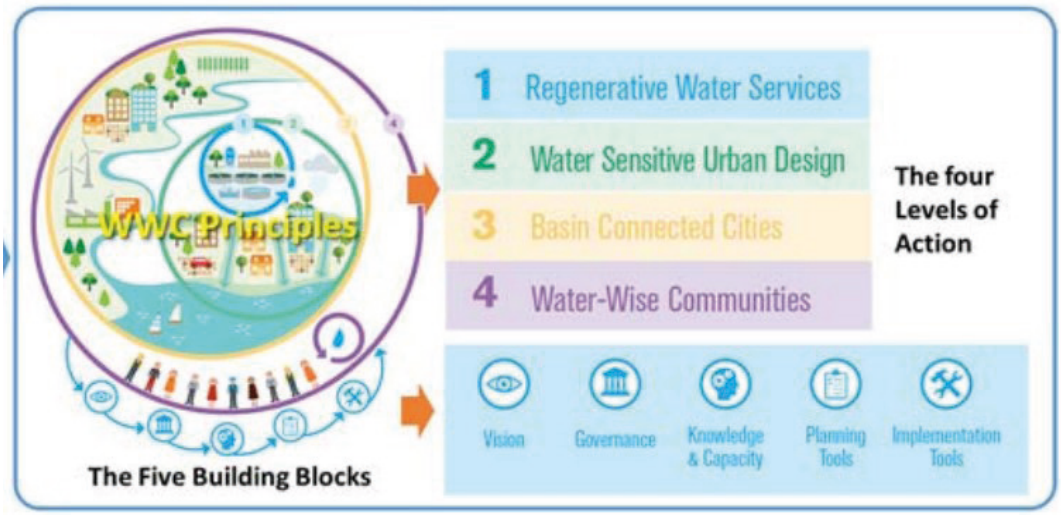

Figure 10: The *Principles for Water Wise Cities* framework (Fu & Wang, 2021).

between water, urban planning, and many more infrastructures in the city. These dependencies have to be utilised by interdisciplinary planning and operation teams and used as co-benefits to create innovative sustainable solutions (Fu & Wang, 2021).

This framework will be used to identify synergies in the mentioned reference projects to determine how projects like these pave the way to water-wise cities and climate-resilience. Thus to break down the complex framework to an applicable tool, the author decided to focus on 4 of the 17 principles defined in the PWWC framework. Each principle represents one *Level of Action* as defined in the framework. The representing principles are:

1. Use a Systemic Approach Integrated with Other Services;
2. Enhance Liveability with Visible Water;
3. Plan to Secure Water Resources and Mitigate Droughts;
4. Transdisciplinary Planning Teams (Fu & Wang, 2021).

Lastly, this allows to highlight actions that cities have to undertake in order to engage in sustainable urban water practices and develop towards a water-wise and climate-resilient city.

The *Five Building Blocks* consisting of Vision, Governance, Knowledge & Capacity, Planning Tools, and Implementation Tools are the backbone for successful implementation of the principles. Therefore this report discusses how Cologne can utilise the tools provided by the *Building Blocks* to shift to a new planning paradigm.

At this point the author would like to highlight that cutting down from 17 to four principles does not mean that it is enough for a city to focus on those four principles. This was only to create a more tangible tool in the course of this report to analyse Cologne´s way to a water-wise city. However, it also needs to be acknowledged that following the PWWC framework will take some time and municipalities have to start somewhere. Therefore, approaching the principles holistically looking at all four levels of actions rather than trying to meet singular principles is recommended.

Chapter 4
Methodology

4

This chapter is intended to describe and argue for the chosen methodological approach for this report. This report is based upon a case study. The initial research was based on an extensive literature review to get an overview of the state-of-the-art of the subject matter and finding knowledge gaps that are of scientific relevance and personal interest for the author. Extensive literature review has furthermore been the basis for the development of the theoretical considerations which build a frame for the present study within which the further analyses are conducted. The data collection for the analyses consists of the semi-structured qualitative interviews complimented by the study of relevant documents. Additionally, in the case of presenting reference projects, site visits have been supplementary. The description of the approaches is supplemented by scientific argumentation for the relevance and justification of each.

4.1 Case Study

A case study is a common qualitative research method used to conduct an in depth description and analysis of a phenomenon in a bounded context. Multiple sources and qualitative research methods feed into the data collection "to provide an analysis of the context and processes which illuminate the theoretical issues being studied" (Njie & Asimiran, 2014, p. 36). Furthermore, Nije & Asimiran (2014) argue that the researcher conducting the case study usually has no or little influence on the case itself. Therefore case studies are a supportive tool to deal with "how" and "why" questions in an exploratory manner. Case studies are useful to scientifically prove certain assumptions. The outcome of case studies depends, to a large extent, on the amount of data collected and thoroughness of the following analysis of the collected data as well as the representation of the information and results (Njie & Asimiran, 2014). Nijie & Asimiran (2014) explain:

"Building the meaning is like illustrating a picture as seen for other people to understand how it is."
(Njie & Asimiran, 2014, p. 39)

Rowley (2002) takes the example of using case studies to examine organisational cultures. Thereby the researcher takes an aerial perspective of the issue and must ensure the holistic perspective on the case (Rowley, 2002).

4.1.1 Choice of Case Study

This report is looking into the organisational culture of governing climate adaptation in Cologne, Germany. Therefore it is reasonable to take a look at the specific case and analyse location specific challenges regarding climate change and how the governance of climate adaptation is organised. Therefore, the assumption has been made that while taking climate action, mitigation and adaptation are still addressed separately (Sharifi, 2020). This implies that municipal actors are still operating in silos when facing challenges of climate change. Based on the occuring extreme weather events in Cologne in the summer of 2021 this study aims to analyse how the municipality of Cologne are addressing these challenges and how climate adaptation is governed.

4.1.2 Reflections

Data collection for case studies is usually qualitative which makes the result subjective to the specific case and therefore challenging to replicate findings to other cases and generalise outcomes (Rowley, 2002). Using the case study and applying it to a German municipality limits the possibilities of generalising the issues identified. Some of the identified issues in the organisational cultures depend to a large extent on the German and European context and can therefore not simply be replicated to other municipalities across the globe.

The author is aware that using a case study requires a time intensive process of data collection, including observations and follow up sessions for conducted interviews (Njie & Asimiran, 2014). However, the timeframe of this study was limited due to a pre-set deadline and therefore it has to be reflected that the result from the case study could vary if there had been more time. Additionally, there has not been any follow up sessions from the interviews due to timely restrictions.

4.2 Data Collection

The collection of data for the present study is multifold based on literature review, document study, semi-structured interviews, and site visits. These data gathering methods are of qualitative nature and leave room for interpretation. However, the author has been aware of possible bias in the collection of data and especially while conducting the semi-structured interviews. The importance of being unbiased in approaching the case study has been considered (Rowley, 2002). For gathering the relevant literature and documents the author used search engines such as Google and Google Scholar supplemented by the databases Scopus and the university library of Aalborg University. The finding of interviewees was an iterative process of researching and reaching out to, presumably, relevant experts and the further recommendations from said experts.

4.2.1 Literature Review

A literature review is the exploration of relevant literature to a specific topic. Review of relevant and contemporary literature is crucial for any kind of academic research activities to get an overview of the state-of-the-art research. The literature review is the foundation to build on any research. It is conducted at the beginning of the process and attempts to collect information resulting in a synthesis of previous research about the broader research topic. Additionally, a literature review can identify research gaps on the state-of-the-art research which is the basis for the following investigation. Literature review is also used to identify and pinpoint the theoretical frame in which the study is operating (Snyder, 2019).

In the present report the literature review has been used to gather background information and knowledge needed to determine the state-of-the-art regarding climate adaptation and climate governance. This knowledge production lays the foundation to the definition of the problem statement and research questions. To begin with the review was conducted broadly covering climate change and its challenges regarding the water cycle and cities. This is followed by covering literature on contemporary approaches to climate adaptation and urban water management including implementation of climate adaptation measures. Additionally, the relevance of climate-resilience and the use of synergies have been explored before narrowing down to governing climate adaptation in general as well as in the case of Cologne, Germany. Furthermore, the literature review provided an overview of the theoretical considerations which are relevant to the following analyses.

4.2.2 Interviews

To supplement data gathered from desk research for the case study interviews are a useful tool. The researcher has to be aware to *"ask good questions, to listen and to interpret the answers"* (Rowley, 2002, p. 22). All interviews have been conducted via an online platform. The following platforms have been used: Microsoft Teams, Wonder Me, and Circuit. All interviews have been recorded either with only sound or both sound and video. The interviews have not been literally transcribed. Since the interviews were conducted in German, and the present report was required in English, the author decided not to

conduct literal transcriptions. Instead, the author created worksheets for every interviewee where the main arguments were gathered, sometimes also highlighting literal quotes, translated to English. For the translation process, the author's personal language skills have been complemented by the translation application *DeepL* as a supporting tool. Therefore, when direct quotations from the interviews are used in the course of this report, they have been previously translated.

The worksheets are already structured in relevant topics to make it easier for the author to navigate within and gather the information. Additionally, the time stamps have been inserted in parentheses in the beginning of a section, to keep track of the arguments in the recordings of the interviews. The transcription tool *oTranscribe* has been used to create the mentioned worksheets. The author conducted six semi-structured interviews with relevant experts. Three interviewees are from the local water utility (StEB), two interviewees are employed in the municipality of Cologne in different departments, and the last interviewee is employed at the Danish stone wool manufacturer ROCKWOOL to get insights in a stormwater management application called Rockflow. Table 1 presents the six interviewees, their organisation, the main content of the interview, and the referral to the Appendix where the worksheets can be found.

Table 1: Overview of interviewees.

Interviewee	Organisation	Content	Appendix
Christine Linnartz	StEB Köln	Current challenges in Cologne, research project iResilience	Appendix 1
Stefan Grönnerud	StEB Köln	Current challenges in Cologne, research project VertiKKA, governance, development hurdles	Appendix 2
Dr Maria Ceylan	StEB Köln	Current challenges in Cologne, duties of the StEB, current developments and aspirations	Appendix 3
Yvonne Wieczorrek	Stadt Köln, Umwelt- und Verbraucherschutzamt	Perspective from the municipality, cross-sectoral planning approaches, barriers of change	Appendix 4
Benjamin Luchterhandt	Stadt Köln, Grünflächenamt	Perspective from the municipality, research projects, barriers of change	Appendix 5
Roy Janssen	Rockflow	The product Rockflow, application, installation, and differences to green solutions	Appendix 6

4.2.3 Document Study

The empirical data collection has been backed up by studying certain documents and reports. Document analysis is a common method to use in qualitative research to review and evaluate data provided in those documents. Therefore, data examination and interpretation is required to gain empirical knowledge (Bowen, 2009). An overview of the most important documents are shown in table 2 in combination with an elaboration about the main contribution from this source.

4.2.4 Site Visits

Two of the chosen reference projects are located in Copenhagen, Denmark. These are the *Klimakvarter* in Østerbro and *Enghaveparken* in Vesterbro. Since the author is currently residing in Copenhagen, this allowed for further on-site study of the reference projects. The author conducted the site visits after extensive research about the projects. The visits supplemented the acquired knowledge and allowed for taking pictures on-site of inspiring climate adaptation measures. After the site visits, the author created worksheets for each reference project which is synthesising the thoughts and impressions the author gained during the visit and supplemented by photographs. The worksheets can be found in the Appendix (Appendix 7 - Klimakvarter and Appendix 8 - Enghaveparken).

Table 2: Document study overview.

Source	Contribution
Klimawandelgerechte Metropole Köln (final report) by Landesamt für Natur, Umwelt und Verbraucherschutz (LANUV) Nordrhein-Westfalen	This report was used to identify main challenges of climate change in Cologne and ambitions to adapt to those.
Stadtstrategie *Kölner Perspektiven 2030+* by Stadt Köln	The strategy helped identify whether Cologne has a shared vision regarding climate adaptation and sustainable water management.
Hydro-klimatologische Einordnung der Stark- und Dauerniederschläge in Teilen Deutschlands im Zusammenhang mit dem Tiefdruckgebiet „Bernd" vom 12. bis 19. Juli 2021 by Junghänel et al. (Deutscher Wetterdienst)	This report thoroughly analysed the heavy precipitation event in NRW in July 2021. Therefore it was used to familiarise with the event and effects of it.

Chapter 5

The Governance of Climate Adaptation in Cologne, Germany

5

In the course of this paper, the status of climate adaptation in Cologne, Germany will be analysed. The analysis begins with a description of the policy levels in which climate adaptation in Cologne is embedded. This is followed by identifying challenges, both related to urban planning and climate change in Cologne. Lastly, the governance of climate adaptation is thoroughly analysed, making use of the theoretical approach to wicked problems and trained incapacity as described in Chapter 3.1.

5.1 Policy Levels of Climate Adaptation in Cologne

This section is dedicated to setting the scene for understanding how climate adaptation is embedded in the case area of Cologne in Germany. Thereby different policy levels have been considered. The scale narrows down from a global perspective to a European level, from there it narrows down to the German perspective covering both national, federal state, regional, and lastly the municipal perspective of Cologne. An overview of the policy levels and related plans, strategies, and regulations is visualised in figure 11 in a hierarchical order. The yellow columns mark legal binding regulations. The rest is non-binding.

5.1.1 Global Level

Globally, the United Nations Framework Convention on Climate Change (UNFCCC) agreed on a global goal of adaptation laid down in the Paris Agreement of 2015. However, the goal is not legally binding (Hall & Persson, 2018). Additionally, the IPCC report *Climate Change - Impacts, Adaptation and Vulnerability* (2022) highlights the key role adaptation is playing in creating climate resilience (IPCC, 2022).

<table>
<tr><th>Policy Level</th><th colspan="2">Plan, Strategy, or Regulation</th></tr>
<tr><td>Global</td><td colspan="2">UNFCCC - Paris Agreement (2015)
IPCC - Sixth Assessment Report (2022)</td></tr>
<tr><td>EU</td><td colspan="2">Climate Adaptation Partnership - Final Action Plan (2018)</td></tr>
<tr><td>Federal Government</td><td>DAS (German Adaptation Strategy - 2008)</td><td>APA (Action Plan Adaptation - 2011)</td></tr>
<tr><td rowspan="3">NRW</td><td rowspan="2">Climate Mitigation Law (2013)</td><td>Adaptation Strategy (2009)</td></tr>
<tr><td>Climate Protection Plan (2015)</td></tr>
<tr><td colspan="2">Climate Adaptation Law (2021)</td></tr>
<tr><td>Regional: Cologne/ Bonn</td><td colspan="2">Climate Change Precaution Strategy (2017)</td></tr>
<tr><td>Cologne</td><td colspan="2">Climate Change Appropriate Metropolis Cologne (2013)</td></tr>
</table>

Figure 11: Overview of policy levels in a hierarchical order (own figure).

5.1.2 European Level

There is a European climate adaptation strategy, the *Final Action Plan* by the *Climate Adaptation Partnership*, which claims to support cities in adapting to climate change *"by launching a voluntary commitment to adopt local adaptation strategies and awareness-raising activities"* (The Partnership on Climate Adaptation, 2018, p. 14). In 2017, the EU adaptation strategy and related adaptation commitments were included in the *Covenant of Mayors* initiative, where Cologne has only committed to mitigation actions but not adaptation actions (Covenant of Mayors, n.d.). The European adaptation strategy emphasises that national regulations have an impact on local climate action since they are the foundation of local strategies and action plans. Countries with compulsory local climate plans are accordingly more likely to have local adaptation plans (The Partnership on Climate Adaptation, 2018).

5.1.3 National Level

The Federal Cabinet enacted the *Deutsche Anpassungsstrategie* (DAS - German Adaptation Strategy) in December 2008 which is acting as a framework for climate adaptation in Germany. This is the foundation for federal states and other stakeholders to assess climate risks and related required actions as well as thereafter define climate adaptation goals and solutions. This strategy is built upon the three pillars of sustainability as it aims to protect society, natural habitats, and the economy from risks related to climate change (BMUV, 2020). Thereupon, three years after the enactment of the DAS, the *Aktionsplan Anpassung* (APA - Action Plan Adaptation) laid the foundation for further development and implementation of the DAS (Umweltbundesamt a, 2019).

5.1.4 Federal State Level - Nordrhein-Westfalen

Beyond that, many of the federal states have developed their own adaptation strategies. This is important since climate adaptation measures usually have to be implemented and planned locally which gives the federal states as well as the municipalities a lot of responsibility. This section is dedicated to describing the specific organisation of climate adaptation in Nordrhein-Westfalen (NRW). The political frame for climate action in NRW is threefold consisting of:

- *Klimaschutzgesetz* (Climate Mitigation Law - 2013),
- *Klimaschutzplan* (Climate Protection Plan - 2015),
- *Anpassungsstrategie* (Adaptation Strategy - 2009) from which the *Klimaschutzplan* was further developed (Umweltbundesamt b, 2019).

The first two are focused on mitigation and the latter, as the name says, is an adaptation strategy. However, the *Klimaschutzplan* also has a section on climate adaptation, aiming to *"weather-proof"* NRW (MKULNV NRW, 2015). Actions such as increasing water sensitivity, risk management of urban flash floods, and climate optimised reconstruction of urban squares serve to prepare the state and municipalities in case of a flooding crisis. In the *Klimaschutzplan*, the chapter on adaptation is structured in 16 fields of action which each recommend actions, instruments, and responsibilities for implementing these actions (MKULNV NRW, 2015).

Additionally, building upon the mentioned political frame, the *Klimaanpassungsgesetz* (Climate Adaptation Law) for NRW was passed in July 2021. This law dictates the federal state to limit the negative impacts of climate change and encourages the state to establish climate adaptation that furthermore prevents the state from environmental hazards,

provides general health, and protection of the natural basis of life while having future generations in mind. It likewise promotes a sustainable and competitive economy. Therefore it is mandatory to consider climate impacts for all plans and decisions (Ministerium des Innern des Landes Nordrhein-Westfalen, 2021). However, this regulation has been criticised by scientists for not being ambitious enough and not being concrete enough (Scientists4Future Köln/Bonn, 2021).

5.1.5 Regional level

As previously mentioned, NRW is a very densely developed federal state in North-West Germany with an agglomeration of many medium-sized and large cities. Therefore, it is reasonable to have regional development strategies as well, since the impacts of climate change exceed municipal borders. The municipalities of Cologne and Bonn have created a regional *Klimawandelvorsorgestrategie* (Climate Change Precaution Strategy) that started in 2017. The purpose of this project was to prepare the local government at an early stage to react to possible climatic changes and raise awareness amongst regional and municipal stakeholders of the need to adapt to climate change. The subject of the project was a climatic impact analysis in correspondence with further regional plans and concepts. The outcome of this project was a practical guide with recommendations for actions both on a regional and municipal level (Umweltbundesamt b, 2019).

5.1.6 Municipal level - Cologne

The previous sections have been attempting to show how climate adaptation in Cologne is embedded and what the institutional guidance looks like. Since the scope of this analysis is focusing on the municipal level, the following section is split into elaborating on the actors that are responsible for the execution of climate adaptation in Cologne as well as plans and projects addressing the same. The relevant information has been gathered from desk research and conducted interviews with relevant stakeholders.

Actors

The responsibility for both conceptual and strategic climate adaptation in Cologne lies with the municipality and the *Stadtentwässerungsbetriebe Köln* (StEB - Water Utility Cologne) as illustrated in figure 12. According to StEB

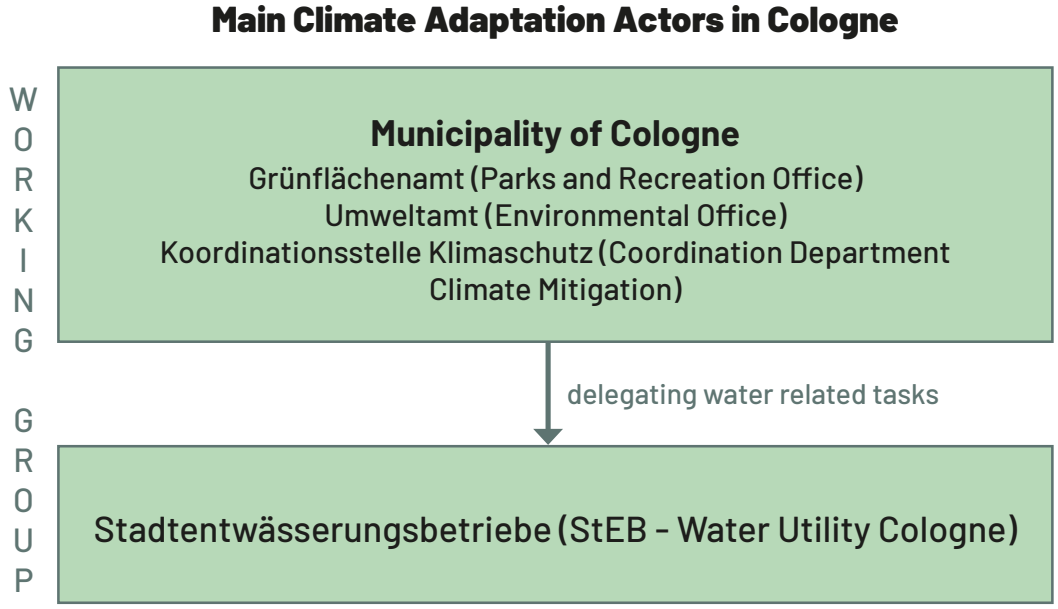

Figure 12: Overview of main climate adaptation actors in Cologne (own figure).

employee and leader of the subject group "Climate Adaptation" Dr Maria Ceylan, the main departments within the municipality taking responsibility for climate adaptation are the *Grünflächenamt* (Parks and Recreation Office), *Umweltamt* (Environmental Office), and the *Koordinationsstelle Klimaschutz* (Coordination Department Climate Mitigation). The StEB is *„just another player"* and there is no comprehensive coordination within StEB since they are officially not the municipality of Cologne but rather a company (Appendix 3 - Dr Maria Ceylan). The StEB's main task is to manage the discharge of the water from public streets and spaces on behalf of the municipality. Ceylan explains that there is a cooperation between all those actors and they are taking on shared projects (Appendix 3 - Ceylan). However, there is no dedicated coordination department for climate adaptation in place but a working group of all relevant stakeholders, which meets twice a year. This is confirmed by Christine Linnartz from the StEB and the municipal employee Yvonne Wieczorrek (Appendix 1 - Christine Linnartz; Appendix 4 - Yvonne Wieczorrek).

Plans and projects

The municipality published a climate adaptation strategy in 2013: the *Klimawandelgerechte Metropole Köln* (Climate Change Appropriate Metropolis Cologne). This strategy was the first (and up until now) only thorough assessment of climate-related changes and risks in the city of Cologne with a focus on heat stress and heavy precipitation. The report is presenting ideas and concepts for climate-friendly urban development and to this day it is still the foundation for climate adaptation in Cologne (LANUV, 2013).

There are several projects mentioned under climate adaptation in the city of Cologne. Some to mention are:

- *Hitzeaktionsplan* (Heat Action Plan), aiming at reducing health risks during heatwaves for the elderly (>65 years) by providing information systems (Stadt Köln, n.d.-b);
- *Vertikale Klimakläranlage* (VertiKKA - Vertical Climate Treatment Plant), as a resource-saving water management system for reusing greywater for green facades and photovoltaic to power those (VertiKKA, n.d.);
- *Grün hoch 3*, subsidising green facades, roofs, and unsealing surfaces (Stadt Köln, n.d.-a);
- *iResilience*, testing social innovations for a novel approach to climate adaptation (iResilience, n.d.)
- The creation of a *Starkregengefahrenkarte* (Heavy Precipitation Hazard Map) and *Hitzesimulation* (Heat Simulation)(Appendix 1 - Linnartz).

Cologne has defined climate mitigation goals until 2030 which require the city to cut down a significant amount of CO_2 per year. The CO_2 emissions thereby need to be reduced by 50% by 2030 compared to a 1990 baseline. In connection with this, the municipality is working on several projects and strategies to reach those goals which include the *Green City Masterplan*, *Fernwärmeausbau* (Expansion of District Heating), and *Radverkehrsförderung* (Promotion of Bicycle Traffic)(Stadt Köln, 2019b). However, there are no specific targets formulated for climate adaptation. The municipality of Cologne has announced that climate adaptation will be in focus in the future. Important key points mentioned are keeping fresh air corridors open, increased urban greenery, the connection of greenery and open urban spaces, climate change adaptive development and densification, and measures to improve the urban climate in densely developed areas. According to the municipality, future measures will focus on adaptation to heavier precipitation and extended heat waves with days above 30°C. Cologne thereby highlights the cross-sectoral planning approach

which is needed. One focal point mentioned is the improved local retention and infiltration of precipitation and thereby keeping the water in the city instead of discharging it immediately into the sewer system and transporting it to the nearest treatment plant. Cologne hereby mentions multifunctional spaces to enhance the functionality of the measures (Stadt Köln, n.d.-c). However, climate adaptation is still a voluntary task, it is not mandatory for municipalities. Nevertheless, there is a climate adaptation law in NRW (see previous section "Federal State level - Nordrhein-Westfalen"), but this does not make the task mandatory (Appendix 4 - Yvonne Wieczorrek).

Climate adaptation is embedded in different policy levels, also internationally. There are many different actors involved in Cologne which shows the complexity of the topic. Based on the current plans and projects, it appears that the focus is slowly shifting from sole mitigation to additionally adapting to the changes provoked by climate change.

5.2 Challenges in Cologne

Cologne is facing challenges in relation to climate change and its adaptation. The following sections highlight the main challenges identified both for urban planning and climatic challenges. The aim is to show the multifold complexity of the challenges that Cologne is facing.

5.2.1 Challenges for Urban Planning

Climate adaptation is closely linked to urban planning. Urban design can severely influence the effects of climate change such as the urban heat island (UHI) effect and flooding. On the other hand, urban planning is a tool to adapt to these challenges and soften the impact. Stefan Grönnerud, who is employed at the *Stadtentwässerungsbetriebe Köln* (StEB - Water Utility Cologne), identifies Cologne´s historical urban development as a curse and a blessing at once. Grönnerud mentions the *„horrible urban planning"* which was conducted after the war which is characterised by large scale demolition and new construction, guided by the principle of the car-friendly city. However, on the positive side, Cologne also developed a distinctive green belt concept in the early 20th century under the mandate of Konrad Adenauer who was Mayor of Cologne at that time. These green belts on the outskirts of the city are currently further developed mainly to create air corridors (Appendix 2 - Stefan Grönnerud). Nevertheless, Ceylan is not perceiving Cologne as a green city, especially since the inner city is lacking green infrastructure (Appendix 3 - Ceylan).

Additionally, the default for stormwater management in Cologne is still based on grey infrastructure. Linnartz mentions that the stormwater is usually drained through the sewer system which subsequently means that it cannot evaporate or infiltrate locally since there is little green infrastructure available (Appendix 1 - Linnartz). Nevertheless, the StEB´s objective is to focus on stormwater infiltration, especially where sewers are overloaded. In this regard, contaminated road runoff is a big challenge since there is a set of rules called the *Trennerlass* (Separation Decree) which enshrine the need to classify and categorise runoff and eventually treat it before reusing it. Therefore, uncontaminated drains are in focus for implementing Nature-based Solutions (NbS) for stormwater management. Having said that, especially in already dense existing structures where there is a competition for space, underground solutions are further considered and not generally excluded. Ceylan says that the interaction of both would be the best case (Appendix 3 - Ceylan).
Grönnerud mentions the extreme housing shortage which is putting pressure on urban development and planning. Around 5.000-6.000 new housing units

per year are required to meet the demographic developments, however, only 3.000-4.000 units are actually built. Currently, two new urban districts are being developed which are *Parkstadt Süd* (Park City South) and *Deutzer Hafen* (Deutzer Harbour) as well as *Kreuzfeld* on the outskirts of the city. These projects have been criticised since they are densifying the already dense city but the pressure of the housing market seems to be more relevant (Appendix 2 - Grönnerud). Eventually, these difficulties and problems are accumulating which indicates the complexity of the situation. The city seems to be slow in developing and meeting the needs not only regarding housing but also with e.g. educational institutions. Hereby Grönnerud makes the example of the lack of schools in close proximity to home which results in pupils commuting through the entire city to get to school (Appendix 2 - Grönnerud). This points out the competition for space in Cologne and further the current urban planning trajectory which is still focused on building more structures. More buildings and grey infrastructure result in more impermeable surfaces which exacerbate the impact of climate change.

5.2.2 Climate Challenges

NRW's climate challenges are, amongst others, heatwaves with extended drought periods as well as heavier and stronger precipitation. The map in figure 13 indicates the proportion of the population which are affected by heat stress. It shows that especially metropolitan areas, such as Düsseldorf and Cologne, are affected with more than 75% of the population suffering from heat stress (MULNV, 2020). Other impacts mentioned by the municipality of Cologne are extreme precipitation resulting in pluvial flooding, especially in dense urban areas (Stadt Köln, n.d.-c; StEB Köln, n.d.).

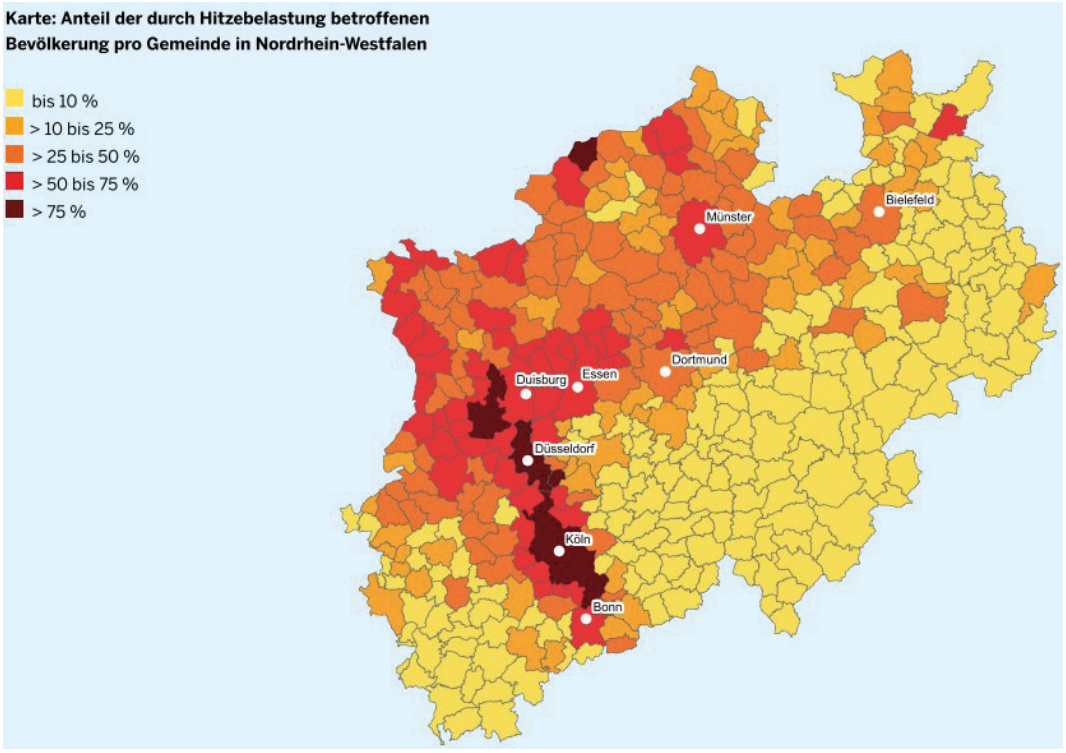

Figure 13: Proportion of the population affected by heat stress per municipality in NRW (MULNV, 2020).

5

Heat stress

The mean air temperature in Cologne increased by almost 1°C from 1958 to 2010. Additionally, hot days (defined as days above 30°C) almost doubled in the same time span as can be observed in figure 14.

The *Klimawandelgerechte Metropole Köln* identified that the densely developed inner city is severely affected by the UHI effect with a maximum difference of 10 degrees in relation to the outskirts (LANUV, 2013). Linnartz mentions one of the main challenges regarding climate change in Cologne is heat stress, especially in the inner city since it is densely built and consists of a high amount of sealed surfaces (Appendix 1 - Linnartz). Grönnerud points out the obvious changes in the city that can be felt during summer with temperatures rising above 40 °C in the last three years. Additionally, he highlights the settling of invasive species such as parrots and flowers blooming much earlier than in other parts of the country (Appendix 2 - Grönnerud). During hot summer days, the outskirts of the city are measuring several degrees lower temperatures compared to the inner city which is dominated by concrete structures (Appendix 3 - Ceylan). Additionally, Grönnerud mentions three cities in Germany that have reported striking heat records in the past years which are Freiburg im Breisgau, Frankfurt am Main, and Cologne (Appendix 2 - Grönnerud). Connected to the heat stress of the past years, Benjamin Luchterhandt from the municipality mentions the severe droughts, especially in the years 2017 and 2018 that have affected the city and especially the vegetation within (Appendix 5 - Benjamin Luchterhandt). Concluding, Grönnerud says that heat and air quality are the main challenges in Cologne. In combination with increased temperature Grönnerud emphasises that the higher the temperatures are the more water vapour the air can absorb, ultimately increasing the magnitude of precipitation events (Appendix 2 - Grönnerud).

Precipitation

Following on from this, the *Klimawandelgerechte Metropole Köln* determined an increase in heavy precipitation events

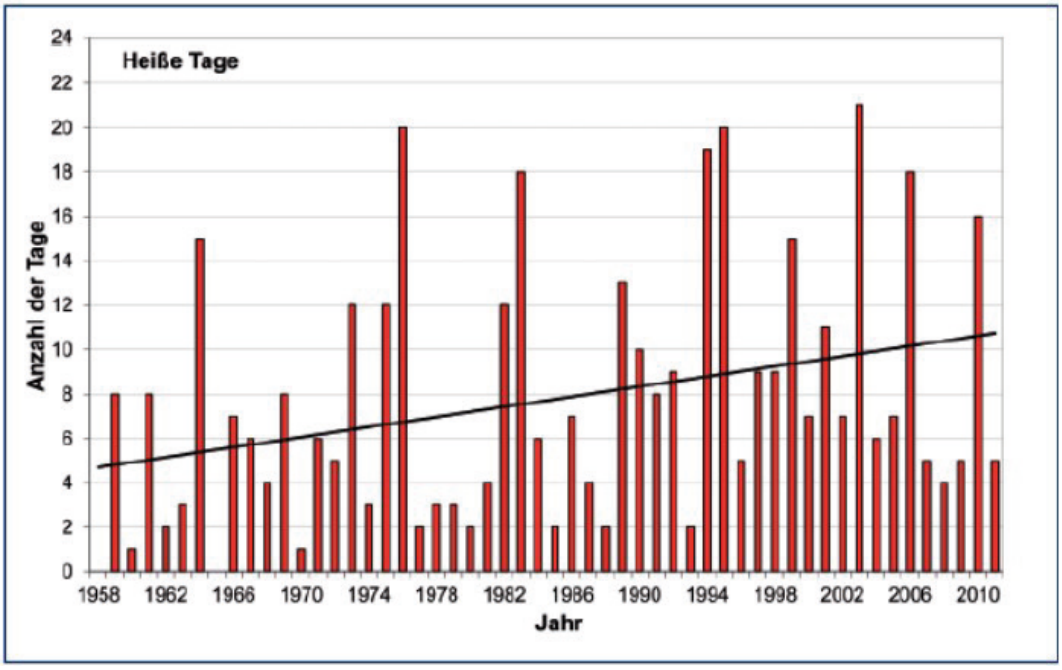

Figure 14: Number of hot days (>30°C), illustrates the number of days per year and linear trend (LANUV, 2013).

from 2005 to 2011 resulting in local flooding (LANUV, 2013). Grönnerud mentions heavy precipitation as a threat in Cologne as well. As an example, he mentions heavy precipitation events in July 2021 where it continuously rained heavily for 24 hours. One of the main traffic roads was flooded with water so high *„you could ride boats on [it]"* (Appendix 2 - Grönnerud). This goes hand in hand with Ceylan's elaboration on the challenges of heavy precipitation. Ceylan mentions three heavy precipitation events in 2021, especially having an emphasis on July 14th, which did not only affect Cologne but also neighbouring municipalities. More than 150mm of precipitation fell in 12 hours, which is 20% of the entire year's precipitation falling on one day. This led to interferences with infrastructures due to large-scale flooding (Appendix 3 - Ceylan). The cloudburst resulted in property damages and fatalities in Cologne and surrounding municipalities. Some neighbourhoods had to be evacuated (Junghänel et al., 2021). Those blue spots in the city have been identified and are now subject to finding solutions - both sewers-based but also surface-based to improve or even dissolve those problems (Appendix 3 - Ceylan).

Besides the obvious challenges that result from heavy precipitation events, Ceylan is highlighting the unpredictability of these events and the difficulties alongside. She argues that heavy precipitation events are difficult to foresee, unlike heat:

"The problem with heavy precipitation is that potentially there might be no precipitation for a long period of time which is desensitising people for that topic and its inevitable negative effects. On the other hand there are periods of time, such as June and July 2021, where there are many effects in a short period of time which then create a higher significance compared to heat".
(Appendix 3 - Ceylan)

Fluvial Flooding

Additionally, the city of Cologne is crossed by the river Rhine which is the second-longest river in Germany. The Rhine, and especially the part which is located in Cologne, is experiencing floods due to moderate precipitation over a longer period of time (10-20 days), usually during the winter. Therefore, Cologne has experienced several fluvial floods throughout the time. Furthermore, the Rhine has its origin in the alps, where melted ice and snow from warmer climates can put pressure on the river bed as well which subsequently leads to floods (Merz & Thieken, 2009). Linnartz confirms the occasional overflow of the Rhine during heavy precipitation resulting in flooded streets. However, there are areas of the river which are not flooded (Appendix 1 - Linnartz). Even though climate change is affecting the Rhine which is causing challenges for Cologne, the effect of fluvial floods will not be subject to this analysis. The scope of the present study is stormwater management in connection with pluvial floods and heat stress which does not undermine the importance of addressing fluvial floods as well.

Geographical Challenges

According to Grönnerud, Cologne has some geographical disadvantages that enhance the effects of the changing climate. Cologne is located in the *Rheinische Tiefebene* (Rhine-lowlands) in between two low and medium mountain ranges. This results in a lack of wind which can be observed in summer with a haze over the city combined with severe heat stress and lack of precipitation (Appendix 2 - Grönnerud).

5.3 The Complexity of Climate Adaptation in Cologne

The previous analyses of policy levels in which climate adaptation in Cologne is embedded, and the challenges that Cologne is facing are the foundation to

subsequently pinpoint the complexity of the problem in Cologne. Additionally, this section is dedicated to identifying paths to approach such complexity and to what extent Cologne is following it.

5.3.1 Cologne´s Adaptation is a Wicked Problem

Climate change and connectedly adaptation are inherently wicked problems as identified in Chapter 3.1.1. The previous section about challenges in Cologne has confirmed the multifold problem for the chosen study area of Cologne. To be more specific, Conradie (2020) argues that a wicked problem consists of interconnected singular problems. The challenges that the adaptation regime in Cologne is facing include car-dominated historical developments in the city as well as demographic challenges such as the housing crisis and urbanisation (Appendix 2 - Grönnerud; Appendix 3 - Ceylan; Stadt Köln, 2019a). Furthermore, the city is affected by heat stress and droughts (Appendix 5 - Luchterhandt), pluvial and fluvial floods (Appendix 2 - Grönnerud; Appendix 1 - Linnartz), which are partially amplified by geographical disadvantages (Appendix 2 - Grönnerud).

These problems are rooted in each other and solutions for those are possibly contradicting. Linnartz states that a municipality has many objectives and targets which are often contradicting. As an example, she mentions the guiding principle *Innenentwicklung vor Außenentwicklung* (Internal Development before External Development) to ensure that the space in the existing structure of the inner city is used as efficiently as possible before new structures are built on the outskirts (Appendix 1 - Linnartz). This guiding principle is legally formalised in the *Baugesetzbuch* (BauGB - Building Code), the federal law for all building measures (BauGB, 1960). However, this puts more pressure on the inner city's infrastructure. Therefore, space in the inner city that could be redesigned into green and blue infrastructure to adapt to the effects of climate change will instead be prioritised for constructing new buildings, for example, to tackle the housing crisis. Consequently, unsealing surfaces to open up space for green infrastructure would mean converting traffic roads, since this is the *"reasonable solution"* according to Linnartz, but this results in further problems regarding mobility. *"These conflicts of objectives in urban development make it tough to be a decision maker"* (Appendix 1 - Linnartz).

5.3.2 Integrated Planning as a Tool

Planning is argued to be an effective tool for addressing wicked problems. According to Conradie (2020), the complexity of the problem in Cologne requires an integrated and prospective planning approach which is properly coordinated, while ensuring participation and continuity (Conradie, 2020). The overview of the climate adaptation responsible actors, plans, and projects show that Cologne's planning regime is currently not set up to effectively approach wicked problems - at least partially. An indicator of this is that climate adaptation is not a mandatory task and therefore not integrated into the legal framework. Wieczorrek argues that *"voluntary tasks are being pursued in municipalities, but in the end you are not obliged"* (Appendix 4 - Wieczorrek). Wieczorrek argues that because there is no obligation to do climate adaptation there is no specific human and financial resources allocated to these posts. This means that capacities, both human and financial, have to be (re)organised internally within the municipality because there are no external resources (Appendix 4 - Wieczorrek). If climate adaptation would be integrated and legally anchored, the development would be accelerated (Appendix 5 - Luchterhandt). Connectedly, Grönnerud explains that *„if you want to change something you need to take a lot of money in your hand"* (Appendix 2 - Grönnerud). Further, he elaborates that once a municipality is running out or is low on money, there are certain

mandatory tasks that need to be done by the municipality, which is dictated by the federal state. In the worst case, the federal state provides money for that. These mandatory tasks are education and social obligatory tasks (Appendix 2 - Grönnerud). This implies that there are tasks which are clearly prioritised over climate adaptation which could change if climate adaptation would be legally anchored and resources provided.

Additionally, there is no centralised coordinating body for climate adaptation. It is a shared, decentralised discipline between the municipality's different departments and the StEB. This leads to conflicting objectives in the urban development in Cologne. Luchterhandt describes that during the bi-annual meeting of the climate adaptation working group there seems to be a consensus about what needs to be done. However, in the end no one wants to provide space for implementing cross-sectoral climate adaptation solutions to *"keep their flexibility"* (Appendix 5 - Luchterhandt). He thinks that many departments are afraid that they are limiting themselves and their department´s goals by agreeing to those cross-sectoral measures and to not reach their own goals in the end (Appendix 5 - Luchterhandt). A central body as a coordinating authority and decision maker could identify synergies between the objectives of different departments and create coordinated and integrated solutions.

5.4 Governing Climate Adaptation in Cologne

The preliminary analysis of the complexity of climate adaptation in Cologne implies that there is an awareness in the municipality about the complexity and importance of climate adaptation. Having said that, the execution of climate adaptation in Cologne appears to be somewhat unorganised and therefore partially inefficient. Since integrated and cross-sectoral planning is an efficient tool to address climate adaptation, this section is dedicated to analysing the current organisational culture and governance of climate adaptation in Cologne to pinpoint organisational hurdles. The concept of trained incapacity is used to highlight the influence of planners in the regime in Cologne and connected lock-ins and development trajectories.

5.4.1 The Organisational Culture of the Climate Adaptation Regime in Cologne

Aylett (2011) claims that a municipality usually consists of individual entities, operating in silos in a hierarchical order. The phenomenon of the siloistic organisational structure is confirmed by interviewees from within and outside the municipality in Cologne. Ceylan elaborates:

> *"Urban planning projects are generally supported by many different departments of a municipality [...] which all need to be brought together. Each of them has different interests, needs, and usage claims that all need to be considered."*
> (Appendix 3 - Ceylan)

She says that climate adaptation is a cross-sectional task but the StEB is still the water utility and has to have water management in focus. Ceylan´s department is mainly focusing on heavy precipitation and flooding precautions. Thereby she also mentions heat and urban greenery which goes hand in hand with the stormwater management in terms of synergy effects since evapotranspiration of plants can contribute to heat reductions. However, Ceylan mentions that this field of expertise lies with the *Umweltamt* and is not part of the StEB, even though it is clearly interlinked (Appendix 3 - Ceylan).

Linnartz feels that currently there is no prioritisation about which measures are preferably implemented and about

what is more important, but that there are always extensive debates for the individual cases (Appendix 1 - Linnartz). Ceylan further explains that the failure of planning or implementing cross-sectoral measures is predestined since they might result in trade-offs and conflicts. She identifies that *"the political will has to be above all, otherwise municipalities will not do anything. It is not possible without political backup"* (Appendix 3 - Ceylan). This political will is, unfortunately, still lacking in Cologne. Arguments, therefore, are the missing obligation to actually execute climate adaptation on a municipal level, resulting in a lack of resources. Successful governance of climate change entails linking those multiple actors and creating an independent entity to govern, in this case, climate adaptation. In the case of Cologne, this is missing since there is no centralised department taking responsibility.

Additionally, money from the federal state is pumped into the development of conceptual adaptation papers and consulting for climate adaptation but not into strategic implementations (Wirtschaftswoche, 2022). Grönnerud sees that as very critical. He is of the opinion that knowledge about what is the problem and what to do about it is not the issue. The issue is, according to him, economic restrictions to actually do something. His explanation for this behaviour is the speculation about lobbying interest in Germany to maintain consultancies and scientific advisors for economic interest (Appendix 2 - Grönnerud). In contrast, Wieczorrek is of the opinion that the awareness is there, however, *"acting on it is slowed down because people are a bit helpless about what there is to do"* (Appendix 4 - Wieczorrek).

5.4.2 Changing Trajectories

The organisational structure of a municipality is somewhat stable which makes it difficult to change development trajectories. To visualise changes within big municipalities and organisational structures of metropolitan areas Ceylan refers to a *"big tank ship which takes a long time to change direction, it is not happening very fast. It is possible to initiate change but the way to get there might be long and tenacious"* (Appendix 3 - Ceylan).

The stability creates a hurdle for individuals to steer the trajectory (Aylett, 2011). However, it is not impossible. Therefore Ceylan argues that the trajectory of an organisation is, amongst others, also dependent on individuals. She claims some think of climate adaptation as something important and therefore push for change and then there are others that are locked-in to their old ways of thinking and not that open-minded about trying out novel approaches. Personally, Ceylan is noticing the lack of courage to try out new things, at a stage where the perfect solution is not available just yet. *"Sometimes you just need to try out things, and even though there is no practical experience about specific measures you just need to build it"* (Appendix 3 - Ceylan). Ceylan's argument clearly indicates the trained incapacity of municipal employees, where they are accommodated with the conventional tools and concepts used in the municipality and therefore it is difficult to break out of the current trajectory of how to approach problems. Additionally, Grönnerud expresses concern that *"many employees in the municipalities in Germany are mistrained, away from the actual problems"* (Appendix 2 - Grönnerud). He counts himself into that phenomenon as well since his background is in political science and as he argues himself *„he doesn't know what to do with it [his degree in political science]"*. He argues that *"there are too few practice-oriented engineering programmes at the universities and many theoretically based [...] programmes"* (Appendix 2 - Grönnerud). He argues that he could not build anything in the city since he is not educated to do that. He

calls himself *„useless"* in some aspects of his job (Appendix 2 - Grönnerud). Wieczorrek confirms his concern. She is an educated biologist and she says that her academic education is almost irrelevant after 25 years of working in the municipality and she *"grew into"* working with climate change and adaptation (Appendix 4 - Wieczorrek). Further, she elaborates that, especially working in a municipality, there are administrational tasks that have to be learned within the system where people can only grow into (Appendix 4 - Wieczorrek).

Chapter 6
Regime Transitions

After identifying hurdles for effectively governing climate adaptation in Cologne, the possibilities for change will be explored, making use of the Multi-Level Perspective defined by Geels (2002). The three levels of landscape, regime, and niche will therefore be outlined, followed by a section about shifting the regime's trajectory. The focus is on how change can be triggered, both within and from outside the regime. Following the information provided in this section, it is elaborated upon how reference projects can help push a regime shift. Subsequently, four international reference projects are presented for further analysis.

6.1 Climate Change is Applying Pressure on the Regime

In the case of Cologne, the changing climate and its effects in the form of extreme weather events in July 2021 apply pressure on the existing regime and are, therefore identified as the landscape. The external pressure of increased heavy precipitation and extreme weather events are challenging the current status quo of climate adaptation and water management in Cologne. This dynamic is confirmed in the expert interviews. Wieczorrek has the understanding that pressure is created through environmental hazards such as heavy precipitation leading to flooding and causing significant damage or even fatalities (Appendix 4 - Wieczorrek). Additionally Ceylan agrees: *„Yes, the extreme weather events of 2021 have definitely exerted pressure which I still feel today"* (Appendix 3 - Ceylan). There are also a lot of requests from politicians that came to StEB to look for solutions for those problems because *„it can not continue like this"* (Appendix 3 - Ceylan). On the other hand, Grönnerud is the opinion that even though the municipality is aware of the risks and challenges and the need to adapt to those, he is unsure whether the politicians are aware since the focus is still on mitigation rather than adaptation (Appendix 2 - Grönnerud). This clearly indicates the slow changing dynamic of the landscape. Even though the environmental pressure is apparent, the political will of the higher policy levels (e.g. policy makers in the federal government in Germany) is slow in reacting to it and thereby not exerting enough pressure on the regime in Cologne.

6.2 Cologne´s Response to Climate Change

The responsibility for climate adaptation lies with the municipality which is delegating water management tasks to the *Stadtentwässerungsbetriebe* (StEB - Water Utility). Therefore, the regime actors are different departments within the municipality as well as the StEB with the main actors located in the department of Water Management Principles. Ceylan is leading the subject group Climate Adaptation and Development within the aforementioned department. She explains the current objective of the StEB regarding climate adaptation is identifying challenges and developing *"ad hoc, fast but still efficient solutions to communicate the relevance of the topic"* (Appendix 3 - Ceylan). However, it is taking a long time to implement measures but this has gotten priority in the StEB (Appendix 3 - Ceylan).

In the municipality, the focus is to a large extent primarily on mitigation with specific targets focusing on reducing CO_2 emissions (Stadt Köln, 2019b). Especially regarding the fact that Germany will most likely miss their climate mitigation targets, adaptation will hopefully gain more attention in the future because *"in the end there is not much more to do than adapt"* (Appendix 4 - Wieczorrek). From the side of the municipality there is already the aspiration of having adaptation in the focus in future. Indicators include the development of the adaptation strategy and highlighting the importance of keeping the water in the city to address both

heavy precipitation and heat waves under a cross-sectoral planning approach. Therefore, structural challenges in the current regime are identified. The municipality is currently working on creating a coordination office for climate adaptation, but it is depending on finances and political support to create a department from scratch. Up until now there has not been a lot of staff working on climate adaptation which is indicating the lack of resources, both human and economic. The relevant actors meet twice a year in a working group to discuss climate adaptation across sectors and departments. Wieczorrek claims that she, as a *"singular person, can not redesign the entire city. But the working group is the first step to conduct the needed networking, but actually a lot of new human resources would be needed"* (Appendix 4 - Wieczorrek).

6.3 Living Labs and Pilot Projects Trying to Change Trajectories

The landscape pressure has only resulted in small changes at the regime level. However, when looking at the niche level, several novel innovations are beginning to emerge. Research projects and living labs such as VertiKKA and iResilience are testing novel structures and approaches. These are only two examples of innovations that materialised as a response to the change in climatic patterns. To understand the scope of such projects, both VertiKKA and iResilience will be described in detail in the following.

6.3.1 VertiKKA

VertiKKA is a research project which is developing low-maintenance modular facade greening. The idea is to combine resource-efficient water management and solar energy to develop novel multifunctional facade greening modules while making use of synergies. Reuse of domestic greywater provides nutrients to the plants and saves resources (VertiKKA, n.d.). This has been tested over a three year period and the project was phased out in May 2022. However, the modules will further be tested in living labs over a period of 2 years in Southern Germany. Involved in the project were scientific institutions such as universities as well as one municipal representative to coordinate scientific research with municipal requirements, provide legislative guidelines, and communication between stakeholders. Grönnerud has been taking the position of the municipal representative in the project *VertiKKA* (Appendix 2 - Grönnerud). This project does not utilise stormwater for the modules, but it is still adapting to climate change by attempting to mitigate the urban heat island (UHI) effect.

6.3.2 iResilience

iResilience is a 3-year long project which is partly funded by the *Bundesministerium für Bildung und Forschung* (BMBF - German Federal Ministry of Education and Research). It is a research project with the title *Soziale Innovationen und intelligente Stadt Infrastrukturen für die resiliente Stadt der Zukunft* (Social Innovations and Intelligent Urban Infrastructures for the Resilient City of the Future) (iResilience, n.d.). The name *iResilience* stands for intelligent, innovative, and resilient (Appendix 1 - Linnartz). The project is led by an interdisciplinary team from both research and practical experience. The aim is to create cities that are resilient to the changing climate, where both people and cities have to adapt. The project is testing new approaches and cooperations for local climate adaptation in three pilot case areas in Dortmund and Cologne. The aim is to gain new insights and approaches to implementing measures regarding heavy precipitation precaution, heat prevention, and climatic function of urban greenery (e.g. private building protection against heavy precipitation, shady paths for heatwaves, or cooperation of tenants and

owners for more greenery in the backyards). The project emphasises the importance of social and technical innovations in the process. All ideas will be compiled into roadmaps for the climate robust development of each pilot case area. Additionally, there will be a "script" with general outcomes, guidelines, and frameworks which can be used by other municipalities (iResilience, n.d.).

6.4 Shifting the Regime

The stability of the regime makes it challenging to steer the trajectory in a new direction, however, it is not impossible. Generally, there are two options from which change can emerge. One is the rise of niche innovations that break through the window of opportunity (Geels, 2002) and the second is incumbent actors that attempt to change the regime's trajectory from within (Quitzau et al., 2013).

6.4.1 Change from Below - Emerging Niche Innovations

The two projects described previously are testing novel approaches on how to address climate change and its adaptation in Cologne. Eventually, such projects can emerge from the niche level and nest in the regime and therefore change its trajectory. *VertiKKA* is currently attempting that breakthrough. After a three-year research and testing period within an institutional incubation room, the next step is to actually go outside of the universities in order to understand if the project can be implemented in reality. The facade modules will face challenges which have been eliminated in the testing period. There are high restrictions and guidelines on reusing greywater which currently needs to be treated first in Cologne. For the testing of these modules, the authorities gave an experimental exception (Appendix 2 - Grönnerud). In order to emerge from the niche level, this exception has to become a new norm in the regime. Unfortunately in the case of *VertiKKA* it is not possible to report on the status of implementation since by the time the present report is written, the implementation phase has not yet begun.

The living lab *iResilience* has a completely different approach compared to *VertiKKA* to challenge the regime. The aim of this research project is to test social innovations and novel forms of cooperation of actors across sectors and citizens, which is urgently needed when attempting successful climate adaptation. The focus is on a bottom-up approach, supported by municipal actors and professionals. Therefore, the outcome of the project is not the implementation of specific measures but to determine and document how to design solutions and the implementation processes. *"The solution itself is the cherry on top which is not subject to the project but the natural outcome of the project"* (Appendix 1 - Linnartz). To grasp the difficulty of implementing citizen driven projects Linnartz is using an example of two urban gardening projects that have been implemented within the project. One urban garden was initiated top-down by the municipality, another one bottom-up by the citizens. The municipal initiated project did not get enough acceptance and the citizens did not maintain it sufficiently, therefore the municipality took over taking care of it. On the other hand, the citizen driven urban garden is a success and sufficiently maintained.

The physical outcome of the project *iResilience* is a roadmap addressed to the citizens and a script for professionals to use in other municipalities in Germany. Grönnerud criticises that development since he is of the opinion there has to be *"less writing, more doing"* (Appendix 2 - Grönnerud). On the other hand he is in favour of projects such as *VertiKKA* and *iResilience*:

"In general these projects are good! But there are problems for specific kinds of funding that are not granted for these projects because these projects are based on funding. In the case of iResilience the problem was that it was not developed to implement solutions (ergo no funding for that) but citizens do not want to participate and then get nothing out of it. Which leads to frustration in civil society. But the important question for these research projects is, if the research subject has a chance to find a way from academic research facilities to reality."
(Appendix 2 - Grönnerud)

Grönnerud points out the dependency these niche innovations have on e.g. the federal government since they are usually fund-based projects. This is limiting the innovation´s scope and opportunities. This confirms that radical niche innovations require the pressure of the landscape to have a chance to change the current regime. Wieczorrek is complimenting this argument by saying that *"it is going in the right direction"* with research projects and institutions offering networking and training, *"but in the end they are not the ones implementing measures, in the end this is the municipality´s task"* (Appendix 4 - Wieczorrek).

6.4.2 Change from Within - Incumbent Actors Triggering the Shift

Alternatively, the regime can be adjusted from within through *"conscious and planned efforts in response to perceived pressures, using regime-internal resources"* (Quitzau et al., 2013, p. 140). In some way, both niche innovations previously described are driven by regime actors (mainly the StEB) even though they are still allocated in a niche. However, both projects are financed by the regime's external resources since they are funded by the federal government.

Furthermore, endogenous regime adjustments can be observed within the municipality through the aspiration to develop a central body to coordinate climate adaptation. This indicates that the working group, which is meeting twice a year to exchange status of affairs, is not a sufficient tool to coordinate climate adaptation and this is recognised by the municipal actors. Wieczorrek elaborates:

"Cologne is a big municipality with many departments and I am currently unsure how a cross-sectoral approach can be ensured."
(Appendix 4 - Wieczorrek)

This obstacle is also identified by Luchterhandt. *"Lately, there is the aspiration to have better collaboration with the traffic office, especially early on in projects"* (Appendix 5 - Luchterhandt). Generally, he thinks that this collaboration is constantly growing which, according to him, is partly due to a change of personnel in the traffic department (Appendix 5 - Luchterhandt). This statement confirms that regime endogenous actors actually influence the development trajectory.

Largely, triggering a regime shift from endogenous actors in Cologne is slow. Opinions differ among the interviewees on whether individuals within can influence the current trajectory or not. Ceylan concludes that there is generally missing the courage in individuals to try out new things that do not have practical experience. However, according to her, that is what it is all about - *"we need to dare!"* (Appendix 3 - Ceylan). She hopes that all current projects which are still in the development phase will be reconsidered having climate adaptation in mind in order to gain new insights and experience (Appendix 3 - Ceylan).

Nevertheless, climate change is a global phenomenon and adaptation is performed in many places already. Therefore, the next section is presenting some reference projects which could inspire Cologne´s adaptation regime.

6.5 Reference Projects to Inspire Regime Shifts

Making use of and getting inspired by reference projects can help overcome barriers of change. This does not mean that reference projects can simply be copied and implemented at another location since planning problems are inherently wicked and therefore vary (see Theories section).

> *"There is no one-size-fits-all adaptation solution to the challenges of adapting to the impacts of climate change as solutions will differ depending on context and scale, as well as on the local culture and internal capacity."*
> (Bierbaum et al., 2013, p. 371)

Nonetheless, reference projects are a vital tool to share lessons learned and knowledge gained from practical experience and therefore accelerate a climate adaptation oriented regime shift (Bierbaum et al., 2013). Grönnerud supports this statement. He is of the opinion that the problems related to climate change are somewhat similar. He argues that there are blueprints for solutions in different regions that can be used to get inspired by (Appendix 2 - Grönnerud). Furthermore, Ceylan sees networking with other municipalities as a very important aspect to see how other municipalities are managing climate adaptation and thereby answering some arising questions (Appendix 3 - Ceylan). In the end, Luchterhandt argues that climate adaptation is not as novel as people think and therefore there are many cases and projects to learn from (Appendix 5 - Luchterhandt).

In the following, four reference projects will be presented that could inspire Cologne´s planning regime. The projects vary in scales and impact which reflects the complexity of climate impacts and the various solutions that can be implemented with different scopes and scales. The focus is on Nature-based Solutions (NbS), an engineered stone wool solution from ROCKWOOL, and a climate adaptive modified existing structure. Two reference projects are located in Copenhagen, Denmark which allowed for further investigation in the form of site visits.

6.5.1 Klimakvarter

Klimakvarter (The Climate District) is a climate resilient neighbourhood in Østerbro, Copenhagen. It is a *"showcase for climate change solutions"* and claims to be Copenhagen´s first climate-resilient neighbourhood (Klimakvarter, n.d.). The project kicked off in 2012. Actors involved in the development are the municipality, the local water utility HOFOR, the self-owned foundation *Miljøpunkt Østerbro* (Environmental Centre Østerbro), and the local citizens residing in the neighbourhood. The shared objectives have been to develop Copenhagen´s greenest inner-city neighbourhood while at the same time providing green solutions to manage stormwater from increased heavy precipitation which Copenhagen is experiencing. Thereby the district itself functions as a reference project for the rest of Copenhagen to *"future-[proof the city] against heavier rain and torrential downpours"* (Klimakvarter, n.d.).

In *Klimakvarter* urban squares, courtyards, buildings, and streets have been transformed to a climate-resilient neighbourhood as visualised in figure 15. These transformational projects are supplemented by local green projects initiated by the residents such as a rooftop farm and urban gardening projects. Synergies are playing a key role in *Klimakvarter* where urban greenery is combined with stormwater management, managing microclimate, and recreation. In Klimakvarter, the planners made use of rain gardens which are combined with walking paths and benches to enjoy the urban greenery. Figure 16 shows a picture of a rain garden in the neighbourhood around *Sankt Kjelds Plads* with walking

Figure 15: Visualisation of *Klimakvarter's* design (Klimakvarter, n.d., modified to locate *Sankt Kjelds Plads* and *Tåsinge Plads*).

paths and a bench. The rain gardens are fed by roof runoff from neighbouring buildings through inlets as can be seen in figure 17. The water is transported to the inlet via a trench as can be observed in figure 18 (Appendix 7 - Klimakvarter). *Tåsinge Plads* uses urban design to communicate the importance of considering

Figure 16: Rain garden at *Sankt Kjelds Plads* (own figure).

water as a resource. The design component as can be seen in figure 19 replicate raindrops and an umbrella. The raindrops can be used to play with while the umbrella provides shade during a sunny day. Additionally, the square has information boards educating the visitors about the locally conducted stormwater management and the connected water flow (see figure 20). Thereby mechanical filter and UV-purification is mentioned to filter the runoff water (Appendix 7 - Klimakvarter).

Figure 17: Rain garden with water inlet and pedestrian path (own figure).

Figure 18: Trench for water transport (own figure).

This project represents a large-scale redevelopment project of existing structures. Especially in already established cities such as Cologne, climate adaptation has to be considered in the redesign of existing structures (Appendix 3 - Ceylan).

Figure 19: Raindrops and umbrellas tell the story about water as a resource on *Tåsinge Plads* (own figure).

One identified issue in Cologne is the contamination of runoff water which has to undergo pre-treatment before reuse. *Klimakvarter* addressed this issue in a pilot project using the First Flush method on *Bryggervangen* (Klimakvarter, n.d.). This method argues that the first flush, as in the urban stormwater runoff in the initial stage, *"contains considerably higher amounts of pollutants compared to the latter phase of the event"* (Maniquiz-Redillas et al., 2022, p. 2). On *Bryggervangen*, the first flush is directed into the sewer system for treatment and the subsequent second flush, which is significantly cleaner, is infiltrated into the green areas (Klimakvarter, n.d.).

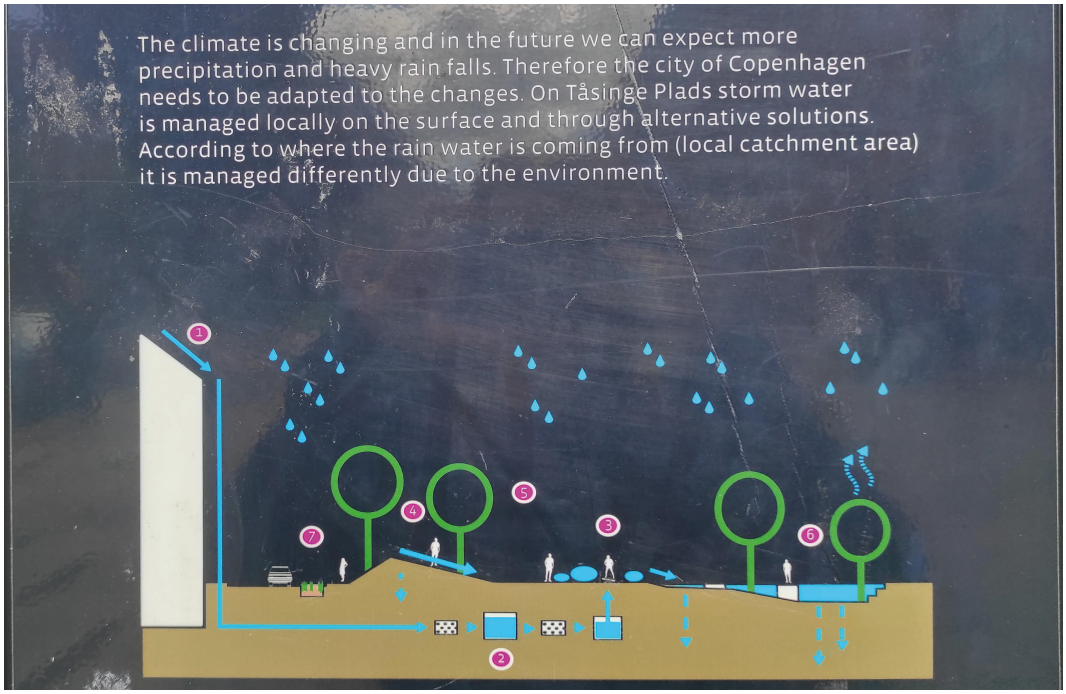

Figure 20: Information board to explain the water flow at *Tåsinge Plads* (own figure).

6.5.2 Enghaveparken

Copenhagen accommodates another prestige climate adaptation project - the climate park *Enghaveparken* in the city district Vesterbro. *Enghaveparken* is, like the *Klimakvarter*, a response to the increase in heavy precipitation and cloudbursts in Copenhagen. It is *"the largest green climate adaptation project in Copenhagen"* (City of Copenhagen, n.d.). The project was initiated in 2014, the square which can be seen in figure 21 inaugurated in 2019 (TREDJE NATUR, n.d.).

Copenhagen municipality claims that the applied approach of combining stormwater management, recreational, and educational aspects can be scaled to other projects globally that are facing similar challenges and therefore help

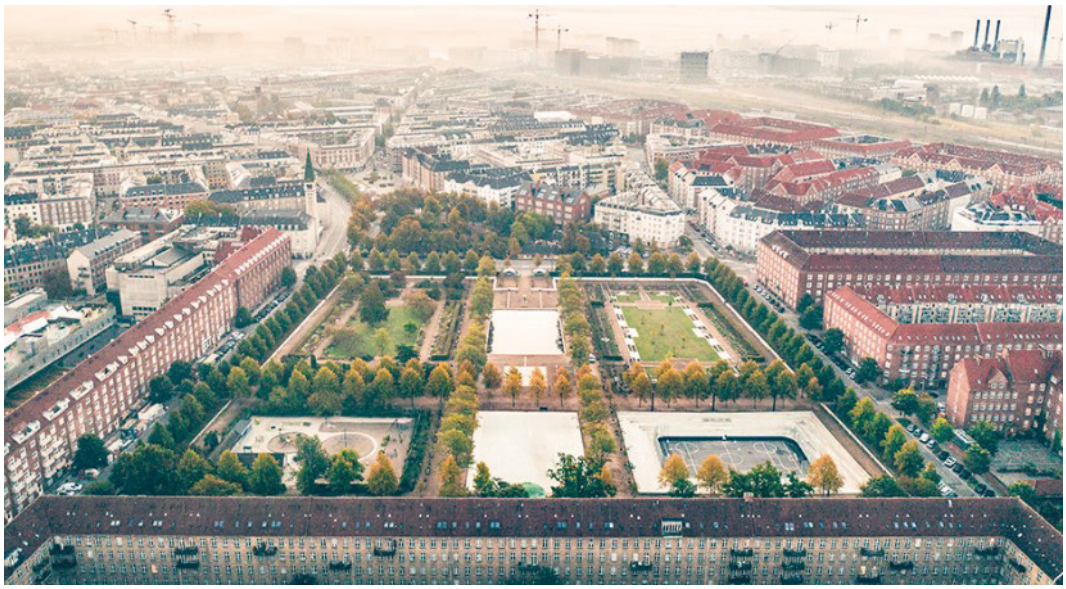

Figure 21: *Enghaveparken* in Vesterbro, Copenhagen from above (TREDJE NATUR, n.d.).

making cities more secure and resilient to the changing climate (City of Copenhagen, n.d.).

The climate park is strategically located at the bottom of a hill to handle extreme precipitation. It consists of multifunctional cloudburst pools and an encircling water wall that functions as a dike with a channel for the stormwater to run through. This water is mainly clean roof runoff from surrounding buildings that can be used for water play and irrigation of the plants in the park such as the flower beds in figure 22 (TREDJE NATUR, n.d.). From the water wall there are outlets leading to the cloudburst pool with a fountain via trenches as illustrated in figure 23. Additionally, the multifunctional water wall can be used as a sitting bench and creates some privacy in a public park which was perceived as comfortable during the site visit. The water wall is displayed in figure 24 (Appendix 8 - Enghaveparken).

Furthermore, there is an automated gate which closes off the park in the case of a heavy cloudburst and therefore protects the surrounding buildings

Figure 22: Flower beds which are watered by collected stormwater (own figure).

Figure 23: Water outlet from water wall (own figure).

Figure 24: Multifunctional water wall (own figure).

and infrastructure (TREDJE NATUR, n.d.). Figure 25 shows a picture of this gate which is discretely incorporated in the design of the multifunctional water wall. This gate is facing towards the park from *Enghave Plads* and the metro station *Enghave Plads*. Both are protected from stormwater runoff as soon as the gate closes (Appendix 8 - Enghaveparken).

The multifunctional pools can be filled with stormwater during heavy cloudbursts. When dry, these pools can e.g. be used as a multifunctional sports arena (TREDJE NATUR, n.d.). Figure 26 shows the recessed sport rink that fills up with water during heavy precipitation events. When dry it can be used for different sport activities and spectators can sit on the surrounding stairs which leads the water into the ditch during heavy precipitation (Appendix 8 - Enghaveparken).

Therefore, the park is both handling everyday precipitation by sustainably saving resources and storing stormwater from up to a 100-year event, as can be observed in figure 27 (TREDJE NATUR, n.d.). *Enghaveparken* stands out for its extraordinary multifunctionality (City

Figure 25: Automated gate that keeps water masses in the climate park (own figure).

Figure 26: Multifunctional sports arena that fills up with water (own figure).

of Copenhagen, n.d.; TREDJE NATUR, n.d.). Cologne is aspiring to increase its multifunctionality in combination with climate adaptation in the future, therefore, *Enghaveparken* has been chosen as a reference project in the present paper (Appendix 3 - Ceylan).

The recreational aspects of water such as water plays in *Enghaveparken* are fully provided by stormwater contrasting to the usual approach of using groundwater. To emphasise the water scarcity, raise awareness about the importance of climate adaptation, and educate citizens, the recreational water part of the park disappears in times of droughts where it is needed to irrigate plants in the park (TREDJE NATUR, n.d.). This is an easy feature to raise awareness amongst citizens about the importance of sustainable urban water management which can be applied in Cologne as well.

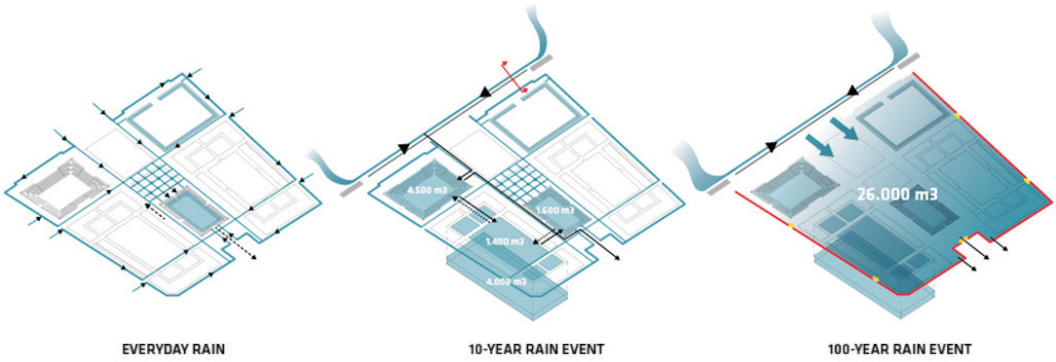

Figure 27: *Enghaveparken* is handling different scales of precipitation events (TREDJE NATUR, n.d.).

6.5.3 Blue-green swales using Rockflow

The next reference project is using the novel engineered stone wool solution Rockflow from the building insulation manufacturer ROCKWOOL. A specific description of the product's features can be found in Chapter 2.3.2. This specific solution was chosen to highlight how an engineered solution can still contribute to keeping stormwater in the city while at the same time enhancing urban greenery and unlocking synergy effects.

The chosen reference project is a climate bioswale located in the climate-adaptive municipality Zoeterwoude in the Netherlands. The swale is both infiltrating and retaining stormwater. Rockflow has been chosen as a solution in Zoeterwoude specifically due to high groundwater levels and moderate hydraulic conductivity of the soil. It was combined with a bioswale on the surface consisting of perennials that can make use of the water reservoir during dry periods. To guarantee both infiltration and retention for the water reservoir, Rockflow installed a capillary seal with gravel between two layers of Rockflow. A cross sectional view of the system can be seen in figure 28. Figure 29 is a picture taken during the installation process.

The perennials provide a nice visual appearance and increase biodiversity significantly compared to solely green strips as can be observed in figure 30. A challenge in Zoeterwoude was the availability of space with only a narrow strip between the road, parking spaces and the cables and pipes (ROCKWOOL, n.d.-b). Thereby, Rockflow can be used to make swales shallower without losing

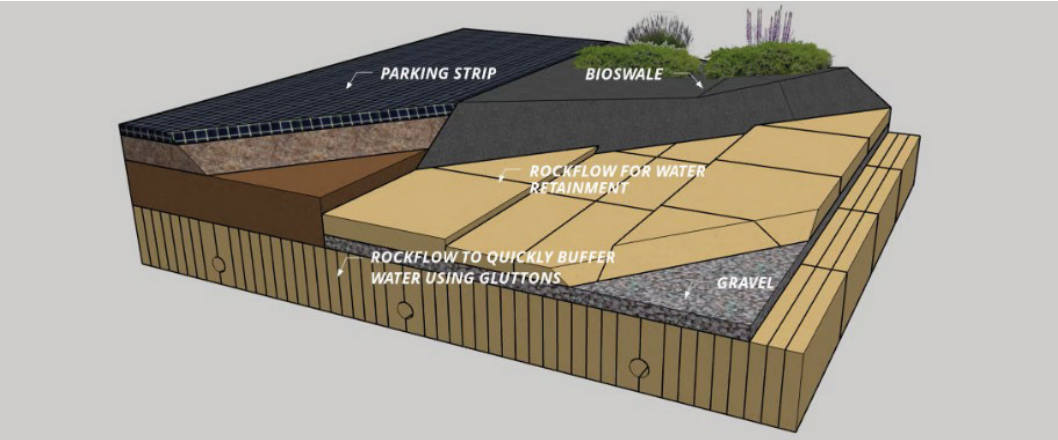

Figure 28: Cross section of Rockflow system with bioswale (ROCKWOOL, n.d.-b).

their capacity while still providing greenery (ROCKWOOL, n.d.-a). Since Cologne is identified as a very dense city, these features may help the city cope with both sustainable urban water management to adapt to the changing climate while at the same time enhancing the urban greenery, biodiversity, and address the UHI effect through evapotranspiration.

Figure 29: Installation of Rockflow in combination with a bioswale in Zoeterwoude (ROCKWOOL, n.d.-b).

Figure 30: Pleasant design of the blue-green bioswale with Rockflow (ROCKWOOL, n.d.-b).

6.5.4 Green Bus Stops in Poland

Since 2018, Poland has developed several green bus stops which are placed in different municipalities across the country (Zielone Przystanki, 2018). The green bus stops were developed by *The Institute of Environmental Protection* which is the national research institute in Poland operating under the mandate of the Ministry of Environment. The bus stops are placed in city centres along the busiest roads. There are different models available varying between 10m^2 of planted area on the roof or a green wall covering 12m^2. Every model is designed to collect stormwater for irrigation of the plants. Excess water from precipitation can be used for irrigation of surrounding green areas. Therefore, local floodings can be reduced and pressure from the sewer system released. Consequently, an intact green system can contribute to mitigate the UHI effect through the plants evapotranspiration resulting in local reductions on a sunny summer day reaching approximately 9°C compared to normal roofs. This effect gets complimented by reducing air pollution and thereby improving air quality. Lastly, the green bus stops improve biodiversity and create ecosystems for birds, insects, and other species. Figure 31 shows a model with both a green roof, green wall, and a raised garden bed at one end of the structure. The model is managing stormwater, enhancing the microclimate and biodiversity, and providing shade at the same time (Klimada 2.0, n.d.).

This innovative design can be installed within one day. Higher maintenance costs compared to normal bus stops are expected, however, the green bus stops provide added value that most likely balance the extra costs (Klimada 2.0, n.d.).

A small-scale project such as the green bus stops can find application in the dense inner city of Cologne which would benefit from the enhanced microclimate and local stormwater management. The previous analysis about challenges in Cologne have determined the lack of

Figure 31: Green bus stop in Poland (Zielone Przystanki, 2018).

space in the inner city for new development in combination with already to a large extent sealed surfaces (Appendix 3 - Ceylan). Therefore, making use of already existing grey structures such as bus stops can bring innovative designed green space into an otherwise grey dominated urban environment.

The preliminary study of transition barriers leading up to the presentation of international reference projects illustrate the multifaceted possibilities to overcome barriers of change. Climate change is a global phenomenon and adaptation therefore executed all over the world. Cologne can take advantage of this and learn from reference projects like the ones previously presented. The variety of presented solutions paints a picture of the various scales and scopes of blue-green climate adaptation solutions.

Chapter 7

Utilising Synergies for Sustainable Urban Water Management and Climate-Resilience

7

The previously mentioned reference projects have been chosen as prestige projects since they all work across sectors by utilising synergies. The importance of synergies to reach Sustainable Urban Water Management (SUWM) and climate-resilience is highlighted in the *Principles for Water Wise Cities* (PWCC) framework developed and promoted by the International Water Association (IWA). Thereby the focus is on interdisciplinary planning and operating teams to identify dependencies and subsequently utilise synergies to reach SUWM (Fu & Wang, 2021).

For this analysis, four out of the 17 principles have been selected, each representing one of the *Four Levels of Action* needed to become a water-wise city. Additionally, the choice of principles allowed for each of the four reference projects to be linked to one of the principles to exemplify measures taken that contribute to climate-resilience and water sensitive urban design. The aim of this chapter is to identify the employed synergies in the reference projects and link them to the four principles of water-wise cities to determine how climate-resilience and water sensitivity can be achieved. Figure 32 highlights the chosen principles within their level of action.

The Four Levels of Action

1 Regenerative Water Services
- Replenish Waterbodies and their Ecosystems
- Reduce the Amount of Water and Energy Used
- Reuse, Recover, Recycle
- **Use a Systemic Approach Integrated with Other Services**
- Increase the Modularity of Systems and Ensure Multiple Options

2 Water Sensitive Urban Design
- Enable Regenerative Water Services
- Design Urban Spaces to Reduce Flood Risks
- **Enhance Liveability with Visible Water**
- Modify and Adapt Urban Materials to Minimise Environmental Impact

3 Basin Connected Cities
- **Plan to Secure Water Resources and Mitigate Drought**
- Protect the Ecological Health of Water Resources
- Prepare for Extreme Events

4 Water-Wise Communities
- Empowered Citizens
- Professionals Aware of Water Co-benefits
- **Transdisciplinary Planning Teams**
- Policy Makers Enabling Water-Wise Action
- Leaders that Engage and Engender Trust

Figure 32: 4 principles chosen from the PWWC framework (own figure, adapted from Fu & Wang (2021)).

7.1 Use a Systemic Approach Integrated with Other Services

The first action defined is *Regenerative Water Services* which employs the principle of using a systemic approach while integrating other services. Regenerative water services are crucial to sustainably protect the quality and quantity of water resources while at the same time meeting all current needs related to water as a service. Thus, this principle demonstrates that a systemic and integrated approach is the foundation for regenerative water services. Fu & Wang (2021) argue that water services are closely linked to other services such as waste, energy, and transportation. This demands integrating those related infrastructures and services, and fostering the use of synergies in between (Fu & Wang, 2021).

Projects such as the green bus stops in Poland are utilising synergies resulting in added value across sectors. The modified bus stops are managing stormwater while at the same time dealing with the lack of space for urban greenery and enhancing the microclimate and biodiversity. The modules are actively contributing to regenerative water services by utilising stormwater for watering the plants on the modules and in surrounding areas instead of using groundwater. The green bus stops are furthermore providing added value to the citizens that benefit from cool spots in the city while waiting for public transportation and thereby improve urban liveability (Klimada 2.0, n.d.). The successful integration of different services in one systemic approach toward climate-resilience can be observed in the green bus stops in Poland.

7.2 Enhance Liveability with Visible Water

Integrative urban planning in connection with protecting the water cycle from disturbances is of utmost importance for water sensitive urban design. The *Water Sensitive Urban Design* level of action thereby ultimately enhances a city's liveability. The connecting principle of the visibility of water in cities can be improved by connecting urban spaces and infrastructures with water. Strengthening the visibility of water results in *"sustainable irrigation of parks and gardens, providing shade and mitigation of heat islands"* (Fu & Wang, 2021, p. 43).

The climate park *Enghaveparken* in Copenhagen, Denmark is actively applying this principle in the design of the park. Stormwater from roof runoff gathered from surrounding buildings is openly displayed in the water wall and water play. Additionally, this water is used for the irrigation of plants in the park and provides recreational value. Besides, the park is educating citizens about water as a scarce resource, as the visible water disappears during episodes of droughts. The multifunctional use of the sports pitch allows for a synergistically used urban space that provides added value to citizens during dry weather and captures stormwater during heavy precipitation events (TREDJE NATUR, n.d.). The water sensitive design of *Enghaveparken* results in added value for both citizens and users of the park and urban infrastructure and thus contributes to a liveable city as envisaged in this principle of action.

7.3 Secure Water Resources and Mitigate Droughts

Basin Connected Cities are maintaining intact water basins to ensure an intact water cycle. Neglect of the water basin may result in overexploitation, contamination, and inadequate utilisation of the basin's catchment area. As a consequence, the water cycle will be disturbed and the provided service by the basin degraded. In order to maintain an intact water basin, cities have to follow the principle of securing water resources and mitigating

droughts by ensuring a sustainable water supply in the city. Therefore, basins have to be recharged to guarantee an intact water cycle (Fu & Wang, 2021).

The application of Rockflow in the form of a blue-green swale in Zoeterwoude, the Netherlands is addressing these issues by ensuring that stormwater can be infiltrated locally. This allows for groundwater recharge and keeps the water in the city instead of leading the water into the sewer system where it is transported to a treatment plant. In Zoeterwoude, the bioswale is using synergies by combining successful stormwater management with urban greenery to enhance biodiversity and ecosystems. Additionally, the plants growing on the bioswale are cooling the area through evapotranspiration and thereby managing the microclimate (ROCKWOOL, n.d.-b). Rockflow products in combination with urban greenery therefore have the opportunity to generate synergies between protecting the water cycle and managing stormwater and thereby actively contribute to the principle of securing water resources and mitigating droughts.

7.4 Transdisciplinary Planning Teams

The above-mentioned principles and synergistic approaches require a holistic planning concept and utilisation of interdisciplinary professionals to combine different expertise. Therefore, this principle is part of the foundation for water-wise cities. The holistic planning approach allows for innovative sustainable solutions to evolve by identifying and utilising synergies and co-benefits (Fu & Wang, 2021). Fu & Wang (2021) highlight that:

> *"A city planning organization recognizing these inter-relations and bridging over existing individual departments is needed to enable urban professionals to implement sustainable urban water."*
> (Fu & Wang, 2021, p. 45)

The *Klimakvarter* successfully managed to collaborate and create an interdisciplinary approach to redesign an entire neighbourhood. Actors involved are, besides the municipality of Copenhagen, the local water utility, and a locally-driven environmental foundation. Particularly noteworthy is the intensive and active citizen participation from the beginning of the process (Klimakvarter, n.d.). Especially when changing the built environment, citizens need to be included to gain acceptance and further get insight from the residents about what they aspire to have.

The actors that worked together to design the *Klimakvarter* identified extensively asphalted surfaces. In the initial construction of the neighbourhood the planners aspired to have wide and green avenues. However, the trees that were supposed to green the streets were never planted. Therefore, the new design dedicated 20% of the sealed surface area in the neighbourhood to urban greenery that can manage stormwater and up to 30% everyday precipitation locally (Klimakvarter, 2016). In order to successfully achieve an aspiration like this, a transdisciplinary planning team related to roads, water, and urban green has to be guaranteed that is pushing for water sensitive urban design.

7.5 Linking Synergies and Water Sensitivity to Become Climate-Resilient

Climate-resilient cities are hosts to urban infrastructures that are able to repeatedly recover from crises. The recovery means either going back to a pre-equilibrium or enhancing performance to reach a new, improved equilibrium (Wong & Brown, 2009). The scope of the present report limits climate-resilience mainly to resilience in connection to extreme weather events. However, climate-resilience could have a broader understanding when looking at long term

changes of the climate such as melting permafrost resulting in sea level rise (Mattox & Duda, 2022).

Scholars are continuously emphasising the relevance of a paradigm shift in order to have climate-resilient systems. This new paradigm needs to be founded on the 17 principles of the PWWC framework, enabling water sensitive design and SUWM. Therefore, conventional grey water management solutions are not sufficient and new innovative solutions have to be developed and applied. The solutions have to be developed integratively and combined with nature to gain most benefits. Approaches to this new paradigm can be seen all over the world with different concepts such as Sponge City from China, Low Impact Development from the USA, and the Australian Water Sensitive Urban Design (Fu & Wang, 2021). The Australian terminology is applied in the present report.

This chapter has attempted to identify synergies in innovative niche developments that actively participate in climate adaptation and SUWM. The added value that utilising synergies provides is crucial for shifting a regime to a new paradigm. There seems to be consensus in literature about the benefits synergistic planning approaches bring. However, there appears to be a discrepancy between cost and benefit of green climate adaptation solutions. Added value is inherently difficult to monetise whereas damages arising from extreme weather events are easier to calculate and estimate. Nevertheless, empirical and modelling studies have discovered that economic benefit gained from added value usually exceeds cost for climate mitigation. This cost benefit seems difficult to grasp since economic value starts showing after 2-14 years of implementation (Chastin et al., 2021). Consequently, climate mitigation and adaptation should most certainly be considered together which unfortunately is not the case in most municipalities (Sharifi, 2020). Unfortunately, policy evaluation tools to understand both added value and trade-offs are lacking. Scholars argue that sustainable impact can be enhanced when taking a different perspective on system dynamics and the fact that resources are scarce and planetary boundaries exceeding - both socially and environmentally (Chastin et al., 2021). Therefore, scholars demonstrate the relevance of addressing co-benefits in policy planning:

> *"As such, there should be a requirement to assess co-benefits and co-harms and identify trades-offs during policy planning and decision making."*
> (Chastin et al., 2021, p. 4)

This last section highlights the impact that water-wise policy planning can have on creating climate-resilient cities. Decision makers have to be briefed to become water-wise and equipped with knowledge and tools to successfully design water sensitive cities.

7.6 Cologne´s Way to Become a Water-Wise City

The previous analysis on Sustainable Urban Water Management (SUWM) linked theoretical principles of water-wise cities with concrete solutions that enhance climate-resilience. These solutions have already been projected to possible application in the city of Cologne. However, the implementation of such solutions requires a planning regime which is willing to make decisions in favour of those. Therefore, a new paradigm for the regime, decision makers, and planners must emerge. Apart from the *Four Levels of Action*, the *Principles for Water Wise Cities* (PWWC) framework provides *Five Building Blocks* to assist the development of a vision for sustainable urban water and facilitating successful implementation. Hereby, the foundation is the shared vision

which is guiding the collaborative action amongst local decision makers, urban experts, and individuals. The PWWC framework recommends a set of five *"instruments including the new Vision, more adaptive Governance, enriched Knowledge and Capacities, novel Planning Tools, and effective Implementation Tools"* (Fu & Wang, 2021, p. 38). These five blocks are shown in figure 33. This section is dedicated to outlining how the climate adaptation regime in Cologne can transition to a new paradigm based on water-wise cities and water sensitive urban design making use of the PWWC framework.

7.6.1 Create a Shared Vision for Cologne

According to the PWWC framework a shared vision is needed to ensure successful policy and strategy implementation. This vision should foster cross-sectoral planning approaches over different scales. This creates a common understanding which supports decision makers, implementations, and public participation (Fu & Wang, 2021). Whether Cologne already has a vision or not will be analysed in the following section.

In 2020 Cologne's municipality published the *Kölner Perspektiven 2030+* (Cologne's Perspectives 2030+) where both development goals and recommendations for action are presented. Both are vague perspectives rather than concrete supporting tools. Nevertheless, a common understanding about the need for blue-green climate adaptation measures is communicated. Synergy effects such as urban cooling and infiltration of precipitation are recognised to provide *"invaluable added value"* (translated from German - Stadt Köln, 2020, p. 67). Additionally, the paper calls for the implementation of retention areas for stormwater in face of the changing climate.

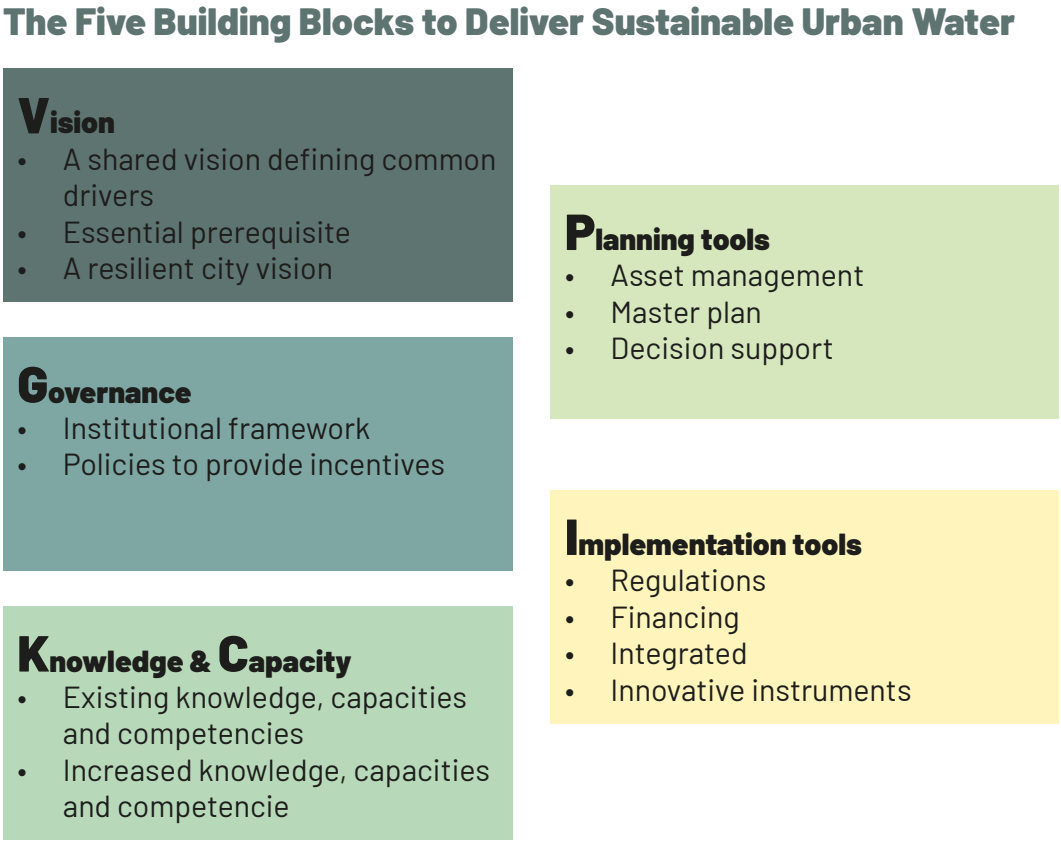

Figure 33: The Five Building Blocks from the PWWC framework (own figure, based on Fu & Wang, 2021).

Therefore, climate adaptation must be considered early on in all projects in the city, especially in urban planning projects (Stadt Köln, 2020). This is vital for Cologne to become climate-resilient by 2030:

"Only then can Cologne develop resilience on its own to remain a livable metropolis despite climate change."
(translated from German - Stadt Köln, 2020, p. 117)

The vision of blue-green infrastructure to create climate-resilience is also represented by the interviewed experts from the municipality and the water utility (StEB). Ceylan and Luchterhandt are talking about the *Strategiekonzept zur wasserwirtschaftlichen Klimafolgenanpassung* (Strategy Concept for Water Management Based Climate Adaptation) which was published by the StEB in 2020. She refers to the concept as a *Sponge City* concept which looked into examples from other cities and countries to get inspiration. A conceptual markup has been developed on how to redevelop existing structures in a climate adaptive manner applying blue-green urban design. The concept was developed with different departments of the municipality within workshops (Appendix 3 - Ceylan; Appendix 5 - Luchterhandt). Additionally, Wieczorrek and Linnartz talk about multifunctional retention areas that are planned to be implemented in Cologne under the principles of *Sponge City* (Appendix 4 - Wieczorrek; Appendix 1 - Linnartz).

Even though the common understanding of a vision seems to be present in Cologne, there has not been a formally formulated vision for Cologne. This would help Cologne to bring climate adaptation stakeholders together and support those on decision making and concrete implementations.

7.6.2 Strengthen Governance to Maximise Co-Benefits

This building block is highlighting the need of adaptive governance when attempting to plan water-wise cities. Therefore, an institutional framework which is unlocking cross-sectoral synergies is postulated. Better policies can support the development of maximising benefits across sectors by integrating water in all relevant services (Fu & Wang, 2021). The governance of climate adaptation in Cologne has previously been touched upon in section 5.4. The following section further elaborates on the governance in Cologne and whether it is adaptive and progressive enough.

Climate adaptation in Cologne is not a mandatory task, even though it is mandatory to consider climate adaptation in planning processes (Stadt Köln, 2020). Luchterhandt opinionates that having climate adaptation as a mandatory task would help accelerate the development and *„create incentives you can not refuse"* (Appendix 5 - Luchterhandt). He mentions that climate adaptation has to be attractive to be implemented easily (Appendix 5 - Luchterhandt). Furthermore, national and EU legislations are affecting the development in Cologne and thereby have power to steer development trajectories. Grönnerud is observing that adaptation is continuously playing a bigger role both nationally and in the EU. For example water scarcity and saving water resources is increasingly addressed in EU guidelines. However, Grönnerud also mentions that *"adaptation to climate change is not (yet) a mandatory task"* (Appendix 2 - Grönnerud). Grönnerud thereby implies that it might be obligatory to adapt to climate change in Cologne at some point.

Luchterhandt talks about difficulties of acquiring space to implement blue-green measures in Cologne. His department,

which is the *Grünflächenamt*, is limited to the green spaces in the city because it is the properties that they are managing. Otherwise, space for measures has to be created alternatively like deconstructing traffic areas which is *"not the easiest to do"* (Appendix 5 - Luchterhandt). He elaborates:

"There is little flexibility which is kind of frustrating."
(Appendix 5 - Luchterhandt)

He believes the political will exists, but that more political pressure would stimulate the uptake even further (Appendix 5 - Luchterhandt). Looking at climate adaptation in Cologne undoubtedly needs to be considered in a wider context since institutional frameworks of different policy levels influence the planning in Cologne. This guidance appears insufficient due to minimal binding agreements.

7.6.3 Build Upon Existing Knowledge and Capacity

The building block on *Knowledge and Capacity* highlights the need for both building on existing knowledge and accumulating and utilising novel knowledge. Urban stakeholders should employ their current knowledge, capacities, and competencies which they have gained from long-term experience within the regime. However, in order to push for a paradigm shift as envisaged in the PWWC framework, novel knowledge, capacities, and competencies are needed to complement the existing ones. Thereby, cities can get inspired by other cities or through learning by doing (Fu & Wang, 2021). This report already elaborated on reference projects and how Cologne could get inspired by them. The following section is dedicated to describe how Cologne is approaching novel knowledge in regards to climate change.

The awareness about the need to gain new knowledge is confirmed by Ceylan. She points out that new solutions require new processes, planning approaches, and rethinking. An example she mentions is the implementation of decentralised infiltration systems with blue-green measures that has not been done at StEB for a long time and therefore it is still considered a novel approach (Appendix 3 - Ceylan). She expands further:

"New installations require new operating instructions and different maintenance is required. Large scale rethinking and acting differently is demanded from the executors and responsible stakeholders."
(Appendix 3 - Ceylan)

Nevertheless, according to Grönnerud the main challenge is not the lack of knowledge, but rather economic restriction regarding the implementation of solutions. He points out that solutions are already available and implemented in other places which Cologne could benefit and learn from. He implies that those concepts could be used and the money which is provided by the federal state to write new concepts would better be used to fund the implementations of solutions. But this requires hiring of qualified professionals such as engineers, architects, energy experts, and further experts (Appendix 2 - Grönnerud).

Additionally, Grönnerud is aware of the usefulness of reference projects (Appendix 2 - Grönnerud). Ceylan further mentions that there are many great examples nationally and internationally that Cologne gets inspired by. She highlights Copenhagen and the Netherlands as *"progressive in processes regarding climate adaptation"*(Appendix 3 - Ceylan). German inspiration originates from Hamburg with the project *RegenInfraStrukturAnpassung* (RISA - RainInfraStructureAdaptation). Ceylan sees networking with other municipalities as a very important aspect to see how other municipalities are managing and thereby answer occurring questions (Appendix 3 - Ceylan).

Cologne is making use of reference projects to draw inspiration from. Additionally, there is awareness regarding the need for novel knowledge. However, opinions differ between the experts whether more knowledge is needed or not. Nevertheless, knowledge has to eventually be applied to become meaningful therefore implementations have to follow knowledge production.

7.6.4 Planning Tools to Support Decision Making

Novel planning tools are needed to analyse consequences of projects to support decision making and the development of master plans. Such tools can be models to project possible co-benefits or risks. It is relevant that these tools are used by cross-sectoral teams to unlock synergies and identify trade-offs in between (Fu & Wang, 2021). Cologne's efforts to map risks and potentials are highlighted in the following section.

Linnartz describes that a big step for the professionals in the municipality was to create maps to identify areas that are affected by heavy precipitation and heat stress. These are the *Starkregengefahrenkarte* (Heavy Precipitation Hazard Map) and *Hitzesimulation* (Heat Simulation). These identified hotspots are where measures are preferably implemented and therefore actively supporting decision making processes (Appendix 1 - Linnartz).

As previously mentioned, the project *Klimawandelgerechte Metropole Köln* (2013) is still today the basis for climate adaptation decisions. During the project, effects of climate change have been identified and thereby fields of action defined which are still valid today. Furthermore, subject to the report are professional inputs or guidelines about e.g. how urban land use planning can become more compatible with climate change. Wieczorrek's department is currently working on an updated version of the project report where cross-sectoral tasks will get more attention (Appendix 4 - Wieczorrek).

It is important that modelled maps, such as the *Starkregengefahrenkarte*, are considered in the updated version. Even though the attempt to further include cross-sectoral planning approaches, contemporary data about climatic effects can support decision making and push for water sensitivity even more. This is especially relevant in Cologne where Linnartz feels that there is currently no prioritisation on which measures are preferably to be implemented and what is more important. This results in extensive debates for each case which is time and resource intensive. (Appendix 1 - Linnartz)

7.6.5 Implementation Tools

Lastly, efficient implementation tools are needed to create incentives for investments in sustainable urban water management. The PWWC framework sees the greatest potential in regulations to provide a solid framework for urban stakeholders. Thereby, sound financing can be guaranteed which is highly relevant since it is linked to implementations. The PWWC framework argues that integrated services will result in shorter investment cycles that benefit from added value which are welcomed by municipalities to overcome the usual *"lack of financial capacity for cities"* (Fu & Wang, 2021, p. 41). The lack of legal guidance was highlighted in the previous chapters. Therefore this section is dedicated to elaborate on the interviewees' awareness about the importance of regulations and pinpoint why Cologne would benefit from stricter regulations.

Firstly, Ceylan highlights that it is important that climate adaptation gets more attention in combination with urban planning. She recommends legally establishing climate adaptation

at an early stage in legal documents for local developments such as urban land use plans (*Bauleitplanung*). Furthermore, Ceylan highlights the importance of incorporating the Water Sensitive City framework into the legally binding urban land use planning at an early stage (Appendix 3 - Ceylan).

Grönnerud talks about finances and the lack thereof in municipalities. He believes that in Germany there is the trend to write more concepts and strategies instead of implementing solutions since it is economically more feasible to write than implement (Appendix 2 - Grönnerud). He elaborates:

„If you want to change something you need to take a lot of money in your hand."
(Appendix 2 - Grönnerud)

Grönnerud assesses that the financial status of Cologne is mediocre but slowly improving (Appendix 2 - Grönnerud). Therefore, Cologne will most certainly benefit from efficient implementation tools that would help coordinate finances more adequately.

Building upon the presented *Five Building Blocks* and using them to apply the principles within the *Four Levels of Action* will pave the way for Cologne to become a water-wise city which is performing water sensitive urban design to move towards climate-resilience. Therefore it is crucial to identify synergies across sectors and unlock the co-benefits and added value in between. In order to successfully utilise synergies, cross-sectoral teams and planning approaches are needed that are capable of making decisions at an early stage. Thus, Cologne is in need of a shared vision to guide the future trajectory of the planning regime and shift the paradigm towards a Water-Wise City.

Chapter 8
Discussion

8

This chapter is dedicated to discussing and reflecting upon the previous analyses of this report. It attempts to take a critical view on the previous analytical work and is mainly expanding on thoughts that occurred during the process. The discussion starts with an elaboration on the diversity of climate adaptation measures followed by a critical reflection on the locational factor of conducting climate adaptation. Furthermore, the dilemma of operating on different policy levels is presented and discussed and lastly, this chapter closes off with a personal view on how academia can prevent trained incapacity in organisational structures.

8.1 Diversity of Solutions

As previously mentioned, there is no one-size-fits-all solution for climate adaptation. Solutions vary in complexity and scale, but also in impact and resource input (Bierbaum et al., 2013). This is reflected in the presented reference projects in chapter 6.5. Therefore the following sections elaborate and discuss different scales or types of climate adaptation solutions for successful climate adaptation.

8.1.1 Large-Scale versus Small-Scale Solutions

The presented reference projects cover different scales from redesigning an entire neighbourhood or urban park, enhancing urban greenery through a blue-green bioswale next to road parking and adding greenery to local bus stops. Both large-scale and small-scale projects are relevant in cities to adapt to the changing climate. It is implied that bigger redevelopment projects have a bigger impact but are consequently also more expensive and resource intensive. Additionally, it takes a long time to implement large scale projects. For example, the redevelopment of *Enghaveparken* lasted over five years whereas the green bus stops can be installed within one day (Klimada 2.0, n.d.; TREDJE NATUR, n.d.). Additionally, scholars argue that adaptation measures that are operating across different scales in ecological systems are inherently more complex due to different biological and ecosystem processes that need to be coordinated (Neil Adger et al., 2005).

Small-scale projects, such as the green bus stops, have potential to quickly raise awareness amongst citizens about the effects of climate change and positive impacts of adaptation measures on e.g. the microclimate. This can ultimately influence acceptance of large-scale projects such as redesigning entire neighbourhoods or parks which rely on active citizen participation and approval. Large-scale projects can utilise synergies on a much bigger scale and therefore have higher impacts on climate adaptation as well. However, there is no right or wrong when talking about different project scales. It depends on the context of the location, the site-specific climate impacts, and availability of resources whether a large-scale or small-scale project is appropriate.

8.1.2 Private versus Public Adaptation

Besides different project scales as presented in the previous section there is also a distinction between private and public climate adaptation. Urban land is usually owned by different proprietors which makes it difficult to implement measures across property owners. Luchterhandt mentions that his department, the *Grünflächenamt*, is limited to the green spaces in the city because it is the properties that they are managing. They are also trying to acquire new spaces to implement measures but it is not the easiest to do. He argues that there is little flexibility from other departments to provide space for green measures since they are afraid to limit themselves and their own department´s goals (Appendix

5 - Luchterhandt). The silostic organisational structure is thereby clearly limiting the public adaptation uptake.

An adaptation scope which has not yet been addressed in the course of this report is private climate adaptation. Ceylan talks about private stormwater management. On private properties, there are more requirements compared to public properties for example a regulation that uncontaminated stormwater has to be infiltrated on the property. Owners with new channel connections have to prove that they can retain stormwater of a 30-year event on the property and in general infiltration of stormwater needs to be prioritised in the planning. However, this only applies to new developments. Nevertheless, big changes in existing structures require the same report on the local stormwater management (Appendix 3 - Ceylan). The StEB published a report on water sensitive planning and construction in Cologne dedicated to homeowners, prospective builders, and architects. It is a guideline for heavy precipitation prevention. The guideline gives examples of possible damages from flooding and how to prevent it. The suggested measures are all structural, and to be implemented on or around private property (StEB Köln, n.d.).

Both private and public climate adaptation measures are relevant to efficient stormwater management in cities even though the processes for implementation of both are different. Whereas public climate adaptation in combination with urban greenery needs to emerge from niche to norm, private adaptation can be influenced by incentives for private property owners. In Cologne, there are already regulations for new developments, but existing structures of privately owned land have the potential for stormwater management too. Incentives to adapt in existing structures can be provided by subsidies and communication about added value for the landowner.

8.1.3 Nature-based Solutions versus Rockflow

In the course of this report, it has become clear that blue-green solutions are to be favoured before grey solutions. Blue-green Nature-based Solutions (NbS) have shown great potential to deal with stormwater management and provide added value. However, the uptake of NbS seems to be still rather slow in Cologne. Therefore, Rockflow has been presented as an engineered niche innovation that could potentially disrupt Cologne´s adaptation regime. This section is dedicated to discussing the product's potential and barriers in relation to Cologne´s transition to climate-resilience. The marketing director of Rockflow at ROCKWOOL Group, Roy Janssen, was interviewed for this report.

Rockflow was invented by Group Developments of ROCKWOOL Group which is based in Hedehusene, Denmark. After development, Rockflow found a market in the urban space where there is a huge demand for stormwater management with high storing capacity, triggered by the effects of climate change in combination with increasing urbanisation. Janssen claims that Rockflow is at the crossroad between those two - climate change and urbanisation. Rockflow is a blue solution since it is basically collecting and emptying stormwater in stone wool panels. Engineers of climate adaptation measures are very much interested in the flexibility and capacity of the system. Rockwool can hold up to 95% of its volume in water, which has a huge advantage compared to conventional infiltration ditches filled with rocks, which can only store water in the voids which will add up to approximately 30% capacity. The contractors on the other hand are very interested in the flexibility regarding installation since the system has to be designed to fit in an existing system of cables and pipes. With the stone wool product *"it is very easy to just take a knife and cut a piece out"* and *„flexibly adjust it*

to existing structures" (Appendix 6 - Roy Janssen).

Janssen is aware of and reflective about the fact that the preferred solution for climate adaptation is green solutions, since they can hold water and cool down the environment simultaneously. He elaborates: *"A traditional Rockflow system is designed to empty as quickly as possible because it needs to be available for the next downpour"* and is therefore a blue solution whereas a green system needs to be full as long as possible - these are two very different approaches to adaptation solutions (Appendix 6 - Janssen). Nonetheless, Rockflow can be combined with NbS such as the reference project presented in Zoeterwoude in the Netherlands but this type of solution is still in the discovery phase. For now Rockflow is mainly used for large scale infrastructure projects, however, there is the ambition to scale it down to smaller solutions such as Sustainable Urban Drainage Systems. Additionally, the product can be installed under artificial sport pitches to cool them down (Appendix 6 - Janssen).

Janssen argues that in cities there is a fight about space where basically *"every square metre already has a function"* and *"it is unlikely that a road would be uninstalled to plant a tree"* (Appendix 6 - Janssen). While it is confirmed by several interviewees from the municipality and water utility in Cologne that the city has lack of space for new developments, Luchterhandt talks about the political will to deconstruct traffic areas to build blue-green measures, but it is still difficult to pursue (Appendix 5 - Luchterhandt). However, there are very strict guidelines in Germany about infiltrating stormwater locally which is also challenging the climate adaptation actors in Cologne in their efforts to blue-green measures. In these cases, Rockflow offers a solution where the system will be wrapped in foil and stormwater then later discharged in the sewer system with a delay. It therefore adds extra capacity next to the sewer system and prevents flooding. However, the water will still be discharged eventually. Currently, ROCKWOOL is investigating the filter capacity of stone wool to address contamination of runoff and support infiltration of stormwater (Appendix 6 - Janssen).

A market research for Rockflow´s plan to expand internationally identified the potential in Germany and especially Nordrhein-Westfalen (NRW). The potential unfolds because of the increased need for climate adaptation which became apparent after the heavy storms in the summer of 2021 and because of the rather small distance to the manufacturing factory in the Netherlands (Appendix 6 - Janssen). Therefore there is potential for the product to invade the German market. However, decision makers should consider the benefits and/or trade-offs of this product compared to pure NbS but there is no general solution for climate adaptation problems. At this point the author wants to emphasise that Rockflow is still a fairly new product which entered the market approximately five years ago and is still developing and unfolding full potential. The filtration function to possibly filter contaminated road runoff in combination with NbS might find application in the dense urban areas of Cologne in the future.

In conclusion, there are many different types of climate adaptation in Cologne and globally. But independently of large or small-scale, private or public, NbS or combined systems there are four attributes which need to be considered and weighed against each other when making decisions on climate adaptation measures in order to have successful adaptation and create resilient systems. Those four attributes are effectiveness, efficiency, equity, and legitimacy of the solutions (Neil Adger et al., 2005).

8.2 Adaptation is Location-Based - A Danish Perspective

When conducting climate adaptation, it is necessary to understand that it is inherently location-based. Even though climate change is a global phenomenon, climatic impacts are highly dependent on the specific location and timing. Scholars argue that *"societies typically react to problems as they occur, and it is reasonable to expect that most adaptation actions will be reactive"* (Bierbaum et al., 2013, p. 362). For example, this implies that the timing of an extreme weather event can provoke climate-adaptive reactions. This was also identified in the analysis using the Multi-Level-Perspective on transitions of the climate adaptation regime in Cologne. However, this can justify why for example Copenhagen, Denmark is viewed as progressive compared to Cologne, Germany when looking at the governance of climate adaptation. Copenhagen experienced a dramatic cloudburst event about ten years ago which became a wake-up call for politicians and decision-makers. The event resulted in the development of a Cloudburst Management Plan (2012) which is a supplement to the Copenhagen Adaptation Plan. Both plans run under the main goal to reach carbon neutrality in Copenhagen 2025. Within the Cloudburst Management Plan it was identified that water knows no boundaries. Therefore, the plan was closely developed with the municipality of Frederiksberg (City of Copenhagen, 2012). This Cloudburst Management Plan was the beginning of a large-scale shift in the climate adaptation regime in Copenhagen.

The heavy storms in Western Germany in the summer of 2021 have created momentum for progressive climate adaptation governance to evolve. Cologne may get inspiration from Copenhagen or other municipalities regarding the response to such a crisis. This present report already presented reference projects to inspire the regime with concrete solutions. But looking at the governance side of things and how climate adaptation is approached by progressive municipalities is relevant for inspiration as well. Nevertheless, the collected inspiration has to be translated into the local prerequisites and preconditions in order to be effective. As correctly identified in Copenhagen´s Cloudburst Management Plan, water knows no boundaries. Therefore, Cologne should find a way of conducting successful climate adaptation across sectors and break down bureaucratic hurdles that hinder adaptation measures to unlock cross-sectoral synergies.

8.3 The Dilemma of Policy Levels

Even though climate adaptation is inherently location-based it is still embedded in a wider institutional and regulatory context that crosses municipal or national borders. Therefore climate adaptation actions are embedded in a *"hierarchical structure that extends beyond the nation state"* (Neil Adger et al., 2005, p. 78). Conducting climate adaptation accordingly requires decision making which is cascading across different social and policy levels. Furthermore, there is a distinction between creating regulations that enhance the adaptive capacity of regimes and actions to support the implementation of adaptive operations. The latter is highly affected by a superordinate institutional framework which is directing the development trajectory of the adaptation regime and therefore limiting the regime's own decisions to the given framework (Neil Adger et al., 2005). In other words, the implementation of local climate adaptation solutions is dependent on higher-level guidance. However, since location-based climate adaptation indicates that benefits of adaptation measures will be felt only locally, it provides little incentive for policymakers to create regulations on a higher level.

Nevertheless, successful climate adaptation requires leadership and clear guidance. This is also emphasised in the *Principles for Water Wise Cities* (PWWC) framework which provides a framework for leaders to develop and implement a vision for sustainable urban water management resulting in climate-resilience (Fu & Wang, 2021). In Germany, municipalities that are suffering from climatic impacts have a bigger incentive and motivation to develop adaptation strategies and gain generally more acceptance for implementation of adaptation solutions. However, they are still dependent on financial assistance and institutional guidance to successfully conduct climate adaptation (Difu, 2015).

Cologne is at the crossroad between success and stagnation regarding sustainable urban water management and climate adaptation. The regime actors from different departments seem to be aware of the need to work across sectors and identify synergies. However, there is no effective institutional guidance present to ensure this type of guidance and coordination. According to Luchterhandt, there is the attempt to establish a coordination body with the main office for climate mitigation which is the *Koordinationsstelle Klimaschutz*. This is an overlapping body which is bringing together a lot of different stakeholders. Nevertheless, Luchterhandt feels that this is not yet established or lived. He thinks that this body needs to grow together over time because in the past everyone has been working for themselves (Appendix 5 - Luchterhandt). Clearer guidance from a higher policy level could make the work of that overlapping body more efficient and transparent. Currently, the policy levels and related guidelines and frameworks in Germany are not straight forward which makes it difficult to navigate between regulations and policies.

There seems to be a discrepancy between power and responsibility. The power to change trajectories and create incentives for a regime shift lies in the high-level policy levels. This is the foundation for implementing legally binding regulations and a tool to communicate the need for immediate action to lower levels. The responsibility for climate adaptation, however, lies with the local stakeholders since adaptation is a local commodity. These local stakeholders are largely bound to the higher-level development trajectory and therefore path-dependent. On the other hand, the local stakeholders are the experts on the local adaptation to climate change whereas the power and the resources to do something lie on a higher level. There needs to be a coordinating body which is balancing this discrepancy of knowledge and resources, power and responsibility.

8.4 Academia can Prevent Trained Incapacity - The case of Sustainable Cities Engineers

In the course of this report the phenomenon of trained incapacity and its effect on planners, organisational cultures, and governance of climate change have been addressed. The trained incapacity of governance actors in Cologne and Germany might be an explanation for the lack of institutional guidance as previously identified. Wieczorrek from the municipality of Cologne has been working for the municipality for 25 years and is of the opinion that employees have to grow into the position they are working in. Additionally, she mentions that she as a singular person can not change much in Cologne (Appendix 4 - Wieczorrek). Thereby she assumes that employees have to follow the current regime's trajectory and have little to no influence on a regime's trajectory. However, this report identifies that there is a chance for regime actors to steer the development

trajectory and provoke transitions. Nonetheless, professionals have to be aware of the phenomenon of trained incapacity to get rid of or reject blinders that prevent them from seeing problems and solutions outside of their expertise.

This is where academia and interdisciplinary educational programmes become relevant. While it is of utmost importance that there are experts in the regime that possess specific knowledge, it is even more relevant to have open-minded and unbiased entities that can coordinate between different needs and utilise synergies in between. One institution that is attempting to communicate this competence is the Aalborg University in Denmark with the Master's Programme Sustainable Cities (SusCi). The programme is a Master of Science in Engineering which is therefore operating at the crossroad of knowledge production and application. SusCi is an interdisciplinary and international study programme focussing on sustainable urban system transitions by looking at infrastructures in the city and synergies in between. Rather than specialising in one professional field and becoming an expert within, SusCi engineers are educated to navigate between different fields, and identify and solve problems across sectors (AAU, n.d.). Therefore SusCi engineers can play a vital role in sustainability transitions such as a paradigm shift to sustainable urban water management in municipalities. Certainly, SusCi is only one example of an interdisciplinary programme which is offering progressive insights into urban transitions for young professionals. These kinds of insights can also be communicated within existing regimes. However, this would require a paradigm shift in current regimes to begin with to create a regime which is open for new structures, processes, and approaches to ultimately push for change.

Chapter 9
Conclusion

Based on the current scientific research status globally it almost feels redundant to mention the complexity of governing climate change at all. However, this does not undermine the utmost importance of addressing the complexity in both today's and the future´s planning regimes. The complexity of climate change and related adaptation has become a generic sense when conducting research on the topic. Nevertheless, the response to this complexity has not become established as a shared new paradigm in climate adaptation governance today, as proved by the case study of the municipality of Cologne.

Cologne is affected by climate change like many other cities globally. Impacts of climate change in Cologne unfold in the form of extended drought periods in combination with heat stress, and heavy precipitation events resulting in fluvial and pluvial flooding. These effects are exacerbated by poor geographical preconditions combined with specific urban planning and demographic challenges in Cologne such as car-friendly urban development and extreme housing shortage resulting in lack of space. Climate adaptation in Cologne is carried out by different departments of the municipality which is further delegating water-related tasks to the StEB, the local water utility. The lack of a centralised coordinating body for climate adaptation in combination with the multicausality of challenges result in inefficient planning responses in Cologne. Additionally, mitigation measures seem to be favoured over adaptation measures which shows in the lack of political will to invest in strategic climate adaptation.

The stability of planning regimes makes it difficult to change the current trajectory (Aylett, 2011). This phenomenon is confirmed in Cologne, where municipal employees are in danger of being incapacitated to work on problems outside of their field of expertise, because the municipality relies the established role of the employees. However, when dealing with a complex problem such as climate change, a cross-sectoral approach is inevitable. The siloistic organisational culture of Cologne´s climate adaptation regime is therefore hindering successful and efficient climate adaptation practices.

To complement these findings, Geels´ (2002) Multi-Level-Perspective was used to analyse a possible transition of the current planning regime´s trajectory in Cologne. Particularly noteworthy is the window of opportunity triggered by the dramatic extreme weather events in July 2021. This provides an opening for niche innovations and incumbent actors to change the current trajectory and exert pressure on the planning regime. Difficulties arise since niche innovation projects usually rely on external funding that is normally provided by the regime itself, which illustrates the dependency of the niche on external pressures. Nevertheless, regime actors in Cologne are aware of the possibility to change trajectories from within. First attempts can be observed with the aspiration to create a centralised coordination body for climate adaptation to overcome challenges related to cross-sectoral tasks.

To support a rapid transition to a climate-resilient Cologne, the municipality can get inspiration from reference projects and thereby answer recurring questions and overcome planning barriers. Therefore, this report includes the presentation of four reference projects complemented by an explanation of how these projects could be applied in Cologne. The various reference projects communicate the wide-ranging possibilities to address climate change in an urban context while making use of blue-green solutions such as Nature-based Solutions (NbS) to perform sustainable urban water management (SUWM). The variety between project scales is also discussed

to illustrate versatile possibilities to address climate change in urban planning.

Additionally, a guiding framework developed and promoted by the International Water Association (IWA) has been presented to support utilising synergies in order to perform SUWM in the form of water sensitive urban design. The following of the *Principles for Water Wise Cities* (PWCC) promises the contribution to climate-resilience of cities by enhancing water-wise decision making. This analysis concludes that utilising synergies provides added value which is crucial for an interdisciplinary planning regime to make use of when attempting integrated SUWM. Therefore, Cologne is in need of formulating a shared vision to create a common understanding about the need and approach towards water sensitive urban design. The PWWC framework demonstrates the importance of strong leadership and guidance which is yet a challenge in Cologne with the complexity of different policy levels in Germany and Cologne. The framework can help overcome this dilemma while bridging the identified discrepancy between power and responsibility. The current organisational culture of the climate adaptation regime is not fit to create a climate-resilient Cologne. Nevertheless, Cologne has competencies and tools to utilise to push for such a paradigm shift. Building upon these competences and following the PWWC framework will pave the way for a climate-resilient Cologne.

VII

REFLECTIONS AND FURTHER RESEARCH

After concluding and synthesising the outcome of this present report, this section is dedicated to reflect upon the chosen empirical tools and evaluate the given findings. This will lead up to an elaboration about further relevant research that was identified in relation to the present topic.

The data gathering in this study is heavily based on the conducted interviews. The scope of this study, which is mainly the analysis of an organisational culture in a given case study, justifies this approach. Additionally, the chosen theoretical frame of the effect of wicked problems on planners and trained incapacities require the conversation with regime actors. There was an attempt to gather more data through further interviews. For example, it was desired to have a conversation with the *Koordinationsstelle Klimaschutz* (Coordination Department Climate Mitigation) which was referred to as the main point of contact regarding climate adaptation by many interviewees. Unfortunately, after several tries to reach out, it was not possible to conduct an interview. Additionally, the author wants to reflect upon the diversity of the interviewees. The majority of the interviewed actors from the municipality and the *Stadtentwässerungsbetriebe* (StEB - Water Utility Cologne) have been in their position for less than five years. Yvonne Wieczorrek is the only interviewee that has been working in the municipality for over 25 years. This might reflect in the given answers as well where Wieczorrek appears to be more sceptical regarding a transition than the other interviewees. On the other hand, the long-term employment within the municipality provides her with a widespread understanding about the regime´s processes but endangers lock-in.

This report suggests that academia can prevent trained incapacity. However, it needs to be reflected that academia can also result in the opposite, which is creating new path dependencies. Educational programmes have to be designed on the crossroads of experts and apprentices where young professionals are trained to ask questions and solve problems but are still experienced enough to grasp the complexity of the subject. This ultimately also requires experts in the system such as engineers that can help resolve technical issues. Therefore, the future is interdisciplinary.

With contemporary literature and research focusing on Nature-based Solutions and multifunctional blue-green solutions to achieve sustainable urban water management it needs to be ensured that this novel paradigm does not create new lock-ins in the system. The ultimate goal is to create systems which are resilient to change and can therefore easily adapt to new evolving pressures. This requires constant updates of the state-of-the-art research and informing policy makers about new trends and challenges. Further research should therefore focus on how to ensure that the new paradigm does not create further path dependencies.

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