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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).

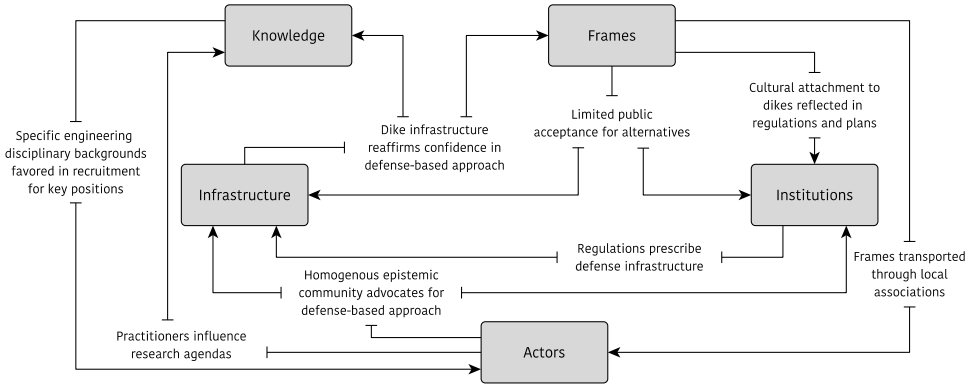
While *actors and agency* for coastal adaptation can be found on multiple governance levels and involves a number of stakeholders, the central actor is the Ministry of Environment (MELUND), which is responsible for strategic planning of coastal defense. Below it, the State Agency for Coastal Protection 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.

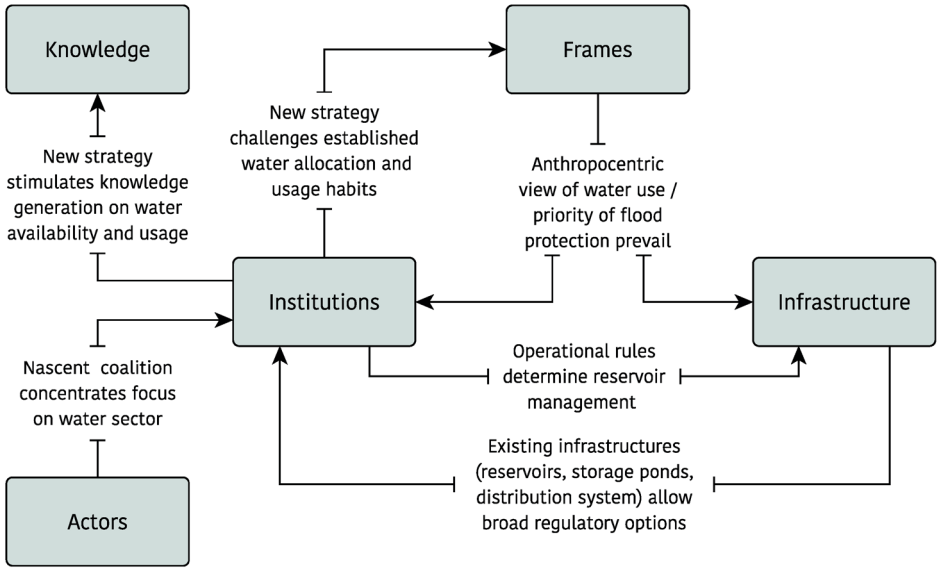
Like infrastructures, *institutions* and regulations were initially drafted under different climatic conditions when the main concern about water quantity was about flooding with scarcity playing a rather minor role. For instance, regulations of the operation of storage water dams, some of which are 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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