Carl von Ossietzky
Universität
Oldenburg

Lock-ins in Climate Change Adaptation:
Comparative Evidence from German States and European Neighbors

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von Frau

Julie Phillips King

geboren am 25.01.1990 in Akron, Ohio, USA

Referent:

Prof. Dr. Bernd Siebenhüner

Carl von Ossietzky Universität Oldenburg

Koreferent:

Prof. Dr. Nicolas W. Jager

Wageningen University & Research (ab September 2025 TU Berlin)

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„Es ist dann häufig so, wenn es dann irgendwie auch wenig Personal gibt, dann gibt es halt so diese Pfadabhängigkeiten und Standardisierungen, die man irgendwie auch jetzt nicht einfach mal so durchbricht und was Neues ausprobiert. Vor allem wenn jetzt eh schon irgendwie die Zeit knapp ist, dann probiere ich jetzt nicht auch noch neue Planungsmethoden aus, neue Beteiligungsformate oder versuche jetzt irgendwie ganz eben diese Startgespräche interdisziplinär alle an einen Tisch zu holen. Das kostet alles Zeit und wenn ich eh schon keine Zeit habe, dann bleibe ich halt natürlich immer gerne bei diesen standardisierten Sachen, die ich schon seit 20-30 Jahren mache, und probiere jetzt mal nicht unbedingt was Neues aus."

– Anonymous interviewee

Abstract

The impacts of climate change, such as droughts, other extreme weather events, and sea level rise, are becoming increasingly noticeable, globally and in Germany, and the subsequent risks pose a steadily growing need for climate adaptation. Dynamics of stability and change within established governance systems determine whether and to what extent societies are capable of adapting to these new and growing risks. With the aim of exploring how patterns of action and inaction within regional German climate adaptation governance can be characterized and explained, this cumulative dissertation research contributes to the greater understanding of how governance responses to adaptation challenges are developed, maintained, and potentially altered over time. Each of the papers investigates how adaptation strategies and policies in different regions or states respond to current and future risks. All of the papers find that adaptation governance in German states display some extent of an adaptation gap or include policies unlikely to induce necessary changes for overcoming the long-term risks of climate change. Paper 1 is the first nationwide analysis of state-level climate adaptation strategies and identifies three different policy approaches. Papers 2 through 4 dive deeper into selected settings and highlight three specific problem domains at the state level in Germany: coastal risk management, water scarcity, and mental health. The selected case studies constitute various examples of policy stability in (and outside) of German adaptation governance that is, to greater and lesser extents, subject to lock-in dynamics inhibiting transformative adaptation measures.

Zusammenfassung

Die Folgen des Klimawandels, wie etwa zunehmende Dürre und andere Extrem-wetterereignisse oder der Anstieg des Meeresspiegels oder, werden global aber auch in Deutschland zunehmend spürbar und erzeugen ein stetig wachsendes Erfordernis zur Klimaanpassung. Ob und inwieweit sich bestehende Governancesysteme an diese neuen Herausforderungen anzupassen vermögen, werden nicht zuletzt von den Dynamiken von Stabilität und Wandel innerhalb solcher Systeme geprägt. Mit dem Ziel, Muster des politischen Handelns und Nicht-Handelns im Kontext der Klimaanpassung zu beschreiben und erklären, trägt diese kumulative Dissertation zu einem besseren Verständnis darüber bei, wie Governance-Reaktionen auf den wachsenden Anpassungsbedarf entwickelt, aufrechterhalten und im Laufe der Zeit möglicherweise verändert werden. Jedes der enthaltenen Artikel untersucht Strategien und Politiken relevant zur Klimaanpassung in verschiedenen Bundesländern oder Regionen, die auf aktuelle und zukünftige Klimarisiken reagieren. Alle Fallbeispiele zeigen, dass die Klimaanpassungspolitik in den deutschen Bundesländern in gewissem Maße Defizite aufweisen oder dass die Politiken unwahr-scheinlich die notwendigen Veränderungen herbeiführen werden, um die langfristigen Risiken des Klimawandels nachhaltig zu bewältigen. Paper 1 enthält die erste landesweite Analyse der Klimaanpassungsstrategien auf Landesebene und identifiziert drei unterschiedliche Politikansätze. Die Papiere 2 bis 4 gehen tiefer in ausgewählte Fallbeispiele ein und beleuchten drei spezifische Klimarisiken auf Landesebene in Deutschland: Küsten-management, Wasserknappheit und psychische Gesundheit. Die ausgewählten Fallstudien stellen Beispiele von stabilen Governance-Systemen innerhalb (und außerhalb) der deutschen Anpassungspolitik dar, die in unterschiedlichem Maße von Lock-in-Dynamiken betroffen sind, welche wiederum transformative Anpassungsmaßnahmen behindern.

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Abbreviations and Acronyms

CCA	climate change adaptation
DAS	*Deutsche Klimaanpassungsstrategie* (German Strategy for Climate Change Adaptation)
DFG	*Deutsche Forschungsgemeinschaft* (German Research Foundation)
e.g.	*exempli gratia* (for example)
ESRC	Economic and Social Research Council
EU	European Union
GDP	gross domestic product
i.e.	*id est* (in other words / that is)
IPCC	Intergovernmental Panel on Climate Change
NWO	*Nederlandse Organisatie voor Wetenschappelijk* (Dutch Organization for Scientific Research)
RQ	research question
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
WG II	Working Group II (of the IPCC)

Overview of dissertation publications

Paper	Title, Authors, Journal	Publication Status	Year of Publication
1	"Sixteen ways to adapt: a comparison of state-level climate change adaptation strategies in the federal states of Germany" By: **Julie P. King** Published in: *Regional Environmental Change*, 22 (40). https://doi.org/10.1007/s10113-021-01870-3	published	2022
2	"New challenges and established policy fields - Assessing stability and change in climate adaptation policy through a lock-in perspective" By: Nicolas W. Jager, **Julie P. King** & Bernd Siebenhüner Published in: *dms – der moderne Staat – Zeitschrift für Public Policy, Recht und Management*, 15 (2), 394-412. https://doi.org.10.3224/dms.v15i2.06	published	2022
3	"Re-examining policy stability in climate adaptation through a lock-in perspective" By: Lisanne Groen, Meghan Alexander, **Julie P. King**, Nicolas W. Jager & Dave Huitema Published in: *Journal of European Public Policy*, 30 (3), 488-512. https://doi.org/10.1080/13501763.2022.2064535	published	2023
4	"Lock-in dynamics hindering climate adaptation for mental health " By: **Julie P. King** & Lisanne Groen	working paper	forthcoming

In addition to these papers, Julie P. King successfully completed the doctoral studies program "UNA: Environmental and Sustainability Economics and Management" within the Graduate School of Social Sciences and Humanities (3GO) and the School of Computing Science, Business Administration, Economics, and Law of Carl von Ossietzky University Oldenburg

1. Introduction

Climate change is an unprecedented crisis and its impacts are becoming ever more frequent and intense. Every year new, record-breaking, catastrophic events cripple regions around the world: fires, droughts, deadly heat, as well as coastal and inland flood events (Bartusek & Kornhuber, 2022; Zhou, Yu & Zhang, 2023). Even incremental impacts are reaching challenging thresholds and represent considerable risks. Adaptation to widespread and diverse climate change impacts poses an increasingly urgent challenge for societies and their governance systems. Even if radical mitigation action were to drastically reduce greenhouse gas emissions, the accumulated stocks of greenhouse gases already in the atmosphere will have continued and unavoidable serious effects (Easterling et al., 2024). Hence, the dire need for effective adaptation measures has been voiced in almost all IPCC[1] reports, in particular those of its Working Group 2 on "Impacts, Adaptation, and Vulnerability" (IPCC 2022). In 2015, the Paris Agreement converged on global goals of reducing vulnerability to climate change and building adaptive capacity (UNFCCC, 2015).

Although decisive adaptation action to limit the negative consequences of climate change impacts is urgent and essential, both global organizations and the scientific community agree that current levels of action are failing to keep up with the diverse and surmounting risks (UNEP, 2023). This mismatch between the recognition of potential responses to identified risks and actual evidence of political (and societal changes) is often described as the "adaptation gap" (ibid.). Global progress on the planning, financing, and implementation of climate adaptation has been tracked since 2014 by the United Nations Environment Programme (UNEP). The 2023 report "Underfinanced. Unprepared." found global adaptation progress to be slowing and highlighted the need for accelerated, wider scale, anticipatory adaptation action and support (ibid).

This observation of insufficient action is not new. Nearly two decades of research have found that inactivity and limited action, often in the form of "wait-and-see" approaches, prevail in many levels of decision-making, and that societies and their institutions and governance systems tend to largely resist change (Barnett et al., 2015; Burton, 2005; Moser & Ekstrom, 2010). In addition to policy inaction, observations have often found a disjoint between existing commitments to adaptation and the actual implementation of those pledges. Effective implementation remains often incremental and limited (IPCC, 2022b; UNEP, 2023). Furthermore, in some cases formulated and implemented policies have been found to make problems worse or lead to new problems, for example, by reinforcing social inequalities or implementing short term solutions that will likely cause significant problems for future generations. These problematic approaches are referred to as "maladaptation" (IPCC, 2022b). Overall, it has been found that current policy approaches to adaptation are not leading to necessary societal changes or larger socio-ecological transformations[2] (Colloff et al., 2017; Fedele et al., 2019; Ulibarri et al., 2022). Considering this, a better understanding of existing deficits and

[1] IPCC refers to the Intergovernmental Panel on Climate Change, which is an international body established by the United Nations to assess and synthesize scientific evidence on climate change and provide comprehensive reports to guide global policy decisions

2 As defined by WG II of the IPCC, "socio-ecological transformations" refer to fundamental changes in natural and human systems (IPCC, 2022a) and are increasingly considered essential for preventing major losses caused by climate change (Ulibarrii et al., 2022)

maladaptive pathways is essential for enabling more effective action and crafting interventions to close existing gaps.

1.1 Research gap

Scientists have been investigating the adaptation gap for almost as long as it has existed. For roughly two decades, the focus has been primarily the identification and descriptions of barriers to adaptation (Barnett et al., 2015; Biesbroek et al., 2013; Eisenack et al., 2014; Moser & Ekstrom, 2010; Young & Essex, 2019). Commonly observed barriers to (effective) adaptation include, for example, lack of political support for adaptation, unclear roles and responsibilities, uncertainty about the regional impacts of climate change, and a lack of resources (ibid.). The term "barrier" implies something static and isolated. The concept suggests that once the hurdles are removed, action would accelerate. Although the identification and documentation of barriers aids in our understanding of widespread adaptation deficits, it is just a first step, seeing as solutions to effectively overcome barriers remain elusive. The pervasiveness of the problem, i.e. the adaptation gap, leads to the question as to whether the problem itself and its complexity have been adequately understood (Biesbroek et al., 2014a; Biesbroek et al., 2014b; Siebenhüner et al., 2021; Wise et al., 2014).

Climate change adaptation is (or should be) embedded in non-linear, complex societal systems – a fact that suggests that causality could more complicated. Less research, albeit some, has gone deeper to investigate the roots of barriers and perceived inaction in more complexity, though the recognition of the need to do so has grown and first attempts have been made (Biesbroek et al., 2014b; Siebenhüner et al. 2021; Sieber, Biesbroek & de Block 2018). Biesbroek et al. (2014), for example, applied a mechanistic view in the analysis of a stagnated climate adaptation project and found it to be a more fruitful lens of analysis than “short-sighted ideas about cause-effect relationships […] in the identification of barriers” (p. 108). Sieber, Biesbroek, and de Block (2018), expand on the 2014 research in their application of the mechanism-based thinking to additional case studies on climate change adaptation and argue for the usefulness of the approach. Siebenhüner et al. (2021) equally emphasize the need to move beyond barriers in their call to apply the concept of lock-in in analyses of the climate change adaptation deficit. Though their chapter successfully argues the suitability of lock-in as a perspective of analysis and suggests how institutional, infrastructural, and behavioral dimensions of a system may be sources of lock-in, the research does not contribute empirical evidence of lock-ins manifesting in cases of climate change adaptation policy. These three examples point to a research gap characterized by the need to take more a complex, and empirically-founded approach to analyzing the intricate root causes of the pervasive adaptation gap.

This dissertation research directly addresses the identified research gap by exploring the complex root causes of the adaptation gap through an empirically grounded approach. The following section introduces the research questions designed to investigate this complexity and provide a deeper understanding of climate change adaptation challenges. The research was intended to build on previous studies and contribute new, empirically distilled insights on inaction and action in adaptation governance.

1.2 Research questions

This dissertation thesis aims to further our understanding of the complex causes of widespread adaptation deficits by applying lock-in as a new conceptual perspective (to the subject), which applies "mechanism-based thinking" (called for by Biesbroek et al. 2014b), to empirical case studies. Specifically, this thesis explores how patterns of action and inaction within regional German[3] climate adaptation governance can be characterized and explained. This overarching question unites the pieces of this cumulative dissertation, which is guided by three more specific research questions:

RQ[4]1: How are German state policies addressing climate change adaptation?

RQ2: How can the concept of lock-in help us understand observed adaptation deficits?

RQ3: What interventions could help contribute towards more effect adaptation action?

These research questions were designed with the intent of conducting a comprehensive analysis of the adaptation governance under focus, in that RQ1 first takes stock of the adaptation governance itself before delving into the search for causal explanations sought after in RQ2. Finally, RQ3 seeks to identify solutions that could help shape governance responses capable of closing the adaptation gap.

2. Conceptual Background

Two main concepts are at the core of this thesis: climate change adaptation governance and lock-in. This chapter lays the conceptual foundation for the dissertation research by first providing a brief overview of climate change adaptation governance and then conceptualizing lock-ins.

2.1 Climate change adaptation governance

As presented in the first chapter, climate change affects natural and human systems around the world. At the same time, concurrent non-climatic crises such as a global pandemic, major demographic shifts, growing social and economic inequalities, and several on-going violent conflicts exacerbate impacts of the climate crisis and equally desperately require action. Amidst these parallel crises the impacts of climate change are becoming increasingly visible and palpable to citizens and societal actors including businesses, infrastructure providers, health professionals, and farmers. In response, governments at various levels around the world (from municipal to national) are reacting with adaptation strategies, plans, and policies. Though governments are not the only actor responsible for reducing vulnerabilities to the impacts of climate change, it is important that they initiate and enable measures for adaptation action (Termeer et al., 2017).

Compared to classic policy fields (e.g. social policy or foreign policy), climate change adaptation remains a unique area of decision making in terms of its institutionalization and instrumentation

[3] The logic behind the focus on German states as the setting of the empirical work is explained in *Chapter 3*
[4] RQ refers to "research question"

(Jurgilevich et al., 2019; Massey & Huitema, 2013). No country has a specialized ministry for climate adaptation for example. As opposed to climate mitigation, which has the more straightforward and universal aim of reducing global greenhouse gas emissions, adaptation requires more uniquely-tailored policy responses based on the nature of the risks and settings they affect. Adaptation is institutionalized in diverse ways from stand-alone policies to "mainstreaming" adaptation into existing or wider policies (Jurgilevich et al., 2019; Russel, 2019). In terms of its instrumentation, thus far, more national governments refrain from the use of command-and-control instruments, and more often employ softer instruments such as action plans, research initiatives, adaptation strategies, or adaptation support structures[5] (Biesbroek & Delaney 2020). Another distinctive feature distinguishing climate change adaptation is that policy effectiveness and success are both contingent and normative and based on baselines and goals, which themselves are subjective or often even absent (Adger, Arnell & Tompkins, 2005; Dilling et al. 2019). Also, adaptation responses are as diverse as the various, specific problem areas they aim to address and encompass, e.g. water management, coastal protection, biodiversity, planning and development, nature conservation, and public health. These challenges are often interconnected and characterized by complexity.

The overarching question of this dissertation research refers to adaptation "governance", rather than "policy." There is not one single definition of governance, and scholars use the term in diverse ways (Kjær 2004). In an exploration of the concept of governance, Bressers and Kuks (2003) for example, describe governance as a concept that extends beyond traditional government policy. They describe how governance includes the interactions of various actors beyond the government alone and encompasses the consequences of these interactions as well as the coordination required across different levels and scales (ibid.). Governance is characterized by multilevel, multi-actor, multifaceted, multi-instrumental, and multi-resource-based elements, and constitutes therefore a wider perspective for analysis. This understanding and definition matches the use of the term within the scope of this thesis.

2.2 Conceptualizing "lock-ins"

The concept of "lock-in" has evolved over decades through numerous disciplines and applications in economics, political sciences, and science and technology studies. Since the turn of the century, the concept has gained traction in the context of climate change mitigation in the form of "carbon lock-ins" (Janipour et al. 2020; Seto et al., 2016; Unruh, 2000). Only most recently has it captured the attention of scholars studying climate change adaptation (Hetz & Bruns, 2014; Ishtiaque et al., 2021; Siebenhüner et al., 2021). This thesis explores how the concept of lock-in help us understand observed adaptation deficits in German states. In order to answer this question, this section aims to first establish greater conceptual and analytical clarity. It does so by briefly summarizing key concepts from the literature, explaining key features of lock-ins, and differentiating between lock-in mechanisms and dynamics.

The concept of lock-in originated in evolutionary economics and is closely tied to the concept of increasing returns. In the context of competing technologies, Arthur (1989; 1994) explained how

[5] Such "structures" include websites and other tools to support different actors with advice on adaptation needs and measures

suboptimal technologies may become "locked-in" and the establishment of superior alternatives hindered. Reflecting the interaction between technology and its social context, Arthur identified four features of increasing returns that can lead to inflexibility, restrict consideration of alternatives, and potentially result in lock-in: large set-up or fixed costs, learning effects, coordination effects, and adaptive expectations. In this early work, lock-ins are presented as an outcome of positive (reinforcing) feedbacks generated by increasing returns.

In policy studies and political science, lock-in is intertwined with path dependency theory and efforts to explain policy inertia. Influential work by Pierson describes path dependence as "a social process grounded in a dynamic of increasing returns" (2000, p. 251). Policy lock-ins result from previous institutional choices that become increasingly sedimented over time as the costs of switching to alternative approaches rises, making change both unattractive and difficult. Path dependency emphasizes the importance of examining political processes over time and how institutional choices are limited by past decisions. Pierson argues that several aspects of the political world make it predisposed to path dependence, such as the high density of institutions, the role of collective action, intrinsic complexity and opacity, and the potential of political authority to shape asymmetries of power (ibid.)

Another concept closely related to lock-ins is policy feedback, which emphasizes the sequence of policy ideas and how they shape the political process and successive policy decisions, with the potential to create self-reinforcing feedback dynamics and thus constrain future alternatives (Béland & Schlager, 2019; Jordan & Matt, 2014; Nohrstedt & Weible, 2010). Within this concept, policy outcomes are not only the result of decisions but instead the product of long-term feedback loops between policies, policy outcomes, and subsequent politics (Schmid, Sewerin & Schmidt, 2020). This perspective in particular emphasizes the influences of policy outcomes and differentiates between external factors (e.g. natural disasters) and internal factors, i.e. feedback loops, and their effects on contemporary societal challenges. Policy feedbacks operate by way of interpretative and resource-based mechanisms, as well as both positive (i.e. self-reinforcing) feedbacks and negative (i.e. self-undermining) feedbacks. These feedback can result in policy stability but also policy expansion, contraction, and transformation (Jacobs & Weaver, 2015).

In the more specific context of climate change mitigation, theories of path dependence and lock-ins have been used to explain inaction and resistance to socio-technological transitions despite available resources and more efficient solutions (Klitkou et al., 2015; Seto et al., 2016; Unruh, 2002). So-called "carbon lock-ins", refer to the constraining mechanisms stalling decarbonization and impeding mitigation progress. These lock-ins are often seen as a form of path dependency, arising from interrelated physical, economic, and social factors that reinforce reliance on carbon-intensive systems (Seto et al., 2016; Unruh, 2000). Unruh explains, for example, how industrial economies have become entrenched in fossil fuel-based technologies due to technological and institutional feedback loops that favor the status quo, thereby excluding alternative, carbon-saving innovations. Seto et al. (2016) identify three primary types of carbon lock-in: infrastructural/technological, institutional, and behavioral. Infrastructural lock-ins are linked to the long lifespan and sunk costs of carbon-intensive infrastructures that disincentivize the switch to low-carbon alternatives. Behavioral lock-ins are perpetuated by societal norms, habits, and lifestyles. Institutional lock-ins occur, for example, when powerful actors shape policies, norms, and resource allocations in a manner that

preserves the status quo. These lock-ins, which are used in the literature to describe both the outcome and what maintains it, are often interdependent and consist of complex feedback mechanisms that sustain carbon-intensive societies. Scholars have observed carbon lock-ins in diverse settings, such as in energy systems and transitions (Buschmann & Oels, 2019; Fouquet, 2016; Trencher et al., 2020), transportation systems (Geels, 2012; Klitkou et al., 2015; Kotilainen et al., 2019), and other energy-intensive sectors (Janipour et al., 2020). Researchers have also developed frameworks to assess the extent and impact of carbon lock-ins, as well as political strategies for disrupting them (Bernstein & Hoffmann, 2018; Rosenbloom, Meadowcroft & Cashore, 2019).

A clear characteristic of lock-ins throughout the literature is that they manifest in rigidity and resistance to change, even in the presence of potentially better alternatives. When the need for change becomes clear, systems are found to have become entrenched or entrapped (Goldstein et al., 2023). Such entrenchment has been widely studied in theories of policy stability and change. In terms of change on the other the hand, exogenous "shocks" to the system, such as sudden disastrous events, have been found to open "windows of opportunity" (Kingdon, 1984). However, Pierson argues that both "big" or seemingly "small" events can have major consequences depending on their timing (Pierson, 2000, p. 263). Pressure to change, regardless of the source (exogenous or endogenous) and temporality (sudden or slow), can lead to critical junctures at which decisions are made to either maintain the status quo or try something different. It should be noted however, that Goldstein et al. (2023) found that lock-ins can also be constructed through cumulative, incremental change, depending on the context. Still, critical junctures are significant for two reasons. First, they can play a fundamental role in the creation of lock-in dynamics by triggering or strengthening reinforcing feedback effects. And second, critical junctures can help expose the degree to which a system resists to change and is subjected to lock-in dynamics. Thus, the recognition of such events is key in studying lock-in dynamics.

As summarized above, literature on lock-in encompasses a broad use of the concept and potential indicators, such as irreversibility, durability, reinforcement, positive feedback, and increasing returns. Some of these characteristics of lock-in from the literature are arguably symptomatic of, rather than prerequisites for, a lock-in. For example, so-called "locked-in" outcomes – outcomes that are difficult to reverse and long-lasting effects (such as built infrastructures) – are themselves the result of decision-making processes. Similarly, the durability of a policy or institution does not necessarily signify a lock-in. Though Jordan & Moore (2020) define durable policies as those that foster political support, trigger legacy effects, and endure it is possible for policies to be durable without lock-in dynamics.

Despite the common negative connotations of lock-in and the of potential lock-ins to maintain undesirable outcomes, lock-in dynamics do not need to be inherently negative (Siebenhüner et al., 2021). Theoretically, lock-ins could in fact be desirable and advantageous. Jordan and Moore (2020) argue, for example, that continuity and durability are important requisites for effective policy systems. Nonetheless, stability should be balanced with policy change when it is necessary. Hence, it is key that researchers identify the potentially detrimental lock-in dynamics that may hinder necessary change (Moodysson, Trippl & Zukauskaite, 2017).

Based on this review of the literature, this thesis defines the concept as following: a lock-in dynamic refers to a stabilizing, reinforcing force driven by (i) increasing returns and the benefits from maintaining a specific course of action; ii) the increasing costs of adopting an alternative option (i.e. transition costs); and iii) connectivity within the system that is tied to increasing returns exit costs, thus making alternatives undesirable. Within this definition the terms "returns", "benefits", and "costs" are broadly defined and include e.g. economic, social, ecological, and political benefits and costs. These core features of a lock-in can be used to diagnose the presence of a lock-in dynamic. Furthermore, lock-ins are created and maintained through the interactions within and between different systems (e.g. political, social, economic, built, and natural systems); therefore, to understand lock-ins we must adopt systems thinking and a mechanistic perspective can further reveal the causal explanation for why lock-ins exist.

Systems thinking is perspective often applied in the analysis of public policy and is useful because of its suitability for representing and assessing dynamic complexity (Nguyen et al., 2023; Sweeney & Sterman, 2000). In short, it is a "system of thinking about systems" with the basic principle that "something is more than its collection of parts" (Arnold & Wade, 2015, p. 670; Meadows 2008). Systems thinking helps decode complexity of a system and examine the consequences of decisions – steps that are key in the identification and analysis of lock-ins.

Another key concept that is compatible with systems thinking and key to this dissertation is the concept of a (causal) mechanism. Other researchers, such as Ebbinghaus, 2005; Klitkou et al., 2015; Popp, Feindt & Daedlow, 2021, have also applied a mechanistic perspective to understand the underlying causal processes constituting lock-in dynamics. Mechanisms are structured by entities, activities, and relations, that lead to a specific effect (Machamer, Darden & Craver, 2000; Hedström & Ylikoski, 2010). In brief, mechanisms represent theoretical schemes of cause-effect that are validated through the data. A mechanism is thus identified by the effect or phenomenon it creates (Hedström & Ylikoski, 2010). Causal mechanisms are, as explained by Goertz (2017) the "black box" (p. 27) M that "explains how X produces Y" (see Figure 1):

Figure 1: Conceptualizing a causal mechanism (adapted from Goertz, 2017, p. 27)

Quite a number of (causal) mechanisms have been identified in relation to lock-in dynamics and have correspondingly been called "lock-in mechanisms" (Klitkou et al., 2015; Kotilainen et al., 2019). Examples of lock-in mechanisms from the literature are found in Table 1. These mechanisms exhibit self-reinforcing qualities or are part of an overarching reinforcing dynamic in which more than one mechanism is present, combined, interconnected, and/or form a nested network of mechanisms (Hedström & Ylikoski, 2010; Klitkou et al., 2015).

Table 1: Examples of lock-in mechanisms found in the literature

Lock-in mechanism	Description
Adaptive expectations	Individuals and actor groups shape their expectations and actions based on their perceptions of what others will do; refers to i.e. "the self-fulling nature of expectations" (Pierson, 2000, p. 254).
Collective action	The framing of problems and solutions for (complex) issues are (re)produced via social networks, which leads to shared values and commitment towards collective action (Klitkou et al., 2015).
Economies of scale	Typically described in the context of production capacity and units; as production becomes more efficient and the scale of the operation increases, costs are spread over units of production, thus reducing the cost per unit and generating cost advantages (Arthur, 1994).
Habituation	Actors become attached to certain practices or technologies despite the availability of superior alternatives. Routines and repetition play a key role as well as actors' tendency to weigh earlier gains against future efforts (Barnes, Gartland & Stack , 2004; Kotilainen et al., 2019).
Institutional learning effects	The adoption of institutions over time leads to complementary institutions. The connectivity of the institutions has potential benefits, such as improved efficiencies and coordination but can also create undesired consequences e.g. increased complexity and interdependencies that block change (Foxon, 2002; Kotilainen et al., 2019).
Learning effects	Increasing benefits result from "learning by doing" associated with the production and/or application of a specific technology, product, or approach (Arthur, 1994). Increasing knowledge and skills enable incremental improvements that promote continued use (David, 1985).
Network effects	A specific technology, product, or practice becomes more widely used as benefits of its use increase with its adoption by other users (Ebbinghaus, 2005). This mechanism is also called "network economies" (Arthur, 1994; Janipour et al., 2020) and "coordination effects" (Foxon, 2002).
Power differentiation	Actors wield their power to impose or change rules or determine a specific course of action that advances their agenda and/or adds to their power. This mechanism is also referred to as "power asymmetries" (Foxon, 2002) or "differentiation of power and institutions" (Klitkou et al., 2015; Kotilainen et al., 2019).

2.3 Summary of key concepts: lock-in dynamics vs. lock-in mechanisms

The research in this dissertation often refers to lock-in dynamics and lock-in mechanisms. Though both terms were defined in the previous section, they are summarized in parallel here. The key difference between lock-in mechanisms and dynamics is their complexity. Mechanisms are specific, simpler feedback loops, whereas dynamics may consist of more elements and display a higher level of connectivity within the system. Their difference is unrelated to temporality and intensity.

Stemming from the concept of a causal mechanism which constitutes the explanation about how and why a certain outcome is produced, e.g. resulting from the interaction between actors and the actions/activities they engage in. A lock-in mechanism refers to a specific type of mechanism that operates in a reinforcing, stabilizing manner. One or more lock-in mechanisms may form a lock-in dynamic.

A lock-in dynamic refers to a reinforcing, stabilizing feedback loop (consisting of one or more mechanisms) that displays increasing returns, rising transition costs, and increasing connectivity with other system elements, which (un/intentionally) serves to sustain a specific course of action and (in/advertently) hinder alternatives.

3. Research Design and Methods

This chapter describes the overarching research design and methods that were employed throughout the dissertation research. Here, the research design and phases are laid out, followed by an explanation of the selection of the case studies, and an outline of the methods of data collection and data analysis.

3.1 Research design and phases

This dissertation research has taken a multi-method approach in its exploration of the question how patterns of action and inaction within regional German climate adaptation governance can be characterized and explained, thereby facilitating a more nuanced understanding of an area of research in which gaps remain. On the whole, the research was crafted in a macro-comparative study design, in which larger institutional structures were compared with each other. For these comparisons, I applied a mix of structured methods consisting of some more classically qualitative methods, such as process tracing, and more qualitative methods, such as a cluster analysis, and with some methods rather in between qualitative and quantitative (causal loops). Hence the dissertation research is best described as a multi-method study but does not fully fulfill typical definitions of "mixed-method" approaches due to its limited use of quantitative research methods in triangulation with qualitative methods (Goertz, 2017).

In order to approach the overarching research question in a structured and differentiated manner, my thesis and research consisted of four phases: (1) scoping and taking stock, (2) searching for explanations, (3) looking for solutions, and (4) synthesizing findings (see Figure 2).

The aim of the dissertation research was to identify and explain patterns of action and inaction and thus essentially a search for causal mechanisms. The absence of universal laws in social sciences (as opposed to natural sciences) makes it impossible to definitively prove causality. However, through observations, one can make inferences about causality and demonstrate its plausibility and probability through the identification of examples. Thus, comparative studies are a fitting choice for explaining adaptation policy dynamics (Purdon & Thornton, 2019). Because simple (single) case studies lack the comparisons that support generalization of hypotheses (ibid.), the research design consists largely of the comparative analyses of five in-depth case studies.

These case studies (described in more detail in the next section) were not scrutinized in the isolation of this dissertation research, but instead embedded within the context of a larger, interdisciplinary research project titled "Climate Adaptation Policy Lock-ins: A 3x3 Approach."[6] The project took an empirical and theoretically reflective approach to analyze climate change adaptation governance and deficits in the sectors water management, public health, and nature management – in Germany, the Netherlands, and the United Kingdom. In total the research team collected and analyzed data from 18 case studies, five of which are featured in this dissertation.

[6] The project's short name was "Adapt Lock-in." Funding for the project, which was conducted between 2019 and 2023 was provided by the Deutsche Forschungsgemeinschaft (DFG), the British Economic and Social Research Council (ESRC), and the Nederlandse Organisatie voor Wetenschappelijk (NWO).

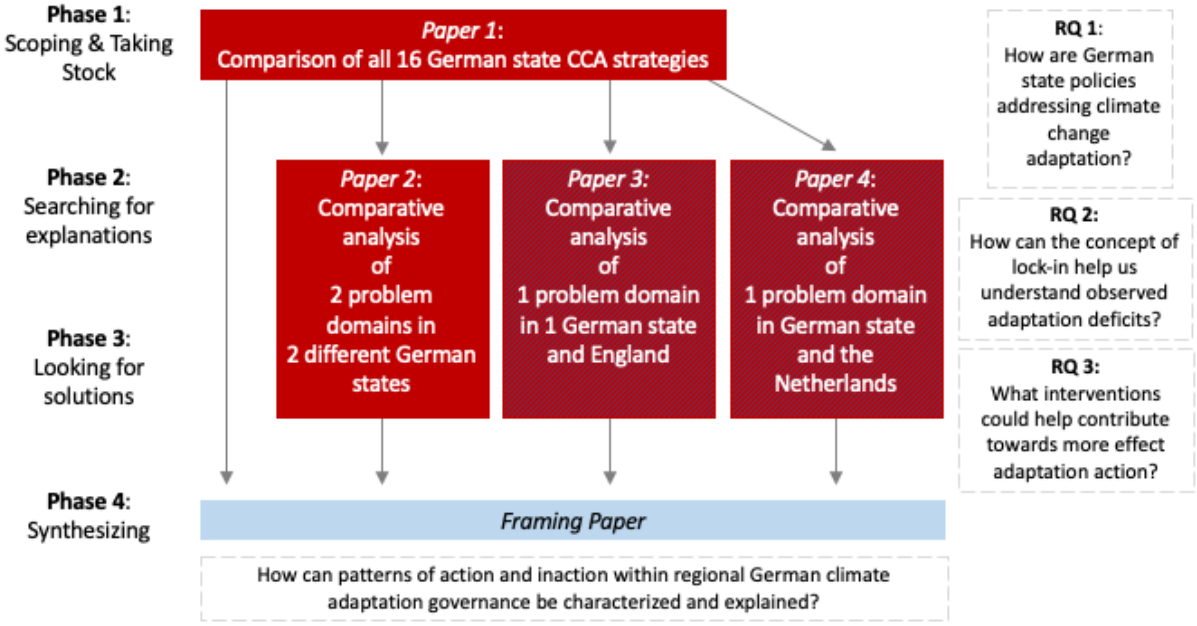

Figure 2: Thesis structure by research phases and research papers. The arrows depict the flow of findings, red indicates a focus on Germany and the blue stripes represent a cross-country comparison with a European neighbor

3.2. Selecting and delineating case studies

Due to both internal and external factors and the 2013 European Union call for national adaptation plans, many Northern and Western European countries were early adopters of adaptation strategies and are often perceived as leaders in climate adaptation policy (Biesbroek et al., 2010; Massey et al., 2014). However, observations have shown that adaptation actions in Europe are also scattered and largely incremental, despite their vulnerability to climate change, "with only a few examples of local transformative action" and "a gap remains between planning and implementation of adaptation action" (Bednar-Friedl et al., 2022, p. 1819). These findings suggest that Europe offers a fitting setting for examining more complex dynamics that could help explain adaptation deficits even in governance settings with higher policy capacity than other areas of the world.

The UK, Germany, and the Netherlands were the selected settings for the empirical research within the Adapt Lock-in project. All three are industrialized nations with advanced democratic institutions and significant political, economic, and social capabilities. Each country has a distinct multi-level governance system: devolved governments in the UK, collaborative levels in the Netherlands, and cooperative federalism in Germany, with all subject to EU law[7] (Capano et al., 2022). Economically, they rank among the top ten in Europe by GDP per capita and benefit from highly-reputed universities, research institutions, and non-profit organizations that inform adaptation governance.

[7] The UK was formerly subject to EU law but officially left the Union in 2020

Geographically, given their positions around the North Sea, these nations face similar climate change impacts, such as coastal flooding, droughts, heavy rainfall, and heatwaves. Each have dense urban areas alongside rural regions with protected landscapes. Adaptation governance in these countries has a long history, with national policies pre-dating the call to action from the EU and extensive scientific research programs exploring climate change impacts and responses, providing a rich context for studying adaptation governance.

For the purpose of this dissertation research, I have chosen Germany as the main setting for an in-depth analysis climate adaptation governance as a fruitful example for several reasons: Germany was early adopter of climate adaptation with the first established national framework calling for action from 2008, the German Strategy for Adaptation to Climate Change (*DAS*[8]), and there is a rich data for exploring adaptation strategies and approaches. The relatively high level of resources and policy capacity combined with the complexity of federalist structures offer depth and diversity for exploring adaptation governance progress and contextual explanations.

The *DAS* provides important framing for the research on climate change adaptation in Germany, in that it formulates an overarching goal, suggests courses of action as well as central actors, and defines further milestones. The long-term goal of the strategy is to reduce the vulnerability of natural, social and economic systems to climate impacts, to increase the adaptive capacity of these systems, and to seize possible opportunities of climate change (Bundesregierung, 2008). However, as noted above, Germany is a federalized nation, and due to the subsidiarity principle, climate change adaptation policy is primarily the authority and responsibility of states and municipalities.

The focus of this thesis within Germany is set at the state level, i.e. sub-national governments situated above county and municipal authorities. Thus far, existing academic research and governmental reporting on adaptation progress in Germany has mainly focused on the national and municipal levels, leaving the state level under researched. Within the climate change mitigation discussion, however, sub-national governments have been found to play a pivotal role (Hsu et al., 2020). In many policy areas that affect mitigation *and* adaptation, states have the power to initiate action through their jurisdiction over the municipalities (Vogel, Henstra & McBean 2020). Furthermore, state governments are equipped with larger administrations, more financial resources, and a broader scope than municipal governments. Clear state commitments to adaptation at higher levels of government have been shown to increase collaboration and innovations in local adaptation efforts (Heidrich et al., 2016; Jurgilevich et al., 2019; Vogel, Henstra & McBean, 2020). These findings and consensus among scholars highlighting the importance of action at *all* levels of government in tackling the climate crisis indicate the need for a better understanding of adaptation policy action (or inaction) at the sub-national, i.e. state, level.

For (multi-method) research on causal mechanisms, Goertz (2017) suggests making a list of all possible case studies and then developing criteria to help justify case selection. To ensure appropriate case selection, the first phase of research included a study of all sixteen German state adaptation strategies (see Section 4.1). This analysis was conducted in parallel with a small number of expert interviews for case screening conducted within the research project. Considering the aim

[8] *Deutsche Klimaanpassungsstrategie*

of uncovering insights on patterns of action and inaction, it was decided to select case studies displaying different levels of climate adaptation action and to focus on multiple climate risks. Drawing on the collective findings of the first research phase, case studies were selected based on the following criteria:

- A mix of active/less active states regarding overall CCA (based on Paper 1)
- States' respective impact through climate change (vulnerability)
- Recency of the available documents and data
- Statements from the screening interviews on the aforementioned criteria
- Geographic distribution throughout Germany

For the sake of comparability and to remove an additional layer of complexity related to scale, it was decided to omit the city-states (Berlin, Bremen, and Hamburg). The case studies in Germany selected for the empirical research within this dissertation are shown in Figure 3.

These case studies look at three different adaptation challenges, which are referred to as "problem domains". This term and delineation were chosen because it summarizes the challenge of examining the so-called "wicked problem" of climate change, which is characterized by significant uncertainty as well as complexity (e.g. non-linearity, problem interconnectivity, multi-scale dynamics) (Head & Alford, 2015; Levin et al., 2012). As a wicked problem, climate change adaptation straddles multiple sectors of policy and is often not a contained or well-structured policy area in itself (Termeer et al., 2017). Therefore, the term "problem domain" is arguably a fitting term for the unit of analysis that extends beyond typical policy areas and sectors. However, examples in which the concept of problem domains has been explicitly defined or applied to climate change research remain limited (e.g. Patterson & Huitema, 2019). Inspiration for the concept was drawn from the Policy Arrangements Approach (Arts, Leroy & van Tatenhove, 2006; Liefferink, 2006) and in the context of this research it refers to the arrangement of actors, resources, and institutions relevant to a collective problem. A problem domain may stretch across policy areas, sectors, and various geographic and jurisdictional scales, depending on the nature of the problem. The concept is thus conducive for a problem-led (as opposed to a policy-led) approach to the empirical research.

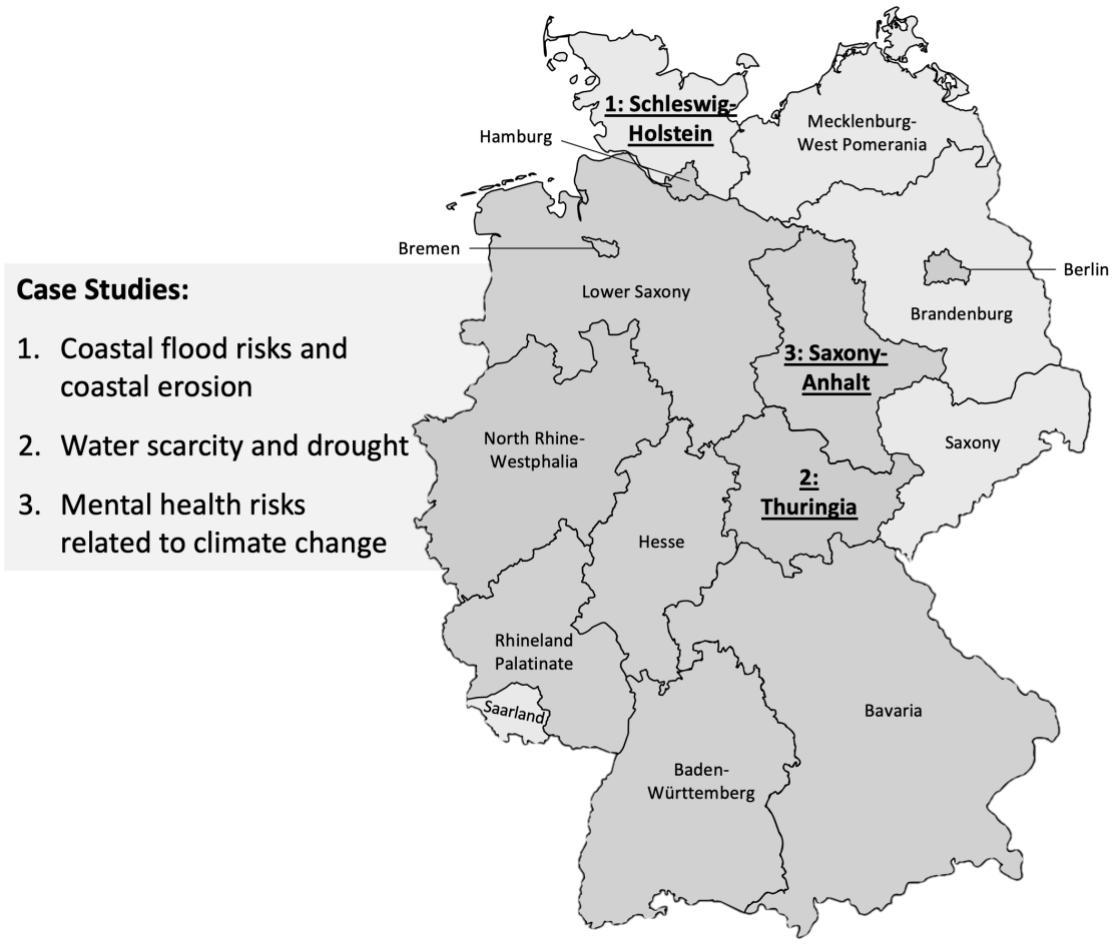

Figure 3: Case studies of this dissertation research that are set in Germany

The context of the "Adapt Lock-in" project provided a pre-selection of the three issues widely impacted by climate change: water, nature, and health. The more specific problem domain foci of the case studies for this research, i.e. coastal risks, water scarcity, and mental health, were selected for several reasons. First, coastal risks represent a policy challenge with a long history of policy responses and constitute a problem domain relevant to many governments around the world. Water scarcity is becoming an equally ubiquitous issue but differs in its nascence as a challenge in Germany. Finally, mental health risks of climate change pose an equally new issue and are observed to be left unaddressed in most governance settings. The policy problems thus display a mix of policy action observed in other settings and research, and the timeframes of emergence, characteristics that may contribute to the likelihood of existent lock-in forces. Further arguments for the relevance of the problem domains can be found in the individual research papers.

3.3 Data collection

The majority of data was collected through 27 semi-structured interviews with key practitioners, public servants, and researchers within Germany, and 17 interviews with experts in the Netherlands and England (UK), spanning three problem domains – coastal adaptation, water scarcity, and mental health (see Table 2). The interview guide of questions was developed within the Adapt Lock-in team and then translated into German. Only slight adjustments were made to the interview guide for each

of the problem domains. The interview guide can be found in the *Appendix* of this dissertation. The majority of interviews were conducted between January 2020 and June 2022 (with some occurring in early 2023), either on the telephone or online due to restrictions during the COVID-19 pandemic. Only a couple of the screening interviews that took place pre-pandemic were conducted in person. Prospective interviewees identified through purposive and snowball sampling (Parker, Scott & Geddes, 2019). Most interviews lasted between 30 minutes and 1.5 hours. The semi-structured approach allowed interviewees to reflect on a core set of questions and expand on additional issues of relevance to them. These conversations were audio recorded (with the consent of the interviewees) and transcribed[9] into written form for the purpose of data analysis described in the next section (*Section 3.4)*. The specific roles and remits represented of the interviewees sampled in German case studies can be found in the Annex of this thesis and within the individual research papers. Details on the Dutch and English interviewees is available through the UK Data Repository.

Table 2: An overview of the semi-structured interviews, presented by case study, who conducted them, and when

Case Study	Total no. of Interviews	Conducted by author	Conducted with/ by colleagues	Interview Timeframe
Case selection	6	**6**	3	Jan. 2020 - Feb. 2020
Coastal risks (Schleswig-Holstein)	10	**9**	3	Oct. 2020 - Jan. 2021
Coastal risks (England)	10	**0**	10	Jan. 2020 - Feb. 2022
Water scarcity (Thuringia)	7	**0**	7	Oct. 2021 - Mar 2022
Mental Health (Saxony-Anhalt)	4	**4**	1	Feb. 2022 - May 2022
Mental Health (Netherlands)	7	**0**	7	May 2021- Jul. 2021
	44	**19**	31	

Accompanying these interviews, data for this dissertation research was drawn from in-depth document analyses for the comparison of all state strategies and each of the case studies. The collection of documents ranged from policy documents to academic literature and grey literature. The majority of documents were state reports, strategies, budgets, laws, and plans. The documents examined also included federal reports, strategies, legislation, and webpages.

3.4 Data analysis

The data collected throughout the research was subjected to several types of analysis: qualitative document analysis, a hierarchical cluster analysis, process tracing, and causal loop diagrams. This section presents an overview of the different methods applied, and details on each of the analyses can be found in the individual research papers.

Document analysis is a common qualitative research method that is a systematic procedure for evaluating documents and written material, in order to develop empirical knowledge, elicit meaning, gain understanding on a certain topic or themes (Bowen, 2009). This method was applied for each of the research papers 1-4. In the analysis for Paper 1, data was coded by themes related to the

[9] Interview transcripts are available online and accessed through the UK Data Service.

criteria of the analytical framework. For Papers 2-4 data was coded using a codebook, developed iteratively within the Adapt Lock-in team based on both theoretical literature and empirical data, which resulted in both theory- and data-driven codes. This approach supported both deductive and inductive forms of inquiry and enabled us to examine, for example, whether previously documented lock-in mechanisms from other settings and contexts are equally applicable to climate adaptation, while simultaneously allowing for new mechanisms to emerge. MaxQDA software was used for coding in the document analysis.

A **hierarchical cluster analysis** was used in the data analysis within research Paper 1 in order to systematically identify patterns among the German state approaches to climate change adaptation (RQ1). Cluster analysis is statistical method used to organize data (or cases) into two or more groups by maximizing the similarity of the data within the identified clusters as well as the dissimilarity between the clusters (Roy et al., 2015). The qualitative data on the variables of the analytical framework was translated into binary quantitative data, and the resulting data set was put into a hierarchical cluster analysis using the Gower's general dissimilarity coefficient and Ward's method of agglomeration. These were applied to minimize within-group variance while maximizing between-group dissimilarity. For the results of this method, see *Section 4.1.* The open source software R was used for this analysis.

Process tracing was used to identify lock-ins in the analyses at the bases of Papers 2-4. It is a qualitative research method that aims to uncover reasonable causal mechanisms to explain a situation as it unfolds over time (Beach & Pedersen, 2019; Collier, 2011). Causal inferences are determined in accordance with rival explanations and using counterfactual reasoning (Collier, 2011). Biesbroek et al. (2014), also used process tracing in their mechanism-based-approached analysis to adaptation barriers and argue for its suitability, in that the method essentially renders alternative explanations obsolete, or at least less plausible. Starting with a chosen baseline "outcome", one then traces backwards, for example in the case of this research, from perceived barriers to adaptation in order to identify their origins, and how and why they persist. For this research process tracing techniques were used to identify if and to what extent, observed stability or inaction could be attributed to underlying lock-in mechanisms (RQ2). Rather than pre-determining a shared baseline date for analysis, process tracing was pursued as far as inferentially necessary for each respective case study.

Lastly, **causal loop diagrams** were used in Papers 2-4 to summarize and visualize observed lock-ins mechanisms and dynamics within the case studies. As a technique, causal loop diagrams are often used in combination with systems thinking and map the connections between different parts of a system under analysis. Causal loop diagrams "are used to understand how a behavior has been manifesting itself in a system so we can develop strategies to work with, or counteract the behavior. We also want to know to what extent and how the problem is connected with other 'systems'" (Haraldsson, 2004, p. 20). Hence, causal loop diagrams are a fitting mental model for the reflection of both research questions two and three (i.e. the presence of lock-ins and how they could be unlocked). Both open source software yEd and Microsoft Powerpoint were used to make the causal loop diagrams in this papers of this thesis.

4. Research Papers

This cumulative dissertation consists of four research papers surrounding the question "How can patterns of action and inaction within regional German climate adaptation governance be characterized and explained?" Table 3 presents an overview of the four papers with details on their specific research questions, conceptual approaches, empirical data, methods, and geographic scopes. The rest of this chapter consists of subsections each including a summary of the papers' contents and findings and their contribution to the overall dissertation research.

Table 3: Overview of dissertation papers and their contents

Paper	1) Sixteen Ways to Adapt	2) New challenges and established policy fields	3) Re-examining policy stability in climate adaptation through a lock-in perspective	4) Lock-in dynamics hindering climate adaptation for mental health
Specific research questions (shortened)	(i) How are German state CCA strategies fostering adaptation? (ii) To what extent do policy approaches and commitments vary within the federal context? (iii) What patterns have emerged?	(i) How do adaptation challenges emerging with intensifying climate change interact with established policy fields? (ii) How do forces of policy stability respond to the need for change? (iii) How do emerging challenges fit into policy paradigms and what mechanisms determine that fit?	(i) What self-reinforcing mechanisms contribute to policy stability and hinder dynamic responses in coastal climate adaptation? (ii) How do these lock-in mechanisms manifest in the different governance and socio-cultural settings of England (U.K.) and Schleswig-Holstein? (iii) What implications do these lock-in mechanisms have for policy and practice?	(i) To what extent are lock-in dynamics hindering adaptation to address the mental health impacts of climate change in Saxony-Anhalt (Germany) and the Netherlands? (ii) And what types of lock-in dynamics appear to be the most influential and detrimental for mental health adaptation?
Conceptual approach	Synthesis of indicators drawn from literature on the emergence of climate adaptation policies and their evaluation	Lock-in perspective of policy stability (vs. change) with 4 system dimensions: Technologies and infrastructures, Institutions, Actors and agency, and cognitive frames and knowledge	Lock-in perspective of policy stability: self-reinforcing mechanisms preserve status quo	Lock-in perspective of adaptation gap in that status quo is reinforced by lock-in dynamics
Empirical data	34 state-level policy documents (most recent from 2021)	22 expert interviews[10], and policy documents (most recent from 2022)	18 expert interviews[1], policy documents (most recent from 2022), and peer-reviewed literature	11 expert interviews, policy documents (most recent from 2022), news articles, and peer-reviewed literature
Methods	- qualitative document analysis - (hierarchical) cluster analysis	- qualitative case study that combined document and interview analysis with process tracing	- qualitative case study that combined document and interview analysis with process tracing	- qualitative case study that combined document and interview analysis with process tracing
Scope	Germany (16 federal states)	Schleswig-Holstein & Thuringia	Schleswig-Holstein & England	Saxony-Anhalt & the Netherlands

[10] 10 of these interviews conducted within the Schleswig-Holstein case were used in both papers

4.1 Paper 1: “Sixteen Ways to Adapt: A Comparison of State-Level Climate Change Adaptation Strategies in the Federal States of Germany" (Regional Environmental Change)

Climate change adaptation is a complex governance challenge that demands multi-level policy action. Existing research has shown that no single level of governance is the most effective for substantial adaptation action (Jurgilevich et al., 2019) and that interactions across different levels are inevitable but not yet well understood (Clar and Steurer, 2019). In federalist systems, sub-national governments are among key actors for enabling adaptation and their clear commitments can increase collaboration and innovation at the local level. Relative to municipal governments, state governments often wield over larger administrations and more financial resources and better access to national level institutions and programs.

This research paper provides an in-depth analysis of how Germany's federal states are addressing climate change adaptation and constitutes the first systematic assessment of all sixteen state adaptation strategies. Here I examined how German states are fostering adaptation, the extent to which their approaches vary, and which patterns have emerged, based on a qualitative document analysis of over 30 documents and a hierarchical cluster analysis. This assessment applied an analytical framework focusing on five indicators synthesized from three overlapping and complementary streams of adaptation literature surrounding the evaluation of adaptation policies and common barriers and facilitating factors of adaptation. The five indicators of analysis are: (i) the use of climate change data and vulnerability assessments, (ii) sectors and areas of action addressed, (iii) policy goals and commitments, (iv) institutional organization and coordination, and (v) plans for policy adjustments and continuous action.

The comparative analysis found that German state strategies are often non-committal sets of recommendations and identifies three clusters based on the analytical criteria that display different degrees of institutionalization and guidance (see Figure 4): “coordinated, directed strategies” (Cluster 1), “loosely coordinated, informative strategies” (Cluster 2), and “uncoordinated, informative strategies” (Cluster 3). Cluster 1 states (shown in green) were found to have comprehensive, well-coordinated plans that include not only legal commitments to CCA but also have set implementation timeframes, designated bodies focused on CCA, and plans for continuous action. The four states in this cluster (Berlin, Hamburg, North-Rhine Westphalia, and Thuringia) were deemed the most likely to foster effective climate adaptation. Cluster 2 (shown in blue), consists of seven states (including e.g. Bavaria, Hesse, and Saxony-Anhalt), whose strategies often include clear plans for continuous action and designated authorities for CCA but do not include binding goals or legal commitments. Finally, Cluster 3 (shown in yellow), consisting of five states, represents those whose CCA strategies are the least likely to foster adaptation action. The states within this cluster do not have stand-alone strategies for climate adaptation or vulnerability assessments (as of 2021), nor

plans for continuous action or a designated authority coordinating adaptation. The five states in this cluster are Brandenburg, Mecklenburg-West Pomerania, Saarland, Saxony, and Schleswig-Holstein.

The results of this analysis underscore the complexity and variability of climate change adaptation efforts within a multilevel governance system. While federalism allows for flexibility among state responses, the absence of federal mandates and policy standards allows some states to fall behind while others continue to develop their strategies to foster adaptation. These sixteen diverse approaches each have implications for adaptation governance at other levels and for policy action in specific sectors. Within the cluster identified as the states mostly to foster adaptation, only the city-state of Berlin fulfilled all of the criteria of the framework. Thus, the analysis identified and characterized some extent of an adaptation gap on the strategic level in almost all German states.

Figure 4: Clusters identified in Paper 1. States in green were found to have coordinated, directed strategies for CCA, states in blue loosely coordinated, informative strategies, and states in yellow uncoordinated, informative strategies

This paper fit perfectly as a first step within the dissertation research as a broad and comprehensive analysis of all of the German states' adaptation strategies. It addresses the research question "How are German state policies addressing climate change adaptation?" (RQ1) and identified patterns relevant to the overarching theme of adaptation action and inaction. The analysis yielded results that were fundamental to the selection of the case studies for the further research. The findings provide key context for the following research papers and add depth to the findings on the individual states in the later papers.

4.2 Paper 2: "New challenges and established policy fields - Assessing stability and change in climate adaptation policy through a lock-in perspective" (der moderne Staat)

Climate change-induced changes in annual precipitation and sea level rise, are becoming increasingly perceptible around the world and within many regions of Germany, thus increasing the need to adapt. Although water management is one of the most well established and proliferous sectors of climate adaptation in Germany (King, 2022; Otto et al., 2021), new challenges continue to arise and

adaptation gaps remain. This paper examines how established policies resist change and adapt to challenges in the management of water (in one case “too much” and in the other case “too little” water) and thus explores the dynamics of policy stability and path dependency despite pressures to change in the context of climate adaptation. Here we aimed to assess the ways in which emerging challenges fit into established policy paradigms and programs relating to the challenge, and identify the mechanisms that determine this fit.

Forces of stability and change within established policy fields significantly shape the extent to which governance systems can adapt to new challenges from climate change impacts and worsening existing risks. In this paper, we applied a lock-in perspective in our comparative analysis of the governance of coastal risks in Schleswig-Holstein (i.e. sea level rise, storm surges, and coastal erosion), which has a long history, and drought-induced water scarcity, a relatively new problem, in Thuringia. These two cases are similar in their vulnerability to significant climate impacts but differ in the extent to which the need for climate adaptation results in a deviation from existing policy approaches, thus constituting rich examples at analyzing dynamics of change.

In the conceptual background of this paper, we explain lock-in as stabilizing, self-reinforcing forces of existing policy fields that hinder changes even in the presence of (superior) alternatives. In our definition of the concept we draw on Pierson (2000) and Rosenbloom, Meadowcroft & Cashore (2019) and describe how positive feedback and self-reinforcement of decisions are the central drivers of resistance to change and reduce the range of possible future choices. Here we highlight the multi-disciplinary roots of the concept of lock-in, which integrates policy and institutional dynamics within the wider scope of a complex systems perspective, thus going beyond a limited focus on a specific problem aspect or subsystem. The systems perspective includes human actor, material (e.g. technologies and infrastructures), and non-material (e.g. cognitive frames and knowledge) dimensions (Hegger et al., 2020; Trencher et al., 2020), and is thus conducive for capturing complex societal dynamics.

In this research we employed a comparative case study approach, drawing on data derived from both document analysis and 18 semi-structured interviews with key policy actors and stakeholders in Schleswig-Holstein (coastal risks) and Thuringia (water scarcity). Case data was analyzed with a co-developed set of codes consisting of both theory-based (deductive) and data-based (inductive) codes and were then subject to process-tracing, a method known for its suitability for identifying causal mechanisms (Collier, 2011).

Our findings focus on four dimensions serving as analytical categories (introduced in the conceptual section) for mapping and “diagnosing” the lock-ins we observe: (i) infrastructures, (ii) institutions, (iii) actors and agency, and (iv) knowledge and cognitive frames. In Schleswig-Holstein, we observed the strong lock-in effects of well-established coastal protection infrastructure and long-standing institutional frameworks. Existing policies, primarily focused on maintaining and reinforcing the line of coastal dikes, limit the feasibility and exploration of alternative adaptation options, such as managed retreat. The coastal case study demonstrates how established (and effective) technological and institutional arrangements, in combination with homogenous and strong cognitive frames, can significantly hinder policy innovation, i.e. change, in light of climate change risks. In Thuringia, we found that the policy response to the emergent issue of water scarcity is more adaptive and less

entrenched due to the relative flexibility of existing water management infrastructures and newly developing arrangement of actors. Though some institutional resistance was observed (e.g. in the form of learning effects and pre-existing fixation on flood prevention), we generally observed that the nascent policy problem is less entangled in intertwined forces of stability. The absence of heavily restrictive institutions and dominant actor coalitions has allowed greater flexibility, for example in the introduction of more sustainable water storage and usage practices. The case study highlights how fewer dynamics of lock-in are more conducive to more responsive and innovative policy changes and action. Together, the case studies indicate that the fit between policies and problems are more complex than binary and that fit is determined by multiple factors and dynamics, including but going beyond financial and political resources.

Overall, this paper investigates two case studies in detail and depth and contributes to the dissertation's findings on multiple research questions, including how German states are addressing climate change adaptation (RQ1) and how the concept of lock-in can help us understand observed adaptation deficits (RQ2). While prior studies of lock-in have pointed to the high significance of infrastructures and technologies (e.g. Klitkou et al., 2015; Seto et al., 2016), these findings demonstrate that actors and agency as well as knowledge and cognitive frames are the sources and drivers of several lock-in mechanisms identified in Schleswig-Holstein and Thuringia. In both cases we uncovered how knowledge systems or cognitive framings justify institutional and infrastructural policy choices that are reproduced by other stakeholders. The examples and the identified mechanisms in this paper suggest that cognitive frames and knowledge systems are a highly influential dimension and carry high potential as sources of lock-in mechanisms and with that determine the fit policy responses to risks of climate change.

In addition, this paper provides some insights relating to the question of this dissertation about interventions that may help contribute towards more effect adaptation action (RQ3). The findings on the role of dominant frames and knowledge systems and the influence of actor coalitions suggest that those dimensions may be potential entry points for interventions. Referring to findings from Abson et al. (2017) we suggest that these dimension could be "deep leverage points" in the systems studied and wield strong influence on the systems' behavior. Thus "unlocking" interventions could involve the diversification of involved actors or widening the scope of knowledge systems – i.e. interventions also found in literature on transformative climate governance (Fedele et al., 2019; Hölscher & Frantzeskaki, 2020).

4.3 Paper 3: "Re-examining policy stability in climate adaptation through a lock-in perspective" (*Journal of European Public Policy)*

Climate change is accelerating coastal risks, such as flooding and erosion, which, in many areas, constitute historical challenges with existing policy responses. Despite the growing recognition of the need for more transformative adaptation, policies are often observed to remain the same and resist change in the form of climate adaptation. Coastal management is a well-established policy area with developments often spanning decades, and in some cases centuries. However, the impacts of climate change may make incumbent approaches relying on "hard" defenses unsustainable over time (Jones, Hole & Zavaleta, 2012) Against this backdrop, this paper takes a lock-in perspective to

examine the sources of such policy stability in coastal and flood risk management in the state of Schleswig-Holstein (Germany) and in England (U.K.).

This paper begins with the conceptualization of lock-in and a synthesis of known lock-in mechanisms from a range of literatures including technology studies, political science, economics, and climate mitigation research. It then presents findings on lock-in mechanisms as sources of policy stability from the inductive analysis of two case studies drawing on data from documents (e.g. legislation, strategies and key plans, reports, and existing academic research) and 20 expert interviews[11].

The analysis of the two case studies revealed the presence of several known lock-in mechanisms, as well as the identification of newly observed lock-in mechanisms. In both England and Schleswig-Holstein, for example, "economies of scale" were observed in the scaling up of coastal management practices (in this case hard flood defenses), which made it difficult to depart from the existing approach and introduce more diverse or innovative adaptation strategies. "Adaptive expectations" were another identified mechanism playing a role in policy stability, with stakeholders' actions and expectations being shaped by their perceptions of what other would do and thus reinforcing existing practices. One newly identified mechanism observed, for example, is "framing (re)production", in which the perceptions of problems and their solutions are co-constructed and reproduced by different actors and institutions and thus continually reinforced in their legitimacy and prevalence. Another newly identified mechanism from these case studies is "co-dependency", which describes a specific relationship between two or more actors, in which the parties involved require something from the other(s) and have established formal measures to secure mutual gains, thus reinforcing that arrangement. These and the whole networks of observed mechanisms are summarized in the form of causal loop diagrams, both of which show the complex and interconnected sources of stability reinforcing the implementation of defense infrastructures for managing coastal risks. Based upon the lock-in mechanisms observed, the paper suggests policy interventions that may help dissolve lock-ins, such as new institutional frameworks to support alternative adaptation approaches and increased collaborative dialog among diverse stakeholders in order to challenge entrenched practices and explore new adaptation pathways.

This paper contributes to the overall dissertation research in its exploration of all of the research questions. It adds detail and depth to the findings on the case study of coastal risk management in Schleswig-Holstein (RQ1), provides a thorough exploration of how lock-in mechanisms actively contribute to the persistence of existing policy responses and at the same time deter the success of alternative approaches introduced in the context climate adaptation (RQ2), and reflects on potential interventions to break up lock-ins (RQ3). It adds to the previous findings of the dissertation research in its comparative analysis of two case studies from different countries, which prove to share some common sources of policy stability in the case of coastal risk management. All in all, it underscores the importance of understanding the complex sources of policy stability in order to facilitate more effective and transformative adaptation strategies.

[11] Ten of these interviews were conducted by this author and also analyzed as the empirical basis for Research Paper 2

4.4 Paper 4:“Lock-in dynamics hindering climate adaptation for mental health” (working paper)

As climate change risks, such as extreme weather events and rising temperatures, increase, its impacts on mental health are becoming increasingly evident and widespread. Yet, new and adapted policies to address these issues remain almost non-existent and constitute a growing and observed adaptation gap (WHO, 2022). Mental health as an issue of climate adaptation is relatively new. Though health systems and related policy areas (such as disaster planning) are well-established in most European countries, many systems struggle to meet mental health care demands and these systems may become increasingly unsustainable as climate-related stressors increase. Against this backdrop, this research paper applies a lock-in perspective to explore the sources of policy inaction in the context of mental health and climate adaptation, focusing on the Saxony-Anhalt (Germany) and the Netherlands.

With a conceptual focus on lock-in dynamics, the paper presents findings from the inductive analysis of two case studies, drawing on data from policy documents, legislation, media articles, and 11 expert interviews. The analysis identifies similar lock-in dynamics in Saxony-Anhalt and the Netherlands that reinforce the status quo of the issue of mental health – in both cases a neglected problem within climate adaptation. Strong dynamics of normalization effects were found to prioritize curative care over preventative measures, and the stigmatization of mental health issues and cost-effectiveness-focused decision-making were found to hinder the entrance and development of more holistic approaches into relevant policies and programs. Dynamics of coalition building, related the powers of certain actors, were observed lock-in forces perpetuating existing policies and preventing change. The most clearly observed lock-in dynamics are summarized for each case study in the form of causal loop diagrams, which clearly demonstrate the interconnectedness of the lock-in dynamics reinforcing the inattention to mental health within the realm of climate adaptation but also overall within society.

This paper contributes to the overall dissertation research in several ways. It explores all of the research questions of the dissertation and further demonstrates the usefulness of the lock-in concept for characterizing and explaining patterns of policy inaction. Empirically, it adds additional anecdotal evidence in a comparative analysis focused on a relatively new problem domain, i.e. mental health in the context of climate change. The focus on mental health as an aspect of climate adaptation policy is a research gap and constitutes a new and necessary niche of adaptation research. Furthermore, the conceptual focus is on lock-in dynamics, rather than the dimensions used in Paper 2 or only on the specific mechanisms in Paper 3. As opposed to the findings on the nascent issue of water scarcity in Thuringia, this paper finds strong lock-in dynamics hindering policy change in the case of another relatively “new” issue, i.e. the mental health impacts of climate change. This finding suggests the ubiquity of lock-in dynamics in diverse governance contexts and further underscores the need for additional research other problem domains of climate adaptation with the lens of the lock-in concept.

5. Synthesis Discussion of the Research Questions and Findings

Widespread evidence show that the impacts of climate change continue to increase around the world with growing frequency and intensity (IPCC, 2022b). Considering the insufficient state of adaptation action and the inadequacy previous research to address deficits, this research has recognized the need for a deeper look into the complex relationship between climate change adaptation (in)action and the dynamics in which it is embedded. This dissertation research has explored why certain policies remain stable over time and what factors might drive changes or adaptations in these policies. The suspicion that inaction and stability are the result of active dynamics and mechanisms reinforcing existing arrangements that prevent change, i.e. the concept of lock-in (*see Chapter 2*), acted as a point of departure for the research.

This synthesis discussion returns to the question binding all elements of the dissertation research: How can patterns of action and inaction within regional German climate adaptation governance be characterized and explained? Three sub-questions add depth and structure the research into more differentiated steps of analysis from stocktaking, to explanations, to contemplating solutions: (i) How are German state policies addressing climate change adaptation? (ii) How can the concept of lock-in help us understand observed adaptation deficits? (iii) And finally, what interventions could help contribute towards more effect adaptation action?

All four papers of this dissertation research delve into action and inaction within climate adaptation policies. The research found, similar to McConnell and t'Hart (2019), that inaction is often in fact an active process and that inaction and action constitute patterns that can also be characterized as stability and change. As for patterns of adaptation action, this dissertation research yielded fewer explanations of what creates action and induces change due to the conceptual focus on lock-in. The comparative analysis of state strategies, however, found that scientific data and vulnerability assessments may be initiators for change in the sense of motivating policy formulation. The case studies also found that critical events, such as flooding or droughts, also incite change by revealing vulnerabilities to climate risks.

The sub-questions structure the following sections of this discussion, which then ends with reflections on the concepts and methods applied throughout the dissertation research and their limitations.

5.1 How are German state policies addressing climate change adaptation?

The comparison of all sixteen German states' adaptation strategies and the research on individual case studies within selected states and problem domains reveal heterogenous approaches to climate change adaptation. Though all federal states have some form of a strategy or proposed action for adapting to climate change, most approaches consist of non-committal recommendations and are thus unlikely to suffice for managing wide-ranging and long-term climate change risks. The first research phase identified three clusters displaying varying degrees of institutionalization and specificities of responsibilities and goals, a finding which was also observed in the problem domain-focused research papers (2-4). In those case studies, data also displayed a mix of policy progress for adaptation: well-established policies that are expected to address increasing risks for the coming

decades (e.g. coastal risks in Schleswig-Holstein), emergent policies to address new problems (e.g. water scarcity in Thuringia), and non-existent policies (e.g. adaptation in the context of mental health in Saxony-Anhalt).

The three German case studies from Papers 2-4 represent each of the three clusters identified in Paper 1: Thuringia was one the "Cluster 1" states which were characterized as having coordinated, directed strategies for climate adaptation, Saxony-Anhalt was found to be one of the "Cluster 2" states described as having loosely coordinated, informative strategies, and Schleswig-Holstein was found to be among the "Cluster 3"states with uncoordinated, informative strategies and approaches for adaptation. The following research phase found however, that overall classification of the states' approaches to climate adaptation policies does not necessarily reflect the progress of the individual problem domains. Though the case study on water scarcity in Thuringia does align with the state's overall approach, in that it is directed and well-coordinated, the findings on coastal risks and mental health do not quite align with the characterization of the states' overall approaches. Schleswig-Holstein, for example, was not found to have a stand-alone or multi-/cross-sectoral strategy for climate adaptation or any set of binding goals, which resulted in its placement into "Cluster 3." However, because of the state's long coastline and long-history of experiencing storm surges and coastal flood events, there is a clear policy for managing coastal risks, which is updated on a regular basis and is responding to sea-level rise with climate change. For the coming decades, the policy is expected to sufficiently address the known risks, and could thus be assessed as being more effective than the state's overall adaptation policy. Saxony-Anhalt, on the other hand, was found to have a better-than-average overall approach to climate adaptation (relative to the other German states) in the first research paper. It fulfilled almost all of the criteria for an adaptation strategy that is likely to foster adaptation except for the legal commitment and binding goals, which determined its placement into "Cluster 2." However, the research focused on the issue of mental health in the context of climate change did not find any institutions or authorities in place for addressing mental health risks increasing with climate change.

In terms of assessing state-level adaptation policies in Germany, the four papers of this research collectively demonstrate how asymmetrical policy progress or efforts may be. States' overall approaches to climate adaptation do not necessarily represent the state of all individual problem domains or specific sectors. In other words, the existence of a multi-sectoral climate adaptation strategies or climate law does not equal adaptation progress across the board, and apparent inaction, in the sense of the lack of a state strategy for climate adaptation, does not inevitably mean there is no adaptation progress. This finding emphasizes the complexity of assessing and understanding adaptation governance, in that governance landscapes are heterogenous and nuanced, setting by setting. Thus, this research question can only be answered to a limited extent in a summarizing manner – German states are addressing adaptation to varied degrees and even the most "progressive" approaches show room for improvement and some extent of an adaptation gap.

5.2 How can the concept of lock-in help us understand observed adaptation deficits?

In this research, the application of the concept of lock-in has given us a nuanced and complex understanding of adaptation deficits in several settings and problem domains. Previous to this research, the concept of barriers acted as the primary explanation for adaptation deficits

(Amundsen, Berglund & Westskogh, 2010; Barnett et al., 2015; Eisenack et al., 2014). The case studies from these research papers, however, demonstrate the value of digging deeper into the mechanisms and dynamics behind adaptation deficits that prove to be interconnected and active hindrances of change.

The research finds that perceived barriers, such as limited funding, for example, are the result of wider dynamics, and connected to cultural norms, power dynamics, and infrastructural decisions, for example. The lack of funding for preventative, resilience-building mental health programs in Saxony-Anhalt, for example, is tied to politicians' decision-making frames of short-term cost-effectiveness and policy priorities, which are influenced by both the lack of knowledge transfer surrounding climate change and mental health as well as the larger cultural stigmatization of mental health issues. In Schleswig-Holstein, funding is limited to specific, pre-approved uses, which reflect regional public preferences and coalitions. All in all, these and other findings demonstrate that more complex mechanisms actively reinforce existing paradigms and institutions and thus hinder change to increase and diverse adaptation efforts. Thus, we can conclude that adaptation deficits are not simply the absence of action but instead often active dynamics preventing changes to existing governance approaches. In the examples of adaptation to coastal risks, water scarcity and climate risks for mental health, we were able to uncover a mix of both previously documented lock-in mechanisms (e.g. economies of scale) and newly identified lock-in mechanisms (e.g. framing (re)production). This finding indicates that the collection of "known", documented lock-in mechanisms is not exhaustive and may continue to grow with increasing empirical observations and the new application of lock-in thinking to investigations of climate adaptation policy. The research findings reveal that manifestations of lock-in are diverse and vary by setting, yet they all share the identifying characteristics of positive feedback and reinforcement of existing system elements.

In our comparison of Schleswig-Holstein and Thuringia, the findings highlight different dimensions that constitute and enable lock-ins (technologies and infrastructure; actors and agency; institutions; and knowledge and cognitive frames). In the comparison of coastal risk cases, the focus is on individual mechanisms and the discussion points to their relation to themes of cost-efficiency, public support, and technology/infrastructure. Whereas in the comparison of Saxony-Anhalt and the Netherlands in the case of mental health we pursue a slightly different approach and have identified four wider dynamics of lock-in, namely normalization effects, capacity building effects, coalition building effects, and asset accumulation effects. This approach of classifying wider dynamics was taken with the goal of identifying more generalizable categories to discriminate the larger processes restricting change as opposed to naming more specific and more seldom lock-in mechanisms, that describe particular manifestations of feedback loops. Though the findings from the case studies on coastal risks and water scarcity did not explicitly include the categorization of the observed dynamics into these four categories, they equally apply to those findings as well. In the case of coastal risks, for example, accumulation effects (e.g. in the form of economies of scales and business network effects) and normalization effects (e.g. such as framing (re)production and adaptive expectations) are highly active in their reproduction of existing policy choices. In the case of Thuringia, though, there are fewer lock-in dynamics hindering policy change, we still observed the impact of normalization effects on adaptation action. For example, frames about rights to water and the focus on flood prevention were found to shape both institutions and behaviors restricting adaptation to the new issue of water scarcity.

In the collective research findings of this dissertation, the importance of norms and framing is clearly discernable in that they are omnipresent in the reinforcement of existing paradigms. Within all of the case studies in the selected states of Germany and within the examples from England and the Netherlands, the influence of public and governmental cognitive frames and perceptions consistently prove to be determining elements of feedback loops. In Schleswig-Holstein, for example, the idea of "fighting the sea" and defending the coastline reinforce the approach to adaptation. Similarly, the idea of "holding-the-line" in England and societal expectations for state interventions reify decisions sometimes contrary to adaptation plans. In Thuringia, though frames are shifting more in the case of the emergent problem of water scarcity, long-held ideas of water use still influence the problem framing in the developing strategies for addressing water scarcity. In the case of mental health, both in Germany and the Netherlands, the stigmatization of mental health struggles and the framing of health care as responsive rather than preventative restrict potential changes that would help adapt to climate change risks. Together these findings reflect the democratic nature of policy, in that government approaches to societal problems reflect the preferences and norms of the majority of the public and their public servants. In terms of climate adaptation this yields the further question as to how normalizing dynamics could be unlocked or redirected in way that would allow for more transformative and risk-appropriate climate adaptation, yet remain democratically legitimate.

As for the role of knowledge and capacity building, all of the papers contain examples of how homogenous or limited knowledge bases reinforce existing policy decisions. In the first paper, states with vulnerability assessments (and thus regionally specific knowledge) were found to have strategies with higher potential for adaptation action. In the case of coastal risk management in Schleswig-Holstein we found that the homogenous epistemic community plays a role in reinforcing existing policy approaches and the direction of new research. In the case of mental health and climate adaptation in Saxony-Anhalt, we found that the lack of regional data on risks combined with the difficulty of informing decisionmakers with existing data and solutions reinforce the neglect of mental health in adaptation and public health policies. In contrast, the recent droughts in Thuringia have led to the recognition of the need for more information, and knowledge generation was found to be the main action point in the state's strategy for addressing water scarcity. The lack of knowledge about water scarcity in that case is observed in combination with no observed dominant problem framing about water scarcity (though established frames from other problem areas appear to be influential). Hence, the impacts of data and knowledge were a reoccurring theme of the dissertation findings.

Lock-in mechanisms and greater dynamics of reinforcement prove to manifest in diverse ways and settings. They affect both established policy areas (e.g. public health, coastal management) and newly emerging issues (e.g. mental health in the context of climate change, water scarcity) and are characterized by their limiting of feasibility of new and diverse adaptation options. We found examples showing how lock-in mechanisms can be passive (e.g. learning effects in the use and management of reservoirs and dams in Thuringia) or active (e.g. framing (re)production in the instance of co-designed research agendas in Schleswig-Holstein). We observed they can also be intentional (e.g. differentiation of power in terms of the Joint Committee's control over mental health care provision) or unintentional (e.g. framing (re)production and adaptive expectations in regard to beliefs about dikes). Additionally, the visualization of lock-ins in the form of the causal loop

diagrams helped reveal that some observed feedback loops (i.e. lock-ins) are simple, such as economies of scale (e.g. in the form of infrastructural sunk costs), and others more complex, such as funding schemes affected by mechanisms of framing, power and or expectations (e.g. in the cases of coastal management and mental health). Overall, the examples of lock-in detected in the research demonstrate the diversity of drivers cultivating and reinforcing the policy stability perceived as inaction and resulting in adaptation deficits: institutional, socio-cultural, behavioral, infrastructural, and economic forces that are often intertwined system elements, reinforcing "business as usual."

5.3 What interventions could help contribute towards more effect adaptation action?

The empirical research in the scope of this dissertation generated far more and richer insights on the dynamics of inaction rather than solutions for more adaptation action. Overall, the findings yielded little evidence on triggers of change, and in each instance, shock events, more so than crafted interventions, played a role in highlighting vulnerabilities and encouraging action. In Schleswig-Holstein, for example, a "catastrophic" storm surge in 1962 was the major impetus for a unified state approach to coastal defense, in the form of the first Master Plan for Coastal Flood Defence and Coastal Protection (*Generalplan Küstenschutz des Landes Schleswig-Holsteins*) adopted in 1963 (MELUR, 2013). Since then major storm surges have occurred regularly, but coastal defenses have succeeded in preventing flooding, and new knowledge about the risks of climate change impacts have led to incremental adjustments rather than a new, more diverse approach to coastal management. Similarly, and more recently, the extreme, hot, dry summers of 2018-2020 led to the recognition of the need for more data and knowledge regarding water scarcity in Thuringia and played a pivotal in the drafting of a new strategy. At the same time of our research however, the main aim of the new strategy was knowledge generation, and due to the nascence of the problem, it is subject to fewer lock-in dynamics requiring planned interventions. The findings from both of these case studies confirm existing research that shows how "shock events" or "focusing events" can be the source of policy change (e.g. Giordono, Gard-Murray & Boudet, 2021; Liefferink et al., 2018).

The strong influence of normalization dynamics in reinforcing existing approaches to problems arising or worsening with climate change and their ties to the availability and distribution of data and knowledge (and larger dynamics of capacity building), indicate that the generation and distribution of knowledge and evidence could be one step in dissolving lock-in dynamics that actively reinforce policies restricting adaptation options. Due to the nature of the observed normalizing and capacity building dynamics, such as ideas about "keeping water out" along the coast or the stigmatization of mental health issues, a mix of public participation and widespread campaigns to improve awareness about climate change risks and alternative approaches may be interventions worth pursuing. Capacity building within circles of practitioners and politicians may not be sufficient, since their job as public servants is to operate according to the will of the people. Thus, the widespread diffusion of knowledge and new frames should accompany capacity building directly within the problem domain. This idea of "re-thinking how knowledge is created and used" is one of the realms of leverage interventions for greater societal transformation (towards sustainability) identified by Abson et al. (2017, p.31).

5.4 Reflection of the applied concepts and methods and their limitations

Overall, the concept of lock-in demonstrates its value for better understanding the complexity of perceived inaction, which at a closer look, is often the continuation of existing policies and paradigms. This research proved that the concept of lock-in can be applied in the context of adaptation governance and adds to the collective understanding of current adaptation gaps. The findings demonstrate that adaptation inaction or insufficient action are subject to dynamic processes in interconnected systems, rather than isolated, static barriers with simple solutions.

Though the origins of lock-in are rooted in economics (*see Chapter 2*), later works have categorized them into wider types as institutional, infrastructural and technological, and behavioral (e.g. Seto et al. 2016). These categories are also a useful conceptualization of the sources of lock-in, but in some cases, they were not a fitting match to our observations. This dissertation work has also delineated broad categories to characterize the wider dynamics[12] at work within climate adaptation governance and the nature of their effects: normalization, capacity building, coalition building, and asset accumulation. Our categorization of dynamics reflects the self-reinforcing nature of lock-ins and can be useful in both looking for lock-ins but also understanding their impact on the system. We do not argue, however, that this is the only or best way to group observed lock-ins. Rather, the range of settings and problem domains yielded diverse findings that can be categorized in equally diverse manners. Hence, our research approach emphasizes the diverse faces of lock-in and that there may not be one "right" or universally fitting way to categorize the observed dynamics.

In terms of the concepts' limitations, the application of lock-in concept to empirical research on climate adaptation yielded rich and complex findings, but the transferability of findings to other settings is presumably limited. One cannot assume that the same lock-in dynamics explain deficits in other sectors and settings. For example, cultural frames related to adaptation problems or the implementation of certain technologies are directly tied to the problem domain settings. This research revealed different constellations of lock-in mechanisms and dynamics in each case study system, which points to the assumption that that no two systems are the same.

Another limitation of this dissertation research is the trade-off between the depth of the case studies and the quantity of case studies analyzed. As described in *Chapter 3*, case study data was collected through both document analysis and semi-structured expert interviews, which were then analyzed using process tracing. Due to the complex nature of the system-wide analysis and the method of process tracing, the data collection included a wide scope of sources, both thematically and temporally. Within the scope of a dissertation this approach was a time-intensive collection of evidence that thus limited the number of case studies included in the comparison. At the same time, it is possible that some evidence relevant to lock-in dynamics remained uncovered, due to the importance of information that is not commonly documented in written form, such as power dynamics, norms and opinions, or inefficient practices and habits. If such information was not revealed within the interviews, it may remain uncovered. Despite these limitations, the chosen

[12] Our categorization of dynamics is inspired by Bernstein and Hoffmann's (2018) typology of political mechanisms for decarbonization

methods proved overall well-suited and effective for identifying causal mechanisms and mapping the lock-in dynamics affecting systems' adaptation action.

Though not a limitation specific to this research per se, it is worth noting that the subject area of climate adaptation governance is volatile, with new and adjusted policies emerging constantly. Hence it is important to acknowledge the time frame of the research findings.

6. Conclusions and Future Research

In sum, through the individual research papers and this synthesis, this dissertation research has achieved its aim of investigating and explaining patterns of adaptation action and deficits and has thoroughly explored the initial research questions. With a detailed analysis of adaptation policies across all German states, the research first mapped patterns of adaptation action and inaction (RQ1), identifying varying degrees of engagement with climate adaptation policy. The application of lock-in theory (RQ2) provided valuable insights into how, e.g. institutional, infrastructural, and behavioral dimensions constitute sources of dynamic policy stability affecting adaptation policy and contribute to the persistence of these deficits. Particularly, aspects of capacity building (tied to material and cognitive resources) and norms and framing were found to have strong reinforcing effects on policy decisions. Additionally, the study looked for potential interventions (RQ3) that could help disrupt lock-in dynamics and encourage more proactive climate governance. Ultimately, this dissertation offers a fresh perspective on adaptation governance in Germany, extending the application of lock-in theory to climate adaptation and providing a foundation for future research in this field. The findings are of interest both for scholars in the field of adaptation governance research and for policymakers and practitioners with any level of decision-making power.

Since the empirical work of this dissertation research a new federal law has been passed at the end of June 2024 that has the potential to improve state level adaptation governance: the (federal) Climate Adaptation Law (KAnG – *Klimaanpassungsgesetz*). The KAnG mandates that each German federal state must develop and implement its own climate adaptation strategy in alignment with a federal strategy that should be developed by September 2025 and include measurable goals. The state strategies must be comprehensive, based on climate risk analyses, and be updated at least every five years – all criteria that were considered in this research's analysis of existing state adaptation strategies. With the law, the federal government has committed to supporting state efforts with the provision of data, research, and a coordinating role (BUMV, 2024). Thus, new questions arise in regard to if this federal legislation may help close the gaps identified by this dissertation research, which were non-binding goals and unclear strategies for adaptation in some states, or if new issues of misfit, or even lock-ins, may result from the changes.

Both within the field of climate change adaptation but also outside it there is a need for further research on lock-ins with new applications of the perspective to other policy areas, such as health or education policy. Additional explorations could add conceptual depth and clarity to the conceptualization of lock-in mechanisms and dynamics, while further illustrating the utility of the concept as an explanation for policy stability.

More specifically, further research is essential for deepening our comprehension of how lock-in dynamics contribute to adaptation deficits across diverse contexts. There is a need for more empirical evidence from different problem domains, countries, and levels of governance that illustrates if and how entrenched policies and practices inhibit effective climate adaptation. The investigation of the persistence of adaptation deficits would benefit from the identification and analysis of cases in which lock-ins have been successfully dissolved, in order to gather insights on strategies to break free from lock-in dynamics and enable change.

Furthermore, further research should explore the concept of beneficial lock-ins—i.e. positive feedback loops that promote sustainability and resilience. Such studies could reveal (if and) how governance interventions can be deliberately designed to create beneficial path dependencies that enhance long-term climate adaptation efforts. By expanding empirical (and conceptual) research in these areas, scholars can contribute to a more nuanced understanding of the conditions that hinder or foster effective climate adaptation, offering strategic guidance for policymakers seeking to close the adaptation gap and leverage positive lock-ins for future resilience (Bernstein & Hoffmann, 2018; Rosenbloom, Meadowcroft & Cashore, 2019).

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8. Appendix

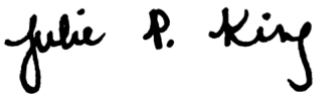
a. Offizielle Erklärungen

Ich erkläre hiermit eidesstattlich (gem. § 9 Abs. 3 Satz 3), dass ich die vorliegende Dissertation selbständig und ohne fremde unzulässige Hilfe angefertigt habe. Aus fremden Quellen direkt oder indirekt übernommenen Gedanken wurden als solche kenntlich gemacht.

Der Inhalt der Dissertation wurde nicht schon überwiegend für eine Bachelor-, Master-, Diplom- oder ähnliche Prüfungsarbeit verwendet.

Alle Regelungen zur guten wissenschaftlichen Praxis der Carl von Ossietzky Universität Oldenburg wurden befolgt.

Im Zusammenhang mit dem Promotionsvorhaben wurden keine kommerziellen Vermittlungs- oder Beratungsdienste (Promotionsberatung) in Anspruch genommen.



Julie P. King, Oldenburg, den 23.09.2024

b. Full Papers and manuscripts (All Open Access)

Paper 1:
"Sixteen Ways to Adapt: A Comparison of State-Level Climate Change Adaptation Strategies in the Federal States of Germany"

Regional Environmental Change

Paper 2:
"New challenges and established policy fields - Assessing stability and change in climate adaptation policy through a lock-in perspective"

der moderne Staat

Paper 3:
"Re-examining policy stability in climate adaptation through a lock-in perspective"

Journal of European Public Policy

Paper 4:
"Lock-in dynamics hindering climate adaptation for mental health"

Working paper / book chapter and Stellungnahme zur Einreichungsfähigkeit

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ORIGINAL ARTICLE

Sixteen ways to adapt: a comparison of state-level climate change adaptation strategies in the federal states of Germany

Julie P. King[1]

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Abstract
Climate change adaptation (CCA) to reduce or prevent negative climate change impacts and, in some cases, maximize potential benefits is a complex challenge demanding multi-level policy action. In federalist systems, sub-national governments are among key actors for enabling adaptation and their clear commitments can increase collaboration and innovation at the local level. Germany serves as a particularly insightful case for observing the variance among sub-national approaches due to its role as a "leader" in CCA at the national level. This paper provides the first systematic assessment of all sixteen state adaptation strategies in Germany and examines how German states are fostering adaptation, the extent to which their approaches vary, and which patterns have emerged. Based on a qualitative document analysis of over 30 documents, this assessment focuses on five indicators synthesized from literature climate policy analyses and on barriers and facilitating factors of adaptation. Results find that German state strategies are often non-committal sets of recommendations and identify three clusters displaying different degrees of institutionalization and guidance. While federalism allows for flexibility among state responses, the absence of federal mandates and policy standards allows some states to fall behind while others continue to develop their strategies to foster adaptation. These sixteen diverse approaches each have implications for adaptation governance at other levels.

Keywords Climate change adaptation · Germany · Policy analysis · State-level · Climate governance · Cluster analysis

Introduction

Climate mitigation and adaptation to climate change impacts are more urgently needed than ever, with extreme weather events becoming "the new normal" (Msuya, 2021). While many impacts manifest at the local scale, e.g., flash flooding, several impacts cross administrative boundaries, e.g., sinking groundwater tables, have cascading consequences for other administrative units, e.g., forest dieback exacerbating flood risks. Though there cannot be total protection from the impacts of climate change, which include extreme temperatures, torrential rains, and damaging storms, widespread and effective adaptation policies can help societies reduce their vulnerability to the impacts of climate change (Adger et al. 2005). Governments can be both initiators of policy innovations and enablers of broader society-driven measures, which gives them an "unparalleled capacity" to steer public governance and adaptation action (Biesbroek et al. 2018a, p. 778).

In the large and growing field of climate policy research, scholars have studied the emergence of climate change adaptation (CCA) policies and strategies. Previous assessments range in focus from international to municipal levels of governance. Numerous studies compare and assess national-level approaches and strategies (Biesbroek et al. 2010; Termeer et al. 2012; Heidrich et al. 2016; England et al. 2018; Jurgilevich et al. 2019) or the municipal level (De Gregorio Hurtado et al. 2015; Aguiar et al. 2018; Lesnikowski et al. 2019; Olazabal et al. 2019; Reckien et al. 2019). Yet, the sub-national level of governance remains underrepresented in climate adaptation policy research (Vogel et al. 2020; Biesbroek and Delaney 2020), especially considering the multi-level nature of the issue.

Climate change is a complex challenge with wide-reaching and diverse impacts across sectors, landscapes, and

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✉ Julie P. King
Julie.king@uol.de

[1] Carl von Ossietzky University of Oldenburg, Ammerländer Heerstr. 114-118, 26129 Oldenburg, Germany

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administrative borders (IPCC 2014). National government policy efforts, for example, play a crucial role in initiating adaptation at lower levels, particularly in unitary states (e.g., UK, Sweden, Finland) (Amundsen et al. 2010). However, the adoption of a national adaptation strategy does not guarantee the implementation of adaptive measures nor is it a prerequisite (Jurgilevich et al. 2019). National mandates for policies at the local level are shown to have a significant impact on the development of city climate policies, but compliance is not guaranteed (Reckien et al. 2018). In the absence of strong national or regional policies, cities with sufficient resources are more likely to initiate their own climate policies, but smaller municipalities often lack the capacity without support from higher levels (De Gregorio Hurtado et al. 2014, 2015). No single level of governance has been found at which climate change policy is most effective for substantial action (Jurgilevich et al. 2019). Like many complex environmental challenges, adaptation to climate change is intrinsically a multi-level matter that requires policy action at various levels of governance (Adger et al. 2005; Urwin and Jordan 2008; Bauer et al. 2012; Clar and Steurer 2019). Interactions across levels are inevitable but not yet well understood (Clar and Steurer 2019).

In federated states, such as Germany, Australia, Mexico, India, Nigeria, and the USA, sub-national governments often wield the authority of certain policy sectors. Within the climate change mitigation discussion, sub-national governments are recognized for their pivotal role (Hsu et al. 2020). In several policy areas, which affect mitigation *and* adaptation, states have the power to instigate action through their jurisdiction over the municipalities (Vogel et al. 2020). In contrast to most local governments, state governments are equipped with larger administrations, more financial resources, and a broader scope than single municipalities. Thus, research to date suggests that this authority combined with more resources makes state governments, as one of several levels, key actors for fostering adaptation action particularly in small- and medium-sized municipalities. Their clear commitments to adaptation can increase collaboration and innovations in local adaptation efforts (Mimura et al. 2014; Jurgilevich et al. 2019; Vogel et al. 2020). Analyses by De Gregorio Hurtado et al. (2015), Heidrich et al. (2016), and Reckien et al. (2018) provide evidence that policies at higher levels of government can positively influence the actions of lower level governments. These findings and consensus among scholar highlighting the importance of action at *all* levels of government in tackling the climate crisis indicate the need for a better understanding of adaptation policy action at the sub-national level.

Roughly 40% of the global population lives in federal countries, which together constitute almost 50% of global landmass (Forum Fed 2021). A greater understanding of the role of state governments in this multi-level challenge may offer lessons how other federal states, especially those in which adaptation is a newer issue, may (better) guide both national and sub-national CCA policy. Examining sub-national[1] CCA policies could offer new insights on adaptation deficits commonly observed by adaptation researchers (Ford and Berrang-Ford 2016; Runhaar et al. 2018). This particular analysis lays the foundation for further investigations of causal relationships and interactions with contextual conditions and other levels of policy and their impact on adaptation action.

Germany provides a fruitful example for analyzing sub-national adaptation policy with more than a decade of evidence and stable support for adaptation at the national level of government (Otto et al. 2021). Germany is considered an "early adopter" and "leader" on adaptation planning at the national level (Massey et al. 2014; Lesnikowski et al. 2020). Due to this reputation, its ample resources, and a policy approach relying on strategies as a dominant policy instrument, Germany poses a rich, multi-level case for analyzing the role of states' strategies in stimulating adaptation. Furthermore, existing research on climate policy at other levels in Germany provides additional context to enrich the discussion in this paper on multi-level governance and adaptation policy (Heidrich et al. 2016; Reckien et al. 2018; Otto et al. 2021).

The following research questions are central to this analysis: how are German state CCA strategies fostering adaptation, to what extent do policy approaches and commitments vary within the federal context, and what patterns have emerged? The research therefore responds to the call for comparative adaptation research, in this case within a single country, that analyzes adaptation policies more comprehensively than insights on the specific types of policy mixes (Lesnikowski et al. 2019) and examines the heterogeneity possible in the federalist system.

From literature on evaluating and designing climate policies and research on facilitators of and barriers to adaptation, the research establishes a framework for assessing and comparing state CCA strategies based on five core indicators: (i) *climate impacts and vulnerability assessments*, (ii) *sectors addressed*, (iii) *policy goals and commitments*, (iv) *institutional organization and coordination*, and (v) *plans for policy adjustments.* These indicators aim to capture factors for fostering adaptation throughout policymaking cycle: from agenda setting to evaluation and policy adjustments. The selection of these indicators is explained in more detail in "Analytical framework."

Adaptation is institutionalized in diverse ways from mainstreaming to stand-alone policies, and diverse approaches

[1] Hereafter referred to as the "state level," which describes the German *Bundesländer*.

help fit individual contexts (e.g., cultural setting, administrative traditions, policy styles) (Heidrich et al. 2016; Biesbroek et al. 2018b). Concepts of effectiveness and success are normative and contingent on goals, which themselves are subjective or in some cases absent (Adger et al. 2005; Dilling et al. 2019). Rather than rank the sixteen states according to their strategies which would suggest a superior approach to adaptation policy, the comparison seeks to map diversity within a single country and identifies similar approaches using a cluster analysis. Drawing on results from research on national- and local-level adaptation policies, the discussion reflects on the role of state-level strategies and their impact on adaptation at other levels of government.

Analytical framework

The analytical framework applied in this paper is a synthesis of indicators drawn from literature on the emergence of climate adaptation policies and their evaluation (De Gregorio Hurtado et al. 2014; De Gregorio Hurtado et al. 2015; Heidrich et al. 2016; Aguiar et al. 2018; Reckien et al. 2018; Jurgilevich et al. 2019; Olazabal et al. 2019; Otto et al. 2021), literature on common barriers to and facilitators of climate adaptation (Smit and Wandel 2006; Moser and Ekstrom 2010; Measham et al. 2011; Eisenack et al. 2014; Uittenbroek 2016; Runhaar et al. 2018; Howlett et al. 2019; Russel 2019; Young and Essex 2019; Vogel et al. 2020), and adaptation progress and effectiveness tracking (Ford and King 2015; Berrang-Ford et al. 2019; Owen 2020). These streams of adaptation literature overlap and often complement each other. The chosen indicators were selected because they are proliferous in these literatures and have been proven useful for characterizing and mapping CCA strategies. These five indicators are certainly not exhaustive of all of the factors determining whether adaptation takes place but provide a comprehensive basis to assess and capture the nature of adaptation strategies, which serve as cornerstones and manifestations of states' policy approach to CCA.

Adaptation strategies serve as strategic policy instruments for continuous commitment to prepare for and cope with changing conditions and coordinate CCA in various sectors. Serving as potential initiators for long-term policy changes within multiple sectors (Clar and Steurer 2019), this analysis examines strategies' diverse approaches to adaptation policy based on five indicators for analysis: (i) *the use of climate change data and vulnerability assessments*, (ii) *sectors and areas of action addressed*, (iii) *policy goals and commitments*, (iv) *institutional organization and coordination*, and (v) *plans for policy adjustments and continuous action*. Drawn from the aforementioned convergent literatures on emerging CCA policies, facilitators and barriers to adaptation, and adaptation tracking, these indicators were chosen with the aim of capturing the extent to which they are suited to fostering adaptation in the respective states. Within the literature on facilitators and barriers to CCA and discussions surrounding the emergence of CCA policies, it became evident that common barriers emerge in different phases of the policy cycle. Similar to Biesbroek et al. (2010) and their analysis of European national adaptation strategies, these five indicators holistically include the different phases of policymaking: from scientific data as the basis for informed policymaking to the depth of policy goals and their institutionalization to monitoring and reevaluation as an opportunity for policy adjustments and tools for iterative planning. Indicators along these policy phases help indicate trends among state CCA strategies.

The first indicator identified is the *use of regional climate change data and vulnerability assessments.* Several studies have shown that scientific data on regional climate impacts and the assessment of regional vulnerability provide an important starting point for effective adaptation policies and act as a driver for CCA (Smit and Wandel 2006; Dupuis and Knoepfel 2013; Massey et al. 2014). Conversely, the lack of knowledge on potential impacts of climate change has been identified as a barrier (Aguiar et al. 2018; Young and Essex 2019). Not only do knowledge and awareness of vulnerabilities allow for the development and planning of adequate measures (Olazabal et al. 2019), but they also provide the framing for action. Understanding of the costs of inaction, not just economically, helps prioritize needs and build acceptance for action (Ford and King 2015). In a systematic review of CCA case studies, Owen (2020) found awareness for and solutions to issues of social justice and equity were often missing in adaptation initiatives and research analyses. Therefore, this indicator explores the use of analyses and concepts that capture the differentiated aspects of vulnerability (ecological, economic, and social aspects) within the broader IPCC definition as the composite of exposure, sensitivity, and adaptive capacity (Adger 2006; Smit and Wandel 2006).

The second indicator for comparison is the breadth of the *sectors or areas of action addressed*. Assessments of national and city adaptation policies have documented the range of sectors and, in some cases, considered the diversity of measures as positive indicators (Biesbroek et al. 2010; De Gregorio Hurtado et al. 2015; Aguiar et al. 2018; Otto et al. 2021) Huitema et al. (2016) explain how trade-offs are tied to the breadth of climate adaptation policies: problem or sector-specific policies may miss conflicts with other policy areas, while broader policies may not result in immediate outputs. Though the necessity for adaptation within a sector or problem domain depends largely on its vulnerability, the omission of certain sectors in comprehensive strategies may be indicative of intentional choices or priorities. For the cluster analysis, this indicator is represented by the variable

"stand-alone strategy" which refers to a multi-sectoral policy focused on adaptation.

The third indicator for fostering adaptation consists of *policy goals and commitments.* This includes the formulation of high-level policy goals, the identification of measures, and the extent of commitment to stated goals. Binding commitments to adaptation can foster policies at lower levels, though compliance cannot be guaranteed (Reckien et al. 2018; Wenta and McDonald 2019). Vogel et al. (2020) argue, "Regional governments making clear and firm commitments to adaptation as an important and ongoing policy priority creates the governance conditions for interjurisdictional collaboration and local innovations in adaptation efforts" (p. 1636). Alternatively, unclear and vague goals and the lack of political commitment have been identified common barriers to adaptation implementation (Aguiar et al. 2018; Runhaar et al. 2018; Howlett et al. 2019). Policy goals do not alone lead to adaptation implementation, but the formulation and explicitness of goals provide a basis for action. Rather than a simple box-checking procedure, this indicator examines the specificity of goals and if measures for their achievement are suggested. Both the identification and prioritization of measures and timeframes for their implementation are taken as variables for the specificity of goals (similar to Olazabal et al. 2019 and Otto et al. 2021), which fosters adaptation action (Owen 2020). Finally, this important indicator helps illustrate the nature of states' approaches to adaptation from state mandates with binding goals to recommendations for voluntary action to the informative strategies without policy goals.

The fourth indicator examines the *institutional organization and coordination* of state CCA, which serves to capture both who is responsible and who is involved in CCA policies. Clear authorities, institutionalization, and coordination are key for fostering adaptation (Biesbroek et al. 2010; De Gregorio Hurtado et al. 2014; Ford and King 2015; Aguiar et al. 2018; Runhaar et al. 2018; Berrang-Ford et al. 2019; Howlett et al. 2019; Olazabal et al. 2019; Young and Essex 2019; Owen 2020). Here, institutional organization refers to the working groups, committees, or departments formed or assigned to coordinate or focus on CCA. Empirical evidence suggests that adaptation efforts are more effective when an interagency group oversees adaptation activities or when one agency coordinates intra-organizational efforts (Biesbroek et al. 2010; Ford and King 2015). Coordination, as part of this indicator, may range from the cooperation, e.g., the exchange information, to collaboration, e.g., co-production of a common governance strategy (McNamara 2012). Particularly in the mainstreaming approach, cooperation and coordination are found to help achieve policy goals (Huitema et al. 2016) and their absence found to be a barrier (Runhaar et al. 2018; Jurgilevich et al. 2019; Russel 2019). Because Germany's national strategy and many other federal initiatives emphasize the cross-cutting nature of adaptation and call for an integrated approach (Stecker et al. 2012), part of this indicator is whether the strategies' development and implementation extend outside of the leading state environmental ministries, either horizontally, with other state-level actors, or vertically, with national or local actors and actors.

The fifth and final indicator evaluates *plans for policy adjustments* in the form of strategies' inclusion of plans for monitoring, reassessment, and continued action. Adaptation is an ongoing process that itself must adapt to new scientific data and contextual changes (Ford and King 2015; Owen 2020). It is not linear with an endpoint but rather a continuous and cyclical process (Smit et al. 2001; Owen 2020). This indicator reviews the inclusion of plans, learning mechanisms, and processes in the adaptation strategies to reassess goals and measures, evaluate implemented interventions, and, if neccessary, readjust them. Olazabal et al. (2019) include this indicator as "learning mechanisms," within "scientific and technical credibility" and Otto et al. (2021) consider these aspects in their indicator on "plans." Progress assessment is key to the reduction of vulnerability and thus a central element of adaptation (Termeer et al. 2012; Berrang-Ford et al. 2019; Jurgilevich et al. 2019).

For a comprehensive list of variables within each of the indicators, a table of codes and sub-codes is included in the electronic supplemental material (Online Resource 2).

Methods

Case study focus on Germany

In accordance with the subsidiarity principle in Germany and considering the regional nature of climate change impacts, the authority and responsibility for adaptation are situated at the state and local levels (Bundesregierung 2008). In samples by Reckien et al. (2018) and Otto et al. (2021), between roughly one-quarter and one-third (respectively) of German cities were found to have CCA policies, with medium and smaller cities less likely to have adaptation strategies. To date, no research has examined the emergence of state CCA policies. Germany's National Adaptation Strategy (DAS) does not mandate but rather requests the states develop adaptation strategies and calls for the integration of climate change in all policy areas. A report from the Conference of the State Environmental Ministers (2008) emphasizes the role of state governments and explicitly calls for the development and implementation of regionally specific strategies to adapt (Bundesregierung 2008). As a key actor in climate change policymaking and agenda setting, state-level strategies for CCA provide an important foundation for assessing adaptation progress across Germany.

The German Environment Agency provides overviews of state documents, projects, and activities on their website, but does not evaluate their progress based on selected criteria or benchmarks in any publicly available reports. The first Federal Progress Report on climate adaptation summarized state activities in succinct, single paragraphs that described rather than assessed the selected examples (Bundesregierung 2015). In peer-reviewed literature, some papers analyze adaptation efforts in single-problem domains (e.g., Blättner et al. 2020; Grecksch 2013) or focus on individual states or regions (e.g., Ebermann 2020; Häußler et al. 2020). Therefore, this paper presents the first country-wide assessment of German state-level adaptation strategies. Because adaptation strategies are often considered the key hub of adaptation policymaking and interact with other levels (Clar and Steurer 2019), this analysis examines state-level CCA strategies based on the analytical framework presented in the last section and their implications for fostering adaptation state-wide and at lower levels of government. Thus, the analysis offers transferable insights on outcomes of a non-binding national policy recommendation in the context of a federal democracy, in which ample resources and political will for CCA are present at the national level; sets the groundwork for further analyses; and may offer lessons for other federated states that have yet to develop adaptation strategies.

Data collection and analysis

The research is based on a qualitative document analysis (as described by Bowen 2009) of German state adaptation strategies. Adaptation strategies refer to written plans of action for multiple sectors that establish a vision for adaptation and either recommend, promote, or mandate specific actions to be undertaken by the state and other governance actors within the state. In some cases, strategies for adaptation were embedded within climate mitigation strategies or sustainable development plans.

Documents were selected based upon the following criteria: a focus on climate adaptation or combined climate mitigation and adaptation strategy, coverage of more than one sector, and published by a state government or ministry. Multiple documents were selected for states that have updated their strategies or released separate documents as part of the same strategy. State laws with a focus on climate policy and paragraphs on climate adaptation were also included. These strategic documents serve as cornerstones and manifestations of states' policy approach to CCA. Project reports, single-sector strategies, or sub-state-level regional strategies were excluded from the analysis. In total, 34 government documents were analyzed. The documents were primarily downloaded from the German Environment Agency's website and state websites but partially acquired by email from state ministries in cases of broken links or for older versions of updated strategies. An overview of the primary sources is included in the electronic supplemental material (Online Resource 1).

The second step of analysis was an iterative assessment process, in which I subjected the data to a thematic analysis and coded according to the five criteria, with sub-codes developed therein to reflect nuances in the data and provide structure for their analysis. This process was supported by keyword search, which served to ensure that no data was missed in the coding of the documents. Coded data were then transferred to spreadsheets for sorting and analysis.

In order to identify patterns among state adaptation strategies, in the final step of analysis, I performed a cluster analysis (similar to those of De Gregorio Hurtado et al. 2015 and Otto et al. 2021). For this, I translated qualitative data into binary quantitative data, where 0 stood for the absence of the variable and 1 for its presence. This was done for 8 variables: use of climate change impact data; performance of a vulnerability assessment; stand-alone CCA strategy; formulation of binding goal(s); set timeframe for implementation; legal commitment to CCA; designation of leading authority for CCA; and plans for continuous action. These variables represent all five indicator areas with an emphasis on policy goals and commitments (as the focus of one research question) and the addition of the presence of a stand-alone strategy. Using this data set (see Table 1), I conducted a hierarchical cluster analysis for the 16 states using the Gower's general dissimilarity coefficient and Ward's method of agglomeration. These were applied to minimize within-group variance while maximizing between-group dissimilarity, and by graphical inspection, it was decided to cut three clusters (Figs. 1 and 2).

Findings: German state adaptation strategies

As of 2021, all sixteen federal states of Germany have strategies or recommendations for adapting to climate change. Strategies *either* are solely focused on adaption to climate change for multiple sectors (56% of the states) *or* have integrated adaptation within climate mitigation or sustainable development plans. The approaches vary in detail from extensive strategies, including climate change projections, risks, impacts, potential measures, and evaluation procedures, to short paragraphs in strategies not solely related to CCA. Based upon the chosen indicators, the majority of states solidly base their strategies on scientific data and vulnerability assessments, have designated authorities for coordinating adaptation and plans for continuing efforts in place, but often lack explicit and binding goals and commitments (see Table 1). In this section, subsections are not structured

Table 1 Summary of the presence (1) or absence (0) of variables in state adaptation strategies with arranged by clusters

Indicator	Variables	Schleswig–Holstein	Saarland	Brandenburg	Mecklenburg-West Pomerania	Saxony	Hesse	Saxony-Anhalt	Bavaria	Lower Saxony	Baden-Württemberg	Bremen	Rhineland-Palatinate	Hamburg	North Rhine-Westphalia	Thuringia	Berlin	%
i	Regional data on CC impacts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100%
	Vulnerability assessment	0	0	0	0	0	1	1	1	0	1	1	1	0	1	1	1	56%
ii	Stand-alone CCA strategy	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1	56%
iii	Formulation of binding goal(s)	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	25%
	Implementation timeframe	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	38%
	Legal commitment to CCA	1	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	44%
iv	Designated authority for CCA	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	63%
v	Continuous action plan	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	75%

strictly by the five indicators but by relevance and the results of the cluster analysis.

Policy goals and commitments

Overall, state strategies tend to be informative, loosely coordinating, and non-committal. Seven states (44%) have solidified commitments to adaptation through legislation (see Table 1). Of these, three (19%) have binding goals. Berlin, for example, made its "Energy and Climate Protection Program" binding with the 2017 amendment to the *Berlin Energy Transition Act* (2016) and selected 20 measures to be completed or in progress by 2021. North Rhine-Westphalia passed the *Climate Adaptation Act* in 2021 (Landtag Nordrhein-Westfalen 2021), which commits to implementing adaptation measures and legally anchors other existing institutional commitments. Executive decisions in four states call for CCA action through the creation of a CCA strategy, but these decisions are less binding than legislative decisions, i.e., laws. All other state strategies are either explicitly non-binding recommendations or ambiguous in the level of commitment with no evidence of executive or legislative action.

All strategies include at least one or more overarching goals to adapt to the impacts of climate change. These range from data collection and vulnerability analyses, such as "providing the executive and legislative branches of government with information and advice on the need to act and potential adaptation measures" (own translation, Mecklenburg-Vorpommern 2010, p. 3), to high-level agenda setting, e.g., "integrate climate change adaptation into the general performance of state duties" (own translation, Nds. MU 2012) to more specific formulation of policy goals, e.g., "decrease vulnerability and increase robustness, protect the residents […] and to avoid the costs of damage from climate change impacts" (own translation, Bremen 2018). Stated policy goals display a diversity of detail, scale, and scope, yet the majority of aims are formulated in a manner that their progress would be difficult to measure. A quarter of strategies contain any kind of binding goals, half of which are city-states.

All strategies describe adaptation measures at varying lengths of detail. Data for this indicator signifies diverse approaches among states, in that some identify and prioritize specific measures and their implementation, while others present potential measures that state and other actors could consider. Lower Saxony's recommendations include roughly 590 highly detailed measures, of which 380 could be carried out by state-level authorities. However, the implementation strategy states that the prioritization of measures and descriptions of the conditions necessary for their implementation were intentionally excluded from the process (Nds. MU 2013, p. 6). Similar to the goals, state documents display a heterogenous mix of measures ranging from data collection to highly specific tasks such as "liming forest soils," for example.

Fig. 1 States colored by cluster, with green states as the highest levels of institutionalization of CCA and yellow states with the lowest degrees of institutionalization

Institutional organization and coordination

The majority (63%) clearly state which institutions or newly established committees coordinate state CCA actions and initiatives. Several states have multiple working groups and committees focusing on CCA policy and sectors. In contrast, Brandenburg and Saarland have no institutions or working groups mentioned in their strategic documents that explicitly focus on adaptation.

As for vertical coordination, the documents provide scattered evidence referring to the local, county, regional, national, and European levels. The city-state strategies (Berlin, Bremen, and Hamburg) inherently include the local level in the nature of their administrative structures. A quarter of states report the inclusion of representatives from cities and municipalities in the participatory process of strategy development (e.g., North Rhine-Westphalia) or in established working committees (e.g., Saxony-Anhalt). Almost all state documents refer to federal strategies and efforts or funding, embedding their strategies in the national context, and 19% mention participation in national working groups and forums. Horizontal coordination, such as exchanges with other states or participation in national networks, is mentioned in less than 35% of strategies, and roughly 45% of state strategies document coordination between state-level actors within their states.

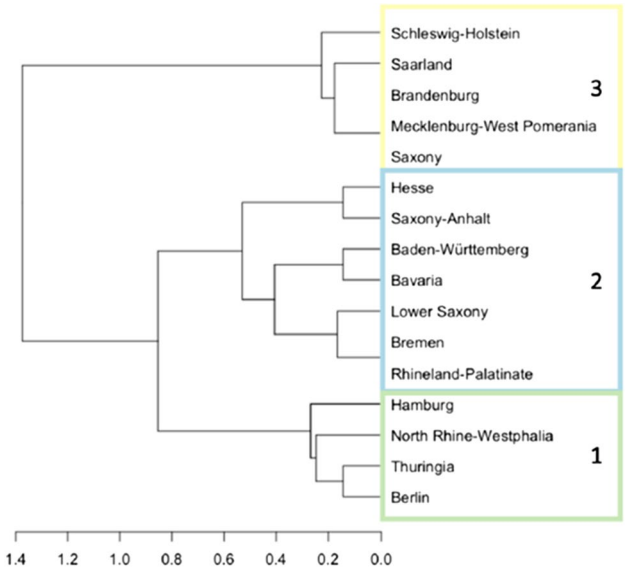

Fig. 2 Dendrogram of clusters with the numerical scale measuring dissimilarity

Impacts, vulnerability, and sectors addressed

All state strategies draw on climate change data and 81% include regionally specific data and/or projections. Though the majority use the concept of vulnerability and 56% reference vulnerability assessments, fewer states (44%) evaluate the vulnerability of individual sectors. Berlin's strategy contains the most in-depth analyses of vulnerability (Reusswig et al. 2016). It includes the ecological, economic, and social aspects of vulnerability and also considers indirect impacts (e.g., climate refugees, negative effects on international trade and tourism, and damage to European energy grids). At the other end of the spectrum, Brandenburg does not explicitly reference vulnerability in any form. The remaining state strategies display varying degrees of risk and vulnerability awareness and refer often more implicitly ecological, social, and economic aspects of vulnerability. Social aspects of vulnerability are rarely considered, and the economic and ecological costs of inaction are often only implicit.

The DAS identifies fifteen areas of action for adaptation, but the sixteen federal states display a wider range of sectors, subsectors, and action areas. Table 2 displays the breadth of areas of sectors in state CCA strategies. These relate to their exposure to climate change impacts but also their geographic characteristics (city-states, e.g., Berlin, do not have large agricultural areas). Water management is the only area of action included in all state CCA strategies and often includes multiple subsectors, e.g., flood protection, surface water, groundwater, and/or water quality. With the exception of Bremen, which structures the strategy by humans, natural environment, and built environment, all other state strategies are structured by sectors and subsectors.

Continuous action

Twelve states (75%) include plans for continuing CCA strategies. Among these states, 44% aim to reassess their plans in the light of new scientific data or other types of knowledge. Calls for new reports and strategies range in timeframes between 2 and 5 years. Thuringia solidified its commitments to adaptation by including requirements of monitoring and adaptation planning reassessments at least every 5 years in its *Climate Mitigation and Adaptation Act* (Thüringer Landtag 2018). In contrast, although Saxony-Anhalt has no explicit plans for continuous monitoring and reassessment, updated strategies and implementation reports have been published every 2 to 4 years since 2010.

Four states' (25%) strategies show no concrete plans for continuing or reassessing but often call for further research and monitoring of climate change impacts. Saarland and Mecklenburg-West Pomerania have not added or adjusted stand-alone policies for CCA in over a decade. In Lower Saxony, on the other hand, the state parliament gave an Interministerial Working Group the task of presenting progress reports every 2 years. The last report was published in 2015 and includes information on which measures were still planned, in progress, finished, or dismissed as unnecessary or unfeasible (Nds. MU 2015), but since then no reports have followed.

Patterns among state approaches to adaptation

The cluster analysis based on eight central variables of the indicators (see Table 1) identified three similar clusters (see Figs. 1 and 2). Cluster 1, in green, includes four states whose strategies include a legal commitment to CCA, have designated bodies for CCA, set implementation timeframes, and plan for continuous action. Two of these four states are city-states. North Rhine-Westphalia does not have a stand-alone strategy in that adaptation is in a strategy integrated with mitigation, but it also has sector-specific adaptation strategies. States in this cluster can be characterized as having *coordinated, directed strategies* for climate adaptation. In this cluster, the majority of states also have conducted vulnerability assessments, created stand-alone strategies, and formulated binding goals for adaptation. Cluster 2, in blue, is made up of seven states whose strategies often (86%, or 6 of 7 states) designate bodies dedicated to CCA and plans for continuous action. In this cluster, six states have a stand-alone strategy for CCA, but none has binding goals and the majority no timeframe for implementation or no legal commitments. This cluster consists of states with *loosely coordinated, informative strategies* for climate adaptation. Finally, cluster 3, in yellow, includes five states who have no vulnerability assessments (but data on climate impacts), no stand-alone CCA strategies, no timeframe for implementation, no designated authority, and often (20% or 1 of 5 states) no plan

Table 2 An overview of areas of action (sectors) addressed in the state climate change adaptation strategies. "X" means sector is included; n/a means not applicable (states without coastline). Areas of action mentioned in two or fewer strategies were omitted from the table. Some state names have been abbreviated: Mecklenburg West Pomerania (MWP), Baden-Württemberg (BW), Rhineland-Palatinate (RP), and North Rhine-Westphalia (NRW)

Sectors	Brandenburg	Saarland	Schleswig–Holstein	MWP	Saxony	Lower Saxony	Hesse	Saxony-Anhalt	BW	Bremen	Bavaria	RP	Hamburg	NRW	Thuringia	Berlin	Total	Federal
Water management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	16	X
Coastal risk management	n/a	n/a	X	X	n/a	X	n/a	n/a	n/a	X	n/a	n/a	X	n/a	n/a	n/a	5	X
Human health	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	15	X
Nature/biodiversity	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	15	X
Agriculture	X	X	X	X	X	X	X	X	X	X	X	X		X	X		14	X
Planning and development			X		X	X	X	X	X	X	X		X	X	X	X	12	X
Forestry/forests	X	X	X	X		X		X		X	X	X	X	X	X		12	X
Energy sector		X		X	X	X	X	X	X	X	X			X	X	X	12	X
Economy/industry			X		X	X	X	X	X	X	X		X	X		X	11	X
Soils	X		X		X	X		X		X		X	X	X	X		10	X
Tourism				X		X		X	X	X	X			X	X	X	9	X
Emergency services/disaster protection					X	X	X	X			X		X	X	X	X	9	X
Building/housing					X	X	X	X		X	X			X	X		8	X
Transportation	X	X		X	X	X	X	X						X	X		9	X
Education/research	X					X	X	X					X	X		X	7	
Recreation/culture							X	X		X					X		4	
Fishery				X		X		X						X			4	X

for continuous action. In this cluster, Schleswig–Holstein is the only state with a legal commitment to CCA, in that 2017 *State Climate Act* called for the development of a state adaptation strategy and its implementation (§10, Innenministerium SH), but as of 2021, this strategy does not exist. This cluster is characterized by *uncoordinated, informative strategies* and approaches to adaptation.

Discussion

State strategies for fostering climate adaptation in Germany

Through the analysis of German state CCA strategies based on the five indicators, this paper provides several insights on approaches to adaptation and reveals a number of variations. Table 1 shows that no two state strategies are the same with each state fulfilling different sets of indicators. Findings from the cluster analysis help summarize three general directions states are taking to foster climate adaptation. The minority of state strategies (25%) show *coordinated, directed strategies* (cluster 1) whereas clusters 2 and 3 are more informative and provide less clear direction and lower levels of ambition for state-wide goals and commitments.

Cluster 1 (*coordinated, directed*) shows the highest levels of institutionalization of climate adaptation with clearer, and often binding, goals providing direction for adaptation action. These goals provide directions which are underpinned by legal commitments and the structures in place to coordinate their implementation. Notable in this group is that both Hamburg and Berlin are city-states, which may be an advantage for coordinating and institutionalizing adaptation. These four state strategies are comprehensive in depth and breadth, both temporally and structurally, and the indicators show they are well developed throughout all of the

phases of the policy cycle. Based on the importance of clear authorities, goals, and measures; established institutional structures; and learning mechanisms for continuous action for facilitating CCA (as suggested by, e.g., Olazabal et al. 2019 and Owen 2020), the states in this cluster are most clearly using strategies as instruments for fostering adaptation at state level.

The largest and most internally diverse cluster is cluster 2 (*loosely coordinated, informative*). Compared to the states in cluster 1, these states (≈44% of all states) are more loosely coordinating adaptation with multi-sector strategies and voluntary goals. These strategies are informative and but do not mandate any top-down policies. Bavaria, for example, is a rather representative example from cluster 2 in that its strategies provide ample data, recommended sector goals, and potential measures but have no leading authority for coordinating adaptation and clearly state the overarching goal of helping actors help themselves. Empirical evidence indicates that clear guidance from the central government helps increase local prioritization and support of CCA (Young and Essex 2019). The absence of such clear guidance in some states may later prove to become problematic. Based on the indicators, these strategies themselves are less likely to foster adaptation, but it is possible that other instruments are in place to foster adaptation.

Among the states, cluster 3 (*uncoordinated, informative*) strategies show the lowest levels of institutionalization of adaptation. None has designated authorities and continuous action. Nor do these five states' (≈32% of all states) have stand-alone adaptation strategies. Reasons for this could be different in each state and cannot be explained by this analysis. Explanations could be lack of political will, lack of recognition for coordinated action, or a mainstreaming approach not captured by the assessment of multi-sectoral strategies. Saxony has the most recent plans with adaptation embedded in its Energy and Climate Protection Strategy, but Brandenburg, Saarland, and Mecklenburg-West Pomerania have not developed publicly available strategies for over a decade and have not progressed beyond the identification of climate change impacts for their states. Schleswig–Holstein has a short "road map" for adaptation that documents sectoral and project-based measures but has yet to deliver a stand-alone state strategy. In this cluster, adaptation documents are largely from single ministries (as opposed to state governments or from interministerial bodies). The isolation of adaptation within one department is also shown to be a barrier (Young and Essex 2019). Based on the findings of this analysis, these states' strategies are the least likely to foster adaptation, though other instruments to foster adaptation may be in place.

Consistent among the state strategies are the use of regional climate change data for identifying current and future impacts and the sector-based approach to adaptation (with the exception of Bremen). These approaches model after the federal adaptation strategy and reports, which identify impacts of climate change for different sectors and regions and recommended areas of action. From the analysis of the sectors, it is apparent that "classic" areas for adaptation—water management, nature, human health, and agriculture—are virtually omnipresent in all state strategies. For these topics, horizontal coordination with other states and participation in national networks could help states advance their adaptation planning, yet roughly a third document doing so in their strategies. Common areas for improvement include more attention to social vulnerability and the formulation of measurable goals. Even the states in cluster 1 did not fulfill all of the indicators and sub-codes, i.e., facilitating factors for CCA. Finally, another trend independent of the clusters is weak inclusion of the local level in state strategies. Though several strategies mentioned the importance of local level actor and planning procedures, a stronger emphasis on multi-level action and institutionalized coordination could help further foster adaptation.

State-level policies and multi-level governance of climate adaptation

Climate adaptation scholars acknowledge the importance of multi-level action and diverse, context-specific approaches in adaptation governance (e.g., Adger et al. 2005; Urwin and Jordan 2008; Jurgilevich et al. 2019). Although there is some evidence on the diffusion of climate policies between governments and among levels (e.g., De Gregorio Hurtado et al. 2014; Jordan and Huitema 2014; Heidrich et al. 2016; Kammerer and Namhata 2018), interactions between levels of government and their implications for adaptation are not well understood (Clar and Steurer 2019). For the case of Germany, this analysis offers a first step for further investigations of these interactions between national-, state-, and local-level adaptation strategies and action.

All sixteen states show varying degrees of agenda setting and institutionalization of adaptation, and each of these strategies will have implications for lower levels of government. Municipalities across Germany therefore have different incentive structures and starting points, in terms of information and guidance. Particularly in the cluster of *uncoordinated, informative* strategies, communities are not under pressure to develop and implement adaptation policies and are thus free to act, or not act, as they choose. Larger cities are more likely to have the resources to produce adaptation policies on their own (De Gregorio Hurtado et al. 2014, 2015), but smaller cities and communities in these states may be at a disadvantage. Alternatively, the two states that are not city-states in the *coordinated, directive* cluster have higher ambitions for adaptation but also little power to steer adaptation in sectors with higher concentrations of local level authority (e.g., urban

planning and zoning). The state commitments and goals provide direction and information for adaptation at the local level but are not formulated in a manner that requires lower levels of government to produce their own policies or plans.

More than a decade has passed since the first federal strategy (DAS) and recommendations for states to develop adaptation strategies, yet this analysis demonstrates the diverse stages of progress and varying commitments among the states. While some states are steadily progressing and fostering adaptation, others have not pursued state-wide adaptation strategies. In Germany, the DAS and federal adaptation activities are iterative with progress reports and updates to action plans every 4 to 5 years. Reckien et al. (2018) show that cities are five times more likely to have adaptation plans if there is a national mandate to do so, but there is not yet evidence (to the author's knowledge) of national mandates for state CCA plans and their potential impact on lower levels. This leads to the question if Germany or other federal nations will continue to incentivize and encourage state-level adaptation policies, leading to regionalized deficits, or if at some point, if the federal government will introduce harder instruments and mandate adaptation policies.

Limitations and future research

This framework and analysis are not without limitations. The exclusion of sector-specific policies may also have resulted in the omission of data relevant for the assessment of state CCA strategies. Though some states' current and past versions of CCA strategies were analyzed, the indicators do not capture temporal developments within states' strategies. Furthermore, the qualitative document analysis applied here could not capture relevant data on informal activities or internal documents.

Beyond the indicators within this analytical framework, there are several other factors at play both enabling and hindering adaptation policy and their implementation. Further research should explore which of the state governments implement their strategies more quickly, effectively, or with higher levels of acceptance, and which attributes these more effective policy approaches share. One aim of this research was to lay the foundation for further investigations of causal relationships and interactions with contextual conditions and other levels of policy and their impact on adaptation action, which could provide insights for adaptation policies and planning at multiple levels both within and outside of Germany.

Conclusion

This research analyses and compares state climate adaptation strategies in Germany, based on five indicators: (i) climate impacts and vulnerability assessments, (ii) sectors addressed, (iii) policy goals and commitments, (iv) institutional organization and coordination, and (v) plans for policy adjustments and continuous action, and finds diverging approaches more and less likely to foster adaptation. Three clusters emerged and are described as *coordinated, directed* strategies; *loosely coordinated, informative* strategies; and *uncoordinated, informative* strategies.

By following through on commitments to reassess and further develop CCA strategies and with continued support from the federal government, most German states may have the strategies and structures to foster climate change adaptation. However, the absence of nationally regulated standards for state CCA strategies has thus far resulted in substantial variation in the strategic planning of individual states in Germany. Research on the implementation of the strategies and the impacts of realized measures will be the final assessment of their strategies' coordination and institutionalization of adaptation at state level.

Evidence from the document analysis displays a wide range of levels of commitment and attention to detail throughout various policy phases among the sixteen states. The use of climate change data, the breadth of areas of action, and the creation of oversight committees for CCA coordination are commendable in the majority of states. Comparative analysis has identified common challenges at certain phases of the policy cycle (e.g., agenda setting and passing legislation) and thus highlights gaps that are common barriers to CCA, such as unclear or non-binding goals. The diversity of sixteen policy approaches to similar challenges sheds light on the flexibility inherent in federal polity as both an opportunity and a challenge for adaptation as a multi-level issue. National-level reliance on recommendations rather than regulations does not lead to country-wide progress.

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Nicolas W. Jager, Julie P. King, Bernd Siebenhüner

New challenges and established policy fields – Assessing stability and change in climate adaptation policy through a lock-in perspective

Abstract
Impacts of climate change, such as sea-level rise and changes in annual precipitation, are becoming increasingly visible around the world and within Germany, thus increasing pressures to adapt. Forces of stability and change within established policy fields greatly determine the extent to which governance systems can adapt to worsening existing risks and new challenges. Employing a lock-in perspective and a comparative analysis of the governance of coastal risks in Schleswig-Holstein and water scarcity in Thuringia, we show how infrastructures, institutions, actors, and cognitive framing shape policy landscapes and together constitute dynamics of policy stability and change in the face of long-term climate impacts. This paper offers a comprehensive, systemic perspective of how adaptation challenges fit into established policy paradigms and programs as it highlights how non-material and material components are intertwined and can act as constraints to policy-making.

Keywords: Climate Change; path dependency; institutional change; adaptive governance

Zusammenfassung
Neue Herausforderungen in etablierten Politikfeldern – Eine Analyse von Stabilität und Wandel in der Klimaanpassungspolitik anhand einer Lock-in-Perspektive
Die Auswirkungen des Klimawandels, wie etwa der Anstieg des Meeresspiegels oder zunehmende Dürre und Wassermangel, werden vermehrt auch in Deutschland spürbar und erzeugen einen wachsenden politischen Handlungsbedarf. Widerstreitende Kräfte von Wandel und Stabilität innerhalb etablierter Politikfelder bestimmen dabei, inwieweit sich bestehende Governancesysteme an diese neuen Herausforderungen und Klimarisiken anzupassen vermögen. Mithilfe eines Lock-in-Ansatzes und einer vergleichenden Analyse zweier Fallstudien zur Governance von Küstenrisiken in Schleswig-Holstein und von Niedrigwasser in Thüringen verdeutlicht dieser Beitrag, wie das Zusammenspiel von Infrastrukturen, Institutionen, Akteuren und kognitiven Frames die Stabilität bzw. den Wandel etablierter Politikfelder vor dem Hintergrund langfristiger Klimarisiken beeinflusst. Damit zeigt dieser Beitrag eine übergreifende, systemische Perspektive auf, um zu erfassen, inwieweit bestehende Politikfelder mit ihren etablierten Programmen und Paradigmen fähig und geeignet sind, neuen politischen Problemlagen zu begegnen, und wie materielle und immaterielle Faktoren den politischen Handlungsspielraum begrenzen.

Schlagwörter: Klimawandel; Pfadabhängigkeit; Institutionenwandel; Adaptive Governance

1 Introduction

The policy topography of policy fields and issues (Jones & Jenkins-Smith, 2009) is characterized by a constant tension between the stability of established fields, their paradigms and programs, and the dynamics of emerging issues that challenge the established order (Blätte, 2015). Navigating this tension between policy stability and change is one of the persistent puzzles of public policy research, which is particularly pronounced within the field of climate change adaptation (Groen, Alexander, King, Jager, & Huitema, 2022; Jordan & Moore, 2020; Siebenhüner & Djalante, 2021). The monumental challenges of mitigating and adapting to anthropogenic climate change can be considered, first and foremost, as governance challenges (Huitema et al., 2016). Climate change impacts, such as sea-level rise, extreme weather events, and the spread of new diseases, affect a wide array of policy fields. These risks pose challenges to established policy solutions and often require new responses or even transformative change (Benz & Czada, 2019). Adaptation policies have emerged both in the form of standalone policies and instruments or as mainstreamed goals and measures integrated into existing policies, without one approach being more effective than the other (Runhaar, Wilk, Persson, Uittenbroek, & Wamsler, 2018). In the face of limited adaptive action on the part of policy-makers and authorities (Noble, 2019), policy change, transformation, and their conditions are often the focus of attention (e.g. Stecker, 2015). However, to fully understand the – often absent or selective – policy responses to climate change, research interest is turning towards forces of policy stability and the ways in which emerging climate change challenges interact with established paradigms, strategies, and routines (Siebenhüner, Grothmann, Huitema, Oels, Rayner, & Turnpenny, 2021; Teebken, 2022).

Against this background, the aim of this paper is to explore how adaptation challenges emerging with intensifying climate change interact with established policy fields and how forces of policy stability and path dependency respond to the pressing need for change and transformation. Specific attention is paid to (a) the ways in which emerging challenges fit into established policy paradigms and programs within a field, and (b) the mechanisms that determine this fit.

To this end, we adopt a lock-in perspective (Pierson, 2000; Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016; Unruh, 2000). This perspective considers the stability of established policy fields and focuses on "the tendency for past decisions and events to self-reinforce, thereby diminishing and possibly excluding the prospects for alternatives to emerge" (Fleurbaey et al., 2014, p. 312). It helps capture the tension between policy stability and change by explaining the self-perpetuating dynamics within established policy fields, offering the analytical tools to assess how these systems react to emerging challenges and problem pressures. Grounded in a complex systems approach (Cairney, 2012; Room, 2011), the lock-in perspective strives for a wider, more holistic view of the system under consideration (Cairney & Geyer, 2015). Under this perspective, established institutions, behaviors, infrastructures, and technologies stabilize and reproduce themselves through path-dependent processes of increasing returns at both the social and individual levels, inhibiting more profound changes of policies and practices (Unruh, 2000). This extended focus is fruitful for studying climate adaptation because non-material components – such as framing, knowledge systems, and behaviors –, and material components – such as technologies and infrastructures –,

are particularly relevant to adaptation issues and can act as constraints to policy-making (Derwort, Jager, & Newig, 2021).

Following the delineation of our conceptual background in section 2, we approach our research aim in sections 3 (methods) and 4 (case analysis) through a comparative case study design. We consider two distinct climate adaptation issues in two German states highly impacted by climate change: (1) sea-level rise and coastal erosion in Schleswig-Holstein, and (2) drought and water scarcity in Thuringia. While the climate change impacts are substantial in both cases, policy responses differ in their consideration of path-deviating strategies. Hence, these two cases provide fruitful settings for exploring how lock-in dynamics affect the fit of established policy fields and emerging challenges and determine the opportunity space for policy responses.

2 Conceptual background

In order to assess and understand the fit between established policy fields – i.e. specific and permanent constellations of interrelated issues, actors, institutions and framings (Blätte, 2015; Loer, Reiter, & Töller, 2015) – and emerging challenges, we apply a lock-in perspective. This perspective differs from other explanations of stability and change, such as those around the genesis and maturation of new policy fields (Loer, Reiter, & Töller, 2015; Massey & Huitema, 2013), in that it focuses on the stabilizing forces of existing policy fields that resist change rather than the emerging policy issues entering the established field. It aims to uncover the dynamics and mechanisms through which current policy fields, their paradigms, strategies, and practices reproduce and systematically rule out alternative approaches. Analyzing these reproduction mechanisms helps to show how stability hinders policy change, and how emerging challenges and pressures, such as climate adaptation, fit into established policy fields.

2.1 Lock-in perspective

While the lock-in concept is rooted in complexity studies (Cairney, 2012; Room, 2011) and evolutionary economics (Arthur, 1989), its influence grew in various disciplines, such as science and technology studies (Foxon, 2011), innovation and organizational studies (Sydow, Schreyögg, & Koch, 2009), climate and energy research (Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016), and political science and public policy (Pierson, 2000). In each discipline the perspective is used to explain why and how established systems remain stable and resistant to change despite surmounting pressure and the existence of superior alternatives. The central driver of this resistance lies in the idea of self-reinforcement, where “preceding steps in a particular direction induce further movement in the same direction” (Pierson, 2000, p. 252), reproducing established societal arrangements and gradually closing the envelope of future choices (Rosenbloom, Meadowcroft, & Cashore, 2019). Within public policy, self-reinforcement mainly unfolds through institutional choices by social, economic, and political actors. These actors establish patterns of interest and normative commitments through their policy decisions that cumulate into institutional legacies and then constrain options, thus shaping future courses of action (Room, 2011). Accordingly, policy feed-

back serves as an important entry point for policy analyses to understand how policies themselves affect politics and subsequent policy decisions by shaping and limiting policy processes (Jordan & Matt, 2014).

Given its multi-disciplinary roots, one characteristic of the lock-in perspective is that it integrates institutional and policy dynamics within a wider complex systems perspective, which includes material (e.g. infrastructures, technologies), human actor, and non-material (e.g. knowledge, cognitive frames) dimensions (Hegger, Runhaar, Van Laerhoven, & Driessen, 2020; Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020). In this integrative perspective, "lock-in occurs when interlinkages or feedbacks between these different components collectively create system stability and resist – by design or consequence – the integration of environmentally or otherwise superior technologies and configurations" (Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020, p. 3). Hence, the lock-in perspective goes beyond a reductionist viewpoint, i.e. a limited focus on a specific problem aspect or a subsystem, and relies on a non-linear causal logic of change and stability. Therefore, this approach is suitable for capturing complex societal dynamics of, for example, feedback between policy and technological dynamics.

As mentioned in reference to the wider systems perspective, accumulating observations indicate that lock-ins often manifest across system dimensions, for example, through behavior, institutions, or technologies (Kotilainen, Aalto, Valta, Rautiainen, Kojo, & Sovacool, 2019; Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016). Following recent studies and conceptualizations (Hegger, Runhaar, Van Laerhoven, & Driessen, 2020; Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020), we also hypothesize that lock-ins are created through four distinct but interrelated dimensions that guide this analysis. These are rooted in the understanding of climate adaptation to take place in a social-technical system comprising of material and non-material factors, with the latter including both structural and agency-related elements:

(1) *Technologies and infrastructures*: Established technologies and infrastructures, such as the layouts of settlements, traffic or power grids, or flood defense infrastructure, may literally set specific policy options in concrete while ruling others out. Built infrastructures are often subject to considerable initial investments that are envisaged to amortize over often decade-long lifecycles, leading to considerable financial imperatives to commit to these infrastructures, at least until capital is recovered (Erickson, Kartha, Lazarus, & Tempest, 2015). Another issue pertains to the asset-specificity of certain technologies, which refers to technologies being built for a single purpose (Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016). This also concerns the supporting and related infrastructures which, technologically, may rule out the removal or construction of other types of infrastructure. Beyond their material characteristics, infrastructures are often deeply interlinked with institutions and expose patterns of co-dependence: infrastructures have been shaped by regulatory patterns reflecting the ideas, discourses and knowledge of certain periods (Siebenhüner, Grothmann, Huitema, Oels, Rayner, & Turnpenny, 2021). New technologies, in turn, may be disruptive and not fit these established patterns (e.g. incompatibility between electric vehicles and established fueling stations), so that established technologies and infrastructures can become physical barriers to policy change and to the adoption of alternative solutions (Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020).

(2) *Institutions*: Formal institutions, such as policies, regulations and standards, but also strategies, plans and roadmaps, guide and constrain collective and individual behavior (North, 1990). Such institutions are designed to provide stability and predictability to societal interactions (Scott, 2014), and once established they may be hard to change and persist for long durations (Unruh, 2000). Powerful decision-making actors often consciously construct institutions for specific purposes and, in some cases, with the intention of reinforcing the status quo or a trajectory that favors their particular interests. Intentional or not, some formal institutions have spillover effects for other policy fields and societal realms (e.g. historical heritage protection laws preventing adaptation measures from improving unhealthy urban climates), in which cases their seemed permanence may be seen as problematic or suboptimal from a societal welfare perspective (Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016).

(3) *Actors and agency*: Actors, their interests, networks, and power are of particular relevance for understanding lock-in and policy stability (Sandén & Hillman, 2011). Power disparities between actors serve as significant drivers for institutional lock-in dynamics, as incumbent actors with vested interests can hamper change and reinforce current trajectories (Geels, 2014). Additionally, actors may coalesce in networks and form advocacy coalitions by sharing knowledge, resources, and beliefs, thus, reinforcing existing cognitive frames (Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020). These networks among policy-makers, bureaucracies, and interest groups constrain unfettered dialogue and learning. Hence, through this self-reinforcing pattern, incumbent actors' influence can grow over time and further sediments a particular policy trajectory, even if that trajectory is considered suboptimal from other perspectives.

(4) *Knowledge and cognitive frames*: Questions of what is known and how issues are framed provide powerful sources of lock-in (Simoens, Fuenfschilling, & Leipold, 2022). Knowledge and competences are often the cumulative result of previous decisions and actions that spur learning and expertise in a specific direction (Pierson, 2000). Once set, alternative policy trajectories requiring new knowledge and different skills become less likely to gain acceptance due to high cognitive switching costs and actors' attachment to certain approaches, related knowledge and competences (Kotilainen, Aalto, Valta, Rautiainen, Kojo, & Sovacool, 2019). Often, predominant knowledge is part of larger cognitive frames, i.e. "underlying structures of belief, perception, and appreciation" (Schön & Rein, 1994, p. 23) or set into larger "narratives" (Shanahan, Jones, McBeth, & Lane, 2013). These frames set the boundaries for how situations are interpreted and problems are perceived, and what is deemed as acceptable or desirable action (Buschmann & Oels, 2019; Foxon, 2011). In consequence, lock-ins occur where frames have a "blinding effect" (Trencher, Rinscheid, Duygan, Truong, & Asuka, 2020, p. 4) excluding alternative ways of seeing a situation and related ways of action.

These four dimensions serve as analytical categories for mapping and diagnosing existing lock-ins in established policy fields and for our assessment of problem and policy fit in the cases of emerging challenges of climate adaptation. While each of these dimensions in themselves constitute important sources of lock-in, in reality, they overlap and interact, cumulating into larger dynamics of self-reinforcement and lock-in (Groen,

Alexander, King, Jager, & Huitema, 2022; Seto, Davis, Mitchell, Stokes, Unruh, & Ürge-Vorsatz, 2016). Hence, beyond describing each dimension separately, our analysis further elaborates on their interlinkages to arrive at a nuanced picture of stability and change and the multi-dimensional drivers that determine this relationship.

3 Methods

To meet its aims this research takes a case study approach. The problems arising from climate change impacts (i.e. sea-level rise and water scarcity) and state-level governance form our main unit of analysis. Building on and operationalizing our understanding of policy fields, we define this unit of analysis as a 'problem domain'. Following Arts, Leroy and van Tatenhove (2006), a problem domain refers to the topography of actors, resources, rules, and discourses surrounding and related to a collective problem. This approach is particularly appropriate for examining adaptation challenges as an emergent and nondelineated policy issue often spanning several sectors. In Germany, the authority to adapt to climate change impacts often lies with federal states (*Länder*) and municipalities. Due to the regional, rather than local nature of sea-level rise and drought, and considering the administrative resources of federal state governments compared to municipalities (King, 2022), this research focuses on state-level policy responses to adaptation challenges.

Based on a qualitative document analysis of state climate adaptation strategies (King, 2022) and interviews with national-level adaptation experts conducted between January and February 2020, two case studies were selected based on the following criteria: states' respective climate vulnerability; evidence of adaptation efforts; recency and scope of available documents and data; and statements and opinions from scoping interviews. Coastal risks and water scarcity were chosen because they represent different natures of policy issues: coastal risks (i.e. sea-level rise, coastal erosion, and flooding) have a long history in coastal protection and do not pose new challenges per se but now incorporate increasing risks due to climate change, whereas drought and water scarcity pose a new or at least severely intensified challenge to states which have historically had higher risks of inland floods than of insufficient water supplies (van Rüth, Schönthaler, von Andrian-Werburg, & Buth, 2019). Schleswig-Holstein and Thuringia have been selected as emblematic cases of these developments. While Schleswig-Holstein resembles a mature policy field and can look back on several centuries of coastal protection, drought and water scarcity have only recently landed on Thuringia's nascent policy agenda. Yet, in both cases considerable policy action is under way. Hence, this case selection represents varying – institutional and infrastructural – starting conditions when it comes to climate adaptation and thus is deemed instrumental to highlight the diverse lock-in dynamics, their implications for policy and problem fit, and ultimately their impact on policy stability and change.

Data was derived from both document analysis and semi-structured interviews with key policy actors (see *Table 1*, N=18). Documents included policy statements, legislation, strategies and plans as well as scientific reports and academic research papers. Interviews provided additional data not found in the documents and were conducted by videoconference and telephone between November 2020 and January 2021 (Schleswig-Holstein) and August 2021 and June 2022 (Thuringia). The majority of interviewees

were selected primarily by their roles within relevant organizations or prominence in the analyzed documents, but a few contacts were recommendations acquired through snowball sampling (Parker, Scott, & Geddes, 2019). Interviews typically lasted around an hour and were recorded, transcribed, and analyzed using thematic analysis (Fereday & Muir-Cochrane, 2006). Co-developed in an iterative process using both theory-based and data-based codes, a shared coding protocol helped the two coding researchers to ensure consistency in identifying themes. The protocol departed deductively from the lock-in dimensions identified in section 2, but also included the inductive search for mechanisms influencing the fit of emergent challenges within established policy fields. These were then discussed in the author team to assure comparability of both cases. In this way, we aimed to combine the conceptual ideas of lock-in thinking with the empirical openness of case-based research.

Table 1: Summary of organizations represented by interviewees (abbreviations will be used for referencing in the text)

Scoping interviews on federal level (N=4)	
German Federal Environmental Agency German Federal Institute of Hydrology Academic experts (2)	
Schleswig-Holstein (N=10)	**Thuringia (N=8)**
State Ministry of the Environment (2) – SH01, SH02 State Administration of Coastal Defense and the National Park – SH03 State Ministry of the Interior (2) – SH04, SH05 Dike and Drainage Association – SH06 NGOs (3) – SH07, SH08, SH09 Academic expert – SH10	State Ministry of the Environment – TH01 State Administration of the Environment, Mining, and Nature Protection (2) – TH02, TH03 Reservoir Operator – TH04 NGOs –TH05 Water maintenance association – TH06 Academic expert – TH07 Industry representative – TH08

Source: Own illustration.

As a method suited for identifying causal mechanisms to explain a situation or outcome as it develops over time – here patterns of policy change and stability –, process tracing was used to analyze the collected data (Collier, 2011). Starting from 2021 for both case studies, we systematically traced backwards (as far as inferentially deemed necessary to explain current outcomes) through documents, supported by interview data, to look for mechanisms behind perceived barriers to policy change. Although other contextual factors and singular barriers were considered in the analysis of the fit of emerging challenges into existing policy, this research primarily focuses on the mechanisms found to largely determine that fit. Hence, our analysis may less be considered as a complete picture of the situation in each case but rather concentrates on the self-reinforcing dynamics that determine change and stability within the studied policy fields.

4 Case analysis

In this section we begin with a succinct but necessary context on each of the adaptation challenges in our selected case studies: coastal risks in Schleswig-Holstein and water

scarcity in Thuringia. Following the context, we present findings from both case studies structured by the four dimensions of lock-in in mechanisms (technologies and infrastructures, institutions, actors and agency, knowledge and cognitive frames) that affect the fit of the different adaptation challenges with the existing policy landscapes.

4.1 Adapting to Coastal Risks in Schleswig-Holstein

As a consequence of climate change, sea-level rise exacerbates existing coastal risks, which include storm surges, flooding, and coastal erosion and necessitate adaptation (OECD, 2019). In the face of future sea-level rise, there is growing recognition that traditional coastal management relying on 'hard defenses', such as dikes and seawalls, may not be environmentally, economically, and socially sustainable long-term. Alternative approaches to defending the land from water could include ecosystem-based adaptation, accommodation ("living with the water") or even resettlement (Fritsch et al., 2021). In Germany and Schleswig-Holstein, in particular, coastal protection is a mature policy field reflecting centuries of work and developments. Here, we focus on the North Sea coast where the authority for coastal protection lies primarily with the state government and agencies (Bisaro, de Bel, Hinkel, Kok, Stojanovic, & Ware, 2020). If all updates and installations are implemented as planned, the approach is expected to mitigate flood risks until at least 2100 based on the data project for the worst case scenario of IPCC reports, RCP8.5 (MELUND, 2022).

Infrastructures along the North Sea coast and islands of Schleswig-Holstein play a central role in the state's approach to mitigating coastal risks which shaped the coastline and landscape over thousands of years. On the mainland, 407 km of dikes protect low-lying areas from flooding which are home to 140,000 inhabitants and 28.5 billion Euros of capital assets (MELUND, 2022). With use of weirs and sluices to drain the inland and the continual reinforcement and heightening of dikes in preparation for rising sea levels, investments both into the infrastructures themselves and the settlements they protect have increased over time. The value of material assets in the flood-risk areas of the North Sea coast has increased by roughly 40% between 2012 and 2022 (MELUND, 2022; MELUR, 2013). Through these investment decisions cost-benefit ratios shift as increasing returns (flood safety) incentivize continued spending in defense activities. Annually, 74 million Euros of funding go towards coastal defense, with 52% from the state, 37% federal funds, and 11% from the EU, and costs continue to grow with increasing material costs (MELUND, 2022).

Formal institutions provide the underpinning for the defense-based approach to coastal risks via the *State Water Act,* as the legal basis for coastal defenses to provide for the "general welfare" (LWG, 2008, §63 (1)), and via the "Master Plan for Coastal Defense" which sets standards and procedures for the maintenance of the line of defense and is renewed every ten years to include new data and document investments (MELUND, 2022). Here the planning and approval processes are outlined, including necessary consultations of local populations and stakeholders for substantial changes to the defense infrastructure. The "Master Plan" outlines the primary strategy for adapting to current and future sea-level rise: "climate dikes," which will protect 90% of the flood-risk areas and inhabitants for up to one meter of sea-level rise and can retrofitted to maintain current safety levels to two meters of sea-level rise (ibid.). The most recent

"State Development Plan" designates priority areas behind the dikes, in which adaptation measures, such as dike alterations, have priority over new structural installations or other land uses (MILIG, 2021).

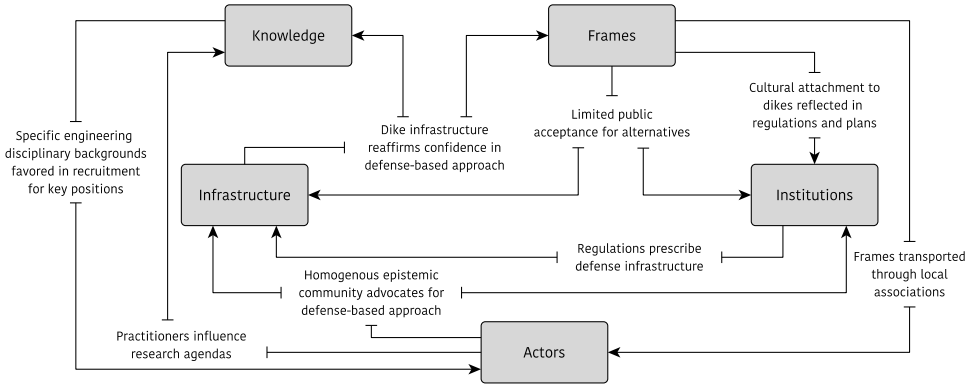
While *actors and agency* for coastal adaptation can be found on multiple governance levels and involves a number of stakeholders, the central actor is the Ministry of Environment (MELUND), which is responsible for strategic planning of coastal defense. Below it, the State Agency for Coastal Protection wields operational responsibilities for monitoring and maintaining coastal defenses. Often trained in hydrological and coastal engineering, the state servants within these bodies have close ties with a coastal engineering research network and even co-design research agendas (SH01, SH10). Dike and drainage associations consisting of landowners and volunteers help maintain infrastructure for coastal protection and drainage of the hinterlands. These regional and local organizations often embody social communities in coastal towns and therefore have both practical (e.g. maintenance of infrastructures) and social value (i.e. as local clubs with traditions and social events) (SH06, SH10).

Cognitive frames and a largely homogenous *knowledge base* contribute to the continued domination of technical approaches to coastal risks (SH09, SH10). Over centuries, the long-term reliance on and mainly successful use of dikes for habitable land and safety has become embedded in regional tradition and part of cultural identity for some, as demonstrated by a known adage that roughly translates "whoever doesn't maintain their dikes, must go."[1] These ingrained values indicate a widespread cognitive frame helping prevent alternative adaptation approaches from gaining the necessary public acceptance (SH07, SH10). Near the city of Husum, for example, a proposal for dike realignment and the re-design of a polder to allow for salt marsh creation failed to win local approval despite the economic and ecological benefits (Hofstede, 2019). Such outcomes impede future considerations of alternative approaches when decision-makers assume they will fail to gain the necessary public acceptance or deem them taboo and refuse to discuss them in the first place (SH08).

Here we identify a mechanism where framing and assumptions around what is considered acceptable determine outcomes and operate in a self-reinforcing manner, whereby actors opt for the familiar choice based upon past decisions. The homogenous epistemic community of practitioners and decision-makers, as mentioned in multiple interviews (SH09, SH10), is an example of a mechanism of framing (re)production (Groen, Alexander, King, Jager, & Huitema, 2022). Homogenous values and knowledge systems co-evolve and reproduce, thus reinforcing commitment to defense-based adaptation and its dominance in training and education programs (SH01, SH03). Furthermore, learning effects reinforce this mechanism as the continuation of established practices, procedures, and implementation of defense-based interventions helps optimize knowledge, skills, and routines. These dynamics are further illustrated in *Figure 1*.

The self-reinforcing lock-in mechanisms described here are not the only factors at work in the policy landscape addressing coastal risks in Schleswig-Holstein (see Groen et al., 2022) but constitute significant sources of stability in the policy field. Efforts to change the system, i.e. diversify the portfolio of measures to adapt to increasing coastal risks beyond the defense of the coastline (e.g. accommodation or even retreat), mainly exist outside of state-based activities and plans (i.e. nature advocacy groups or academic research), which pursue the long-term commitment to dikes.

Figure 1: Illustration of lock-in dynamics in coastal adaptation in Schleswig-Holstein



Source: Own figure after the example of Trencher et al., 2020.

4.2 Adapting to drought and low water in Thuringia

The subsequent hot and dry years of 2018, 2019 and 2020 immediately brought awareness to the threats and impacts of droughts and heat waves. This was especially the case in central and eastern regions of Germany and the state of Thuringia where "Germany's driest city" Artern (Macherowecz & Sußebach, 2020) is located. Impacts of this dry period can already be observed in ground and surface water levels and in reduced soil moisture, which have serious consequences for ecosystems and human water use (TLUBN, 2020). While these impacts appear to be exceptional, worst-case projections for the region show that such climatic conditions could become the new average in the near future (2025-50) (TLUBN, 2020). Hence, significant policy and management efforts are needed to adapt to these changing environmental conditions.

Water *infrastructure* in Thuringia comprises of more than 200 storage and drinking water dams and reservoirs, wells, and a wide-spread water distribution system (TMUEN, 2022). These infrastructures were often built for different purposes other than addressing scarcity and drought, such as mitigating flood risks or providing drinking water (TLUBN, 2020) and often are intended to operate with different water levels. This also includes established urban water infrastructure, which is usually designed to drain water quickly, rather than retaining water in settlements for local use (TH07). The functionality of these infrastructures came under considerable stress during the dry period between 2018 and 2020. In 2018, drinking water reservoir levels fell as low as 68% to 41% of their capacity levels (TLUBN, 2019), and private and commercial water abstraction had to be restricted in parts of the state (TMUEN, 2022). Despite this considerable water stress, basic system functions, such as the provision of drinking water and wastewater treatment, could be maintained, as e.g. water from reservoir dams was available to compensate for insufficient supply by dried-out drinking water wells (TLUBN, 2019). Since then, the functionality of water infrastructure has come under scrutiny, and abandoned small-scale storage ponds (*"herrenlose Speicher")* have regained attention as potential means for drought mitigation by retaining water in the landscape and thus providing water for agricultural or other uses (e.g. TH02, TH06).

Hence, as interviewees maintained (TH05, TH07), water infrastructure in Thuringia does provide some resilience against changing climatic conditions but may not be able to fully counterbalance the grave and extensive future climate impacts.

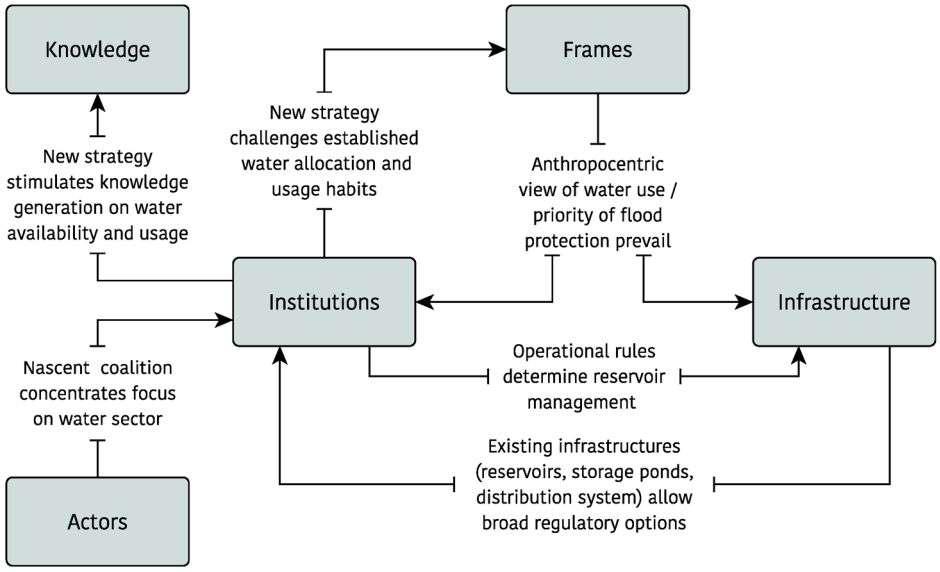
Like infrastructures, *institutions* and regulations were initially drafted under different climatic conditions when the main concern about water quantity was about flooding with scarcity playing a rather minor role. For instance, regulations of the operation of storage water dams, some of which are decades old, prescribe fixed water levels for winter and summer seasons in order to mitigate the risk of winter floods (TH02). Yet, with changing precipitation patterns in the wake of climate change, these fixed rules appear increasingly outdated, leaving much of the winter precipitation unused and less leeway in summer levels. Similarly, abstraction rights in the past were allocated long-term and in bulk, and actual withdrawals were not systematically metered (TMUEN, 2022). This approach changed only recently in the aftermath of the recent dry years. Water scarcity management became a continuous task within the Ministry of Environment and the state environmental administration in 2020, and a first water scarcity strategy ("*Niedrigwasserstrategie*") was issued in May 2022 (TMUEN, 2022), to be updated every six years together with the state water program. Within eight priority areas of water governance (drinking water, water budgeting, abstraction, reservoir management, water efficiency, retention, water ecology, early warning), the strategy lists goals and measures worth 2.6 million Euros (ibid.) for the next six years on how to adapt to changing water availability. In its basic principles, the strategy prioritizes drinking water supply over all other water usage forms, while not prioritizing any other water uses.

In line with the policy nascence, the contours of the *actor* landscape within water scarcity governance have only recently begun to develop. Water departments at the Ministry of the Environment and the subordinate state agency take a leading role in shaping the field and drafting the scarcity strategy (TH01, TH03). At this stage, the strategy narrowly focuses on the water sector, while acknowledging interlinkages and co-dependencies with other sectors, such as forestry or spatial planning. This initial narrow focus, as interviewees indicated (TH01, TH03), was intended to establish administrative structures and basic principles to address water scarcity while gaining attention for the problem and momentum for its management, which should, at a later stage, include further sectors and actors. Distinctive coalitions among other actors, such as water users or other stakeholders do not appear to have yet manifested, despite affectedness during the last dry periods. Rather, stakeholders have acknowledged the general issue and welcome the initiative to establish regulatory clarity but are also cautious of the regulatory, environmental, and economic consequences (TH05, TH08).

Most of the measures – almost three quarters – included in Thuringia's drought strategy are steps for monitoring, capacity building, or conceptualization in the different priority areas, illustrating that *knowledge* generation is one of the most pivotal tasks for the next years. In fact, information on e.g. water availability projections, demands, and withdrawals is lacking or dispersed throughout different administrative branches preventing a coherent and integrated perspective up to this point (TH01). Accordingly, *cognitive frames* and narratives around scarcity appear rather nascent and little sedimented among actors. Instead, established frames and priorities from other problem areas appear influential. For example, for the management of reservoirs and dams, flood protection continues to be the main concern determining operation routines (TMUEN, 2022), which can be interpreted as a result of learning effects around these practices.

Yet, despite the early stage of the policy issue, initial framing and paradigms have emerged. Instead of a focus strictly on water supply for the allocation of water use rights, the scarcity strategy includes a set of focal areas and also places responsibility on water users to reduce their demand. Water will no longer be allocated freely by volume irrespective of how it is used but instead considering standards based on best practices for most efficient and technically-feasible water use (e.g. drip instead of sprinkler irrigation) (TH01). This implies a considerable change in the valuation of water. However, through its initial limitation on the water sector, the water strategy transports and reproduces certain problem frames (despite these shifts) as depicted in Figure 2. As some interviewees highlight (TH05, TH07), the strategy relies on a rather anthropocentric perception of water use, where nature and natural processes are perceived at the end of a chain and one of many water demands, rather than as an integral part of the water cycle and thus also part of water supply. Even though this focus is intended to be broadened at a later stage (TH01, TH03) the current narrow framing sets the scene for scarcity being perceived as a problem of water supply and demand, undervaluing the integrated nature of the issue and the complex feedback effects between the water cycle and the different water and land use practices (Totsche, 2021).

Figure 2: Illustration of lock-in dynamics in water scarcity governance in Thuringia



Source: Own figure after the example of Trencher et al., 2020.

5 Discussion and conclusions

Our analysis of the two case studies through the lock-in perspective revealed insights on the fit between existing policy paradigms, programs, and adaptation challenges as well as how the four dimensions (technologies and infrastructure; institutions; actors and agency; and knowledge and cognitive frames) both individually and collectively

constitute sources and reifications of lock-in mechanisms that act as stabilizing forces despite pressure for policy change. We identify selected differences in the dynamics of the more historically-rooted policy field of coastal risks in Schleswig-Holstein as compared to the nascent issue of water scarcity in Thuringia. Despite these differences, however, we also find similarities in lock-in dynamics and their stabilizing forces.

At first glance, our findings indicate that both cases display neither a perfect fit nor a complete misfit. Adaptation efforts between both cases differ considerably regarding their financial and thematic scope. While Schleswig-Holstein alone invests more than 38 million Euros per year (excluding significant federal and EU funding) in its coastal protection, activities under the new water scarcity strategy in Thuringia have a budget of mere 2.6 million Euros for six years. From these figures alone, it could be assumed that the policy field of coastal protection in Schleswig-Holstein is well-equipped for climate change and thus fits well for addressing future challenges of climate change. In practice, though, adaptation efforts in Schleswig-Holstein are concentrated on a smaller range of established, mainly infrastructural measures. These are expected to be sufficient for mitigating increasing coastal risks until the end of the century (MELUND, 2022) but it remains unclear if and for how long it can be considered financially reasonable and sustainable (Bisaro, de Bel, Hinkel, Kok, Stojanovic, & Ware, 2020). On the other hand, the portfolio of focal areas in Thuringia is more diverse, also envisaging considerable shifts in established water distribution practices, which however have yet to become manifest. Based on our findings, we argue that policy and problem fit are more complex than binary, but multi-layered and the product of several factors and dynamics, including but not limited to financial and political resources.

This complex understanding of fit becomes even more comprehensive when comparing the different underlying, self-reinforcing dynamics between framings, actor arrangements, institutions, and infrastructures. In considering *Figures 1* and *2*, it becomes apparent that the case of Schleswig-Holstein is much more entangled, as shown by the number of connecting arrows between the different dimensions of lock-in, than the case of Thuringia. In the coastal case, established frames, actor coalitions, and knowledge systems, in interaction with dominant dike infrastructure, each play a pivotal role in reproducing stability and moderating change. These strong, intertwined forces of stability can be seen as a sign of maturity of the policy field that developed over decades and has sedimented as the current coastal protection regime. The policy landscape of the more nascent issue of water scarcity in Thuringia looks quite different. Interconnections between the various lock-in dimensions are sparser and much more centered around institutions. Since cognitive frames, knowledge systems, and actor coalitions are less established and still developing, they are more easily influenced by emerging strategies and activities or are developing in reaction to those new activities and institutions. Hence, our results suggest that policy stability and change may not be discrete, linear processes but rather the result of multiple, interlinked dynamics involving political institutions and actors, but also drivers beyond the actual policy system, such as infrastructures and cognitive frames.

Apart from these differences, which are likely influenced by their different stages of maturity, the two cases also show similarities. While studies of lock-in so far raised significant attention to technologies and infrastructures (e.g. Klitkou, Bolwig, Hansen, & Wessberg, 2015), here we find that actors and agency as well as knowledge and cognitive frames are the sources and drivers of many of the lock-in mechanisms we observe in Schleswig-Holstein and Thuringia (see also Teebken, 2022). In both cases we could ob-

serve how knowledge systems or cognitive framings provide the foundation for institutional and infrastructural choices that are made by decision-making actors and reproduced by other stakeholders. In Thuringia, for example, despite recent droughts between 2018 and 2020, framings in water supply or urban water management often perceive 'too much water' to be the dominant threat rather than 'too little water.' This framing laid the foundation for formal rules, such as the allocation of water rights and regulations of water tables in reservoirs, which can no longer be considered sustainable. Similarly, in Schleswig-Holstein the notion of 'fighting the sea' and defending the coast by keeping water out has also long constituted the framing of coastal risk management. Therefore, potential adaptation approaches like accommodation, with measures such as controlled flooding and 'living with the water' (Baumeister, 2021) are considered infeasible and undesirable by both decision-makers and other stakeholder groups. Consequently, institutions and infrastructures are crafted accordingly. These examples and the identified mechanisms indicate that cognitive frames and knowledge systems are a highly influential dimension, carry high potential as sources of lock-in mechanisms and with that determine the fit of established policy fields to emerging issues of climate change.

Given this significant role of cognitive frames and knowledge systems in reproducing lock-in and ultimately determining the fit of policy fields to the challenges of climate change, the question arises how such lock-ins can be broken up or 'unlocked'. Where lock-ins may be less entangled, such as the case of water scarcity in Thuringia, policy change may be easier to implement than in more matured fields such as coastal protection in Schleswig-Holstein. In the latter cases, our insights suggest dominant framings and knowledge systems, as well as actor coalitions as potential entry points for interventions. These dimensions can also be considered deep leverage points within systems and thus have potentially strong influence on systems' behavior (Abson et al., 2017). Diversifying knowledge systems or actor involvement could be one fruitful avenue for unlocking, as also suggested in the literature on transformative climate governance (Hölscher & Frantzeskaki, 2020).

Insights of this study are subject to limitations. As analyses of path dependency and lock-in reconstruct longstanding and multi-faceted historical processes, a comparative study approach, such as the one used here, is only able to provide a snapshot of these complex dynamics. Hence, findings from our study should rather be considered as a comprehensive illustration of the systemic forces of policy stability and change that may determine future trajectories of climate change adaptation. They serve to highlight the added value that a lock-in perspective provides to capture these systemic forces that span across many, often separately regarded material, institutional, and actor dimensions.

In this paper, we study the case of climate adaptation as an emerging or increasingly urgent policy issue that inherently stimulates processes of change, stability and continuity within concerned established policy fields. In order to answer the question on the interaction and tension between policy stability and change and the fit of established policy fields to mounting climate risks, this paper has identified nuanced dynamics of fit within existing policy fields. Our study indicates that policy stability and change are not discrete, linear processes but rather the result of multiple, interlinked dynamics involving institutional, but also technical and infrastructural dimensions embedded in long-standing framings and knowledge systems. Hence, we see the added value of the lock-in perspective in that we could in more detail shed light on the mechanisms through which these multi-layered dynamics unfold and culminate into self-

reinforcing lock-ins, ultimately feeding back into policy fields and establishing patterns of stability and change in the face of new challenges. Subsequent studies may pick up this thread and dive deeper into the complex self-reinforcing mechanisms that drive lock-in in the respective cases, or include additional cases, e.g. from renewable energy policy or biodiversity governance, to distil patterns of the ways and conditions under which lock-ins unfold and determine the fit of existing policy fields to emerging issues.

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Note

1 German: "Wer nicht will deichen, muss weichen"; in regional dialect „Keen nich will dieken, de mutt wieken" translates roughly to 'whoever doesn't maintain their dikes, must go'.

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Contact the authors:

Dr. Nicolas W. Jager, Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstr. 114-118, 26111 Oldenburg, email: nicolas.jager@uni-oldenburg.de.

Julie P. King, Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstr. 114-118, 26111 Oldenburg, email: julie.king@uni-oldenburg.de.

Prof. Dr. Bernd Siebenhüner, Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstr. 114-118, 26111 Oldenburg, email: bernd.siebenhuener@uni-oldenburg.de.

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Re-examining policy stability in climate adaptation through a lock-in perspective

Lisanne Groen[a,b], Meghan Alexander[c], Julie P. King[d], Nicolas W. Jager[d,e] and Dave Huitema[a,f]

[a]Department of Science, Open University of the Netherlands, Heerlen, the Netherlands; [b]Brussels School of Governance, Vrije Universiteit Brussel, Brussels, Belgium; [c]School of Politics, Philosophy and Language and Communication Studies, University of East Anglia, Norwich, UK; [d]Department of Business Administration, Economics and Law, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany; [e]Institute for Advanced Study, Hanse Wissenschaftskolleg, Delmenhorst, Germany; [f]Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

ABSTRACT

Responding to current and future climate change demands urgent, transformative adaptation, yet in many policy systems inaction continues to prevail. This paper examines apparent resistance to policy change and the persistence of business-as-usual through a 'lock-in perspective', which means that attention is paid to how reinforcing mechanisms drive stabilisation and resistance in policy systems. Offering a fresh synthesis of known lock-in mechanisms in the literature, this paper explores the role of those mechanisms in two empirical cases of coastal adaptation: England (U.K.) and Schleswig-Holstein (Germany). While several known lock-mechanisms are observable, some are newly identified in this adaptation context. We offer a critical reflection on the added value of the lock-in perspective for understanding policy stability. In turn, the identification of self- and mutually reinforcing mechanisms provides a much-needed foundation for targeted policy interventions and efforts to 'unlock' climate adaptation pathways.

KEYWORDS Dynamic policy stability; lock-in mechanisms; path dependence; policy feedback; climate change adaptation; coastal management

Introduction

Understanding policy dynamics has long been a staple of policy studies and political science. Policy stability is being studied more and more too. Initially seen as the mere absence of dynamics, it is becoming increasingly clear that policy stability is actually the outcome of dynamic processes (Weible & Sabatier, 2018). Such stabilising dynamics can include, among others, self- or

CONTACT Lisanne Groen lisanne.groen@ou.nl

mutually reinforcing mechanisms that make policy (sub)systems rigid and resistant to change, or 'locked in' (Pierson, 2000). Lock-ins have been studied in a range of different contexts (such as infrastructure projects, government policies and consumer products) and through different disciplinary lenses, including political science, economics, geography and science and technology studies (Siebenhüner et al., 2021). In line with the increasingly prominent view of dynamic stability, it has been suggested that lock-ins are characterised by positive feedbacks and their net reinforcing effect on policies (Barnes et al., 2004; Foxon, 2002; Pierson, 2004).

Lock-ins have come under increasing scrutiny in the research on *climate mitigation*, where studies of 'carbon lock-in' have demonstrated how these self-reinforcing dynamics restrict decarbonisation agendas (Klitkou et al., 2015; Kotilainen et al., 2019; Seto et al., 2016). Interest in the lock-in perspective has only recently emerged in the field of *climate change adaptation* (CCA), which focuses on the process of adjustment to experienced or expected climate change impacts (UNEP, 2021). Here too, the necessity of transformational change is contrasted with the lack of action on the ground, and the notion of an 'adaptation gap' has been employed (Huitema et al., 2016; UNEP, 2021). Moreover, the notion of stabilising dynamics is becoming increasingly important as more and more calls are heard to move beyond the simplistic heuristic of 'barriers' to change, towards the deeper, systemic dynamics through which policy stability is constructed and sustained and adaptation hindered (Biesbroek et al., 2014; Siebenhüner et al., 2021).

Responding to these calls, this paper considers the transferable potential and utility of the lock-in perspective to the CCA literature and asks whether and how lock-in mechanisms help sustain business-as-usual and restrict adaptation efforts. The research focuses on coasts, where the need for adaptation is paramount given projected sea level rise and increasing coastal hazards (storm surges, flooding and erosion; OECD, 2019). Coastal management is a mature policy field that often reflects decades, if not centuries, of developments. Yet, aforementioned climate change impacts will mean that in many jurisdictions traditional coastal management based on 'hard' defences may not be economically, environmentally or socially sustainable in the long run (Jones et al., 2012). Adaptation demands innovative and diverse approaches, involving a combination of protection, accommodation, recovery and retreat strategies (OECD, 2019). However, coastal management is notably complex and involves disparate terrestrial and marine policy domains, with different institutional arrangements, agendas and sometimes competing interests. Moreover, each of these policy domains is subject to internal dynamics and varied in terms of rigidity and the extent to which adaptation is recognised as a policy issue and acted upon. Coastal management, therefore, provides a useful testbed for the lock-in perspective.

To engage with lock-in issues in coastal climate adaptation, the paper starts by drawing from various bodies of literature, including policy studies and political science, economics and climate mitigation to synthesise known lock-in mechanisms. Second, we present the results of a primarily inductive case study analysis of coastal CCA in England (United Kingdom) and Schleswig-Holstein (Germany) from which we identified whether known lock-in mechanisms are present, and whether new types of mechanisms exist in this context. While several known lock-in mechanisms were discernible, our analysis reveals four new types of lock-in mechanisms and demonstrates the interdependencies between institutions, actors and infrastructures and the contexts in which they are situated. This research demonstrates the utility of the lock-in perspective and added value in terms of revealing otherwise hidden sources of stability that are hindering adaptation. In turn, we reflect on the policy implications for targeting and tailoring interventions to dissolve undesirable lock-in dynamics and open up opportunities to accelerate adaptation action.

Taking a lock-in perspective

The concept of lock-in and mechanistic approaches to characterising lock-in dynamics have evolved through various disciplines, including economics, economic geography, policy studies and political science, science and technology studies and, more recently, climate mitigation. This section synthesises the key concepts in lock-in thinking and collates a list of previously documented lock-in mechanisms (Table 2).

In policy studies and political science, dynamic policy stability has been subject to considerable scrutiny (for instance Levin et al., 2012). Two theoretical concepts are central in these discussions: *path dependence* and *policy feedback*. Path dependence is rooted in historical institutionalism and emphasises the stabilising role of the structure and power relations of institutional systems (Pierson, 2000; 2004). It understands path dependence as 'a social process grounded in a dynamic of increasing returns', involving positive, self-reinforcing feedbacks, which make deviation from the chosen path increasingly costly (Pierson, 2000, p. 251). For example, previous institutional choices can create normative and interest-driven commitments that determine future events. These 'institutional legacies' create positive feedbacks that reduce the feasibility of change for subsequent policies and serve to reinforce the status quo (Howlett, 2009; Pierson, 2000). Accompanying historical institutionalist perspectives, other schools of institutionalism in political science emphasise different drivers of policy stability. Rational choice institutionalism stresses the role of institutional cost–benefit structures and large switching costs, which make the alternative paths less palatable (e.g., Lindner, 2003). In contrast, sociological institutionalism focuses on cultural

norms and values that shape actors' expectations about how institutions ought to be structured to be socially legitimate, thus reinforcing familiar institutional structures (Hall & Taylor, 1996).

Sources of policy stability are also considered through adjacent scholarship on *policy feedback,* which examines the means through which policies affect politics and subsequent policy decisions (Jordan & Matt, 2014). Weir (1993) interprets policy as a process of sequences in which new ideas restrict future initiatives. These sequences may cumulate into self-reinforcing feedbacks that 'serve to stabilise or expand early policy events' (Skogstad, 2017, p. 24). Policy feedback scholars identify specific design features that make policies more susceptible to self-reinforcing dynamics, such as those associated with high start-up costs or long-term sunk costs (Ibid.). More recently, scholars have highlighted how the intertwined development of policies and infrastructures or technologies can also create policy feedback and limit the decision space for future decisions (Derwort et al., 2021; Schmid et al., 2020).

The emphasis on self-reinforcing feedbacks has sparked interest in the concept of lock-in dynamics and specific lock-in mechanisms that 'reinforce a particular path or trajectory' (Pierson, 2004, p. 49). Mechanisms, consisting of agents, their properties, actions and relations producing an effect/phenomenon, form the causal building blocks that connect a continuous and contiguous chain of links between different elements in a policy system, which together create emergent system behaviour (Hedström & Ylikoski, 2010). Contextual conditions influence the type of mechanisms that are activated or deactivated, as well as the magnitude of the causal force and its effect on the outcome (Falleti & Lynch, 2009). While mechanisms more broadly may drive both change and stability in policy systems, *lock-in mechanisms*, by their self-reinforcing nature, exert a stabilising force. Therefore, the study of lock-in is concerned with identifying which specific lock-in mechanisms drive stability and what constructs, sustains or ultimately dissolves these under certain conditions.

It is important to consider agency in self-reinforcing dynamics, as these are not automatic. Both path dependence and policy feedback concepts include elements of agency and draw attention to the central role of actors in forging reinforcing, stabilising dynamics. To this end, Galik and Chelbi (2021) distinguish between passive, non-purposeful policy stability on the one hand and active, purposeful policy stability on the other. Whereas reflexive actions (e.g., framing, discourse) steer passive stability with standards regarding what is right or acceptable, active stability is driven by actors' intentional, proactive actions (Galik & Chelbi, 2021). The distinction between passive and active stability highlights the importance of examining policy stability (and lock-in dynamics therein) through the lens of intentionality.

The existing literature has documented a number of mechanisms through which institutions, infrastructures, technologies and behaviours drive self-reinforcing dynamics. For example, early economic research highlighted infrastructural and technological lock-in mechanisms related to *economies of scale, economies of scope* and *learning effects* (Arthur, 1994; David, 1985). Interest has since expanded to the role of institutional and behavioural mechanisms. Prominent examples include *institutional learning effects, network effects, adaptive expectations* and *habituation* (Barnes et al., 2004; Ebbinghaus, 2005; Foxon, 2002; Pierson, 2000). A combination of these mechanisms is often represented in studies of so-called 'carbon lock-ins' within climate mitigation research, as researchers have sought to understand the persistence of carbon-dependent socio-technical systems and barriers to decarbonisation (e.g., Klitkou et al., 2015; Kotilainen et al., 2019). Studies of carbon lock-ins have drawn attention to different types of institutional, infrastructural, technological and behavioural mechanisms that underpin lock-ins (Kurz et al., 2015; Seto et al., 2016).

However, such lock-in mechanisms have yet to be documented in the context of climate adaptation. Addressing this gap, this research examined the presence of these known mechanisms (see Table 2) in selected case studies of coastal adaptation. Whilst self-reinforcing mechanisms have been introduced here individually, it has to be noted that in reality mechanisms may combine or overlap (Hedström & Ylikoski, 2010). Therefore, the same institutional development may be ascribed to more than one mechanism, i.e., causing observational equivalence and representing equifinality. That being said, each mechanism is still analytically distinct and must therefore be highlighted in the analysis of lock-ins.

Methods

To test the analytical potential of the lock-in perspective for studying policy stability in CCA, this research adopts a case study approach, focusing on the coastal adaptation problem domain as our unit of analysis. Drawing inspiration from Arts et al. (2006), we define the *problem domain* as the arrangement of actors, rules, resources and discourses that coalesce around a collective problem. This approach recognises that CCA spans multiple policy areas and is often not a policy field in itself (Massey & Huitema, 2016). Therefore, we looked to a number of relevant policy areas, including coastal flooding and erosion risk management, terrestrial spatial planning, environmental conservation and water management. Two European case studies were selected as illustrative examples: England (U.K.) and Schleswig-Holstein (northernmost state in Germany). These cases share a similar risk profile under future climate projections but differ in governance traditions, approaches to coastal management and institutional scales (Bisaro

Table 1. Summary of organisations interviewed.

England, U.K. ($N = 10$)	Schleswig-Holstein (Germany) ($N = 10$)
• Committee on Climate Change (CCC) • Academic experts (3) • National Flood Forum • Flood Re • Engineering consultancy • Department for environment, food and rural affairs (Defra) • Former employee for Defra and CCC • Environment Agency	• State Ministry of the Environment (2) • State Ministry of the Interior (2) • State Administration for Coastal Defence and the National Park • Dike and Drainage Association • NGOs (3) • Academic expert

et al., 2020). Although comparison was not the primary objective, these differences enabled us to interrogate the utility of the lock-in concept in divergent settings.

The research adopted a qualitative case study approach, involving document analysis and semi-structured stakeholder interviews. Documents ranged from legislation, policy statements, strategies and key plans, to inquiry reports and existing academic research. Stakeholder interviews were undertaken between November 2020 and January 2021 (Schleswig-Holstein) and June 2021 (England; Table 1). Discussions typically ranged from one to two hours and were recorded, transcribed and analysed using software packages NVivo and MAXQDA. Documents and interview transcripts were subject to thematic analysis (Fereday & Muir-Cochrane, 2006). To ensure consistency in coding, a shared coding protocol was developed through an iterative process, bringing together both data-driven and theory-driven codes informed through sensitisation with the literature. Although analysis was primarily inductive, this approach enabled us to examine whether known lock-in mechanisms documented in other settings are also applicable to CCA in coastal contexts.

Data were subject to a 'fingerprints approach' to process tracing, which aims to uncover plausible causal mechanisms to explain an event or situation as it unfolds over time (Collier, 2011). Starting from 2021 as a baseline, we traced backwards from perceived adaptation gaps to identify their origins, how they are sustained and why they persist, and used process tracing techniques to identify whether these could be attributed to underlying lock-in mechanisms. Process tracing was pursued as far as inferentially necessary. Although lock-in mechanisms were examined alongside other factors as part of a wider analysis, this paper focuses on identified lock-in mechanisms and the added value of the lock-in perspective for understanding climate adaptation gaps.

Results

The results of the empirical analysis from both case studies are summarised in Table 2. Here we document the presence and absence of known lock-in

Table 2. Summary of lock-in mechanisms affecting coastal adaptation in England (U.K.) and Schleswig-Holstein (Germany), some of which are mechanisms from the literature, while others are newly identified.

	Lock-in mechanism	Description	England, UK	SH, Germany
Known mechanisms	Economies of scale	This mechanism is typically described in the context of production capacity and units of production; as production becomes more efficient and the scale of the operation increases, costs are spread across units of production, which decreases the cost per unit and generates cost advantages (Arthur, 1994). Though typically related to technologies and infrastructures, it is also applicable to specific approaches in CCA (such as the scaling-up of Natural Flood Management techniques)	✓	✓
	Adaptive expectations	Individuals, organisations and actor groups adjust their expectations and actions based on their perceptions of what others will do; i.e., 'it derives from the self-fulling nature of expectations' (Pierson, 2000, p. 254)	✓	✓
	Learning effects	Increasing benefits result from 'learning by doing' and 'learning by using' associated with the development, production and/or application of a specific technology, product or approach (Arthur, 1994). The acquisition of knowledge and skills enables incremental improvements, which in turn promote continued use (David, 1985)	✓	✓
	Collective action	Problems and solutions for complex environmental issues are framed and (re)produced through social networks, culminating in shared views and commitment towards collective action (Klitkou et al., 2015)	✓	
	Habituation	Actors develop attachment towards certain approaches or technologies even when potentially superior alternatives exist. This is driven through routines and repetition and strengthened by actors' preference to weigh earlier gains compared to future efforts (Barnes et al., 2004; Kotilainen et al., 2019)	✓	
	Power differentiation	Actors impose rules on others and/or implement rule changes or a specific course of action to strengthen their position of power and advance their agenda. This mechanism is referred to in the literature under various guises, as 'differentiation of power and institutions' (Klitkou et al., 2015; Kotilainen et al., 2019) or 'power asymmetries' (Foxon, 2002)	✓	
	Economies of scope	This refers to the cost and/or competitive advantages induced by the production and use of a broader range of products (rather than specialising in the production of one type) (David, 1985; Klitkou et al., 2015)		
	Institutional learning effects	The increased adoption of institutions over time leads to complementary institutions. This can lead to a range of potential benefits, such as improved coordination and efficiencies, but may also have undesired consequences -e.g., increased complexity and interdependencies may prove resistant to change (Foxon, 2002; Kotilainen et al., 2019)		
	Learning effects	Where there are (increasing) advantages of adopting a specific technology, product or approach, it becomes more widely used (Ebbinghaus, 2005). This mechanism has also been described as 'network economies'		

(*Continued*)

Table 2. Continued.

	Lock-in mechanism	Description	England, UK	SH, Germany
		(Arthur, 1994; Janipour, de Nooij, Scholten, Huijbregts, & de Coninck, 2020) and 'co-ordination effects' (Foxon, 2002)		
New mechanisms	Social contracting	The (re)production of normative values and expectations concerning the perceived state-society relationship influences the acceptance (or rejection) of proposed technologies or approaches and the decision-making process. Values and expectations related to the perceived social contract are actively wielded to lobby (or alternatively contest) an agenda	✓	
	Co-dependency	This mechanism describes a type of relationship between two or more actors, whereby the parties involved require something from the other and have established specific formal arrangements to secure mutual gains. This mechanism can be viewed as a specific type of the differentiation of power mechanism; although power may not necessarily be equally dispersed between parties, each are able to leverage the other based on their co-dependency on one another. This reflects what Trencher et al. (2020) describe as a lock-in by design (as opposed to a lock-in forged by consequence), in that this arrangement has been intentionally constructed and maintained between the parties involved	✓	
	Business network effects	Business network effects occur when economic gains are bolstered as a result of specific public policies; as these gains accrue and the number of businesses and jobs tied to these policies increase, this incentivises political actors to continue to maintain and/or strengthen commitments towards the policy in question. This mechanism is thus propelled by the motivations of political actors (rather than through direct lobbying from business actors). This mechanism displays similarities with network effects (Pierson, 2000), but relates specifically to network effects associated with businesses that flourish as a consequence of policy decisions		✓
	Framing (re)production	The framing of problems and their solutions are co-constructed or reproduced by different actors and institutions. These shared beliefs, norms, or values are communicated by different actor groups thus reinforcing their legitimacy and prevalence		✓

mechanisms (documented in other contexts within the literature), alongside newly identified lock-in mechanisms. These are discussed in-depth below.

Case study: England

In England, an estimated 520,000 properties are currently located in areas with a 0.5% or greater annual risk of coastal flooding, with 8,900 properties exposed to coastal erosion (CCC, 2018). This is projected to increase significantly under future climate scenarios and sea level rise (CCC, 2021). Coastal change and flood risk thus remain top priorities in the National Adaptation Programme (Defra, 2018).

Flood and Coastal Erosion Risk Management (FCERM) policy is set by the Department for Environment, Food and Rural Affairs (Defra) (HM Government, 2020), who are also responsible for climate adaptation policy more widely.[1] The Environment Agency, as an executive, non-departmental public body, maintains strategic overview for FCERM and responsibility for developing and monitoring the implementation of the National FCERM Strategy for England (EA, 2020). Operational responsibilities are divided across designated Risk Management Authorities, including the Environment Agency, Lead Local Flood Authorities (namely unitary authorities, county councils or district councils where no unitary authority exists), Internal Drainage Boards, highways authorities and water companies (regulated by Ofwat). Coastal local authorities are also designated as Coast Protection Authorities, with permissive powers to protect the land against erosion and encroachment from the sea. Preferred coastal management policies are outlined in shoreline management plans for different epochs (0–20, 20–50 and 50–100 years); including policies for No Active Intervention, Managed Realignment, Hold The Line or Advance The Line (i.e., of existing defences). These are overseen by Coastal Groups, with representatives from the local authority, Environment Agency, Natural England and other bodies with vested interests. Although the shoreline management plans are intended to support long-term decision-making in other policy areas such as spatial planning, these are non-statutory documents and ultimately represent unfunded proposals only (CCC, 2018).

FCERM governance has evolved incrementally through three key paradigms – from land drainage (ca. 1930–1970s) and flood defence (1980s–1990s) to risk management (ca. 2000s–today) (Johnson et al., 2005). Contemporary policy recognises the necessity of a holistic approach, drawing from a portfolio of equally important strategies. However, translating this discourse into practice has remained challenging, with the Committee on Climate Change concluding that the current approach '*is unsustainable in the face of climate change*' (CCC, 2018, p. 9). Despite FCERM policy promoting a diversified approach, legacy effects from the defence paradigm sustain a tendency

towards defence-dominance and restrict the implementation of alternative approaches in FCERM. Several self-reinforcing mechanisms were discerned from document and interview analysis (Figure 1).

The current funding instrument employed by the Environment Agency to allocate national FCERM Grant-in-Aid funding is a central trigger for several lock-in mechanisms. Although Partnership Funding was introduced to enable additional sources of funding (public, private and civil society) to contribute to FCERM schemes, while aiming to stimulate innovation (Defra, 2012), the funding formula continues to prioritise the protection of people, property and businesses, and reductions in flood probability. This makes it easier for defence schemes to achieve more favourable cost–benefit ratios compared to alternatives (such as natural flood management or managed realignment). Once constructed, such schemes foster a sense of security and reinforce *adaptive expectations*, whereby land use decisions are driven by expectations that the Environment Agency will continue to maintain defence assets. In turn, as investment and development behind the defences grows, this mobilises *economies of scale*, as cost–benefit ratios increase and provide greater returns for continued investment in defence activities. Thus, *adaptive expectations* and *economies of scale* operate in mutually reinforcing ways. This effect has widely been documented in the flood risk management literature and often described as 'the levee effect' (OECD, 2019).

The design of funding policy instruments reflects established institutional cultures and identities, where defence-preferences arguably remain in the wake of the engineering paradigm (Harries & Penning-Rowsell, 2011). Although these preferences are slowly dissolving as the Environment Agency diversifies its identity, there is still a degree of *habituation* and attachment to established ways of working. For example, one interviewee explained how the conventional '*predict and provide*' approach to delivering defence projects is in stark contrast to the process required for complex coastal change management. Similarly, the language enshrined in the shoreline management plans continues to reinforce the notion of 'the line' of defence when '*it's not a line it's a zone … it doesn't lead you in a way that will start solving the problems*' (FCERM consultant interviewee). *Habituation* goes hand in hand with *learning effects* as knowledge, skills and routines have increased with the adoption of established practices, procedures and implementation of defence-based interventions. Interestingly, document and interview analysis reveals how the Environment Agency is actively trying to counteract these reinforcing dynamics as it seeks to maintain a central position of power in FCERM governance by broadening the scope of its activities over the past 15 years. In turn, Partnership Funding is also evolving, with reforms announced in April 2020 intended to unlock funding for alternative approaches, though it is too soon to assess the extent to which this will be the case.

Nonetheless, efforts to implement alternative strategies in FCERM typically encounter resistance from civil society, which expects state intervention and defensive action, despite the absence of statutory rights to flood protection. This expectation has been forged through the increasing centralisation of FCERM governance since the 1950s and the increasing complexity of roles and responsibilities, which are often poorly understood by the public. Expectations for state intervention are further exacerbated by politically judged commitments of capital funding towards flood defences that often follow significant flood events (Alexander et al., 2021). This relationship between the State and civil society has been described in political philosophy as a 'social contract', referring to 'how governments and responsibility evolve over time as emerging risks pose challenges to the established consensus concerning the role of the state' (Adger et al., 2013, p. 330). Our analysis indicates how *social contracting* can operate in an active sense as a self-reinforcing mechanism, whereby civil society groups leverage their expectations for flood protection and lobby for action, which, when also combined with political pressure, can lead to defensive steps being taken even when this might not be sustainable long-term. Furthermore, research has shown how this mechanism can be mobilised through public consultation procedures to legitimise institutionalised defence preferences (Harries & Penning-Rowsell, 2011). As a mechanism, *social contracting* displays similarities with *adaptive expectations*, as society's actions are influenced by the (expected) actions of public actors. However, we argue that *social contracting* pertains more specifically to the (re)production of normative values and expectations attached to the state-society relationship, and how these are actively wielded to lobby (or alternatively contest) an agenda. This often coincides with *collective action* through locally led community flood action groups, wherein shared beliefs about problems and solutions are constructed and collective agency is mobilised (EA, 2020; Mees et al., 2018). Interestingly, *social contracting* is also utilised by the state in an effort to re-shape this perceived social contract, with increasing emphasis placed on the need for citizens to adopt ownership for managing their personal risk. Thus, this mechanism plays an active role in both self-reinforcing and counteracting feedbacks and appears to flourish under the English governance system as a result of complex and often misunderstood roles and responsibilities.

The dominance of the defence-based paradigm has further been reinforced through various mutually beneficial agreements between the insurance industry and the UK Government, which have maintained the availability of flood insurance for high-risk households since the 1960s (Penning-Rowsell et al., 2014). This is broadly characteristic of the *power differentiation* mechanism (Klitkou et al., 2015). However, more specifically it reflects a symbiotic dynamic, whereby the parties involved require something from the other and have established specific formal arrangements to secure mutual

gains; although power may not necessarily be equally dispersed between parties, each are able to leverage the other. We refer to this self-reinforcing mechanism as *co-dependency*. As flood frequency and damages increased, the insurance industry increasingly demanded improved FCERM to minimise their financial exposure and only consented to agreements on the condition that public investment in defences be maintained, reinforcing the status quo (Harries & Penning-Rowsell, 2011). In turn, the availability of private market insurance has relieved the Government of obligations to pay compensation. This arguably reflects what Trencher et al. (2020) describe as a lock-in by design (as opposed to a lock-in forged by consequence), in that this arrangement has been intentionally constructed and maintained between the two parties. This co-dependency has intensified for an interim period with the introduction of the Flood Reinsurance Scheme in 2016, a government-backed, not-for-profit scheme, which is intended to facilitate the transition to risk-reflective market pricing by 2039 (Flood Re, 2019); upon which we would expect this mechanism to be extinguished.

Coastal adaptation is further hindered by the absence of policy instruments and delivery mechanisms for implementing alternatives such as managed realignment. Whilst coastal risks fall within Defra's remit, adaptive responses extend beyond Defra's jurisdiction and require broader considerations of spatial planning, welfare, infrastructure and decommissioning of assets, to name a few. Not only are formal responsibilities for adaptation unclear, but the functionalist structure of national and local government departments and quasi-privatisation of key sectors has created governance silos, as well as misalignment in planning and funding cycles which make it difficult to integrate agendas (Alexander et al., 2021). In the absence of clear responsibilities (and accountability) for adaptation, certain actors appear reluctant to embrace problem ownership and seem to employ avoidance tactics, typically justifying inaction in relation to resource constraints, statutory duties and remits. This is evidence of the *responsibility avoidance* mechanism. A notable example is Network Rail which frequently cites constraints created by the 5-yearly asset management periods through which funding is allocated to maintain (rather than enhance) the network. Examining this in detail, Wilson and Russel (2018) show how institutional fragmentation, and absence of deliberative structures for coordinating climate adaptation across government departments, enable blame and responsibility avoidance. Interviewees similarly confirmed the presence of this mechanism, particularly at the local scale; '*just because it's not written in the statute doesn't mean you don't do it … they can push the system a bit … [but] it's compliance leadership*'. Responsibility avoidance is not a self-reinforcing lock-in mechanism per se and is therefore not represented as such in Table 2. Instead, it is part of a causal chain of barriers which collectively impede adaptation (Figure 1).

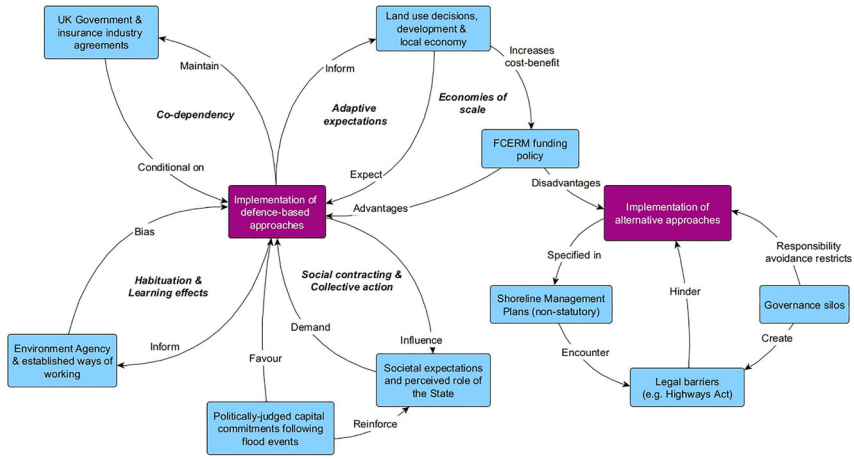

Figure 1. Systems flow diagram of lock-in mechanisms identified in coastal governance in England, U.K. [Arrows indicate feedbacks, blue boxes indicate entities and purple boxes indicate outcomes.]

Case study: Schleswig–Holstein

Situated between the North and Baltic Seas, Schleswig-Holstein is defended against coastal hazards on the North Sea coast by 407 km of embankments, which protect ca. 140.000 inhabitants and €28.5 billion worth of capital assets from flooding during storm surges (MELUND, 2022). Coastal protection is constitutionally defined as a joint task between federal, state and municipal governments (Bisaro et al., 2020). We focused strictly on the North Sea, where risk management responsibilities are primarily situated at the state level and outlined in the State Water Act. Whereas the state Ministry of Environment (MELUND)[2] is responsible for strategic planning, operational responsibilities for monitoring and maintaining coastal defences are assigned to the State Agency for Coastal Protection, the National Park and Marine Protection. A coordinated approach to coastal defence has been pursued since 1963 and is outlined in the state Master Plan for Coastal Protection, which specifies the standards for coastal protection and is updated on a decadal basis (MELUND, 2022).

In 2015 MELUND published the Strategy for the Wadden Sea 2100 (WS2100) and in 2017 the State Plan for Adapting to Climate Change, which outline recommendations for future management options in response to projected sea level rise (MELUND, 2017; MELUR, 2015). Measures primarily focus on adaptive management of dike infrastructure and sediment management practices. However, additional adaptation measures and other strategies such as accommodation or retreat are notably absent (Hofstede & Stock, 2018) and not considered necessary (Hirschhäuser & Hofstede, 2020).

Although the State Water Act and State Development Plans recommend non-statutory standards for development-free zones behind dikes and along sandy coasts prone to coastal erosion (Innenministerium des Landes Schleswig-Holstein, 2010), these decisions are ultimately made by the municipalities.

The State's approach to coastal protection has remained largely stable since the 1960s, where significant flooding in 1962 catalysed a state-coordinated approach to coastal protection (Reise, 2017). However, gradual paradigm shifts have occurred since. Land reclamation ceased in the 1980s and diverse policy goals have increasingly become more integrated with more cooperation between coastal defence, disaster management and nature conservation actors. Efforts to diversify the portfolio of measures deployed in coastal risk management are constrained by a host of barriers described by both governmental and non-governmental interviewees; therein, we identified the presence of several self-reinforcing lock-in mechanisms which serve to maintain the dominance of defences (Figure 2).

Dike heightening and maintenance and sediment management are ongoing activities that provide jobs along the coast, which has resulted in the emergence of engineering and construction firms with a strong interest in the continuation of the current coastal protection approach, as was described by an academic interviewee. This exemplifies a new lock-in mechanism that we refer to as *business network effects*. This occurs as a number of businesses and regional economic gains are fortified by specific public policies to maintain coastal defences. In turn, regional jobs are one of many incentives for political actors to continue to sustain their commitment to defence infrastructures. This notably differs from the *co-dependency* mechanism seen in England, in that *business network effects* is not a formalised arrangement. From economic theory and a known lock-in mechanism, network effects (Pierson, 2000) classically refer to gains increasing with the number of users of a product or service; here we refer to gains increasing with the number of jobs and businesses.

Additionally, the nature of federal capital funding and institutional rules favour continued investment in defence infrastructure. Due to high capital costs, alterations are limited to 3.6 km of dikes annually and require approximately 15 years of planning. This is primarily funded through federal finances, which can be used for pre-approved purposes only, including dike reinforcements and sediment distribution (Schleswig-Holsteinischer Landtag, 2020); thus, funding for these established measures is notably easier to access than for alternative approaches. This policy feedback, documented in funding reports and described by interviewees, acts as a barrier to the implementation of more diverse measures. However, it also contributes to increasing investments as documented in England. These developments are forged by mechanisms of *adaptive expectations* and *economies of scale*,

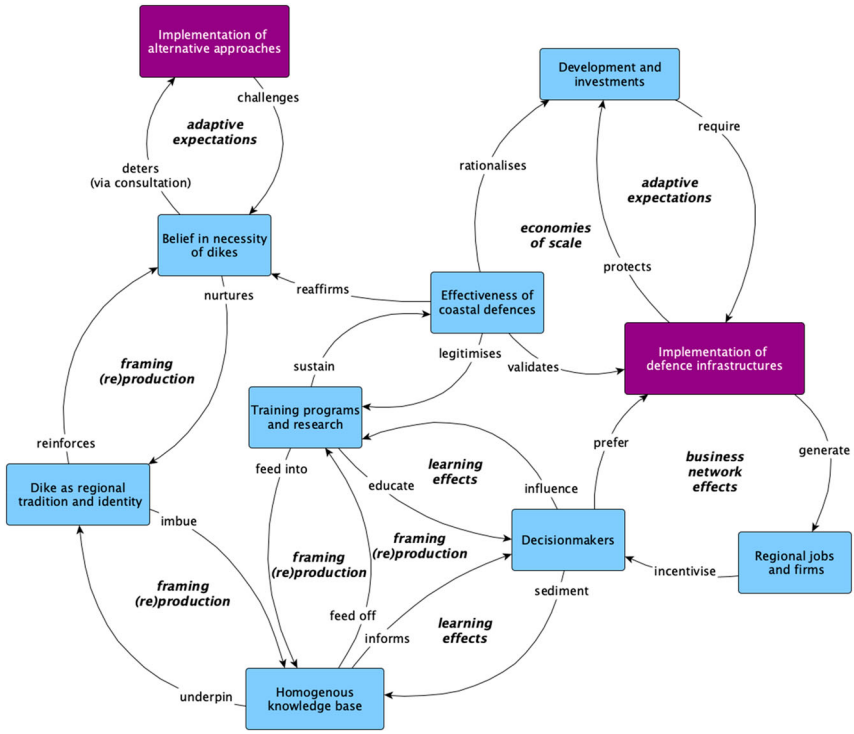

Figure 2. Systems flow diagram of lock-in mechanisms identified in coastal governance in Schleswig-Holstein, Germany. [Arrows indicate feedbacks, blue boxes indicate entities and purple boxes indicate outcomes.]

as assets amass behind the dikes and strengthen the case for continued defence investment.

Long-term reliance on dikes for safety and habitable land is further embedded in regional tradition. Over centuries, the pursuit of land reclamation and 'fighting' the sea (Reise, 2017) has become a cultural narrative of success that is credited to the effectiveness of the dikes. The data also revealed a regional saying that '*whoever doesn't support dikes, must go*'. Thus, the dikes, and the safety they afford, have become an established part of cultural identity. This is further reinforced through the Master Plan and risk awareness-raising documents, which emphasise the mortality of historic flood events and continued necessity of defences (MELUR, 2013). These policy documents both reflect and underpin the cultural framing around defences via a new type of lock-in mechanism that we describe as *framing (re)production*: the reaffirmation of values shared by separate actors.

Perceptions of the '*holiness of dikes*', as described by an NGO interviewee, permeate the regional culture, from the state administration and engineering contractors to dike and drainage associations. These latter associations help

maintain infrastructure but also embody a social community in coastal towns and therefore have both practical and social value. These ingrained values mean alternative measures struggle to gain the necessary public acceptance. In one instance near Husum, proposals for dike realignment and the re-design of the polder to allow for saltmarsh creation failed to win local approval despite the economic and ecological benefits (Hofstede, 2019). Such outcomes deter future proposals of alternative approaches because decision-makers assume they will fail to achieve the necessary public acceptance. Here, *adaptive expectations* and assumptions around what is considered acceptable determine outcomes and operate in a self-reinforcing manner, whereby actors prefer the familiar choice based upon past decisions. This mechanism coincides with their sense of identity attached to the dikes, part of the aforementioned *framing (re)production* mechanism.

This, in turn, legitimises the dominance of engineered defences managed and advocated for by a homogenous epistemic community of practitioners and decision-makers, many of which are trained in hydrologic and coastal engineering. Furthermore, state servants have close ties with (engineering) research networks and co-design research agendas, as mentioned in multiple interviews and supported by the document analysis. Consequently, 'hard' approaches to coastal protection remain prominent and preferences towards traditional defence infrastructure prevail. This is a further manifestation of *framing (re)production*, in that these values and homogenous knowledge systems co-evolve and reproduce, thus reinforcing commitment to defence-based adaptation and its dominance in education and training programmes. Classic *learning effects* reinforce this dynamic as knowledge, skills and routines optimise with continuation of established practices, procedures and implementation of defence-based interventions.

Discussion

This research demonstrates the applicability of the lock-in concept to climate change adaptation, and its usefulness in operationalising the growing interest in stabilising dynamics and the growing desire to understand the 'adaptation gap' in global and national responses to climate change (UNEP, 2021). In this paper, we have vetted the relevant literature for known lock-in mechanisms and subsequently studied the presence of these mechanisms in two case studies on coastal risks, namely England and Schleswig-Holstein. Not only did we observe lock-in mechanisms previously documented in other contexts (such as energy and decarbonisation transitions), we also identified new lock-in mechanisms of *social contracting, co-dependency, frame (re)production* and *business network effects* (Table 2).

Crucially, the research highlights how these mechanisms intersect and dynamically interact to reinforce the dominance of defence-based

approaches in flood risk management. As a consequence, these lock-in mechanisms indirectly impact and restrict the implementation of alternative approaches to 'hard' defences (particularly nature-based approaches and managed realignment). Such alternatives are confronted by lock-in mechanisms that, whether intentionally or unintentionally, advantage defence-based approaches. This may coincide with other barriers and enabling conditions that make it harder to implement alternatives, such as governance silos and responsibility avoidance (as is the case in England; Figure 1). The added value of the lock-in perspective is that it brings to light these otherwise hidden system dynamics that are restricting the ability to deliver fully diversified approaches to flood risk management and are thereby contributing to the adaptation gap.

In addition, the lock-in perspective supports processual, dynamic interpretations of policy stability that have increasingly been advocated by policy scholars (Ishtiaque et al., 2021; Jordan & Moore, 2020). Furthermore, it draws attention to the diversity of drivers that cultivate and reinforce stability, including institutional, technological, infrastructural, socio-cultural and behavioural forces, and the importance of understanding the interaction between these. The lock-in perspective thus promotes a more holistic analysis of lock-in dynamics and understanding of the co-evolution and interaction across different system elements and beyond policy systems (Derwort et al., 2021; Schmid et al., 2020). In this regard, lock-ins can be seen as a bridging concept for integrating different disciplinary interests and schools of institutionalism (historical, rational choice, and sociological) within political science, and bringing this to a new audience within adaptation scholarship.

Interestingly, we observe how the dominance of defence-based approaches is supported by both shared and different types of lock-in mechanisms in the two case studies. While behavioural dynamics (e.g., *adaptive expectations, habituation* and *learning effects*) and *economies of scale* are common features, unique mechanisms exist in England (*social contracting, collective action,* and *co-dependency*) and Schleswig-Holstein (*framing (re)production* and *business network effects*), which appear to flourish under these different governance and socio-cultural settings. In England for example, *social contracting* is enabled by the complex distribution of roles and responsibilities, and absence of statutory rights to flood protection, whereas this mechanism is not present in Schleswig-Holstein, where coastal protection is largely collectivised and legally codified as a public responsibility. These observations demonstrate that while the outcome may be similar in terms of defence-dominance and difficulties diversifying adaptation strategies (as observed elsewhere in Europe; Hegger et al., 2016), different sets of mechanisms, driven by the underlying institutional and societal fabric, are responsible for this homomorphism.

The observations from our two cases align with the framework of this special issue, which outlines cost-efficiency, technology/infrastructure and public support approaches to climate governance: all three aspects are components of lock-in mechanisms observed. For example, cost-efficiency rationales are reflected in the mechanism *economies of scale,* while technology/infrastructure is central to this. Moreover, the *collective action* and *social contracting* mechanisms demonstrate how public support influences the types of approaches that are supported (and contested).

Another important observation from the empirical analysis is that lock-in mechanisms operate in both passive and active forms, with unintentional and intentional effects. Whereas mechanisms such as *habituation* and *adaptive expectations* are initiated and maintained unintentionally, other mechanisms are consciously motivated and activated to either advance or contest policy agendas (such as *co-dependency* in England). This holds interesting insights for contemporary debates about passive and active stability (Galik & Chelbi, 2021). For example, whilst we observed that stability is sometimes brought about by lock-in mechanisms linked to framing about standards, norms and values, framing is not always passive (as Galik and Chelbi (Ibid.) indicate); indeed, the *framing (re)production* mechanism in Schleswig-Holstein demonstrates how actors sometimes subconsciously and sometimes intentionally reaffirm '*the holiness of dikes*'. Research needs to appreciate the complex role that mechanisms can play in this regard.

As our analysis focuses on the problem domain of coastal adaptation, our results should be seen in light of the particularities of this issue. Coastal protection against storms, floods and coastal erosion is not new but steeped in centuries of experience and tradition, which appears to be reflected in the lock-in mechanisms documented. In contrast, other climate adaptation challenges may be more recent and newly emerging without such legacies, and therefore subject to different types of lock-in dynamics. Nonetheless, our study proves the fruitfulness of approaching the adaptation gap with a lock-in perspective. However, the recency with which this perspective has entered adaptation scholarship means that significant knowledge gaps remain. Further research and comparative studies are warranted to better understand how lock-in dynamics emerge within different adaptation contexts, different policy areas (outside of coastal adaptation) and different governance settings, and the underlying conditions through which lock-in mechanisms are initiated and flourish or are constrained and terminated.

Implications for policy and accelerating adaptation action

By revealing the otherwise hidden self-reinforcing mechanisms that maintain business-as-usual and hinder alternatives, lock-in analysis identifies opportunities for targeting and tailoring interventions to dissolve undesirable lock-in dynamics and open up opportunities for enabling innovative, diversified

responses to adaptation. In this regard, further interdisciplinary research is needed to identify potential 'unlocking' strategies and how these might compare between different types of lock-in mechanisms. Herein, attention should be given to how certain mechanisms might be activated to counteract self-reinforcing lock-in dynamics, the mode of leverage, and crucially the point of intervention (e.g., targeting specific entities within the mechanism itself or through changing the enabling contextual conditions).

Inspiration can be drawn from climate mitigation scholarship and complex systems theory, where authors have highlighted how intervention points could be used to assist post-carbon transitions (Farmer et al., 2019). For example, two types of intervention points (a kick and a shift) are identified by Farmer et al. (2019): whereas 'a kick' moves the current system onto a new trajectory while maintaining system dynamics, 'a shift' fundamentally changes these underlying dynamics and rules of the system. An understanding of lock-in dynamics can therefore help to direct purposeful interventions by revealing where and what types of intervention points may be required, and crucially, what forms of resistance these may encounter. Similarly, the concept of leverage points has been examined in the context of sustainability transformations. For example, Abson et al. (2017) identify different realms of leverage based on reconnecting people to nature, restructuring institutions and rethinking knowledge production. In turn, an understanding of lock-in mechanisms and the ways in which these incorporate institutional structures, human-nature connections and knowledge types, can help inform appropriate types of levers to stimulate incremental and transformative change in CCA.

In order to generate actionable knowledge, there is a need to establish methods for assessing the intensity of lock-ins and determining where to prioritise interventions. For instance, it may be useful to consider the lead and lag times between the point of intervention and realisation of benefits for climate adaptation. More widely, fundamental questions need to be asked about how desirable lock-ins and specific mechanisms could be intentionally established to avoid maladaptive pathways and minimise the risk of policy backsliding (Ürge-Vorsatz et al., 2018; Wilson & Russel, 2014), as well as the possibility of applying lock-in thinking to forestall and prevent detrimental lock-ins from occurring in the future.

Conclusion

This research demonstrates the utility of the lock-in perspective for understanding policy stability and resistance in climate change adaptation. Through two coastal case studies, we illustrate the added value of lock-in thinking for revealing otherwise hidden, self-reinforcing forces that interact across institutions, actors and infrastructures and collectively hinder

adaptation efforts. We show how lock-in mechanisms create both intentional and unintentional effects, fostering active and passive forms of stability, respectively. This provides a useful approach for not only diagnosing the root causes of limited, incremental actions in adaptation and understanding the persistence of the 'adaptation gap', but also holds important insights for targeting and tailoring interventions to dissolve undesirable lock-in dynamics. We therefore call for greater interdisciplinary collaboration to bring lock-in thinking to the forefront of adaptation scholarship and efforts to accelerate adaptation action in response to the climate emergency we face.

Notes

1. This information relates to England only and not the devolved administrations of the UK.
2. The full name is the Ministry of Energy Transition, Agriculture, Environment, Nature and Digitisation for the State Schleswig-Holstein.

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Notes on contributors

Lisanne Groen is a postdoctoral researcher. She is a member of the Adapt Lock-in project, which studies climate adaptation policy lock-ins in Germany, the UK, and the Netherlands.

Meghan Alexander is a postdoctoral researcher. She is a member of the Adapt Lock-in project, which studies climate adaptation policy lock-ins in Germany, the UK, and the Netherlands.

Julie P. King is a PhD student. She is a member of the Adapt Lock-in project, which studies climate adaptation policy lock-ins in Germany, the UK, and the Netherlands.

Nicolas W. Jager is a postdoctoral researcher. He is a member of the Adapt Lock-in project, which studies climate adaptation policy lock-ins in Germany, the UK, and the Netherlands.

Dave Huitema is a full professor. He is a member of the Adapt Lock-in project, which studies climate adaptation policy lock-ins in Germany, the UK, and the Netherlands.

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Lock-in dynamics hindering climate adaptation for mental health

Authors: Julie King and Lisanne Groen

Abstract: The climate crisis has a wide range of global impacts, and evidence is growing showing that it is a threat to mental health as a key aspect of overall well-being. These impacts collide with other global crises and challenge mental health systems that already struggle to meet the needs of affected populations. This research investigates the lock-in dynamics that hinder mental health adaptation to climate change, focusing on case studies in Saxony-Anhalt (Germany) and the Netherlands. The qualitative analysis explores how norms and cultural stigmas, funding biases, and other systemic issues impede the integration of mental health and climate adaptation. In both cases studies, we find that normalization dynamics, such as the prioritization of curative over preventative care and strict interpretations of climate adaptation, combined with capacity building dynamics maintain a status quo that is incapable of caring for society's mental health. The findings emphasize the importance of improving knowledge transfers and destigmatizing mental health among the public and decision-makers as one of many recommendations necessary for closing the adaptation gap.

1. Introduction: mental health and climate adaptation

The intersection of climate change and human health is just another example of the vast extent of the climate crisis and its wide-reaching impacts. Climate change's threat to human health - both physically and mentally - continues to be increasingly acknowledged both among researchers and in larger society (Clayton et al., 2021; Berry et al., 2018; Hayes and Poland, 2018). In addition to the reports by leading global health organizations, such as the World Health Organization (WHO) and the Lancet, highly impactful reports on the climate crisis and its multitude of effects, such as those by the Intergovernmental Panel on Climate Change (IPCC), United Nations (UN) and National Centers for Environmental Information (NCEI), all recognize mental health as a significant issue affected by climate change impacts that requires urgent action. The IPCC Sixth Assessment Report (2022) on the impacts, vulnerability, and adaptation to climate change included a whole chapter focused on health and well-being. Chapter authors agreed with very high confidence, that "a wide range of climatic events and conditions have observed and detrimental impacts on mental health" and that the relationship between mental health and climate change impacts is complex and intertwined with many other non-climatic factors that contribute to vulnerability (Cissé et al., 2022, p. 1076). At the United Nations Framework Convention on Climate Change (UNFCCC)'s 28th Conference of the Parties (COP) in 2023, one day of talks was dedicated to health, with "long overdue talks around environmental health, rising sea levels, and melting glaciers to include the direct impacts of such climate shocks on human health" (United Nations News, 2023). All in all, we see an increase in the recognition of climate change impacts on mental health and the necessity to act.

Climate change influences well-being[1] through diverse pathways, and mental health can be impacted both directly and indirectly (EEA, 2022; Hayes and Poland, 2018; Lawrance et al., 2021). Direct impacts often refer to experiences with acute climate-related events, such as hurricanes, droughts, fires, or flooding. Direct impacts can result in physical injury, personal loss of resources, displacement and/or other consequences detrimental to short- and long-term well-being. Indirect impacts, on the other hand, often refer to perceived or second-hand experiences of the climate crisis from media for example (Clayton and Karazsia, 2020; Reser et al., 2011). While direct impacts of extreme events more often manifest in clinical syndromes including post-traumatic stress disorder, depression, and substance

[1] We often use the term "well-being" because of its inclusive definition. According to the WHO, well-being is not just the absence of disease or infirmity but a state of complete physical, mental, and social health (WHO, 1948).

abuse, indirect impacts tend to be subtler and manifest as negative emotions and chronic stress rather than clinically diagnosed illnesses (Clayton 2020). Diverse mental health impacts, both direct and indirect, can also affect whole communities by eroding social cohesion, in combination with or by exacerbating socio-economic instabilities, through damages to the local environment and cultural heritages, or even displacement and forced migration (Berry et al., 2018; Clayton et al., 2021; EEA, 2022).

As extreme weather events increase in frequency and intensity, loss of livelihoods, displacement, and even the erosion of communities have become stark realities for more and more individuals worldwide (Cissé et al., 2022). This escalation in climate-related stressors, and the general increase in attention to mental health as an important part of overall well-being, have led to the increasing recognition of the intricate interplay between environmental factors and mental well-being. However, despite its significant implications for quality of life and importance for economies, mental health is systemically disadvantaged in public policies and budgets and within most health care systems (WHO, 2021). Thus, climate change compounds existing systematic problems but also creates new challenges requiring solutions.

Within Europe, the discourse surrounding climate change and mental health is gaining traction, with policymakers, healthcare professionals and activists advocating for comprehensive strategies to mitigate the climate crisis's adverse effects on psychological health and increase resilience (EEA, 2022). In regions experiencing more frequent heatwaves, such as Southern Europe and dense urban areas in other parts of Europe, the mental health impacts of extreme temperatures are becoming more pronounced and exacerbating existing vulnerabilities among marginalized communities. Flooding is increasing in frequency and intensity in many regions due to climate change and is shown to negatively affect mental health (Hrabok et al., 2020; WHO, 2013). Moreover, the existential threat of climate change, coupled with feelings of powerlessness in the face of (several) complex global crises, has led to a surge in climate anxiety and eco-anxiety across European societies (as well as globally) (Niedzwiedz and Katikireddi, 2023). In response to the increasing risks, some European countries have begun to recognize the urgency of improving mental health and are starting to integrate mental health considerations into their climate adaptation and mitigation efforts (EEA, 2022). Investments, and not just in the financial sense, in mental health services are both economic and ethical (the Lancet, 2020). As the discourse continues to evolve, there is growing optimism that addressing the mental health dimensions of climate change can foster greater overall societal resilience and facilitate more effective responses to this unprecedented global challenge (Gifford and Gifford, 2016).

The WHO, UN, and EU all advocate for "health in all policies" (HiAP), a governance approach which recognizes that well-being would benefit the most if it were to be integrated into all spheres of policy choices (Leppo et al., 2013; WHO, 2014). Under this approach, which is also recognized in the context of climate adaptation, mental health would be considered in climate change plans and policies and climate change would be considered in mental health policies and programs (Ebi and Bowen, 2019; Jenkins and Minoletti, 2013). A climate-adapted state with the best support for well-being and mental health would comprise effective adaptation measures for healthy living environments, including expansive and accessible blue and green infrastructure, strong social and community networks, and an integrated health system that supports both preventative care and holistic health in a manner accessible to all and adaptive in the case of unexpected events (climatic or non-climatic) (Ebi and Bowen, 2019; Hayes et al., 2020).

The WHO emphasizes a need for decentralized mental health care that is integrated into primary care, which addresses health holistically and does not separate physical and mental health but not at the cost of the quality of care and treatment (WHO, 2021). All organizations relevant to contingency planning and disaster relief should be trained to consider short- and long-term impacts of extreme events on

mental health on affected populations. Long-term availability of mental health support[2] for affected populations should be secured. A special focus on vulnerable groups (e.g. elderly adults, children, socio-economically disadvantaged individuals, and individuals with chronic health issues) would aim to ensure that aid is given to those in need of it. Adequate support (e.g. financial, medical, logistical support) that reduces stressful secondary disaster impacts (such as financial or bureaucratic troubles) are shown to mitigate mental health impacts of disasters, and create significant social and economic benefits (Lawrance et al., 2021).

Against this backdrop we explore the following research questions in this paper: To what extent are lock-in dynamics hindering adaptation to address the mental health impacts of climate change in Saxony-Anhalt (Germany) and the Netherlands? And what types of lock-in dynamics appear to be the most influential and detrimental for mental health adaptation? The identification and characterization of lock-in dynamics are key, in order to plan and tailor interventions that could help close the observed adaptation gaps.

This paper continues (Section 2) by delineating the problem domain of our research and shortly describing the methods and data collection. We then outline the current state of mental health care and climate adaptation with a focus on our two case studies (Section 3). Next in Section 4, we briefly explain the concept of lock-in dynamics before presenting the dynamics we observed in the cases studied. This section analyzes how reinforcing dynamics consisting of, e.g. norms, cultural stigmas, and funding biases, prevent more effective mental health care adaptation to climate change impacts. Section 5 is a comparison of the findings on lock-in dynamics and highlights many similarities between the two cases. The final section of this paper briefly summarizes the findings and provides recommendations for improving mental health adaptation and potentially unlocking the observed dynamics.

2. Delineating the problem domain, methods, and data collection

The delineation of the mental health case studies takes the same approach as the other problem domains in this book. Specific societal problems where climate change challenges established structures and routines, were taken as a starting point, meaning that we looked into key issues ("problems") that will arise or be exacerbated by future climate change. Such "wicked" problems often straddle more than one area of public policy or sector of interest, and the unit of analysis is bounded by the *problem*, rather than pre-defined policy sectors (see Alexander et al., forthcoming). Mental health impacts of climate change constitute a "wicked" problem in that their causality is more complex than one simple source, and rectifying and preventative responses are necessary in several policy areas and by diverse actors. In the case of mental health in the context of climate change in our selected case studies, relevant actors and policy areas included not only public health but also disaster and contingency planning, environmental and urban planning and climate adaptation as an overarching policy area.

The research on these two case studies draws from both an in-depth document analysis, including key legislation, policy plans and strategies and academic literature, and from 11 semi-structured expert interviews (see Table 1). Following the data collection, we then conducted a thematic analysis and a "fingerprints" approach to process tracing using the documents and the interview transcripts. For more details on the research methods refer to Alexander et al. (forthcoming).

[2] In this paper, mental health support refers to and includes mental health services in the planning and/or delivery of mental health promotion, prevention, treatment and rehabilitation services.

Table 1: Summary of interviewees and timeframe of interviews conducted for the case studies Saxony-Anhalt (ST) and the Netherlands (NL)

Saxony-Anhalt (N= 4 interviews)	the Netherlands (N= 7)
• State administration representatives (2) (ST01 & ST04) • Former state administration representative and mental health researcher (ST02) • Federal Office of Civil Protection and Disaster Assistance representative and voluntary first responder (ST03)	• Researcher at Dutch national research institute (2) (NL03 and NL07) • Researcher (NL05) • Academic at Dutch university of applied sciences (NL01) • Former youth representative to the UN (NL04) • Remedial educationalist and systems therapist (NL02) • Psychotherapist and consultant (NL06)
Conducted between February and July of 2022	Conducted between May and July 2021

For the case of Saxony-Anhalt, several individuals we contacted for interviews declined the opportunity. For example, state-level representatives from both the environmental ministry and the ministry responsible for disaster planning, did not see themselves or their institutions as being relevant regarding mental health and climate adaptation. The individual we spoke with from the ministry for health also only agreed to a short interview if we did not record the call. In the case of the Netherlands, we were also not successful in finding interview partners within governmental institutions. Public officials whom we approached did not feel they would be able to speak to the topic.

3. Characterizing mental health care and climate adaptation governance

3.1 Mental health support in the context of climate change and adaptation gaps

Roughly one in four people across European Union (EU) countries and the United Kingdom have had a mental health problem and climate change is worsening mental health outcomes (EEA, 2022; Statista, 2024). Yet, mental health is seen as one of the most neglected and under-funded areas of public health and global health systems are inadequate for addressing these challenges (Liu et al., 2020). The WHO and the EU have identified a gap in mental health care and call for improvements in public health systems to provide more affordable and accessible care, reduce the stigmas around mental health problems, and incorporate key mental health priorities in national plans and policies" (WHO, 2021; European Commission, 2023). Both extreme weather events, which are increasing in frequency and intensity, and more indirect impacts of climate change are negatively impacting the mental health of individuals across Europe and the observed adaptation gap is compounding the existing mental health crisis (Lawrance et al., 2021). Implemented adaptation measures, such as urban greening, building more resilient infrastructure or increasing food security, have positive impacts on mental and physical health by increasing safety and well-being and reducing risks stressors (Flores et al.,2023). Conversely, the absence of climate adaptation but also insufficient climate mitigation leaves increasing risks unaddressed and results in a higher exposure to health risks – both physical and mental. According to the UN Environment Programme (UNEP) Adaptation Gap Report (2022) and a global stock take of adaptation, more adaptation measures have been observed in Europe than in some other regions of the world, but much more than incremental adaptation has not been often documented (Berrang-Ford et al., 2021). The 2018 UNEP Gap Report focused on human health and found there to be a significant adaptation gap and summarized efforts as "well below the level required to minimize negative health outcomes" (UNEP, 2018, p. xiv).

3.2 Outlining the mental health and climate change adaptation case study contexts

Germany (Saxony-Anhalt), and the Netherlands face similar challenges when it comes to the nexus of climate change and mental health. Hotter temperatures, flooding and other extreme events are likely

to exacerbate the existing mental health issues within affected populations but also create new mental health problems. Despite these challenges that face all global populations, the topic of mental health and health infrastructure and policies vary greatly by setting. Here we provide overviews of the problem domain in our three settings of research.

Saxony-Anhalt, Germany

The German Psychotherapist Association's 2021 report on mental health in Germany found that annually more than 1 in 4 adults in Germany (27,8%) has some sort of mental illness or disorder (Rabe-Menssen et al., 2021). Though national reports and statistics on mental health in Germany do not include climate change as a cause or exacerbator of mental health issues, other studies have shown that both extreme weather events and climate change as a global phenomenon have negatively impacted mental health of individuals in Germany (e.g. Bunz, 2016; Kuhlicke et al., 2020; UBA, 2021; Wullenkord et al., 2021). Despite the prevalence of mental health issues, mental health services are inadequate, especially in rural areas where long wait times and insurance restrictions on therapist licensing lead to significant treatment delays and higher societal costs, disproportionately affecting those with lower socioeconomic status (Epping et al.,2017; Niemeyer and Knaevelsrud, 2023; Luft and Weydt, 2018; Rabe-Menssen et al., 2021).

Saxony-Anhalt is a land-locked state in the central part of Germany. It is 20.4 thousand square kilometers and has a population of 2.1 million and thus one of the less populous states of Germany with a relatively low population density (as compared to the other states). Two-thirds of the state area is agricultural land, the state has one national park which is a forest-covered small mountainous area, and is characterized by the Elba river plain and Saale-Unstrut river valley and plains (Sachsen-Anhalt, 2021). Saxony-Anhalt was chosen for the case study due to major flooding events in 2002, 2011, and 2013, and the visible environmental changes through significant forest decline in the national park area. In 2018 and 2019 summer heat and drought had catastrophic consequences for regional agriculture (Interview S02; Trenczek et al., 2022). These kinds of extreme weather events, such as flooding, and also the slow degradation of one's surroundings are identified to have negative impacts on mental health and well-being (Clayton 2020; Cunsolo and Ellis 2018; Hrabok et al.,2020).

Important actors and institutions for mental health in Saxony-Anhalt include the State Ministry for Labor, Social Affairs, Health and Equality (MS), the Federal Ministry of Health (BMG), and the Federal Joint Committee (G-BA). The BMG sets and implements health policies at the national level and the MS implements health policies at the state level. The G-BA is made up of politicians and health insurance companies and is authorized to make binding regulations related to health reform bills passed by lawmakers, along with routine decisions regarding healthcare in Germany, including what is covered by insurance and the provision of mental health care. The Federal Office of Civil Protection and Disaster Assistance (BBK) provides information, training, and recommendations for climate change adaptation (CCA) and disaster planning including mental health. Other actors relevant to this problem domain include the State Cabinet, which sets policy goals and provides data and recommendations, as well as the ministries of the environment (MULE) and the ministry of the interior (MI), which are respectively responsible for climate change adaptation strategies and disaster planning and response. Municipalities play an important role, as the main implementers of climate adaptation, and non-governmental organizations, such as churches, the Red Cross and other emergency response groups play an important role in offering counselling and mental health support in wake of extreme events. Networks such as Psychologists for Future and the National Association of German Psychologists (BDP), which represent the interests of professional mental health workers, are important because they nationally work for more attention to the topic and demand change. Unlike other German states, Saxony-Anhalt has no central state authority for emergency psychosocial care (BBK, 2021b; Interview STO3).

The legal basis for mental health care in Saxony-Anhalt is the "Gesetz der Hilfen und Schutzmaßnahmen für Personen mit einer psychischen Erkrankung des Landes Sachsen-Anhalt" (2020), which only focuses

on mentally ill people and curative care and nothing on preventive care or well-being. Though mental health is one of ten health goals set by the state (InterviewST04), the framing is focused on substance abuse and suicide, and there are no specific instruments or policies in place to improve mental health overall. The Ministry of Health has no policies or instruments related to climate change. The state adaptation strategy is a non-binding instrument that sets high level goals for adaptation, one of which is to protect the population from negative psychical and mental impacts of heat by informing the population of dangers and supporting the development of heat action plans (MULE, 2019, p. 25). Though it calls for various technical and informational measures to reduce flood risks, there are no specific plans or goals related to flooding and mental health. At the national level there are no specific policies or instruments aimed at improving mental health in the context of climate change, and mental health is only briefly mentioned in more detailed adaptation strategies, as being at risk with increasing heat and other extreme weather events.

Past flood events along the Elba and Saale and other rivers in the state were extreme enough that many individuals were evacuated and some lost their households. Flooding and droughts in the state have ruined agricultural seasons and caused millions of Euros of damage. The direct climate change impacts expected for Saxony-Anhalt that are likely to affect mental health include an increase in the intensity and frequency of heat events, water shortages may increase in the summer months, high-water levels in spring may be earlier and higher (though the statistical data is unclear as to the increased frequency of fluvial flood events), and heavy precipitation events are expected to increase slightly and flash flooding is projected to increase by 50% in certain regions of the state (MULE 2019). These climate impacts may add additional stress and trauma to a population that is already burdened by economic troubles combined with demographic change and has dealt with a recent pandemic[3] and migration caused by other global conflicts (e.g. in Syria and the Ukraine) (Interviews ST01 and ST02).

Although Saxony-Anhalt has been one of the more active German states in creating and updating state adaptation strategies (King 2022), there is a substantial adaptation gap regarding mental health and climate change in Saxony-Anhalt. Saxony-Anhalt is one of the only states that mentions mental health impacts[4] in its climate adaptation strategy (MULE 2019), lack of state intervention and coordination and no documented adaptation activities regarding psychological health. A trained psychologist and former representative of the state government stated clearly: "*The topic of psychological stress and restoring mental health does not yet play a role in active political action*" (Interview ST02, 5:12, translated from German), and later said that nothing has changed in the past ten years even though data and observations show that stress has been increasing. An interviewee from the BBK active in disaster planning and psychosocial emergency care said that "*Saxony-Anhalt has strong potential for development" and doesn't have certain institutions in place for offering psychological support to disaster victims that some other states do"* (Interview ST03, 43:25).

Other adaptation activities that have synergies for mental health are recognized as important and suggested by the state government (e.g. reducing flood risk, improving urban climates, increasing green and blue areas), and the state adaptation strategy is assessed in the form of monitoring reports. However, the State Ministry of Health doesn't have an overview of what health-relevant measures have been or will be implemented at the local level, nor sees itself as responsible for monitoring local implementation (Interview ST04). Finally, according to an interviewee within the state ministry, the interdepartmental committee for climate adaptation meets only annually or biannually, and there is little coordination and communication at the working level on a regular basis (Interview ST04). Overall, the lack of policies and institutions and the absence of problem recognition and problem ownership despite increasing risks threatening mental health constitute a wide adaptation gap regarding mental health and climate change.

[3] Reference to the COVID-19 pandemic that began in 2020

[4] The strategy's health section mentions that extreme weather events can have psychological impacts (MULE 2019, p. 20)

the Netherlands

Mental health problems are highly prevalent in Dutch society. In the Netherlands, up to 43 percent of adults have officially been diagnosed with some type of mental health problem at some instance during their lifetime (de Graaf et al., 2010). The sustainability of the Dutch mental healthcare system is under threat, due to financial confinements, increasing shortages of trained healthcare professionals and the high demand for mental healthcare (Lemmens and Prins, 2019). In August 2021, a Dutch national news source reported that the lack of therapists in Dutch mental healthcare was resulting in long waiting lists and even a temporary patient stop (meaning that new patients were not accepted) in some parts of the country (van den Brink, 2021). In November of the same year, the chairperson of De Nederlandse ggz[5], the Dutch industry and network association for mental healthcare and addiction care that represents the providers of such care in the Netherlands (De Nederlandse ggz, 2023), clearly state that it was not possible to tackle the long waiting lists and proverbially sounded the alarm for the state of Dutch mental health care (NOS, 2021b). Mental health problems comprise a large proportion of the (high) total cost of healthcare in the Netherlands. These accounted for 25.1 billion euros of costs related to mental healthcare in 2017, amounting to 28.5 percent of the total budget of 88 billion euros (RIVM, 2021).

In the Netherlands, the ministry responsible for mental health is the Ministry of Health, Welfare and Sport. In terms of human health and climate change, the Dutch National Climate Adaptation Strategy recognizes the urgency of heat stress as a priority issue for human health and wellbeing (NAS, 2016). Mental health in particular though is still absent from climate adaptation strategies in the Netherlands. Another key actor in the mental health domain in the Netherlands is De Nederlandse ggz, the industry and network association for mental healthcare. The Trimbos-instituut is an independent knowledge center and research institute in the Netherlands for mental health, the use of alcohol, tobacco and drugs, and gaming and gambling (Trimbos-instituut 2024). Another prominent actor regarding mental health is the National Institute for Public Health and the Environment, which is an independent agency of the Ministry for Health (RIVM; RIVM 2024).

While the damaging effects of climate change across the globe, such as the dramatic wildfires in Australia or the heavy hurricanes in the Caribbean in 2020, often remain far from home, climate change impacts are also becoming increasingly tangible in Europe and in the Netherlands (KNMI, 2021; Weilnhammer et al., 2021). Torrential downpours in the central Netherlands in June 2021 and the massive floods in the province of Limburg a month later were impactful demonstrations of how the changing climate and its subsequent weather extremes affect the country (NOS, 2021a; van Mersbergen, 2021). A study conducted in the Netherlands, Denmark, and Germany found that flooding has significant mental health impacts, including anxiety and depression (Hrabok et al., 2020). The authors indicate that the effects of climate change contribute significantly to overall mental health problems in the Netherlands and are not limited to social or economic consequences (ibid.). For instance, Dutch farmers have suffered from mental health problems after failed harvests as a result of extreme weather events (Huynen et al., 2019), and after the extreme floods in Limburg during the summer of 2021, experts have emphasized the need for adequate psychological support and care for victims aside from physical and financial aid (van Dam, 2021).

The association Slachtofferhulp Nederland (Victim Support Netherlands) offered psychological support in the aftermath of the floods in Limburg in July 2021 (Ibid.). However, a structural policy approach on how to deal with the mental health effects of extreme weather events in the Netherlands is not in place, and research on the mental health effects of climate change-induced extreme weather events in the Netherlands is limited. Existing research, by the WHO and UK government for example (Public Health

[5] In Dutch, "ggz" stands for "geestelijke gezondheidszorg," which translates to "mental health care" and encompasses the range of services and care provided for individuals with mental health issues, including prevention, diagnosis, treatment, and support for mental health conditions.

England, 2015; WHO, 2013), has raised awareness of the mental health effects of floods, but more investigation regarding these mental health effects is required for improving care and policies.

4. Lock-ins dynamics affecting climate adaptation and mental health

The following case studies are examined through the lens of the research questions focused on the extent to which lock-in dynamics are hindering adaptation to address the mental health impacts of climate change, and what types of those dynamics appear to be the most influential. In Alexander et al. (forthcoming), lock-in dynamics are defined as "reinforcing, stabilizing dynamics that display increasing returns, rising transition costs, and increasing connectivity with other system elements, which (un/intentionally) serve to maintain a specific course of action and (in/advertently) discourage alternatives" (p. 4). Alexander et al. note that the costs and benefits (in terms of increasing returns and transition costs) are defined broadly and extend beyond economic values to include political, social, cultural, and psychological costs. In our research (also as in Alexander et al., forthcoming; Groen et al.,2022; Jager et al.,2022), we apply a systems perspective because lock-ins can emerge from environmental systems, both built and natural, economic systems, social systems and political institutions, which intersect and interact in complex manners (Alexander et al., forthcoming). We have also identified four types of dynamics through which lock-ins establish stability: normalization, coalition building, capacity building, and asset accumulation (see Table 2) (ibid.).

Table 2: Types of lock-in dynamics (adapted from Alexander et al., forthcoming)

Lock-in Dynamics	Description
Normalization	refers to the influence of social and organizational norms, which structure collective behaviors, guide what is deemed appropriate and feasible (i.e. what is considered to be "normal"), and shape expectations
Coalition Building	concerns core coalitions of actors that mobilize their collective power to advocate and advance a specific course of action; this could include neutralizing alternative options or coalitions
Capacity Building	consist of institutional, material and cognitive capacities that reinforce a specific course of action; such capacities may be built through direct means, e.g. funding, education, training, and technical assistance
Asset Accumulation	refers to the process of amassing material and economic assets, which in turn encourage new investments that reinforce the status quo and thus guide subsequent decisions

Specific lock-in mechanisms, which refer to specific mechanisms[6] that operate in a stabilizing, reinforcing manner, may be found within these overarching dynamics and propel them. For examples and an in-depth explanation of lock-in mechanisms, see Groen et al. (2022) and Alexander et al. (forthcoming).

4.1 Saxony-Anhalt, Germany

In the case of mental health and climate change in Saxony-Anhalt we did not observe a single "incumbent regime" within policies and practices that is locked-in by reinforcing dynamics, like in the case of a "defensed-based" approach to coastal and flood management (see Groen et al., 2022). Instead, we observed several lock-in dynamics reinforcing the neglect of mental health, especially in the context of climate adaptation. Several dynamics of normalization reinforce a curative approach to

[6] Mechanisms can be defined as causal explanations about how and why a certain outcome is produced, resulting from the interaction between actors and the actions/activities they engage in (Hedström and Ylikoski, 2010)

mental health and maintaining imbalances in the system that prevent a preventative and more holistic approach to mental health and climate adaptation.
In Saxony-Anhalt, but also in the rest of Germany, *normalization dynamics* play a highly significant role in reinforcing the status quo of mental health as a neglected aspect of climate adaptation. Traditionally, mental health, known as "*seelische Gesundheit*" or "health of the soul" has its origins in the church and Christianity in Germany, while public health has its origins in public hygiene, which may explain the common separation of the two (Interview ST01).Though mental health experts, such as psychologists, and much of the medical community do not differentiate between mental and physical health, there is a societal dichotomy that, especially in practice, values physical health more than mental health. One of the interviewed state representatives who is a psychologist by training, said that people with mental health problems face discrimination, and another interviewed from BBK said, "*People still see a dichotomy [between physical and mental health] and it (mental health) is separate and stigmatized. Like, if I have a psychological problem, then I'm 'crazy'*" (Interview ST03). Mental health issues are seen as a private matter or even a taboo topic in the wider population and by decisionmakers at different levels of government (Interviews ST01-ST03). A former civil servant and psychologist explained that mental health is perceived as individuals' problems, "*If there's a crisis you send in a crisis team and then out of sight, out of mind. But the mental burden and the impairment of mental health, that is still there. But it gets individualized and is no longer a political problem but an individual problem"* (IntST02).

Interviewees also mentioned that in Germany, health is often viewed, particularly by the government, through the lens of working capacity (Interviews ST01 and ST02). Politically, health is a matter of whether or not someone is able to work, not in terms of well-being for the sake of wellness but because from the perspective of politicians that is easier to quantify economically (Interview ST02). This stigmatization of mental health includes an example of the lock-in mechanism *frame reproduction* (Groen et al.,2022), in that mental health is stigmatized and thus not a political priority. Two federal level climate adaptation experts from the German Environment Agency[7] shared with us in the context of other interviews conducted in 2020 that mental health effects of climate change and the need for policy responses are recognized within their institution and certain scientific communities, but the topic remains contentious among some colleagues and struggles to make it onto any policy agendas where the implementation would take place. Little public spending is put into research that would justify campaigns and spending to improve the value of mental health and improve overall mental health. In the context of adaptation, according to interviewees it's more attractive and easier for politicians to invest in infrastructures (e.g. dams or siren systems) that are visible symbols of safety than to try to justify spending on the "diffuse" concept of mental health (Interviews ST02 and ST03). This fixation on cost-benefit-analyses (CBA), which constitutes a significant *normalization dynamic*, is a reoccurring theme in our findings, in that it reinforces easily calculable policy choices, such as investments in infrastructures, and disadvantages measures whose benefits are harder to quantify, such as the ecosystem services of green and blue adaptation measures or preventative health care programs.

Another *normalization dynamic* that reinforces the disadvantaging of mental health as an aspect of climate adaptation is the focus on technical and infrastructural solutions to risks increasing with climate change, especially within disaster planning and response organizations (Interview ST03). Similar to the example above, in which decisionmakers prefer to invest in tangible infrastructures, disaster planning has also focused on technical solutions to emergencies in the past decades. Organizations spend more willingly on more or better disaster response trucks and sirens, for instance, rather than on improving communication amongst the relevant offices and with the public (ibid.). In Germany, psychosocial care first became an aspect of civil protection in the 1990s and is still stigmatized to some extent despite initiatives from the federal government and working groups with some of the states and the scientific community (BBKb, 2021; Interview ST03). The BBK is working to improve communication skills and competencies within disaster planning and civil protection organizations and founded a Federal Training School for Civil Protection in 2021. The academy cites changing circumstances as the motivation for the

[7] Umweltbundesamt (UBA)

restructuring of the Federal Office and for the foundation of the academy, "Interdependent security threats and anthropogenic climate change lead to the need to think more holistically about disaster and civil protection" (BBK, 2021a). The interviewee from the BBK explained that, for decades, Germany has had relatively few crises and the general perception of risks of disasters is different than in the United States of America, for example, where tornadoes and hurricanes have a longer history as reoccurring events. The lack of crises has influenced risk communication, and local level actors are typically afraid to warn the population of impeding risks and erupt panic that may or may not be justified (Interview ST03), "*[The question is] how can we change the idea that people will break out into panic about a potential risk? It's a perception that is deeply, deeply anchored in Civil Protection and is demonstrably false […] we have decades of research within disaster sociology proving that assumption is wrong yet we still can't get the belief out of people's heads*" (Interview ST03)[8]. This hesitation to warn the population is dangerous, not only because more warning could prevent physical harm, but also because victims of extreme events that were not warned are more likely to have psychological damage if they were not warned about a sudden event (Interview ST03; Reser and Swim 2011). Thus, the tendency to respond to risks with technical solutions often continues to override communication-based measures for reducing risks to human health.

Next to the strong *normalization dynamics* preventing better mental health care and climate adaptation in Saxony-Anhalt, we observed *coalition building dynamics* at work within the problem domain. The G-BA is arguably the most powerful actor within the German health system and withholds its power to improve mental health care. The undersupply of therapy treatments is directly related to the number of licenses that allow therapists to provide treatment covered by insurance. The G-BA deemed the number of licenses to be adequate in 1999 and only increased it once in 2019 by 800 licenses, though a study (paid for by the G-BA) recommended at least 2400 licenses be added to meet demands that have risen significantly since 1999 (Schneider 2023; Wengert 2023). Although other actor coalitions, including the BDP and the German Chamber of Psychotherapists (Bundespsychotherapeutenkammer) and even the German media have pointed to the flaws in the system, the power to expand mental health care lies mainly within the authority of the G-BA. The provision of better mental health care coverage would be more expensive for the insurance companies who make up the majority of the G-BA, which incentivizes the decisionmakers within the committee to maintain the current system. This instance is an example of power differentiation[9] in which the G-BA uses its political authority to maintain its profits, and also therefore related to the dynamic of *asset accumulation*. We also see connections to *capacity building dynamics*, in that the G-BA wields high influence over data, studies and the financing that shape the public health system.

At the state-level we observed responsibility avoidance, which relates to *coalition building*. Due to the complex nature of the problem (mental health and climate change) there is little problem ownership and the topic is not on any one sector's agenda or priority list at the state level. At the federal level there is more awareness of the problem, especially within the BBK and some departments of the German Environment Agency, but the state, county, and local governments and offices have more authority to improve the organization of mental health services within civil protection and implement measures that improve mental health. The BBK is trying to educate lower authorities more on the topic, but an interviewee said, "*We try not to tell the states and lower authorities what to do in a top-down matter, because they really don't like that*" (Interview ST03). Within our exchange with a representative from the Saxony-Anhalt Ministry of Health, we heard that mental health in regard to extreme weather events

[8] „Wie ändern wir denn diese Vorstellung davon, dass Menschen sofort in Panik ausbrechen, wenn sie eine Information über eine mögliche Gefahr bekommen? Das ist eine Vorstellung, die ganz, ganz tief im Bevölkerungsschutz verankert ist und die nachweislich falsch ist. Es ist einfach falsch. Wir haben in der Katastrophen Soziologie haben wir jahrzehntelange Forschung, die ganz klar nachweist, es ist falsch und trotzdem kriegen wir diese Vorstellung und diese Erwartungshaltung nicht aus den Köpfen." (IntST03, S. 9)

[9] "Power differentiation" (or "differentiation of power and institutions") has been identified as a lock-in mechanism, in which actors implement a course of action or rules to strengthen their own position or advance a specific agenda (Klitkou et al., 2015; Kotilainen et al., 2019)

is seen as the responsibility of the Ministry of the Interior due to its authority over disaster planning (Interview ST04). However, we could find no evidence that the department for disaster planning considers mental health in the light of climate change as an area relevant to its work and remit, and our request for an interview was rejected. The overall lack of problem recognition and ownership among state actors relates to normalization dynamics, in that mental health is not a prioritized issue. Organizations that advocate for the integration and consideration of mental health in climate adaptation and for a more preventative and holistic approach to well-being include non-governmental groups, such as Psychologists 4 Future, the BDP, and members of the scientific community, but also representatives of the BBK and federal-level public servants. None of these groups has authority when it comes to adaptation or mental health care in Saxony-Anhalt, leaving room for state level actors and powerful actors within public health to continue the most convenient and economic path of excluding mental health from adaptation and leaving the matter of mental health in the aftermath of extreme weather events to non-governmental organizations or the insufficient health care system.

Capacity building dynamics, which relate to institutional and cognitive capacities are closely tied to the dynamics of normalization in the case of Saxony-Anhalt. The institutions that shape mental health in Germany and Saxony-Anhalt treat mental health in a pathogenetic manner, and strictly pertain to treating mental illness and disorders rather than also addressing prevention of mental health issues and the promotion of overall well-being. A former public servant, who is also a politician and psychologist researcher, shared that there is a lack of long-term research studies on well-being and mental health in Saxony-Anhalt, but they didn't think that the lack of knowledge is to blame for the adaptation gap, "*Psychologists and [everyone in] the medical field know what needs to be done. […] Prevention always saves money*" (Interview ST02). Rather, they explained that decisionmakers mainly are limited by costs and the length of fiscal periods which are only a few years at most. As for the lack of knowledge, experts are up to date when it comes to mental health and climate change, but political decisions are made by representatives who sit in several committees and decide on topics they do not have much time to learn about. Several interviewees mentioned that it is this lack of transfer of knowledge that prevents more effective changes from taking place (Interviews ST01-03).

Capacity building dynamics related to funding however, play a large role in terms of mental health in Germany. Nationally, mental health services are inadequate for dealing with the demand, and in rural areas patients have to wait longer to receive treatment. There is not an overall shortage of therapists, but insurance companies wield the power to limit the number of licenses for practicing therapists, whose patients' insurance cover treatment, thus resulting in an undersupply of therapy slots (Niemeyer and Knaevelsrud, 2023). This forces patients to either pay privately for treatment or wait an average of 20 weeks for treatment (Luft and Weydt, 2018). These shortcomings in the health system not only detract from many individuals' quality of life but also have greater societal costs. Furthermore, individuals with low socioeconomic status are less likely to utilize mental care despite higher numbers of mental health issues among low socioeconomic demographics (Epping et al., 2017; Niemeyer and Knaevelsrud, 2023) The German Psychotherapist Association calls for improvements in health care and reports that for every euro invested in psychotherapy, the societal benefits range from €2 to €5.5 (Rabe-Menssen et al., 2021).

Lastly, *asset accumulation dynamics* are relevant in terms existing investments, infrastructures and environments. In the introduction, it was explained how landscapes and physical infrastructures can both positively and negatively impact mental health. In the case of Saxony-Anhalt, we learned through an interviewee that school buildings, for example (which are state property) are seldomly adapted to promote well-being, in that both old and newly designed buildings and campuses do not include any measures to reduce heat stress and often lack green and blue elements. Also, investments in improving structural flood prevention measures are easier for decisionmakers to justify than other adaptation measures for mental health. Our research did not find data that proves lock-in mechanisms at play, but built structures constitute sunk costs, which are always expensive to replace or adapt, and much of our data points to constraints of public funding as a main reason for the observed adaptation gaps

In summary, mental health in the context of climate change and extreme weather events in Saxony-Anhalt is significantly affected by deeply rooted normalization dynamics, but also by dynamics of coalition building, capacity building, and asset accumulation. These dynamics sustain the neglect of mental health as an aspect of climate adaptation and its insufficient prioritization within public health and hinder developments that could improve societal resilience in the face of regional climate change.

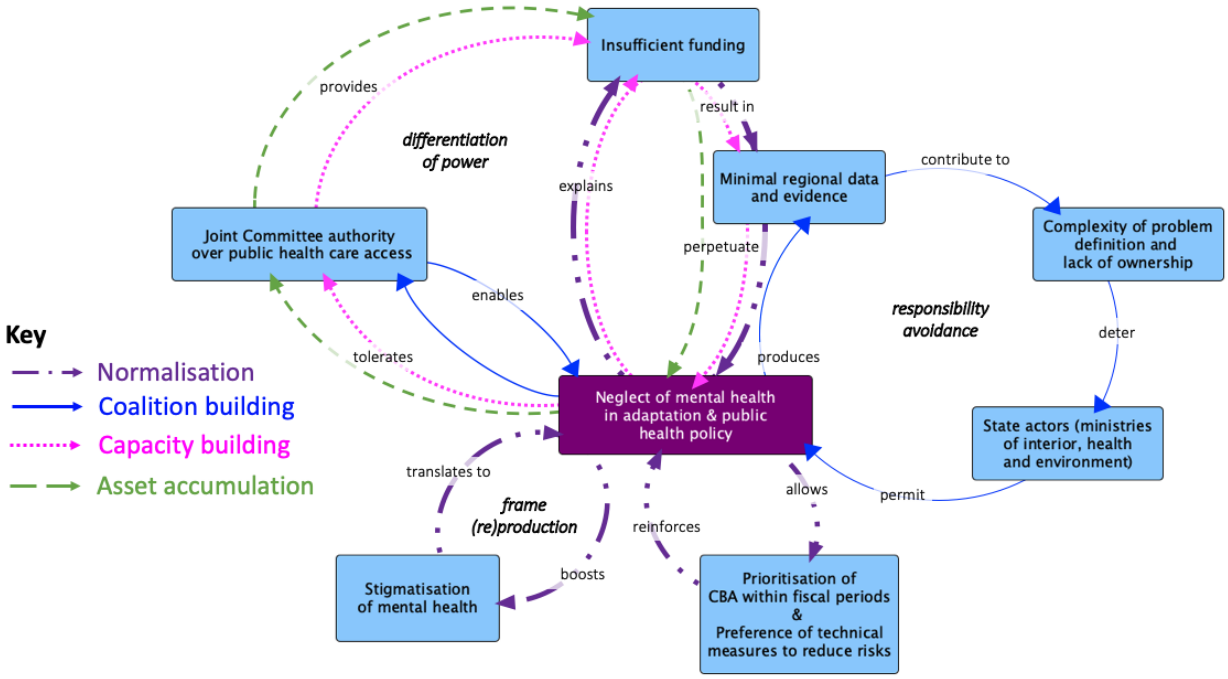

Figure 1: Main lock-in dynamics (arrows) and lock-in mechanisms (italicized text) in the Saxony-Anhalt case study; CBA refers to cost-benefit-analyses and the Joint Committee is the G-BA

4.2 The Netherlands

A long-standing stigma in the Netherlands regarding mental health negatively affects the image of mental health and represents a *normalization dynamic*, via the mechanism of frame (re)production. Mental health is generally not openly spoken about in the Netherlands. The stigma regarding mental health was fortified over time through stereotypes and prejudices, often based on misconceptions about the disorders that those affected by mental health problems face (Corrigan and Watson, 2002). The Trimbos Institute collected data in the Dutch NEMESIS-2 trial that indicates only 11 percent of all people with psychiatric disorders spoke about their mental health problems with people in their direct social circles (de Graaf et al., 2010). For the *Landelijke Monitor Ambulantisering 2019*, research was conducted amongst patients and providers in mental health care which found that 73 percent of respondents reported having experienced stigma that negatively affected their image of themselves and their confidence, hope and quality of life (Van Erp et al., 2019).

This stigmatization of mental health issues also extends to mental health problems linked to climate change and extreme weather events. Several interviewees mentioned that public opinions actively impede mental health from being addressed in climate adaptation policy. The long-standing stigma regarding mental health in the Netherlands may partly originate from the Dutch characterizing their own culture as 'down to earth': "*It seems […] as if people cannot imagine that [mental health problems] would be an issue here in the Netherlands. I don't know if that's some kind of cultural thing, that we think: we are 'no-nonsense Dutch'*" (Interview NL05). One of the respondents, a former youth representative to the UN, mentioned that they personally experienced the stigma when wanting to

express their concern about mental health problems in relation to climate change: *"[T]here is a big stigma on speaking out about [mental health problems due to climate change], because then you are seen as a young snowflake who can't handle reality."* (Interview NL04)

Another dynamic of normalization that is significant for adaptation for more well-being is that curative policies are valued over preventive measures within the Dutch healthcare sector. The majority of healthcare spending focused on curative care (Prince et al., 2015). This trend is based on a predominant and persisting line of thinking that has historically prevailed due to the limited understanding of the origins of disease (Waldman and Terzic, 2019). It remains challenging to deviate from this preference towards curative healthcare, despite the growing body of evidence that indicates a preventive approach can reduce overall healthcare expenditure while also increasing life expectancy (Grootjans-van Kampen et al., 2014). The paradigm of curative care is reinforced by a short-term focus on costs and effectiveness in the sector. Several interviewees, active as researchers (Interviews NL03, NL05, NL07), highlighted this.

Moreover, the financial interests of for-profit companies in the health care sector and societal expectations reinforce a preference towards certainty, as in familiar and more researched approaches, and thus, an under-researched field as the mental health effects linked to climate change becomes irrelevant for them, adding to the limited action in this regard (Ibid.). In addition, in regards to awareness of the issue and policy formulation, in the political arena it is common to examine policy problems with quantitative data. This habit and common procedure persists in many Dutch organizations and is hard to break. This normalizing lens constitutes another factor contributing to the limited policy action related to the mental health effects of extreme weather events, because quantified data on this topic is not readily available (Interviews NL05 and NL07). Attaching greater value to qualitative indicators and other ways of measuring would be useful, according to two interviewees working at a Dutch national research institute (Interviews NL03 and NL07).

Lastly, in terms of normalization and reinforcing frames, multiple interviewees described how Dutch climate adaptation largely focuses on water management, which has developed over time due to the Netherlands' history with "too much water" and become *normalized*. Therefore, climate adaptation measures mainly focus on preparing for rising sea levels, heavy precipitation and inland flooding in terms of physical safety but not necessarily in terms of overall well-being including mental health (KNMI, 2021; Ministerie van Infrastructuur en Waterstaat et al., 2021; Interviews NL03, NL06).

Interview respondents tended to reflect pessimistically on how all of the above-mentioned dynamics of normalization and framing could be overcome: *"you are always dependent on the existing culture, or the hierarchical structure*" (Interview NL06). One respondent suggested that a drastic change of culture would be necessary to get past these ingrained ways of working, which could be stimulated by the government giving incentives. However: "*Cultural changes like that are rare, actually, you need to change paradigms*." (Interview NL01)

In terms of *coalition building* dynamics, there is no significant coalition (although there are some individuals) that advocates for mental health in climate adaptation policies and thus a lack of lobbying for the issue. Even in the Dutch Knowledge Agenda for Climate and Health, mental health is not defined as an area requiring attention. The researchers that put together the Dutch Knowledge Agenda have conducted a survey amongst experts in the field, and in the open field comments of this survey – as answers to the question whether any additions should be made – only one mention of the mental health effects of extreme weather was made, in relation to wildfires (Huynen et al., 2019). The direct and acute effects of climate change – such as floods and other natural disasters – have not yet been as tangible in the Netherlands, allowing stakeholders to distance themselves from the problem more easily (Interviews NL01, NL03, NL07). One respondent, active as psychotherapist and consultant in the Netherlands, goes as far as to say that to increase the sense of urgency, something has to go really wrong (Interview NL06). Besides, the limited visibility of mental health problems, as these are hard to

quantify and objectify, results in limited political attention. A potential factor that could reverse this is the power of civil society and their collective action to advocate for the inclusion of mental health in the climate adaptation debate.

A lack of knowledge – in terms of *capacity building* – on how to deal with trauma victims in the case of a disaster does not seem to be an issue standing in the way of the development of policy in the Netherlands to adequately deal with the mental health effects of extreme weather events. An interviewee highlighted: *"when we talk about disorders related to disasters, a lot of knowledge has been available for a long time. We know about disasters, there are lots of studies into it and institutes that are working on it and handbooks have been written about it a long time ago, […] also in the Netherlands."* (Interview NL01). The same interviewee also mentions specific crises in the Netherlands from which knowledge can be derived: *"already back in the 1980's or 90's, there were floods in the surroundings of the rivers in the Netherlands. […] And back then we were busy drafting protocols […], all over the Netherlands, on disaster relief. Also, with the disaster in Amsterdam, […] the plane crash in the Bijlmer, that has been thoroughly […] investigated. They also certainly considered mental health, with post-traumatic stress disorder, both for the care providers and for the people who lived there. And you can use that knowledge about those disasters just fine."* (Ibid.)

However, there is limited intersectoral policy coherence regarding mental health matters in the Netherlands. The limited sharing of and learning from experiences with/in other sectors reinforces the isolation of the Dutch mental health sector (and simultaneously hampers coalition building efforts to put the issue on the political agenda). Dutch climate adaptation policy is covered mainly by one ministry and its sub-institutions, namely the Ministry of Infrastructure and Water, while the Ministry of Health, Welfare and Sport is not proactively involved. This helps explain why mental health is not being incorporated in climate adaptation policy:

"One of the things we noticed in conversations with the Ministry of Health, Welfare and Sport [VWS], is that they have left the climate issue mostly to the Ministry of Economic Affairs and Climate Policy [EZK], and they have handed it down to the Ministry of Infrastructure and Water [IenW], but [EZK and IenW] are working less on the health component, because health is more for VWS. [W]hen EZK and IenW are doing climate-related things, they occasionally remind [VWS] to think about health aspects, but [VWS] is not very proactively involved" (Interview NL07).

A lack of dialogue, limited research, and difficulties with objectifying and quantifying mental health effects are standing in the way of putting the topic on the political agenda. These factors reveal a lack of *capacity building* on the topic. Several interviewees mentioned that limited dialogue, reducing the visibility of the issue, contributes to limited policy action: "*Especially the socio-psychological side should be included, but that is really often overlooked when it comes to the theme of climate adaptation. Bringing that perspective in is very uncommon*" (Interview NL03).

Furthermore, visibility of the issue and research results are closely related. The limited research on mental health, climate change and extreme weather events in the Netherlands (and beyond) is a cause for the lack of its visibility and the limited public dialogue, and the relationship works both ways. A barrier that impedes research into the mental health problems caused by extreme weather events is that few financial resources are available (Interviews NL01, NL07). In addition, it has proven difficult to quantify the magnitude of mental health problems and to attribute mental health effects to a specific event. This complicates researching the mental health problems resulting from extreme weather events (Interviews NL01, NL07).

On a wider level, policy implementation (across many policy areas) has been increasingly decentralized over time in the Netherlands, a trend in which the responsibility for policy decisions is redistributed to provincial or municipal authorities. This trend of decentralization has been ongoing since more or less the 1970s, when responsibility for the Dutch welfare state was considered to be more efficiently

regulated locally (Boogers and Reussing, 2018). In 2015, a large decentralization of social issues took place, during which the responsibility and implementation of mental health care was relegated to the municipalities (VNG, 2013). Additionally, the execution of the National Adaptation Strategy is one of the many responsibilities of the provinces, the municipalities, and the Water Boards (Ministerie van Infrastructuur en Waterstaat, 2018), and the national government has not offered much supervision. In combination with limited coordination and little policy sharing and learning across decision-making levels, this has contributed to the lack of policy action on adapting to the mental health effects of extreme weather events (Interviews NL03, NL04, NL07). This absence of policy action related to sharing and learning indicates weak dynamics of *capacity building*.

The lack of therapists available in Dutch mental healthcare and long waiting lists for treatment became a more acutely issue after it was reported on in the national news in August 2021 (van den Brink, 2021). Three months later, the chairperson of De Nederlandse ggz, made it clear no short-term solution was possible (NOS, 2021). These long waiting lists result from both insurers' insufficient investments in mental healthcare and the government not setting aside sufficient funds. This shows that in terms of the dynamic of *asset accumulation*, finally, assets are not sufficiently built around mental healthcare.

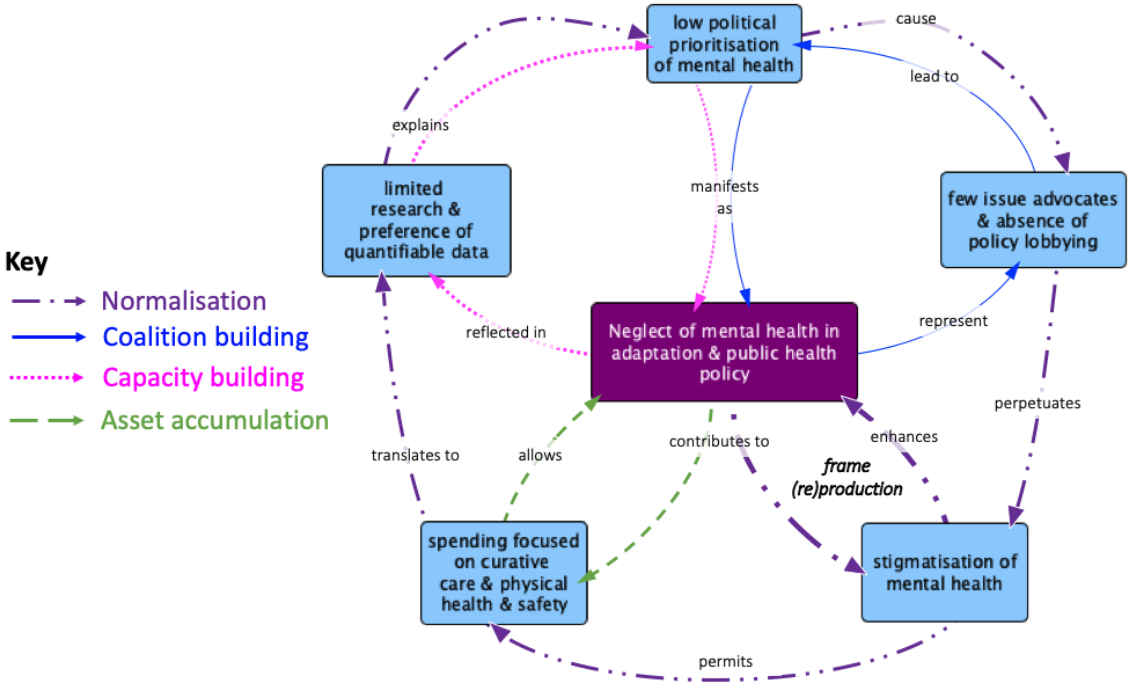

Figure 2: Main lock-in dynamics (as arrows) and a lock-in mechanism (italicized text) observed in the Netherlands case study

5. Discussion: Comparing the observed lock-in dynamics

Our analysis of these two case studies on mental health and climate adaptation through the lock-in perspective uncovered insights about how the four different types of dynamics both individually and collectively work to maintain the status quo, despite the need for change to provide the care and environment necessary for better overall well-being. Looking at both case studies, we recognize very similar profiles of both the adaptation gap and the lock-in dynamics that prevent mental health from becoming more of a priority within public health and policies relevant for adaptation (see Table 3). In all four categories of lock-in dynamics the two case studies share at least one common theme.

Table 3: Overview of the lock-in dynamics from each of the case studies; the underlined points are highly similar in both settings

	Saxony-Anhalt	the Netherlands
Normalization	• Stigmatization of mental health • Curative approach to health (rather than preventative) • Prevalence of CBA decision-making • Dominance of technical measures for risk reduction	• Stigmatization of mental health • Curative approach to health (rather than preventative) • Reliance on quantitative data for policymaking • Narrow interpretation of adaptation (focused on physical risks of water)
Coalition building	• Dominance of the Joint Committee / G-BA (differentiation of power) • Lack of leading authority within government; responsibility avoidance among public actors	• Few advocates for mental health that haven't organized as a coalition • Lack of leading authority within government
Capacity building	• Minimal regional data and evidence on climate change and mental health • Lack of knowledge transfer	• Minimal regional data and evidence on climate change and mental health • Lack of knowledge transfer • Decentralization of policy authorities
Asset Accumulation	• Insufficient funding in mental health care due to focus on curative care • Funding for flood defences rather than mental health programs • Sunk costs in state buildings	• Insufficient funding in mental health care due to focus on curative care

In both cases, there are the most examples of normalization dynamics that are highly significant for the mental health problem domain. In both case studies, we observed a stigma associated with mental health issues that is not isolated to public opinion but also plays a role in funding decisions and political decision making and represent examples of framing (re)productions (Groen et al., 2022). Both health care sectors approach health in a curative approach rather than a more holistic approach that would invest more in preventative care and overall well-being. In both cases we learned that mental health services were not capable of satisfying demands for psychological care and that funding schemes influenced by cultural and political norms were largely at fault.

Interviewees in both cases mentioned cultural norms not only in context of the stigmatization of mental health, but also in reference to attitudes towards risk communication and perceptions. In Germany the interviewee from the federal office for civil protection and disaster assistance explain how climate-related disasters are relatively new in Germany and that role in risk communication, whereas in the Netherlands, there is a long-standing perception of flood prevention, which has narrowed the focus of climate adaptation policy. Even though there are psychological effects of flooding, policy focuses on the management of the water itself and less about wider risks for mental health.

Another similarity in both cases is the prevalence of cost-benefit-based and data-focused decision making among politicians and those in power. This type of thinking often reinforces the status quo and other decisions, which are easily calculable and billable within legislative periods. Preventative health care and investments in awareness-raising initiatives or mental health care training, for example, are harder to calculate in terms of cost-benefit-analyses, in that their benefits are long-term and intangible. It becomes even harder for such adaptation measures to win policy support, when data supporting their value is scarce or limited to examples from other countries and cultures.

These normalizing dynamics are not only detrimental to public mental health on the whole but also prevent progress in terms of adaptation measures and policies related to mental health. We also observed that these normalizing dynamics are permeable and affect the other types of lock-in dynamics.

Normative decisions on policies and investments are closely tied to capacity-building dynamics, for example. In both cases we heard that more regionally-specific data could potentially help prioritize mental health and climate adaptation; but research requires funding and funding-allocation often requires lobbying and public and/or political support for a topic. This lack of evidence and knowledge transfer demonstrate a self-reinforcing dilemma that is also tied to coalition building dynamics. If there were a coalition or lobby with the power to allocate funding to mental health and climate adaptation research, the topic could potentially make it onto the political agenda. However, in the Netherlands advocates of mental health in the context of climate change were observed to be scarce, and in the case of Saxony-Anhalt supporting groups do not wield any policy power and only little societal influence. Neither government we studied has a public actor with authority, leadership or a coordinating role in respect to mental health and climate change which signifies a lack of problem ownership.

One difference between the two case studies, though, is that there seems to be somewhat more recognition of psychosocial care in the context of climate change at the national level in Germany, at least within the BBK, but the national institutions have no policy authority at lower levels of government, such as in the state of Saxony-Anhalt. In the Netherlands, our research did not find that experience and knowledge on psychosocial care had transferred from non-climate related disasters into the context of climate risks.

Finally, asset accumulation dynamics in both case studies are closely tied to normalization dynamics in that funding in mental health and preventative care is insufficient for dealing with the demands for mental health care. In the case of Saxony-Anhalt, the G-BA chooses to continue outdated funding schemes to avoid higher costs, and observations from the Dutch case indicated that some public health decisions are influenced by the economic incentives of for-profit health providers.

Overall, normalization dynamics, such as cognitive frames and the norms that influence decision making, appear to be the most significant sources of lock-in for this problem domain, which is reflected by both Figures 1 and 2 as well as Table 3. This observation is similar to some findings of Jager et al. (2022), who found that knowledge systems and cognitive frames played a significant role in the lock-ins observed within coastal management adaptation and water scarcity in two German case studies, and Groen et al. (2022) who found several lock-in mechanisms related to normalization dynamics in English and German coastal management cases (e.g. framing (re)production, adaptive expectations, and habituation). These collective findings indicate that the problem and policy framing as well as cultural and cognitive norms could be a key intervention point for unlocking change to enable more adaptation. However, in the case of mental health and climate change and the Netherlands an equally important first step may be the formulation of an actor group or coalition with the power or range to initiate change by promoting both mental health and alternative approaches to well-being.

6. Conclusion and Recommendations

This paper is the first of its kind and has explored the lock-in dynamics hindering adaptation to the mental health impacts of climate change in Saxony-Anhalt (Germany) and the Netherlands. In two cases, we observed that normalization dynamics, such as cultural stigmas and funding biases toward curative rather preventative mental health care, are significant obstacles in closing the adaptation gap. The research underscores the interconnectedness of these normative dynamics with other system elements such as coalitions and assets, highlighting the complexity of the challenge to better integrate mental health into climate adaptation governance. Our findings indicate that the lack of policy authority and

leadership and the absence of cohesive advocacy further exacerbate the neglect of mental health in the context of climate adaptation governance.

Based on these findings against the backdrop of growing international research on climate adaptation and mental health (e.g. Hayes et al., 2020; Lawrance et al., 2022; Turnpenny and Alexander, 2024), we further emphasize the need for policy change. To address the adaptation gap in mental health care and climate adaptation, this paper recommends adopting and implementing the "health in all policies" approach, ensuring mental health considerations are embedded in climate adaptation strategies and vice versa. Effective adaptation requires interdisciplinary, interdepartmental collaboration instead of the isolation of mental health within institutions of health. Creating and ensuring access to more green and blue spaces constitute adaptation measures that positively affect mental health and have other synergies in the context of adaptation (Braubach et al., 2021). Another measure to improve adaptation entails capacity building through community collaboration, empowerment, and community building (as described by Hayes et al.,2020) to enhance both long-term resilience and disaster recovery. Hayes et al. (2020), for example, have highlighted how community-based and informal support systems and resources act as key protective factors of psychosocial health in the face of disasters and extreme weather events (ibid). These measures could be preceded or flanked by increased campaigns to destigmatize mental health among German and Dutch societies and inform citizens about climate change related risks to mental health and overall well-being. As suggested by the WHO (2018), the removal of barriers to investments in climate-resilient health systems and "climate-smart" health care facilities is essential. In Germany and the Netherlands, this would potentially mean radically changing funding policies currently restricted by the Joint Committee (in Germany) and classic cost-benefit analysis-based, short-term (and partially for-profit) financial decision-making to allow funding for more holistic, long-term. and preventative approaches to public health. Sustained mental health and social service funding is crucial, and yet both countries' systems were found to be underfunded and incapable of keeping up with the demand for mental health care.

Further research is essential for improving policies to achieve better mental health in the context of climate change. More regionally-specific research and long-term research on the relationship between climate change and mental health are needed, also in the Netherlands and Germany, to inform policy decisions and help change cultural perceptions. Further research specifically on the adaptation gap and the concept of lock-ins could be conducted in other governance settings and on the local level to uncover more detailed dynamics. Asset accumulation dynamics, for example, are closely tied to natural and built environments and are likely to significantly impact mental health and adaptation on a smaller scale than we were able to investigate by examining state and national level cases. Investigating effective coalition-building strategies and knowledge transfer mechanisms and their transferability to other policy settings could be particularly useful for instigating change in cases of active lock-in dynamics, such as those found in this research.

Overall, concerted research and policy efforts are necessary in order to close the adaptation gap and ensure that mental health does not continue to be overlooked in climate adaptation strategies and public health. By embedding the suggested measures within new and existing policies, society may become more resilient and adaptive and thus more capable of withstanding the increasing risks of climate change.

List of Acronyms and Abbreviations

BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe / Federal Office of Civil Protection and Disaster Assistance
BDP	Berufsverband Deutscher Psychologinnen und Psychologen / National Association of German Psychologists
BMG	Bundesministerium für Gesundheit / Federal Ministry of Health
CBA	cost-benefit-analyses
CCA	climate change adaptation
COP	Conference of the Parties
EU	European Union
EZK	*Ministerie van Economische Zaken en Klimaat /* Ministry of Economic Affairs and Climate Policy
G-BA	Gemeinsamer Bundesausschuss / Federal Joint Committee
ggz	Geestelijke gezondheidszorg / mental health care
IenW	Ministerie van Infrastructuur en Water / Ministry of Infrastructure and Water
IPCC	Intergovernmental Panel on Climate Change
MS	Ministerium für Arbeit, Soziales, Gesundheit und Gleichstellung des Landes Sachsen-Anhalt / Saxony-Anhalt State Ministry of Labor, Social Affairs, Health and Equality
MI	Ministerium für Inneres und Sport des Landes Sachsen-Anhalt / Saxony-Anhalt State Ministry of the Interior and Sports
MULE	Ministerium für Umwelt, Landwirtschaft und Energie des Landes Sachsen-Anhalt / Saxony-Anhalt State Ministry of Environment, Agriculture and Energy
NAS	Nationale klimaatadaptatie strategie / National climate adaptation strategy
NCEI	National Centers for Environmental Information
PSNV	psychosoziale Notfallversorgung / psychosocial emergency care
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
VWS	Ministerie van Volksgezondheid, Welzijn en Sport / Ministry of Health, Wellbeing and Sport
WHO	World Health Organization

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Carl von Ossietzky Universität Oldenburg / 26111 Oldenburg

Promotionsausschuss
Department für Wirtschafts- und
Rechtswissenschaften

Im Hause

Carl von Ossietzky
Universität
Oldenburg

Fakultät II - Informatik,
Wirtschafts- und
Rechtswissenschaften
**Department für
Wirtschafts- und
Rechtswissenschaften**

Ökologische Ökonomie
Prof. Dr. Bernd Siebenhüner
Tel.: 0441 798 - 4366
bernd.siebenhuener@uol.de

Sekretariat
Birgit Schelenz
Tel.: 0441 798 – 4384
birgit.schelenz@uol.de

Oldenburg, den 11.09.2024

Standort
Campus Haarentor, Gebäude A5
26129 Oldenburg

Postanschrift
26111 Oldenburg

Paketanschrift
Ammerländer Heerstraße 114–118
26129 Oldenburg

Bankverbindung
Landessparkasse zu Oldenburg
IBAN DE46 2805 0100 0001 9881 12
BIC SLZODE22

Steuernummer
6422008701

www.uol.de

Stellungnahme zur Einreichungsfähigkeit des Arbeitspapiers "Lock-in dynamics hindering climate adaptation for mental health" für die kumulative Dissertation von Julie King

Das Arbeitspapier von Lead-Autorin Julie King, das sie zusammen mit Lisanne Groen (Open University Netherlands) verfasst hat, erfüllt die akademischen Standards wissenschaftlicher, referierter Fachzeitschriften in mehrfacher Hinsicht: (i) Die Forschungsfragen sind schlüssig und relevant, da sie ein bisher wenig erforschtes Themengebiet im Rahmen der sozialwissenschaftlichen Forschung zu Klimaanpassung bearbeiten. Die möglichen Auswirkungen von Klimafolgen, wie Überflutungskatastrophen, langanhaltende Dürren oder gravierende Krankheiten, auf die mentalen Gesundheit von Menschen sind bislang wenig wissenschaftlich untersucht. Auch in der politisch-gesellschaftlichen Behandlung ist das Thema in den meisten Industrieländern in den Kinderschuhen. Gleichwohl konnten die Arbeiten in dem von mir geleiteten vergleichend angelegten Forschungsprojekt "Adapt Lock-In" (DFG-gefördert) zeigen, dass z.B. in Großbritannien insbesondere im Nachgang zu einem Überflutungsereignis politisch-regulative Entwicklungen angestoßen wurden. (ii) Zudem verwenden die Autor*innen anerkannte Forschungsmethoden in Form einer eine tiefgehende Dokumentenanalyse und 10 Expert*inneninterviews. Die Datengrundlage kann auch in Anbetracht des wenig bearbeiteten Themenfeldes als solide bezeichnet werden. (iii) Auch die Auswertung unter Nutzung von anerkannten qualitativen Analysemethoden wie der thematischen Analyse und des "Fingerprints"-Ansatzes im Rahmen des Process-Tracing unterstreicht die methodische Stringenz des Arbeitspapiers. Zudem ordnet sich das Arbeitspapier sehr gut in den aktuellen Stand der Forschung ein und entsprechend relevante wissenschaftliche Diskurse ein, wie wir in dem derzeit in Vorbereitung befindlichen Buchveröffentlichung aus dem o.g. Projekt zeigen.

Zudem basiert der konzeptionelle Ansatz des Papiers auf einer disziplinübergreifenden und -integrierenden Herangehensweise, indem die Perspektiven der Politikanalyse, der Katastrophensoziologie, der Klimaanpassungsforschung und der Psychologie miteinander verbun-

den werden. Damit können mehrere Dimensionen des komplexen Problemfeldes adressiert werden, das mehrere herkömmliche Politikbereiche überschreitet und vielfältige Akteure involviert.

Inhaltlich bietet die durchgeführte Forschung wertvolle Erkenntnisse zu den Dynamiken der Macht- und Verantwortungsverteilung im deutschen Gesundheitssystem und deren Einfluss auf die Anpassungskapazitäten im Bereich der psychischen Gesundheit in Bezug auf den Klimawandel. Die Diagramme der beobachteten Dynamiken sind besonders hervorzuheben, indem sie die Erkenntnisse auf einem Blick zusammenfassen. Diese Erkenntnisse sind nicht nur theoretisch bedeutend, sondern haben auch praktische Implikationen für die Gestaltung zukunftsfähiger Gesundheits- und Klima-anpassungspolitiken.

Insgesamt stellt das Arbeitspapier daher ein gelungenes Beispiel für die Umsetzung hoher akademischer Standards und die Durchführung innovativer sozialwissenschaftlicher Forschung dar. Hiermit bestätige ich als Erstgutachter von Frau King die Einreichungsfähigkeit des Manuskripts.

Prof. Dr. Bernd Siebenhüner

c. Co-Author declarations (3)

<u>Paper 2</u>: "New challenges and established policy fields – Assessing stability and change in climate adaptation policy through a lock-in perspective"

<u>Full reference</u>: Jager, Nicolas W., **King, Julie P**.& Siebenhüner, Bernd (2022) 'New challenges and established policy fields – Assessing stability and change in climate adaptation policy through a lock-in perspective', *der modern Staat – Zeitschrift für Public Policy, Recht und Management*, pp. 394–412. <u>https://doi.org/10.3224/dms.v15i2.06</u>

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<u>Distribution of authorship:</u>

Nicolas Jager	45%
Julie King	45%
Bernd Siebenhüner	10%

The signatures of the co-authors verify that Julie King contributed to this co-authored publication as detailed below and their consent to the use of the co-authored publication as part of Julie King's dissertation at the Carl von Ossietzky University of Oldenburg.

Author	Share	Details of contribution	Signature
Nicolas W. Jager	45%	– Led author team coordination and submission process – Collaborated in the development of the conceptualization and literature review – Led Thuringia case study investigation (conducted 8 interviews) – Supported Schleswig-Holstein case study investigation and analysis – Wrote major sections of the original draft and participated in editing – Contributed to the review and rewriting process	
Julie P. King	45%	– Collaborated in development of the conceptualization and literature review – Led Schleswig-Holstein case study investigation and analysis (conducted 10 interviews) – Wrote major sections of the original draft and helped in editing – Contributed to the review and rewriting process	
Bernd Siebenhüner	10%	– Collaborated in development of the conceptualization – Wrote minor sections of the original draft and helped in editing – Participated in the review and rewriting process	

Paper 3: "Re-examining policy stability in climate adaptation through a lock-in perspective"

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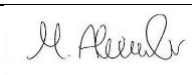
Status: published

Distribution of authorship:

Lisanne Groen	25%
Meghan Alexander	25%
Julie King	25%
Nicolas Jager	20%
Dave Huitema	5%

The signatures of the co-authors verify that Julie King contributed to this co-authored publication as detailed below and their consent to the use of the co-authored publication as part of Julie King's dissertation at the Carl von Ossietzky University of Oldenburg.

Author	Share	Details of contribution	Signature
Lisanne Groen	25%	– Led author team coordination and submission process – Collaborated in the development of the conceptualization – Participated in the literature review and analysis – Wrote sections of the original draft and participated in editing – Worked on developing tables 1 & 2 – Contributed to the review and rewriting process	
Meghan Alexander	25%	– Collaborated in the development of the conceptualization – Led England case study investigation (conducted 10 interviews) – Responsible for the England case study data curation – Participated in the literature review and analysis – Wrote sections of the original draft and helped in editing – Created figure 1 and worked on developing tables 1 & 2 – Contributed to the review and rewriting process	
Julie P. King	25%	– Collaborated in development of the conceptualization – Led Schleswig-Holstein case study investigation (conducted 10 interviews) – Responsible for the Schleswig-Holstein case study data curation – Contributed to literature review and analysis – Wrote sections of the original draft and helped in editing – Created figure 2 and worked on developing tables 1 & 2 – Contributed to the review and rewriting process	
Nicolas W. Jager	20%	– Collaborated in development of the conceptualization – Supported parts of the Schleswig-Holstein case study investigation (participated in 2 interviews) – Participation in literature review and analysis – Wrote sections of the original draft and helped in editing – Contributed to the review and rewriting process	
Dave Huitema	5%	– Collaborated in development of the conceptualization – Supported literature review and analysis – Wrote some sections of the original draft and helped in editing – Participated in the review and rewriting process	

<u>Paper 4:</u> Lock-in dynamics hindering climate adaptation for mental health

<u>Full reference</u>: **King, Julie P**. & Groen, Lisanne (forthcoming) 'Lock-in dynamics hindering climate adaptation for mental health', in Siebenhüner, B., Huitema, D., Turnpenny, J., Alexander, M., Groen, L., Jager, N., King, J. and Rayner, T. (eds.) *Lock-ins in Climate Change Adaptation Governance.* Cambridge: Cambridge University Press.

<u>Status</u>: working paper – chapter of edited volume

<u>Distribution of authorship:</u>

Julie King	80%
Lisanne Groen	20%

The signatures of the co-authors verify that Julie King contributed to this co-authored publication as detailed below and their consent to the use of the co-authored publication as part of Julie King's dissertation at the Carl von Ossietzky University of Oldenburg.

Author	Share	Details of contribution	Signature
Julie P. King	80%	– Led author team – Collaborated in development of the conceptualization and literature review – Led Saxony-Anhalt case study investigation and analysis – Assisted in Dutch analysis and creation of Figure 2 – Wrote major sections of the original draft and led editing	
Lisanne Groen	20%	– Led author team and coordinated submission process – Collaborated in development of the conceptualization and literature review – Led Dutch case study investigation and analysis – Wrote one section of the original draft and assisted in editing	

d. Interview Guide

Sections of text in black were the same in all three problem domains. Alterations to the interview guide for the specific problem domains are color coded: blue for coastal risks, green for water scarcity, and red for mental health.

Interviewleitfaden

Können Sie bitte einen kurzen Überblick über Ihre aktuelle Rolle und Erfahrungen im Bereich Klimaanpassung geben?

Wie und in welchem Ausmaß werden die Auswirkung des Klimawandels in der aktuellen Politik und im derzeitigen Küstenmanagement/Niedrigwassermanagement berücksichtigt?)

Ist sie/diese aus Ihrer Sicht ausreichend?

// Wie und in welchem Ausmaß werden die Auswirkungen des Klimawandels, wie Extremereignisse, in der derzeitigen Gesundheitspolitik/Klimapolitik berücksichtigt?

Ist sie/diese für eine langfristig, gesunde Gesellschaft aus Ihrer Sicht ausreichend?

Wie könnte Klimaanpassung im aktuellen Küstenmanagement an der Nordseeküste Schleswig-Holsteins/ die psychische Gesundheit in Bezug auf dem Klimawandel in der aktuellen Gesundheitspolitik/Planung in Sachsen-Anhalt besser berücksichtigt werden?[13]

Wenn nein bei Frage 2 (Klimaanpassung ist nicht ausreichend berücksichtigt):

- Wo befinden sich Schwachstellen, z.B. ist die Anpassung an den Klimawandel überhaupt ein ausdrückliches Ziel, wird zu wenig gehandelt, fehlen politische Instrumente, sind diese ungeeignet, oder fehlt die Umsetzung?
- Warum wurde das Problem bisher nicht weiter berücksichtigt?
- In welchem Ausmaß wurden alternative oder neue Ansätze/Strategien betrachtet oder ausprobiert?
- Was waren oder sind Hindernisse für das Ausprobieren alternativer oder neuer Ansätze und Strategien?

Wenn ja bei Frage 2 (Klimaanpassung wird ausreichend adressiert/verfolgt):

- Was hat die Aktivitäten zur Klimaanpassung ermöglicht und vorangetrieben?
- Gab es Herausforderungen oder Hindernisse, die überwunden werden mussten?
- Welche alternativen, neuen Ansätze wurden ausprobiert bzw. in die bestehenden Strategien integriert?
- Welche Hindernisse standen diesen Alternativen im Weg?

Was genau steht weitergehenden oder alternative Maßnahmen zur Klimaanpassung im Weg?

Discourses/Practices

- Welche Ziele, Leitlinien und Paradigmen prägen den Bereich? (z.B. Sicherheit, Risikomanagement, usw.)
- Wie haben diese sich im Laufe der Zeit geändert?
- Welche Strategien/Leitlinien werden implementiert und welche werden als sinnvoll/machbar betrachtet, was gilt als nicht machbar?

[13] Diese Frage wurde im Fallbeispiel Thüringen später im Interview gestellt

- Was wird für „innovativ“ gehalten? In welchem Ausmaß werden neue Ansätze/Strategien verfolgt und ausprobiert bzw. in welchem Ausmaß wird darin investiert?
- Ist man eher risikoscheu oder risikofreudig? / Wie wird mit Unsicherheit in der Datengrundlage umgegangen?
- Haben Planungshorizonte sich verkürzt oder verlängert vor dem Hintergrund des Klimawandels?
- Woher kommen neue Ansätze/Strategie oder Innovationen, wenn überhaupt?
- Werden unterschiedliche „Maßnahmentypen“ betrachtet, z.B. infrastrukturelle/technische, informationsbasierte, verhaltensbasierte, und organisatorische Maßnahmen?
- Welche Maßnahmen werden unter Klimaanpassung gefasst?
- Wie beurteilen Sie den gesellschaftlichen und politischen Stellenwert von psychischer Gesundheit? Wie hat er sich über die letzten Jahre geändert?
-

Actors
- durch das Netzwerk der beteiligten Akteure und Organisationen, und wie es sich im Laufe der Zeit entwickelt hat?
- wurden diese Netzwerk formell etabliert oder sind sie informell entstanden?
- Wie vernetzt sind verschiedene Politikbereiche/Verwaltungsbereiche und Akteure untereinander?
- Gibt es Synergien oder Konflikte zwischen den Zielen oder Regelungen verschiedener Politikbereiche oder Organisationen?
- Wie sind die Einstellungen gegenüber Zusammenarbeit? Gibt es Anreize dafür?
- Sind alle relevanten Organisationen/Stakeholder gebührend involviert?

Rules
- Welche zentralen Regelungen/Bestimmung, z.B. Gesetze, Verordnungen, Pläne, schränken transformative Klimaanpassung ein? Warum?
- Welche Rolle spielen informelle Regeln und Erwartungen?
- Wie werden Entscheidungen getroffen (z.B. welche Faktoren spielen eine Rolle): Wie werden Ressourcen verteilt? Wer ist beteiligt und wie?

Resources
- Sind die richtigen Ressourcen verfügbar? Reichen diese aus?
- Besteht Wettbewerb um Ressourcen oder findet sachgerechte Verteilung statt?
- Welche Formen des Wissens/Datengrundlage wird für Entscheidungen herangezogen?

Inwiefern haben bestehende und verfügbaren Technologien und Infrastruktur einen Einfluss auf Politik (oder auf Richtlinien/Vorschriften) und Klimaanpassung? Z.B. ...

Infrastructures & Technologies
- Welche Arten von Technologie und Infrastruktur werden primär eingesetzt und warum? Hat sich das im Laufe der Zeit geändert?
- Werden die Vor- und Nachteile der jeweiligen Optionen aus Ihrer Sicht ausreichend betrachtet?
- Wie wird der Einsatz bestimmter Arten von Infrastruktur oder technischer Lösungen von Gesetzen oder Regelungen vorgeschrieben oder begünstigt?
- In welchem Ausmaß werden Alternativen betrachtet? Wie wird die Einsatzbarkeit evaluiert/bewertet?
- Wie sind die Kosten der Alternativen im Vergleich zu den üblichen technischen Lösungen einzuschätzen? In wieweit stehen Kostengründe Alternativen im Weg?
- In wieweit erfordern bestehende Infrastruktur und genutzte Technologien ihre weitere Nutzung oder die Nutzung kompatibler Lösungen?
- Welche weiteren Barrieren behindern die Investition und Umsetzung alternativer Infrastruktur/Technologien wie z.B. alternative Beregnungsformen, Wasserwiederverwendung

Wie könnte die Klimaanpassung im aktuellen Niedrigwassermanagement in Thüringen besser berücksichtigt werden?

Wenn nein bei Frage 2 (Klimaanpassung ist nicht ausreichend berücksichtigt):

- Wo befinden sich Schwachstellen, z.B. ist die Anpassung an den Klimawandel überhaupt ein ausdrückliches Ziel, wird zu wenig gehandelt, fehlen politische Instrumente, sind diese ungeeignet, oder fehlt die Umsetzung?
- Warum wurde das Problem bisher nicht weiter berücksichtigt?
- **In welchem Ausmaß wurden alternative oder neue Ansätze/Strategien betrachtet oder ausprobiert?**
- Was waren oder sind Hindernisse für das Ausprobieren alternativer oder neuer Ansätze und Strategien?

Wenn ja bei Frage 2 (Klimaanpassung wird ausreichend adressiert/verfolgt):

- Was hat die Aktivitäten zur Klimaanpassung ermöglicht und vorangetrieben?
- Gab es Herausforderungen oder Hindernisse, die überwunden werden mussten?
- **Welche alternativen, neuen Ansätze wurden ausprobiert bzw. in die bestehenden Strategien integriert?**
- Welche Hindernisse standen diesen Alternativen im Weg?

Rückblickend auf die letzten Jahre (oder sogar Jahrzehnte), was hätte zum Beispiel besser oder anders laufen können, um Anpassungen an den Klimawandel zu ermöglichen oder besser zu berücksichtigen?

Inwiefern beeinflussen andere Faktoren oder Themen den derzeitigen Umgang mit Klimaanpassung? z.B. Politische Rahmenbedingungen, die Pandemie, Flüchtlingskrise, …

Wo gibt es Interaktionen?

Sie haben verschiedene Faktoren beschrieben, die Klimaanpassung beeinflussen und/oder erschweren. [Zum Beispiel…] **Welche davon sind aus Ihrer Sicht am wichtigsten?**

Was sind mögliche Chancen und Herausforderungen für weiteren zukünftigen Wandel, um Klimaanpassung besser zu berücksichtigen?

Möchten Sie noch etwas ergänzen oder erzählen, was aus Ihrer Sicht relevant für unsere Forschung ist aber noch nicht angesprochen wurde?

* Mit wem sollen wir auch über das Thema sprechen?

* Der Person über die nächsten Schritte informieren und nachfragen, ob er/sie Interesse hätte in Kontakt zu bleiben.

e. List of interviewees interviewed in Germany

ID	Case Study	Role / remit of responsibilities	Interviewer (initials)	Interview date	UK Repository File Name
Fed01	Case selection	researcher, governmental advisor	NJ & JK	8.1.2020	IntFed01_archive
Fed02	Case selection	federal environmental administration representative, health focus	JK & TG	8.1.2020	IntFed02_archive
Fed03	Case selection	federal environmental administration representative	NJ & JK	14.1.2020	IntFed03_archive
Fed04	Case selection	researcher, water focus	JK	29.1.2020	IntFed04_archive
Fed05	Case selection	researcher, governmental advisor	JK	31.1.2020	IntFed05_archive
Fed06	Case selection	researcher, water focus	JK	6.2.2020	IntFed06_archive
SH01	Coastal risks (Schleswig-Holstein)	scientist	NJ & JK	14.10.2020	IntSH01_archive
SH02	Coastal risks (Schleswig-Holstein)	nature conservation representative, NGO	NJ & JK	22.10.2020	IntSH02_archive
SH03	Coastal risks (Schleswig-Holstein)	state administration representative (coastal mgmt) /scientist	NJ	28.10.2020	IntSH03_archive
SH04	Coastal risks (Schleswig-Holstein)	NGO representative	JK	5.11.2020	IntSH04_archive
SH05	Coastal risks (Schleswig-Holstein)	state administration representative/scientist (disaster response planning)	JK	10.11.2020	IntSH05_archive
SH06	Coastal risks (Schleswig-Holstein)	drainage association representative	JK	17.11.2020	IntSH06_archive
SH07	Coastal risks (Schleswig-Holstein)	state administration representative (planning)	JK	7.12.2020	IntSH07_archive
SH08	Coastal risks (Schleswig-Holstein)	NGO stakeholder, former consultant & scientist	JK	10.12.2020	IntSH08_archive
SH09	Coastal risks (Schleswig-Holstein)	state administration representative (adaptation focus)	JK	18.12.2020	IntSH09_archive
SH10	Coastal risks (Schleswig-Holstein)	state administration representative (coastal mgmt)	JK	14.1.2021	IntSH10_archive
ST01	Mental Health (Saxony-Anhalt)	state administration representative	JK	14.2.2022	IntST01_archive
ST02	Mental Health (Saxony-Anhalt)	former state administration representative/scientist	NJ & JK	7.3.2022	IntST02_archive
ST03	Mental Health (Saxony-Anhalt)	federal disaster planning representative	JK	8.7.2022	IntST03_archive
ST04	Mental Health (Saxony-Anhalt)	state health administration representative	JK	19.5.2022	IntST04_archive
T01	Water scarcity (Thuringia)	water provider	NJ	25.10.2021	IntT01_DE_archive
T02	Water scarcity (Thuringia)	state administration representative	NJ	18.10.2021	IntT02_DE_archive
T03	Water scarcity (Thuringia)	state administration representative	NJ	20.8.2021	IntT03_DE_archive
T04	Water scarcity (Thuringia)	NGO stakeholder	NJ	10.11.2021	IntT04_DE_archive
T05	Water scarcity (Thuringia)	state administration representative	NJ	5.11.2021	IntT05_DE_archive
T06	Water scarcity (Thuringia)	business stakeholder	NJ	22.2.2022	IntT06_DE_archive
T07	Water scarcity (Thuringia)	researcher, scientist	NJ	8.3.2022	IntT07_DE_archive