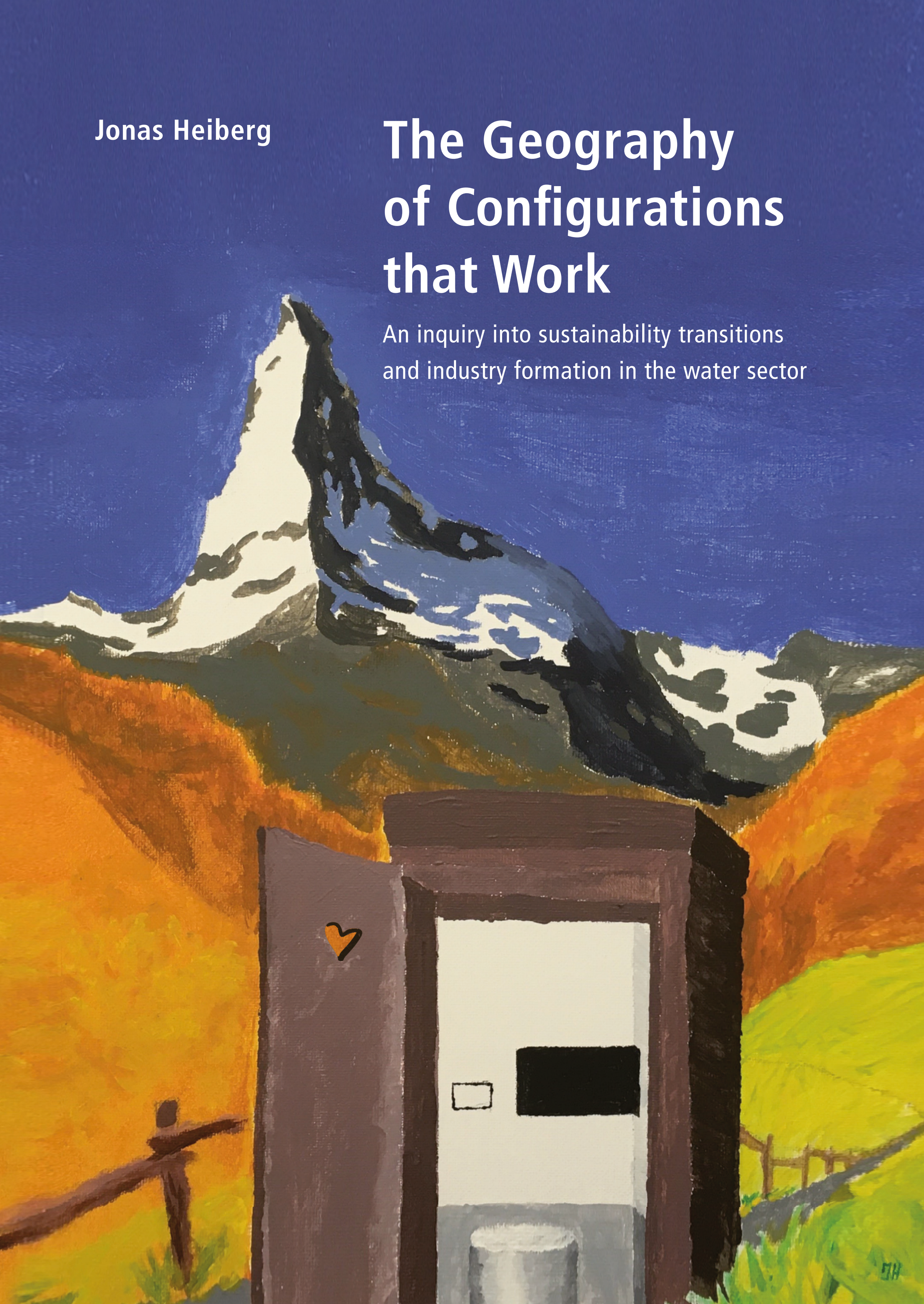
Jonas Heiberg

The Geography of Configurations that Work

An inquiry into sustainability transitions and industry formation in the water sector



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The geography of configurations that work

An inquiry into sustainability transitions and industry formation in the water sector

De geografie van configuraties die werken
Een onderzoek naar duurzaamheidstransities en industrievorming in de watersector
(met een samenvatting in het Nederlands)

Die Geographie funktionierender Konfigurationen
Eine Untersuchung von Nachhaltigkeitstransitionen und Industrieformierung im Wassersektor
(mit einer Zusammenfassung in deutscher Sprache)

Proefschrift

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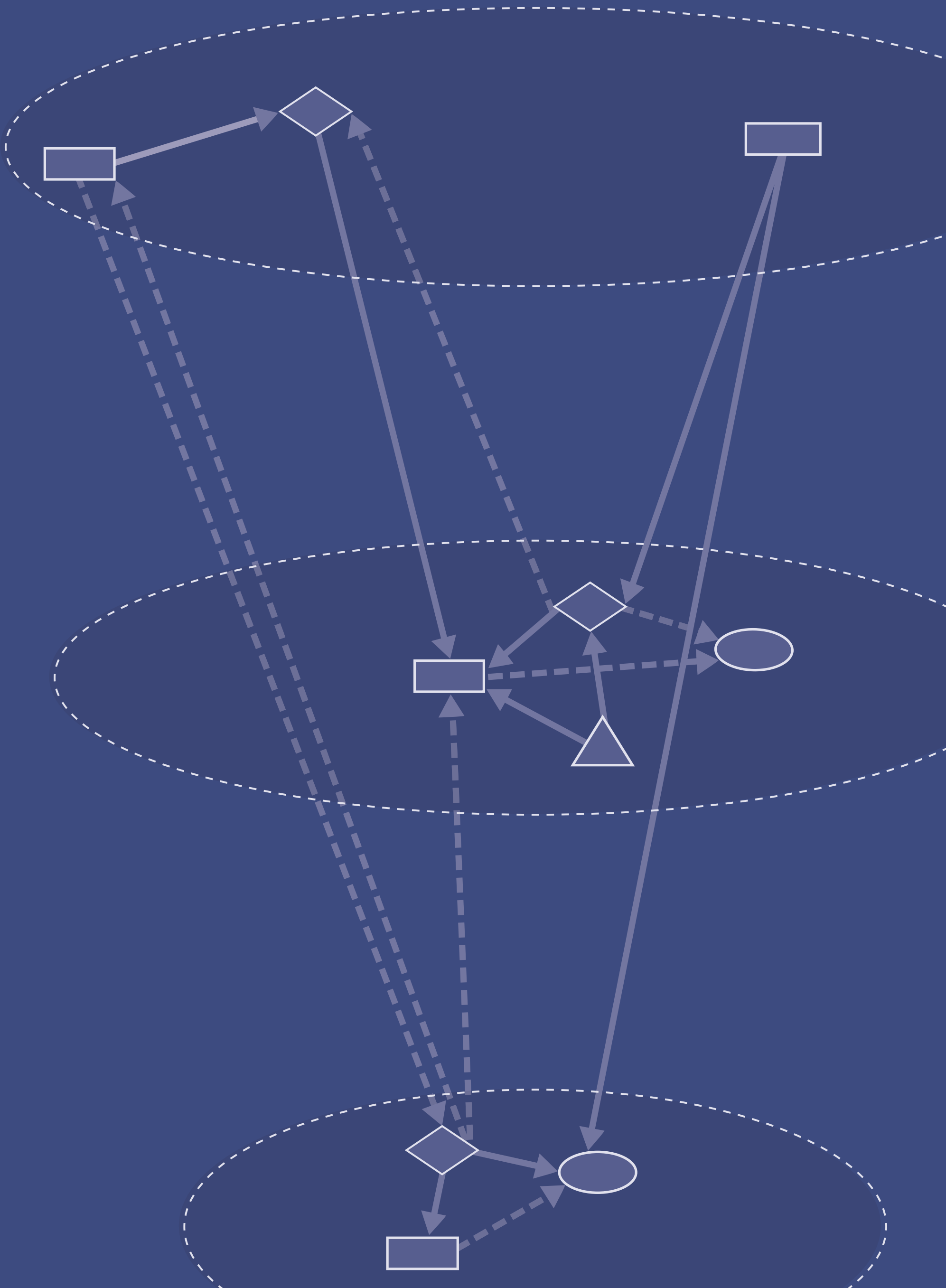
Content



Chapter 1 Introduction

1.1 Background and research objective

Addressing grand societal challenges like climate change, urbanization and social justice will require countries, regions and cities to drastically transform infrastructure sectors concerned with the fulfillment of major societal functions like energy, transport, agriculture, housing or water (Markard et al., 2012). Such sectoral transformations require the development and diffusion of more sustainable technologies. New industries that develop and manufacture these technologies at scale need to form, and existing industries will need to branch into new fields. However, technological innovation alone will not be sufficient to help cities, regions and countries address the grand challenges of the 21st century. Instead, they need to engage in and foster socio-technical transformations that involve the active reorganization of technological as well as social structures (Markard and Truffer, 2008, Geels, 2004). Technologies, knowledge, capabilities, but also institutions, such as values, norms, regulations and laws may have to be altered and re-configured into novel and more sustainable socio-technical "*configurations that work"* (Markard et al., 2009, p. 655, cit. from Rip and Kemp, 1998). For example, the transformation of the mobility sector requires altering the established configuration around personal, and mostly fossil-fueled private vehicles, as well as associated road networks, gas stations, and traffic laws towards more sustainable configurations. This may among other things involve the creation and adaptation of infrastructures and legislation for electric or fuel cell driven vehicles powered by renewable energy, platform based and potentially autonomous mobility services, as well as adapted infrastructures for more cycling and walking within city centers (Nijland and van Meerkerk, 2017, Schippl and Truffer, 2020).

Such re-configurations of technological and institutional structures may play out in different sectors, industries and geographical contexts (Coenen et al., 2012). They may involve emerging industry proponents competing with incumbents for the future direction that the industry should take in a region, country or even globally. Industry and technology innovators will share other values, norms and goals than incumbents who might rather defend the status quo. In face of strong incumbent interests, individual innovators usually cannot implement socio-technical re-configurations alone. They are in need of supportive innovation system structures that help develop and diffuse novel technologies and institutions. Innovation systems are the actors, networks and institutions that create synergies in the development, testing, and deployment of alternative technologies and institutional arrangements (Carlsson and Stankiewicz, 1991, Hekkert et al., 2007, Bergek et al., 2008a). From a systemic perspective, relevant actors in re-configuration processes are not merely the firms that develop novel technologies but also actors form research, policy and politics can contribute to the development of innovations and protected spaces in which radically novel technologies can thrive. Attention, therefore, needs to be drawn not only to the development of knowledge and technology, but also to the creation of market structures, to the articulation of demand for novel technologies, to business models, and to associated practices, codes of conduct and values (Dewald and Truffer, 2011, Dewald and Truffer, 2017, Boon and Edler, 2018). The legitimation of new configurations against established technologies, business models and institutions needs to be understood (Aldrich and Fiol, 1994, Binz et al., 2016a, Markard et al., 2016b), just as the mobilization of the financial means for their creation and diffusion (Binz et al., 2016b, Karltorp, 2016, Geddes and Schmidt, 2020).

While it is widely acknowledged that re-configuration processes are needed to address sustainability challenges in specific places, substantial knowledge gaps remain regarding the role that geography and networks in space play in facilitating or hampering them (Truffer et al., 2015). Evidently, some regions may benefit from and drive re-configuration processes more strongly than other regions due to their specific industrial heritage. Regions with a strong legacy in fossil fuel driven energy production like the German region of Saxony, for example, may have a harder time moving toward renewable energy production than a country like Denmark that has the natural resources to deploy wind-power plants and has been an innovator in this field for decades. Local initiatives and politicians in both regions might respond to the needed re-configuration of the energy system very differently. Multi-national corporations that connect different places through value-chains and organizational hierarchies substantively shape many industries today. Industrial re-configurations, therefore, cannot only take shape within regions or countries but take place at different spatial scales. Policies and strategies oriented towards more sustainable modes of production and consumption also need to take into account existing inequalities within and between world regions. On the one hand, regions in the global south might have opportunities to leapfrog technological advances and implement re-configurations more quickly than developed regions in the global north. On the other hand, regions in the global south might lack capabilities and may champion economic prosperity over broader sustainability concerns in light of poverty, inequality and global power relationships.

Due to the interdependencies created by globalization, questions of geography become crucial for understanding re-configuration processes in different places. How do networks of actors and resource flows at and spanning across different spatial scales affect the prospects for re-configurations to happen in specific localities? Conversely, how do dominant socio-technical configurations affect the ways in which systemic synergies and networks are being developed at different spatial scales? Neglecting the question of geography in re-configuration processes may lead to misconceptions about the proper scale at which to address systemic problems, like for example market, coordination or directionality failures in transformative innovation policy (Weber and Rohracher, 2012). Some systemic effects in specific local contexts may, in fact, only emerge because of resources that are absorbed from abroad. For example, international investors may steer the direction of a technological field in a specific region. Similarly, systemic problems may increase through translocal linkages, e.g. if the branches of powerful global incumbents impede re-configurations in a local context.

Two fields of research appear particularly well equipped to address questions of this kind, namely, evolutionary economic geography (EEG) and sustainability transitions. Socio-technical transformations are complex and evolutionary processes that involve the emergence of new and re-organization or decline of existing industrial and sectoral structures. Having roots in evolutionary economics, both EEG and the transitions field share a common interest in both economic and technological innovation and decline, and they both emphasize the important role of path dependencies in industrial and sectoral change processes (Nelson and Winter, 1982, Garud and Karnøe, 2001, Martin and Sunley, 2006).

EEG has primarily been asking about place-based conditions for economic and technological change, especially related to specific knowledge endowments, but it has increasingly integrated more institutional and relational perspectives that take into focus the institutional conditions for economic change, and the influence of actor networks spanning across multiple spatial scales (Boschma and Frenken, 2006, Boschma and Frenken, 2018). Building on Yeung (2005) notion of “scalar relationality” (p.43), a conceptual perspective that combines a focus on spatial scales at which evolutionary processes of economic change are unfolding, as well as the networks through which actors and spatial contexts may be linked in these processes, will be called *scalar-relational* in the remainder of this thesis.

Transition studies, in turn, has drawn more heavily on sociological and historical perspectives on economic change derived from science-and-technology studies (Bijker et al., 1987). The idea of “seamless webs” of interrelated technological, social and institutional elements originates from this literature (Hughes, 1987). It asks how the interdependencies among different socio-technical elements are socially constructed, conditioning economic and technological change. Building on Rip and Kemp (1998) idea of technology as a “configuration that works”, the underlying perspective that takes into focus how different socio-technical elements are aligned and re-configured into novel socio-technical configurations with emergent properties of their own, will henceforth be called *configurational*.

The synthesis of a scalar-relational and a configurational perspective is one of the core ambitions of the geography of sustainability transitions (GeoST) field of research (Binz et al., 2020a, Murphy, 2015, Truffer et al., 2015, Truffer and Coenen, 2012). As Truffer et al. (2015) have put it, GeoST should aim at addressing geographical dimensions of socio-technical change, such as the socio-spatial embedding of re-configuration processes in specific localities, the multi-scalarity of actors, networks and resource flows involved, and issues of spatially distributed power and inequality. Nevertheless, most existing empirical research on GeoST from transition studies has been content with reconstructing re-configuration processes based on individual case studies embedded in specific containerized urban, regional or national contexts (Coenen, 2015). A major drawback of this approach is the limited comparability and generalizability of empirical insights generated from a containerized understanding of spatial scales that risks overlooking the fluid, multi-scalar character of re-configuration processes in specific spatial contexts (Coenen et al., 2012, Sengers and Raven, 2015, Binz et al., 2020a).

EEG may inform GeoST through its long tradition in studying place-specific preconditions for the formation of industrial paths, and has started to look at the relational and multi-scalar processes of knowledge creation and diffusion (Martin, 2010, Boschma and Frenken, 2010, Neffke et al., 2011, Isaksen and Trippl, 2016, Trippl et al., 2018). Also, institutions have increasingly been recognized by EEG scholars, but predominantly at an aggregate level, e.g. studying varieties of capitalism in different countries or deriving institutions or institutional barriers from aggregate regional industry indicators (Wenting and Frenken, 2011, Boschma and Capone, 2015). However, it has paid much less attention to the micro-processes of institutionalization, and the relational and multi-scalar interdependencies among *institutionalization* processes in different spatial contexts (Binz et al., 2014, Trippl et al., 2018, Boschma and Frenken, 2018, Hassink et al., 2019).

Accounting for multi-scalarity and institutionalization two conceptual additions may complement the *scalar-relational* perspective derived from EEG and the *configurational* derived from transition studies.

Firstly, an innovation systems approach may be suitable to understand how networks, proximity and spatial scales matter in evolutionary processes of economic change. Innovation systems research takes into account not only firm level knowledge and capabilities aggregated at a spatial scale but rather all actors, networks and institutions in the specific spatial or technological context of an innovation system (Carlsson and Stankiewicz, 1991, Lundvall, 1992 , Edquist, 2005). EEG scholars have especially drawn on the regional innovation systems (RIS) framework in order to conceptualize how collective learning and innovation are fostered through regional knowledge and policy infrastructures, and inter-firm relationships (Tödtling and Trippl, 2005, Coenen et al., 2016, Isaksen and Trippl, 2016). Binz and Truffer (2017) have further developed this, by arguing for a multi-scalar conceptualization of innovation systems and their underlying knowledge- and institutionalization-related processes. However, the concept has yet to be tested, validated and further developed in empirical application in different sectoral and industrial contexts.

Secondly, the configurational perspective derived from transitions research may be complemented by insights from organizational sociology when it comes to understanding institutionalization processes. Here, the thesis will build on Fuenfschilling and Truffer's

(2014) conceptualization of socio-technical systems as semi-coherent structures of elements with different degrees of institutionalization. The advantage of this approach is that organizational sociology provides frameworks to conceptualize both the structure of socio-technical configurations, e.g. as elements within organizational fields (Friedland and Alford, 1991), and underlying rule-sets or values, e.g. through the concept of institutional logics. Logics indeed denote "(…) historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals (…) provide meaning to their social reality" (Thornton and Ocasio, 1999, p. 804).

Taking these elements from different conceptual approaches, this thesis seeks to marry a *scalar-relational* perspective that is derived from EEG and innovation systems research with a *configurational* perspective derived from the socio-technical transitions and organizational studies. This is achieved by contributing to novel conceptual and empirical insights regarding the multi-scalarity and institutionalization of novel socio-technical configurations, asking:

> *RQ1: What are the mechanisms through which geography conditions the institutionalization of novel socio-technical configurations?*

Addressing this broader question will require to zoom-in and study mechanisms of institutionalization and re-configuration at and across different scales. First, this will be tackled by exploring re-configuration processes at different spatial scales, such as the global and various national-scale contexts, as well as by studying multi-scalar processes of technology legitimation. These explorations show how alignments of socio-technical elements are reproduced globally but how industrial change processes and transition trajectories differ across countries. Second, the thesis will zoom-in on re-configuration processes and their underlying value-structures within a single country, and on the spatial embedding and multi-scalar resource flows among various urban experimentation localities in different countries. These investigations reveal how values align into larger field logics adhered to by various actors, and how these logics shape their collaboration networks in space and the directionality of the technological field. Further, they show how re-configurations are facilitated by multi-scalar resource flows that emerge among localities with different pre-conditions, both related to knowledge and institutional resources.

Doing empirical and theoretical work in this direction, however, will pose methodological challenges associated with the measurement of changing socio-technical configurations and resource endowments over time and space, the generalizability and comparability of such an analysis, and its ability to understand and explain underlying re-configuration mechanisms. Therefore, the thesis will propose a novel methodology to identify and trace socio-technical configurations over time and space, addressing the question:

> *RQ2: How can we map and measure socio-technical configurations and re-configuration processes over time and space?*

The next section will outline the ways in which these questions will be tackled conceptually and methodologically. Four empirical studies of the global water sector will subsequently address these questions.

1.2 Theoretical background

The following section will shortly introduce the essential conceptual building blocks and definitions from transition studies, organizational studies EEG, and innovation systems research. It outlines what constitutes the *configurational* and the *scalar-relational* perspectives that shall address the research questions of this thesis. Eventually, the different perspectives combine in an overarching framework, to situate the individual research questions and the overall contribution of this thesis in a larger picture.

1.2.1 A configurational perspective on sectoral and industrial change

One of the central conceptual building blocks of this thesis revolves around the notion of socio-technical configurations and re-configuration processes, which originate from the literature on socio-technical transitions (Rip and Kemp, 1998, Geels, 2002). From a socio-technical point of view, sectoral and industrial change processes are re-configurations of technological and institutional elements that align into novel socio-technical configurations. In contrast to a neoclassical understanding that regards sectoral and industrial change as a result of investments in research or human capital, a focus on socio-technical configurations explains transformation processes by the emergent properties that arise from linkages among technological and social elements. A configuration of technological and social elements has properties or causal powers that could not be explained by the properties of its individual elements, much like the properties of water cannot be understood by the individual properties of hydrogen and oxygen alone (see also Sayer, 2000 for a discussion of emergent properties in critical realism). Understanding sectoral and technological change, therefore, requires understanding the emergent properties of socio-technical configurations and the mechanisms behind re-configuration processes.

The origins of socio-technical theories can be traced back to evolutionary economics and Science and Technology Studies (STS) (Smith et al., 2010). Rejecting the predominant view of technology as an exogenous variable in neo-classical models and economic theory, during the 1980s, mainstream economists started to include technology and technological change into endogenous growth models, conceptualizing technology as a product of investments in research and human capital (e.g. Romer, 1986, Lucas, 1988). The endogenous growth models, however, were criticized of lacking explanatory power and of being limited to firm actors in explaining technological change. Evolutionary economists, therefore, started building more heavily on sociological approaches. Nelson and Winter (1982) conceptualized technological change as dependent upon particular cognitive routines among professional communities that channel innovations into specific trajectories (so-called *technological regimes*), but also on the socially constructed *selection environment* of markets and institutional structures, into which these communities are embedded. Dosi (1982), similarly, emphasized the role of technological paradigms, as a "pattern of solution of selected technoeconomic problems (…)" (Dosi, 1988, p. 1127) that encompasses both the technological artifacts to be used as well as the set of heuristics that shall guide their usage. He regarded paradigms as a structural force directing technological change.

Socio-technical theorists from a STS tradition went beyond this view by emphasizing the social construction of technology and technological systems, conceptualizing them as seamless webs of interrelated artifacts, such as technologies and their environment of firms, banks, regulators and users, which facilitate certain trajectories for technological development while hampering others (Hughes, 1983, Hughes, 1987). By acknowledging the social construction of technology, they rejected the technology deterministic idea that technology imposes itself on society that was shared among many social theorists and philosophers of the time. Instead, they argued for a reciprocal relationship of technology and society, emphasizing that "[t]he development of technology is contested and controversial as well as constrained and constraining" (Misa, 2003, p. 10). This reciprocal relationship among technologies and the social environment into which they are embedded implies that social and technological elements are linked into coherent alignments from the very beginning of technological development. New technologies, however, will only be aligned with a few other technological as well as social elements, whereas more mature technologies will have established socio-technical linkages with elements like spare parts, maintenance services, infrastructures or related social practices, that together constitute a socio-technical configuration (Latour, 1987, Rip and Kemp, 1998). For example, the technology of autonomous vehicles is not yet well aligned with many other technological and social elements because existing infrastructures, business models, user practices, and safety regulations are not well suited to accommodate for self-driving, non-privately owned, mostly electric vehicles. Instead, the combustion engine driven car has many socio-technical linkages with these elements, forming a stable socio-technical configuration. Such well-established configurations have formed over long-times spans and resist radical change since they are tied together by a common underlying set of rules, which actors can agree on, and which guides their behavior. This rule-set has been defined as the *socio-technical* regime (Kemp, 1994, Rip and Kemp, 1998). Changing the socio-technical regime requires changing the underlying rule-sets and undoing or re-configuring the socio-technical linkages that constitute and stabilize its core configurations.

Accordingly, sectoral and industrial socio-technical transformations can be conceptualized as re-configurations of alignments among actors, technologies and institutions into new "configurations that work" (Rip and Kemp, 1998, Markard et al., 2009). Path dependency and resistance to change emerge from well-aligned configurations that have established around a set of strongly institutionalized rules, i.e. the socio-technical regime (Geels, 2002, Geels, 2004, Markard et al., 2012). Hence, socio-technical transformations are changes in the core configurations of actors, technologies and institutions that align around a specific socio-technical regime. Picking up the autonomous vehicle example, one might observe a transformation of the existing private-vehicle configuration around gas stations, maintenance workshops, road networks, car dealers, traffic laws, and values like freedom, independence, and growth, into a more hybrid configuration involving similar road networks but new platform-based business models, charging stations, fewer car dealers for privately owned vehicles, and including also other values, like sustainability and equity.

Explaining socio-technical transformation processes requires investigating how configurations of elements are being institutionalized and how associated rule-sets change over time. The transitions literature has therefore started utilizing concepts from organizational studies, which have extensively dealt with institutional structures and processes of institutionalization (Fuenfschilling and Truffer, 2016, Fuenfschilling and Truffer, 2014, Smith and Raven, 2012). For example, it has studied processes like institutional work, technology legitimation, and contestation through a lens on discursive traces and strategies of diverse actors (Geels and Verhees, 2011, Smith and Raven, 2012, Binz et al., 2016a, Rosenbloom et al., 2016, Fuenfschilling and Truffer, 2016, Yuana et al., 2020). These studies have revealed among other things the strategies through which heterogeneous actors drive the (de)-institutionalization of different technologies, laws, regulations, norms and values. A core conceptual building block lent from organizational studies in order to understand the formation of institutional structures and rule-sets are the concepts of organizational fields and institutional logics. Organizational fields are defined as the aggregate of all organizations active in a field of institutional life, such as an economic sector (DiMaggio and Powell, 1983). Various transitions scholars have conceptualized socio-technical systems at the level of organizational fields (Geels and Schot, 2007, Fuenfschilling, 2014). Institutional logics, in turn, are coherent sets of rules, values and beliefs held by various organizations that structure their behavior and processes at the field level (Thornton and Ocasio, 1999). Fuenfschilling and Truffer (2014) applied the concepts of organizational fields and institutional logics to describe socio-technical regimes as the most highly institutionalized core of logics within an organizational field. Thus, these concepts may prove beneficial for a conceptualization of socio-technical regimes and their associated configurations as semi-coherent, rather than homogenous structures.

However, many of these studies, with a few exceptions like Binz et al. (2014), Sengers and Raven (2015), or Fuenfschilling and Binz (2018) have so far remained at the level of regionally or nationally delimited qualitative cases studies, which lack comparability and generalizability (Coenen, 2015). Thus, a conceptual framework addressing questions related to the geography of transitions posed in this thesis requires not only a configurational perspective on evolutionary change processes. In addition, a scalar-relational perspective will be needed, suggesting further engagement with concepts from geography, like space and scale, and multiscalar resource mobilization (Binz et al., 2014, Hansen and Coenen, 2015, Truffer et al., 2015, Binz et al., 2016b). The following section will derive such a scalar-relational perspective deploying concepts from EEG and innovation systems research.

1.2.2 A scalar-relational perspective on sectoral and industrial change

Addressing the question of the role of geography in socio-technical re-configuration and institutionalization processes requires a conceptualization of spatial scales. Any description of the geography of processes or structures needs a concept of scale, i.e. a representation of the geographical area in which to explore any given phenomena. Conceptualizations of scales differ strongly within the geographical literature. Scales may be understood in a containerized way as urban, regional or national administrative borders. Others may describe a scale geometrically as the spatial extent of the organizational networks in specific field. Yet, other researchers argue that scales are socially constructed by the way that groups of actors perceive the spatial environment in which they are acting. Different conceptualizations of scales may have different implications for the ways, in which socio-technical structures, processes and transformation outcomes are perceived and observed. Already three decades ago, human geographers have started to criticize the simplified understanding of scales as mere nested spatial containers, boundaries or arenas, such as the urban, the regional, national and the global scale, which they found to be dominant in much of the geographical social science literature (Swyngedouw and Cox, 1997, Swyngedouw, 2004). Building on the social constructivist ontology of Lefebvre (1991) – they, instead, argued that geographical scales should rather be understood as a "historical presupposition, medium, and outcome" of social relations, and as such they are "(…) continually produced, reconfigured, and transformed" (Brenner, 1998p. 460). Spatial scales, in this sense, are a "nested set of related and interpenetrating" structures that " (…) define the arenas of struggle where conflict is mediated and regulated and compromises are settled" (Swyngedouw, 2004, p. 42). Following this line of reasoning, any exploration of the role of geography in sectoral and industrial transformation, should not exclusively study reconfiguration processes that are unfolding *at* a priory defined spatial scales. Rather, the spatial scales at which processes of re-configuration evolve and through which they are mediated is an empirical question and an analytical category to be explored in itself (Miörner and Binz, 2021). Actor linkages at different spatial scales may not simply reflect collaboration patterns but also spatial and non-spatial proximities among actors. While collaboration networks generally develop more easily among actors in spatial proximity, other types of proximity such as cognitive (knowledge ties), social (friendship ties), organizational (organizational hierarchy ties) or institutional proximity (shared institutions) might drive actors to exchange knowledge and resources over larger distances (Boschma, 2005, Boschma and Frenken, 2010). Scales, therefore, do not exist as independent categories but usually reflect specific underlying proximities, rule-sets, or other types of complementarities.

In this thesis, socio-technical re-configurations will be studied as relational processes, which are rooted in different types of proximities, and which may differ at different scales. At any specific scale, e.g. the urban, technological and institutional elements may be re-configured in a particular way. For example, the dominant personal transport and mobility sector configurations may be altered by a city administration through the repurposing of roads for cars into cycling lanes and areas for pedestrians. But re-configurations at any specific scale may equally be driven or blocked through multi-scalar processes. For example, the national-scale automotive industry association may try to lobby for the delay of the reallocation of road space with local politicians, or an international company may co-fund a piloting project of a new bike-sharing concept that would benefit from the reallocation. Studying re-configuration and institutionalization processes at and across spatial scales creates a natural link for this thesis to different streams within EEG. Insights from EEG may be useful since the field has extensively dealt with re-configurations of industries in different scalar contexts, such as regions or nations, as well as more recently also with institutional and multi-scalar factors influencing industry formation in these contexts.

EEG evolved during the 2000s as a new paradigm in Economic Geography that aimed at studying how and through which processes the spatial organization of production and consumption is evolving over time (Boschma and Frenken, 2006). Applying an evolutionary perspective, EEG puts historically contingent, path dependent, and place-dependent processes at the center to explain uneven economic development in different spatial contexts, such regions or nations (Boschma and Frenken, 2018). EEG has come far in conceptualizing the geographical and evolutionary underpinnings of regional industry formation. It has shown that new industries, technologies, and products are likely to emerge in regions that already host related knowledge and capabilities through a process called related diversification (Frenken and Boschma, 2007, Hidalgo et al., 2007, Neffke et al., 2011, Kogler et al., 2013, Tanner, 2014). Industry emergence and new technological trajectories are, therefore, conditioned by strong path dependencies, which hinder diversification into radically different and novel knowledge fields difficult (Martin and Sunley, 2006).

In face of grand challenges, however, regions may have to deviate strongly form existing paths. Unrelated diversification is, therefore, likely to become more important in the 21st century. More recently, therefore, EEG has been seeing increasing calls for the exploration of what other factors beyond knowledge may foster or block diversification, drawing attention to the role of institutions in stabilizing and disrupting regional industry dynamics (MacKinnon et al., 2009, Pike et al., 2009). In response, EEG scholars have engaged with more institutional perspectives to economic geography (Gertler, 2010), exploring aspects like varieties of capitalism (Boschma and Capone, 2015), institutional relatedness (Content and Frenken, 2016, Carvalho and Vale, 2018) or institutional agency/ entrepreneurship (Dawley, 2014, Grillitsch and Sotarauta, 2020, Glückler and Eckhardt, 2021) that help explain how actors might support regions to purposefully deviate from predefined paths. In line with such contributions, recent research in EEG has started exploring institutionalization processes, and active agency that seeks to establish new institutional structures, mobilize funding or create niche markets for novel technologies to be tested in (Binz et al., 2016a, Binz et al., 2016b, Boschma et al., 2017).

Beyond studying regional knowledge and diversification, EEG has lent arguments from relational economic geography (REG) (Boggs and Rantisi, 2003). Relational economic geography argues that firms and other economic actors should be understood as embedded into social and institutional relations, which may unfold at different spatial scales (Bathelt and Glückler, 2003). Among other things, REG argues that the embedding of regional firms into political, economic, and social multi-scalar linkages, through which resource exchanges and power are mediated, like in global production networks, are crucial for explaining regional economic change. Yeung calls this type of relationality "scalar relationality" (Yeung, 2005). REG has been criticized of failing to explain economic and institutional structures by only describing network relations (Sunley, 2008). Hence, the combination of the institutional, and the relational perspectives within EEG has been argued to provide promising novel insights for understanding the formation of new industrial and technological paths (Hassink et al., 2014). It is due to this synergistic potential that EEG scholars have started looking at multi-scalar mobilization processes of both knowledge and institutional resources (Binz et al., 2016b, Trippl et al., 2018, Gong and Hassink, 2019, Miörner and Trippl, 2019, Gong, 2020). In line with Yeung's notion of scalar relationality, the thesis will coin a perspective as "scalar-relational" that explicitly considers both spatial embedding and multi-scalar processes of knowledge generation and diffusion as well as (de)-institutionalization processes of socio-technical configurations by a variety of firm and non-firm actors.

The innovation system concept may provide valuable insights to a scalar-relational perspective by taking into account the systemic context in which both knowledge and institutionalization related processes unfold in and between different regions and scales. A systemic perspective can complement EEG as it by definition focusses on firm-actors but also other systemic actors, like public authorities, NGOs, or universities, which may provide knowledge and the institutional pre-conditions for the development of innovations. Innovation system research has emerged as a tool to understand and guide innovation dynamics and industrial policy. The boundary of an innovation system may vary according to the research question and the policy it shall inform in its geographical scope (Lundvall, 1992 , Asheim and Gertler, 2005, Edquist, 2005), its sector (Malerba, 2002), or its focal technology, in technological systems of innovation (TIS) (Bergek et al., 2008a, Carlsson and Stankiewicz, 1991). The TIS approach, in particular, has inspired various studies that have explored sectoral transformations from the angle of specific technological innovations in infrastructure sectors like energy, water or transport (Markard et al., 2012). The core idea of TIS is that radically novel technologies need a well-developed systemic environment to develop and diffuse. Different functions or processes need to be in place, namely knowledge creation and diffusion, the formation of markets, the mobilization of human and financial capital, as well as forms of guidance of search and legitimation (Hekkert et al., 2007). This literature provides differentiated conceptual and empirical insights into both innovation and institutionalization processes of nascent technologies. In addition, the TIS literature has discussed how different processes matter during different stages of TIS evolution (Suurs and Hekkert, 2009, Suurs and Hekkert, 2012, Markard, 2020).

Studies from the spatial innovation system literature, e.g. around RIS, have begun elaborating multi-scalar processes of resource mobilization and functional dynamics that stretch beyond national contexts (e.g.Gosens et al., 2015, Wieczorek et al., 2015, Trippl et al., 2018, Miörner and Trippl, 2019). However, innovation systems research has been criticized for predominantly remaining within the barriers of (sub)-nationally embedded, containerized cases (Hansen and Coenen, 2015, Coenen, 2015). Binz & Truffer's (2017) Global Innovation Systems (GIS) framework constitutes a response to these criticisms. It attempts to combine an institutional and relational perspective on EEG in a coherent framework. Depending on the structure of the sector or industry, the crucial innovation and institutionalization-related processes may unfold in subsystems at different spatial scales. Subsystems may be interrelated through what they call structural couplings. These couplings are actors, their networks, or institutions that are able to bridge between processes at different spatial scales and allow for resource flows across space (ibid.).

To operationalize the GIS framework, systematic evidence is needed regarding the scalar-relational processes through which the institutionalization of novel configurations can be driven through agency from outside a local context. Also, the temporal dimension of how and why such relational processes may be instantiated in the formation of novel industries or sectoral transformations needs to be further explored.

1.2.3 Towards a framework linking the configurational and the scalar-relational

Linking the configurational and the scalar-relational may help better conceptualize the geography of transitions in terms of socio-technical structures, mechanisms and transition outcomes in specific industrial, sectoral or technological fields. Fig. 2 provides a basic framework that links together the scalar-relational and the configurational.

Scalar-relational processes (left side of fig. 2) are studied at the level of multi-scalar, global innovation systems providing actors with resources to develop and implement novel technologies or industrial paths at different spatial scales (Binz and Truffer, 2017). Actors may develop networks for the creation and diffusion of knowledge or institutions at specific spatial scales, but they may also absorb resources or attract resourceful actors from outside their own spatial contexts. To study these processes, the thesis will borrow conceptual elements from the literatures on EEG and innovation systems research.

The configurational perspective (right side of fig. 2), in turn, is derived from concepts from transition studies and organizational sociology. It maps and measures socio-technical configurations emerging within the context of an industrial, sectoral or technological field. Configurations are illustrated as socio-technical elements (nodes) that are more or less strongly linked through socio-technical linkages (links with different width). Following a similar representation of organizational fields by Fuenfschilling and Truffer (2014) the socio-technical elements are placed inside a radar plot. They represented an organizational field as a radar plot, in which a central positioning of an element signified a high degree of institutionalization, whereas a more peripheral position denoted a lower degree of institutionalization. The radar plots on the right pick up the same graphical intuition by extends it by adding linkages among the elements. The nodes inside the radar plots conjointly constitute the field under investigation. They may be more or less strongly aligned into coherent configurations. The strength of alignment is indicated by the strength of the link between two elements. The closer an element and its associated configuration are placed to the center of the radar plot, the more institutionalized the configuration is. In turn, configurations closer to the outer circles are less institutionalized, alternative configurations that potentially challenge the core configuration. For the purpose of illustration, two configurations are highlighted by nodes with lighter and darker shadings. The degree of institutionalization of a configuration may differ across spatial scales. Fuenfschilling and Binz (2018) have emphasized that in many sectors, a global standard has developed in terms the desired infrastructure configuration that actors in various countries aim at implementing. For the water sector, they show that a global regime has developed around large-scale, centralized infrastructures and technologies. However, the regime may be institutionalized to varying degrees in different national, regional or urban-scale contexts. In the example of fig. 2, this potential scalar variation in the degree of institutionalization of configurations at different scales is accounted for by an altered positioning of the light- and the dark-shaded elements and by altered linkages among the two configurations at different scales. For example, the light-shaded configuration constitutes the core of the field in the local-scale context, but it is only a weakly institutionalized configuration at the global scale.

The scalar-relational dimension of actor and resource networks and the configurational dimension of socio-technical configurations are interdependent. Actors in a GIS can be characterized by pushing for specific socio-technical configurations, e.g. novel technologies or industrial paths, as well as their associated values, norms, laws and regulations. Doing so, they may be concerned with the transformation of the dominant socio-technical regime and its core configurations, as well as with the institutionalization of an alternative to replace it. In the scalar-relational view, some actors advocating for an alternative may be linked through networks within a specific country. Other actors may predominantly act at the global scale. All advocates of the alternative configuration, both global and national, may work on the development and diffusion of a novel technology and share resources based on resource complementarities in their local contexts, creating systemic synergies among themselves. Together, they are advocating for a specific set of technologies, or for a change of regulations and laws that may foster its deployment, or for the adoption of a new set of values that these technologies align with. This is where the scalar-relational and the configurational perspective meet. Through the joint advocacy for a novel configuration by actors embedded at different spatial scales, they are directly involved in its institutionalization, and hence, the transformation of the established regime configuration. For example, both a multi-national e-car developer, a national e-vehicle association and a regional politician of the green party might purposefully engage in activities that help re-configure the dominant transportation regime towards more conducive regulations and infrastructures for e-vehicles in the same city region. The multi-national might lobby national industrial policy legislation, which will affect the industry of the urban area. The national association might fund research on the matter in the specific city. The politician might utilize insights from this research and refer to the national legislation in order to convince other politicians of prospective public investments in e-charging infrastructures in the city. Hence, specific actor networks, embedded into multi-scalar innovation system contexts, are directly associated with specific configurations and transformation processes in their specific fields and vice-versa. In Fig. 2 solid lines connecting systemic contexts and configurations signify this interdependence of the scalar-relational and the configurational dimension of the framework.

Combining the scalar-relational and the configurational perspective in a joint framework allows to address questions that concern both socio-technical transformations and their geography. A framework of this kind allows to ask questions about the mechanisms through which actor and resource networks on the one hand, and the configurations of socio-technical elements on the other hand are entangled and intertwined in space. As such, it extends beyond frameworks with a more selective focus on knowledge-related factors for regional industry formation or on the institutionalization of alternative configurations in specific national system contexts. This thesis will illustrate how such a holistic framework may be productive by zooming in and comparing individual water sector re-configuration processes and their multi-scalarity at different spatial scales, such as countries (Switzerland, USA, South Africa and India), a continental region (Western Europe), or at the global scale. And by exploring the ways in which multi-scalar processes drive and are driven by specific socio-technical configurations in these exemplar cases.

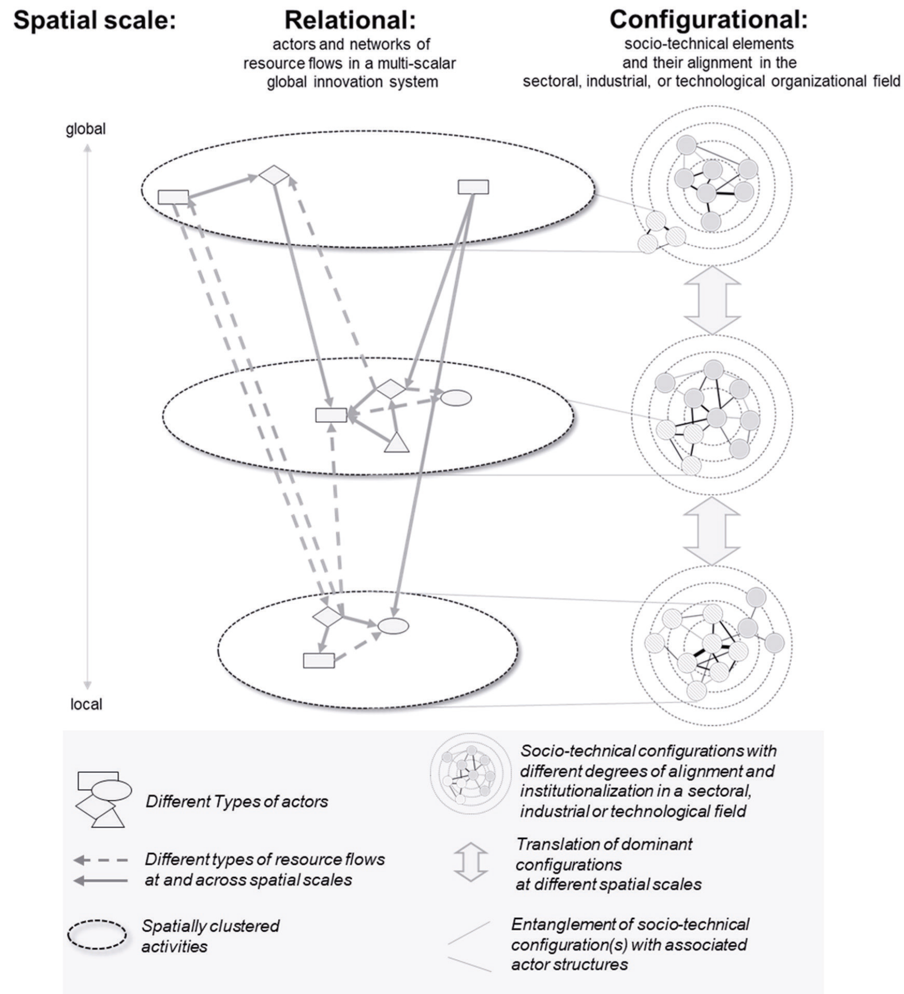


Fig. 1.1: Combining the scalar-relational and the configurational. Own figure.

1.3 Ontology, epistemology, methodology, and empirical case

When answering the stated research questions, one major concern relates to the underlying ontology, epistemology and methodology with which to approach the empirical research. Questions around the geography of re-configuration and institutionalization processes pose a major methodological challenge since the phenomena of interest are hard to observe and to compare across space and time. Correlational quantitative methodologies may compare across spatial entities but will often fail to account for the configurational nature of socio-technical change (Goertz and Mahoney, 2012). Thick qualitative case studies, in turn, may re-construct configurational dynamics within individual spatial contexts but cannot fully account for comparisons among them and for the interdependencies of processes at different scales. Studying scalar relational and configurational structures and processes therefore requires an new methodological approach. Reflecting upon its underlying ontology and epistemology is further crucial since it lays open the fundamental assumptions with which reality is approached. Making these explicit will help other researchers judging the methodological choices made in this thesis.

1.3.1 A critical realist approach and methodology

This thesis reflects upon its ontological and epistemological choices from a critical realist philosophy of science (Bhaskar, 1975, Sayer, 1992). Critical realism regards the world as a set of entities with emergent causal properties emanating from the necessary relations between their individual parts (Bhaskar, 1975). Entities may be material structures, humans or other animals, but also social constructs, such as organizations, markets and institutions that may all contain emergent causal properties and exert causal mechanisms upon each other. The goal of critical realism is to explain when, why and how specific phenomena occur in the real world. To approach reality, it differentiates three layers of reality: the empirical, the actual and the real (Bhaskar, 1998, Sayer, 1992). It assumes that causal powers, mechanisms, and the world as a whole exist independent of whether or not they actualize and become apparent to us. The empirical, in this sense, is only the part of reality that we can actually observe, that we can be aware of. It is a subset of the actual, which includes those phenomena that exist independent of our knowledge about them. The real, eventually includes the causal powers and emergent properties of objects and structures.

Given its imperative to explain phenomena in the social world, a critical realist ontology requires a specific epistemological approach which Danermark et al. (2001) have coined as retroduction. It involves the empirical observation of phenomena, the elaboration of hypothetical mechanisms that may explain the observed phenomena, and the choice of the most likely combination of mechanisms that may have led to the phenomena. While critical realism may be consistent with qualitative and quantitative research designs, researchers approaching the world from a critical realist philosophy have tended to use qualitative methodologies, since they are better able to unveil and explain the effect of the more invisible entities such as norms and values or rule-sets on phenomena in the real world (Sayer, 1992). At same time, qualitative observation and explanation alone often suffers from a lack of generalizability of the mechanisms identified, which is why mixed-method, such as set-theoretic, approaches have been increasingly proposed for research based on a critical realist philosophy (e.g. Rutten, 2020). Thus, a critical realist philosophy favors a qualitative and mixed-method methodology.

Accordingly, in terms of methods, the thesis heavily draws on qualitative research methods involving expert interviews and qualitative content analysis of transcripts as well as newspaper articles. They come with the advantage of potentially providing thick information on institutional processes, such as technology legitimation, capturing underlying values and rationalities of actors, prevalent lines of conflict and coalitions, as well as prevailing narratives among a variety of actors. The thesis is informed by overall 50 expert interviews (mostly contributing to chapter four and five, see App. C and D for an anonymized list), and the selection and coding of over 576 newspaper and expert magazine articles (mostly contributing to chapter two and three, see App. A & B). At the same time, the thesis extends the typical methodological practice in qualitative EEG, transitions and innovation system research that what is *worth knowing* for explanations can be drawn from qualitative content analysis, i.e. the coding of qualitatively generated data, and the creation of associated databases. Rather, both actor networks as well as configurations of socio-technical elements should be understood as networks, which may themselves have emergent properties at the network level. To study these network properties requires making networks of actors in space and network configurations of socio-technical elements explicit.

This, of course, directly leads back to and motivates the methodological question of this thesis, RQ2: *How can we map and measure socio-technical configurations and re-configuration processes over time and space?*

To address this question, the thesis outlines the contours of a novel methodology called socio-technical configuration analysis (STCA) (Heiberg et al., 2022, see chapter two for a detailed introduction). Inspired by Discourse Network Analysis (Leifeld, 2013, Leifeld and Haunss, 2012), a method developed by political scientists to study advocacy coalitions and storylines in policy discourses, it adopts two-mode network analysis to studying shifting socio-technical configurations. The methodology allows to capture configurations of socio-technical artifacts, i.e. bundles of alignments among technologies, infrastructures or institutional elements, explicitly through the way they are associated with actors or other social entities, and ideally situates their alignment in place and time. This type of analysis allows to explore socio-technical re-configuration processes, as well as the degree of institutionalization of different configurations in a sector or industry across different geographies. It may also, for example, be used for more in-depth analyses of specific configurations of institutional elements (e.g. institutional logics) that shape the directionality and geography of an emerging innovation system. The implications of this methodology for the fields of EEG and transition studies and are going to be discussed in light of the individual contributions in the conclusions of this thesis.

1.3.2 Empirical case

The water sector serves as an illustrative example to studying the geography of institutionalization and re-configuration processes, since it is facing strong transformation pressures to provide more climate resilient and adaptive infrastructures and technologies for urban water management. In the industrialized countries in the global north, the urban water management sector is dominantly characterized by large-scale centralized infrastructures for bulk transport, storage and treatment of water and wastewater (Larsen et al., 2016). Typical technologies associated with this pattern are dams, sewer networks and centralized treatment plants. For large parts of the 20th century, the building, operation and maintenance of water infrastructures has been an issue of public authorities and utilities with public funding, which were primarily concerned with securing public health and drinking water safety (O'Flaherty, 2005). This socio-technical configuration around large-scale infrastructures, technologies and supportive institutional structures has evolved into a stable configuration over long time spans, resisting radical changes and innovations (Dominguez et al., 2009, Kiparsky et al., 2013, Fuenfschilling, 2014). In light of ageing infrastructures that require massive investment, increasing environmental concerns related to sustainability and lack of public budgets to maintain existing systems, the privatization and an associated market logic of water infrastructures has become more prevalent in many parts of the developed world towards the end of 20th century (Fuenfschilling, 2014, Pahl-Wostl, 2015, Lieberherr and Fuenfschilling, 2016). Today, global multi-national companies such as Veolia or Suez constitute major players in the global water sector that contribute to the reinforcement and further development of what one could call a global regime configuration around large-scale infrastructures (Fuenfschilling and Binz, 2018). At the same time, it is increasingly unclear whether large-scale infrastructures are able to adequately address the rapidly changing environmental conditions and challenges associated with climate change and urbanization.

Facing these boundary conditions, novel actors are entering the water sector, promoting alternative, modular and decentralized infrastructures and technologies for treating water and wastewater on-site at the level of districts or individual houses (Truffer et al., 2012, Larsen et al., 2013, Larsen et al., 2016, Hoffmann et al., 2020). Unlike technologies for large-scale systems who benefit from economies of large unit scales, these technologies can draw on economies of numbers, which may allow them to become much cheaper and globally accessible when being mass-produced (Dahlgren et al., 2013, Wilson et al., 2020). As such, they will require a radical re-organization not only of technological but also institutional and governance structures, as well as associated business models and modes of operation and management.

Hence, a transition from the dominant socio-technical configuration around large-scale infrastructures, end-of-pipe treatment plants and associated governance- and business models towards more hybrid setups, including decentralized treatment facilities and alternative government arrangement may be likely to take place in various places worldwide. In most developed countries, these emerging configurations are still in their infancy and only produced by small-or medium enterprises in specific niche segments. However, they are increasingly being advocated for by international organizations like the OECD, development agencies or global donor organizations that seek to diffuse them to emerging economies to solve water issues associated with droughts and flooding and safe drinking water (OECD, 2019, Sadoff et al., 2015). Often support for modular and decentralized technologies is associated with alternative institutional logics around environmental engineering and sustainability that diverge from the global socio-technical regime configuration (Fuenfschilling and Truffer, 2014). As such, the water sectors is a field of sectorial and industrial transformations, which will likely unfold at and across global to urban scale. Therefore, it constitutes a suitable case to explore socio-technical re-configuration processes and their scalar-relational embedding.

1.4 Outline of the thesis

Dividing RQ1 into several sub questions may help address the different conceptual aspects highlighted by the scalar-relational as well as the configurational perspective, as well as mechanisms operating at different spatial scales.

RQ1: What are the mechanisms through which geography conditions the institutionalization of novel socio-technical configurations?

From a scalar-relational perspective, empirical research addressing RQ1 will benefit from studying multi-scalar processes and mechanisms both locally and globally. A local analysis may provide insights into why and how multi-scalar resource formation processes are crucial in local industrial and sectoral transformations. A global analysis, in turn, may help understand how global interdependencies and different pre-conditions among distant regions may create a variety of transformation outcomes in different places. From a configurational perspective, too, local case studies may inform the micro-mechanisms behind re-configuration processes, whereas a global analysis of re-configuration processes may allow for comparisons of dominant patterns across various scales. The following subquestions derive from RQ1 by taking into account and selectively combining both different scalar foci as well as the two focal conceptual perspectives.

Applied to the water sector, a central subquestion should explore how scalar-relational processes of resource mobilization drive or impede the transition from the global regime configuration around large-scale water- and wastewater infrastructures towards more hybrid configurations involving decentralized and modular technologies in different places around the world.

To approach the underlying mechanisms of this potential transition, it is crucial to identify the critical periods and spatial contexts in which re-configurations actually occur in the water sector. Where and when do modular water technologies challenge or even transform the global regime configuration around large-scale centralized sewerage infrastructures? How do novel configurations around modular technologies align with existing configurations? How well is the global regime institutionalized in different places and at the global scale and how can we explain differences in the configurational shifts in different contexts? These are all questions that feed into the first subquestion to RQ1, which explores the global water sector field from a configurational perspective:

> *RQ1.1: How and when do water sector re-configuration processes unfold at different spatial scales?*

Having established some knowledge about actual re-configuration processes that unfold at the global scale and in different countries, a second subquestion to RQ1 seeks to explain how multi-scalar processes may contribute to the re-configurations observed in different countries. What are typical local conditions under which the creation of legitimacy for an industry around modular water technologies may benefit multi-scalar legitimation processes? What strategies may different countries chose that seek to create an industrial path in the respective field? These questions subsume under RQ1.2, which seeks to understand how and why multi-scalar legitimation processes around modular water technologies emerge in the diverse countries already investigated in RQ1.1. It explores the global water sector field from a scalar-relational perspective by asking:

> *RQ1.2: how are industrial path creation potentials in specific spatial contexts influenced by and dependent upon multiscalar legitimation dynamics?*

A third angle on RQ1 puts the institutionalization process of modular water technologies at the center of analysis. Zooming-in on a specific national-scale context, it seeks to explain how actors mobilize and combine different value positions in order to legitimize different technological variants of a novel socio-technical configuration at large. Further, it asks how the build-up of other critical resources and collaboration networks for their exchange is conditional upon the diversity of value-orientations that actors adhere to. RQ1.3 moves in this direction by exploring configurations of different values held by actors that work on modular technologies in Switzerland. It and combines the configurational perspective with scalar-relational perspective by asking:

> *RQ1.3: In what respects and how does a value-based perspective on institutionalization enrich or alter existing innovation system frameworks and their geography?*

Eventually, zooming-in on specific regional cases, a crucial question is how regional actors respond to situations in which crucial resources are lacking or cannot be build-up within the region. Under what circumstances do these actors engage in the attraction of other resourceful actors or the absorption of resources from abroad? Addressing these questions requires exploring the mechanisms that lead to transnational resource flows and the emergence of multi-scalar innovation system structures. RQ1.4 seeks to trace these mechanisms for an innovation system that is emerging around a specific variant of modular water technologies in various localities spread across North-Western Europe, namely, district scale blackwater treatment systems. By looking at indigenous resources in different demonstration localities and resource flows among them, it tells a scalar-relational story about how a GIS may emerge in first place. It asks:

> *RQ1.4 : What are the knowledge and institutionalization-related conditions that lead to the emergence of an integrated (global) innovation system?*

Answering these RQs sheds light on RQ1 from very different conceptual and scalar angles, which recombine the scalar-relational perspective and the configurational perspective consistent with a critical realist approach. Each of the contributions in the following four chapters utilizes and combines core conceptual building blocks at the interface of the four knowledge fields of EEG, innovation systems, socio-technical transitions, and organizational studies (Fig. 2).

In addition, the two chapters that explicitly incorporate a configurational perspective address the methodological question RQ2:

> *RQ2: How can we map and measure socio-technical configurations and re-configuration processes over time and space?*

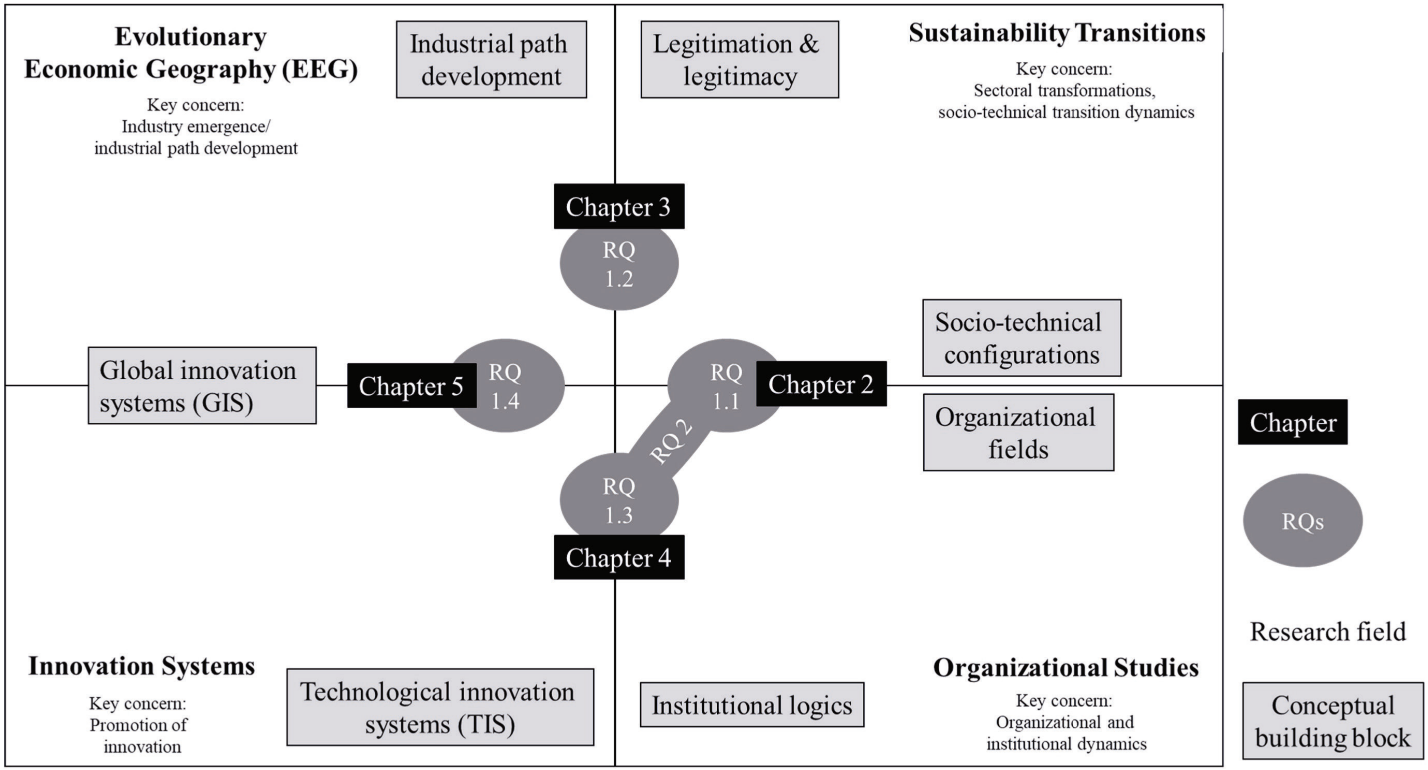


Fig. 1.2: Roadmap of knowledge fields and RQs. Own figure.

On the one hand, chapter two will need to map and measure configurational dynamics in the water sector globally in addressing RQ1.1. The contribution targeting RQ1.3 in chapter four, on the other hand, will explore how values are configured into field logics in a national-scale TIS. Hence, the methodological question will be explored by applying the STCA methodology to cases and questions situated at different scales, in this case, the global and the national.

Chapter two constitutes the core contribution of this thesis, first in analyzing global water sector re-configuration processes at different spatial scales and during critical periods of transformation (RQ1.1), and second in proposing a methodology to map and measure socio-technical configurations and re-configuration processes (RQ2). It rests on a media analysis of 8-years of public media discourses around water technologies in five different countries and among global industry experts. It compares socio-technical re-configuration processes within different countries and at the global scale. It highlights the change and stabilization processes around major configurations related to the two dominant infrastructure paradigms around centralized and decentralized/modular water technologies. As a central contribution, it introduces the methodological approach of this thesis, namely STCA. The approach is applied here to mapping and measuring socio-technical configurations as they emerge from public media discourses during so-called critical moments, that is times of intense external pressures and heated discourse activity during which major re-configuration processes are likely to happen (Yuana et al., 2020). The findings indicate that the dominant socio-technical configuration around large-scale centralized infrastructures dominates the field in most countries and at the global scale. However, throughout the critical period of increased global stress on water infrastructures, re-configuration processes, especially at the global scale and in the US, indicate an increased interest in modular and decentralized technology configurations. Contrastingly, in South Africa the global regime configuration retains its core position despite heavy droughts. In India, the data reveals a hybridized field structure, showing that decentralized and centralized technologies co-exist within a stable core configuration. As depicted in Fig. 3 (top left quadrant), chapter two applies a configurational perspective, as it introduces the STCA methodology to map and measure re-configuration processes at different spatial scales.

In chapter three, we utilize the same dataset of 8-years of coded media discourses in several countries and at the global expert scale, but apply a scalar-relational perspective to it that seeks to explain when and where multi-scalar processes are at work (Fig. 3, top right quadrant). More specifically, it seeks to address RQ1.2, asking how multi-scalar processes of legitimation come into play in early industry formation around modular water technologies. Thus, here, we depart from the existing literature on relational processes within EEG, such as the processes through which knowledge is absorbed in regions to contribute to industrial path development. However, we extend beyond the knowledge domain, arguing that path development in emerging industries may also benefit from the mobilization of legitimacy from non-local sources. We illustrate this by focusing on multi-scalar legitimation processes that emerge from the media analysis in five different countries and among global industry experts. Comparing innovation and legitimation dynamics in these countries, we show that processes of attraction, absorption and export are not restricted to transnational knowledge flows. They are also characteristic feature of industry legitimation processes around an emerging modular water technology industry. The paper, subsequently, builds a conceptual framework, in which regions or countries embark on different path development trajectories depending on their specific indigenous resource endowments and their ability to mobilize and anchor resources from abroad. Our findings indicate that some countries, like Singapore or Israel specialize in exporting knowledge and technologies and in absorbing legitimacy for path development from the success stories around locally-developed modular water technologies that are deployed abroad. Other countries, like the South Africa and India, might not have to absorb legitimacy from elsewhere because problem pressures facilitate the advocacy work of local proponents of an alternative path, but they might have to attract or absorb knowledge resources from abroad. The US, in turn seeks to develop a lead market building on relatively strong local knowledge and legitimation activities, while additionally exporting resources for path development globally.

Taken together, chapter two and three illuminate focal aspects of RQ1 and 2. Chapter two shows how re-configuration and ultimately institutionalization processes are triggered and reproduced at different spatial scales (Fuenfschilling and Binz, 2018). Chapter three, in turn, illuminates how scalar re-configuration processes are interdependent through resource flows across different spatial scales. Thus, while chapter three elaborates sectoral and industrial change from a *scalar-relational* perspective on localized dynamics in terms of resource flows, chapter two actually deploys a *configurational* perspective, applying the STCA methodology to explore the alignment processes that happen at different spatial scales and in different countries.

Chapter four takes a closer look at institutional structures within a specific national context by asking how values shape the directionality of early stage technological innovation systems as well as the geography of their actor networks (RQ1.3). It builds on chapter two methodologically since it deploys the STCA methodology. It reconstructs configurations of values within an emerging TIS around modular water technologies in Switzerland and the directionality battles that these value configurations induce. STCA, here, is utilized to investigate configurations of field logics, i.e. clusters of values shared by various actors in the field, and how they correlate with actors' preferences for directionality and networking partners. In the Swiss field, the field logics are clustered around values associated with ecology, professional engineering and the market. Depending on the field logic that actors subscribe to the strongest, we find a tendency to promote different technological variants, and to engage in different collaboration patterns. For example, in the Swiss field, actors adhering to an ecological field logic tend to favor low-tech modular technologies and tend to collaborate among like-minded organizations at the regional and national scale, whereas actors adhering to a market field logic tend to favor high-tech configurations and tend to collaborate across logics and more internationally. Chapter four provides an insight into how a configurational perspective may enhance the understanding of institutional structures and change. It shows how specific logic configurations may be associated with specific relational patterns at the level of actors. Thus, chapter four links both configurational and scalar-relational perspectives and shows how they both are interdependent (Fig. 3, bottom left quadrant). By zooming in on a specific case, it further sheds more detailed light on the patterns and processes that we observe at higher spatial scales already in chapter two and three. While we explored entire socio-technical configurations in chapter two and three at global and national scale, in chapter four, we look at how underlying logics shape both alignments among socio-technical elements as well as actor networks at the regional and national scale.

Chapter five extends the scalar-relational perspective already explored in chapter three by adding a dynamic view to it. It asks the crucial and yet open question how a GIS around modular water technologies actually emerges in first place (RQ1.4). Thus, it explores more in-depth through what mechanisms trans-local processes of resource mobilization actually emerge and stabilize in a functioning GIS. It utilizes interview and secondary data to explore the emergence of a GIS around modular water technologies built of subsystems at different spatial scales (regional, national and transnational) in and across several North-Western European countries over the course of the past 20 years. It shows that complementarities in local resource stocks among different subsystems, as well as proactive system management at the European level fostered the emergence of a GIS. Once estabilized the coordinating efforts of multi-scalar systemic intermediaries (van Lente et al., 2003, van Welie et al., 2020) were crucial to keep the GIS running. It also reveals how a few early mover subsystem regions (Netherlands and Hamburg) became resource pools for subsystems emerging later (Sweden and Ghent). The dynamic perspective allows for a scalar-relational conceptualization of GIS emergence mechanisms and conditions. It can be situated within the bottom right quadrant of fig. 3.

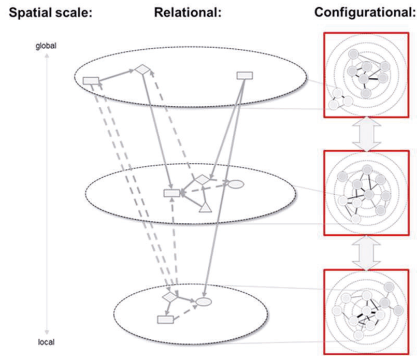
Putting the contributions and conceptual angles of the individual chapters together provides a multi-facetted picture of the geography of re-configuration processes that extends beyond previous conceptualizations of economic and technological change from EEG and transitions. It shows that actor networks (the scalar-relational) and the configurations of socio-technical elements that they reproduce and align (the configurational) should be understood as interdependent. Further, the thesis combines a multi-actor focus with a focus on configurations of both knowledge-related elements (technologies, capabilities) and institutional elements (values, norms, laws, regulations).

The configurational perspective differs from previous attempts to include institutions within EEG frameworks, which have studied institutions as aggregated data points within specific regional or national contexts. The configurational perspective, instead, regards institutional and knowledge-related elements as being linked into configurations with emergent properties that shape the ways in which regional industries or entire sectors may evolve. This can be elaborated by the empirical example of re-configuration processes around modular water technologies, which were analyzed in this thesis. Chapter four has shown how different field logics align with specific technological variants. However, these dynamics are embedded into the wider, global re-configuration processes and multi-scalar legitimation networks that were observed in chapters two and three respectively. The Bill and Melinda Gates Foundation, for example, a global philanthropy donor spending millions on sustainable sanitation is a crucial legitimizer of modular technologies within the global and various national discourses – re-configuring the ways in which these technologies are perceived locally and institutionalizing them through standardization efforts at the global scale. In the Swiss context, too, they engage in funding research and development around modular water technologies, diffusing a market logic within the emerging Swiss TIS, and linking Swiss innovators to various international partners. As can be seen from this example, actor networks, re-configuration processes, as well as underlying rule-sets are mutually interdependent at and across various spatial scales. Studying processes of re-configuration and institutionalization should, therefore, not be done in isolation of the material and geographical contexts with which they align and into which they are embedded (as also emphasized by Svensson and Nikoleris, 2018).

Taken together this thesis combines different scalar, and conceptual angles to arrive at a more holistic picture of the mechanisms through which geography conditions socio-technical transformations.

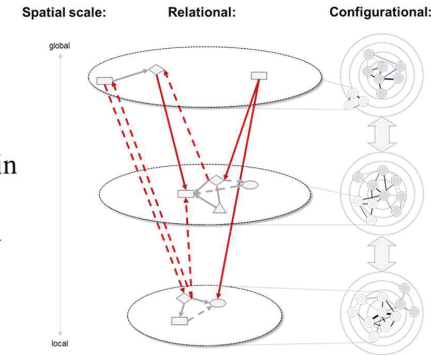
Chapter 2

RQ1.1: How and when do water sector re-configuration processes unfold at different spatial scales?



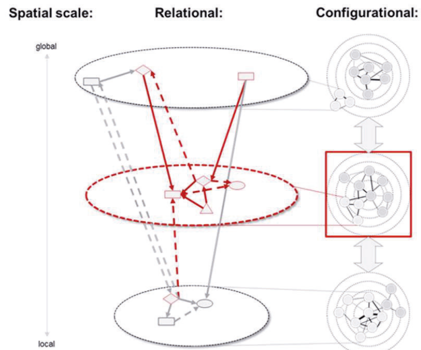
Chapter 3

RQ1.2 : How are industrial path creation potentials in specific spatial contexts influenced by and dependent upon multiscalar legitimation dynamics?



Chapter 4

RQ1.3 : In what respects and how does a value-based perspective on institutionalization enrich or alter existing innovation system frameworks and their geography?



Chapter 5

RQ1.4 : What are the knowledge and institutionalization-related conditions that lead to the emergence of an integrated (global) innovation system?

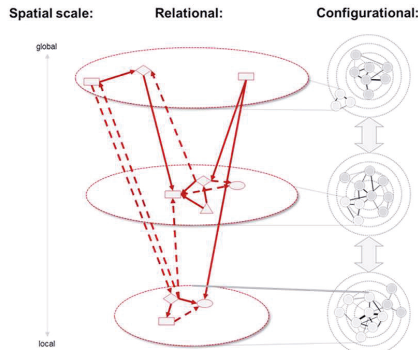
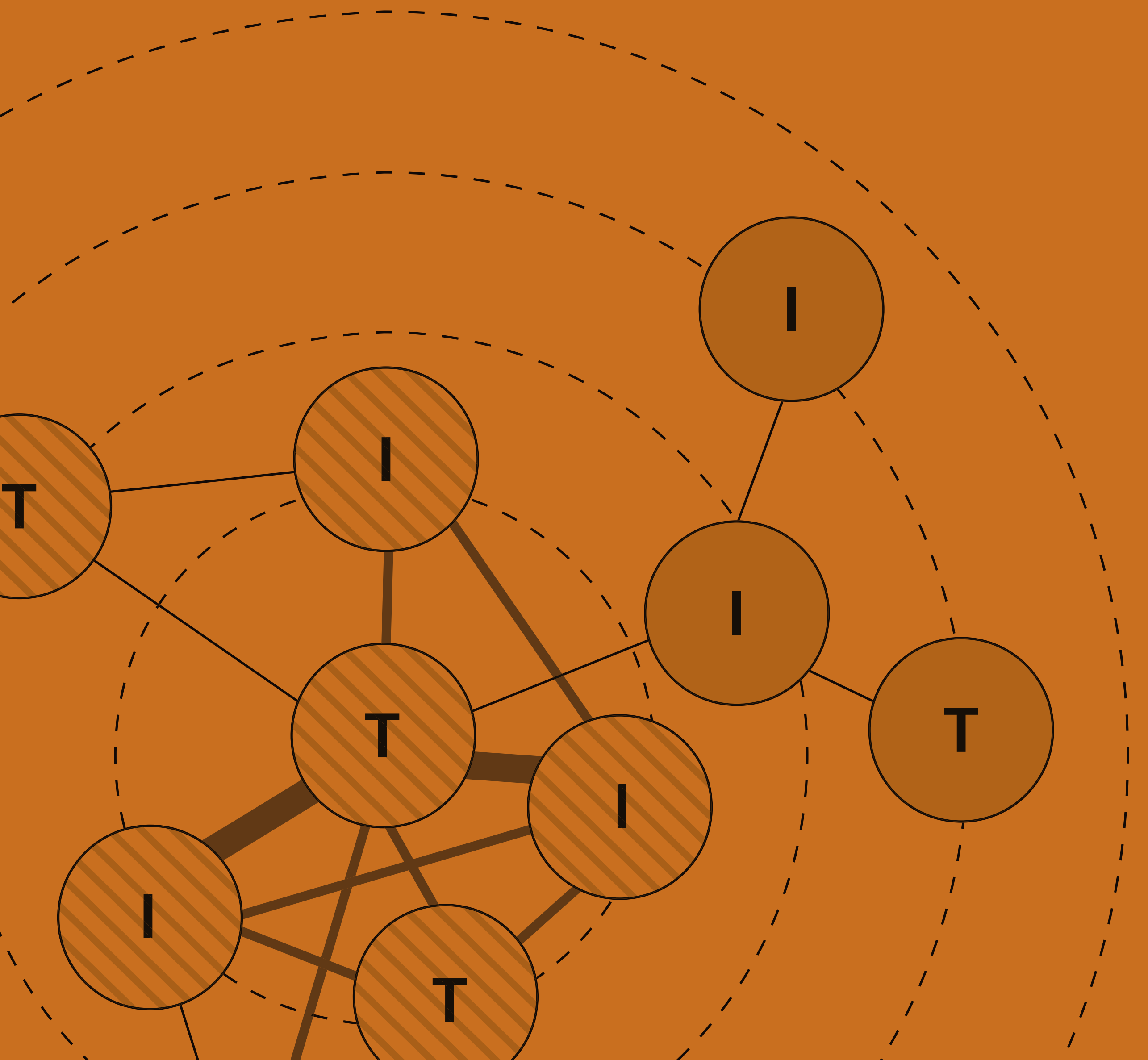


Fig. 1.3: Situating Chapters and RQs in the framework. Framework elements researched are highlighted in red for any individual chapter.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Chapter 2

Assessing transitions through socio-technical configuration analysis

A methodological framework and a case study in the water sector

Abstract

Classic accounts of transitions research have predominantly built on reconstructions of historical transition processes and in-depth case studies to identify and conceptualize socio-technical change. While such approaches have substantively improved our understanding of transitions, they often suffer from methodological nationalism and a lack of generalizability beyond spatial and sectoral boundaries. To address this gap, we propose a novel methodology – socio-technical configuration analysis (STCA) – to map and measure socio-technical alignment processes across time and space. STCA provides a configurational and dynamic perspective on how social and technical elements get aligned into "configurations that work", allowing for the identification of differentiated transition trajectories at and across spatial and sectoral contexts. The methodology's value is illustrated with the empirical case of an ongoing shift from centralized to more modular infrastructure configurations in the global water sector. Building on this illustration, we outline potential contributions of STCA to configurational theorizing in transition studies, sketching the contours of what we believe could become a generative epistemological approach for this field.

2.1 Introduction

Understanding fundamental sector transformations has become a major field of research in innovation studies and related social science disciplines (Smith et al., 2010). In particular, sustainability transition studies have coined key conceptual and analytical frameworks to reconstruct transformation processes in a broad variety of sectors such as energy, water, food, transport or public health (Markard et al., 2012). One of the core tenets of this literature is that sectoral transformations have to be understood as reconfigurations of sociotechnical systems (Geels, 2002). At the core of theorizing lies the alignment of actors, technologies and institutions into socio-technical "configurations that work" (Rip and Kemp, 1998). This implies that if a certain set of actors, institutions and technologies is well-aligned and deeply institutionalized, a sector will evolve along rather narrow trajectories for long periods of time before a deep structural reconfiguration can take place (Markard et al., 2012, Geels, 2004, Markard and Truffer, 2008, Levinthal, 1998).

Due to the complex and systemic nature of socio-technical change processes, the vast majority of transition studies draws on historical or qualitative case studies. These enable a detailed reconstruction of the dynamic realignment processes between technological and institutional elements, and of struggles between proponents and opponents of newly emerging socio-technical configurations (e.g. Geels, 2002). Moreover, even though transition studies have moved beyond historical reconstructions of technology substitution processes and adopted a wide variety of methodological approaches, most studies still remain restricted to in-depth reconstructions of transition processes in specific urban, regional or national contexts (Hansmeier et al., 2021). As a result of this implicit methodological nationalism (Coenen et al., 2012, Hansen and Coenen, 2015, Binz et al., 2020a), transition research tends to emphasize context-sensitivity, blurring the fact that many of the relevant alignment and change processes are driven by forces operating at international/transnational levels and in between several places at once (Sengers and Raven, 2015, Binz and Truffer, 2017, Fuenfschilling and Binz, 2018, Bauer and Fuenfschilling, 2019, Heiberg et al., 2020, Miörner and Binz, 2021).

More substantively, over-relying on singular case studies implies that cross-comparisons and generalizations between transition trajectories in different spatial or sectorial contexts remain a challenge. This is likely to hamper progress in the future theoretical development of the field (Alkemade, 2019, Andersen et al., 2020). One of the methodological challenges is that evolving configurations - i.e. complex, dynamic relationships between interconnected variables - underpin transition dynamics, rather than a set of independent variables, as assumed in conventional statistical methods and correlational theorizing. A move towards more "configurational theorizing" thus requires methodologies that are able to capture and visualize complex interaction patterns and interdependencies between relevant variables (Weber and Truffer, 2017, Furnari et al., 2020). Hence, we propose a novel, semi-quantitative methodology for mapping shifts of socio-technical configurations over space and time, which we call 'socio-technical configuration analysis' (STCA). The STCA methodology builds on - and substantially extends - a recently established method from the political sciences known as Discourse Network Analysis (DNA) (Leifeld, 2017). We adapt this method in a way that allows to assess (dis-)alignments among actors, institutions and technologies in transition processes.

STCA builds on the coding of network ties among actors and concepts. Concepts may encompass technological solutions, formal rules and regulation, policy measures but also more intangible institutional structures, such as norms, values or logics, which are recorded from any type of textual data. We identify ties between actors and concepts through actor statements recorded in public newspapers and expert magazines in which they relate to technological and institutional concepts. Newspapers and magazines have increasingly been used as sources to capture discursive dynamics in transition studies and economic geography (Geels and Verhees, 2011, Rosenbloom et al., 2016, Meelen et al., 2019, Ozgun and Broekel, 2021). Discourses are defined by the ideas or concepts through which actors ascribe meaning to material or non-material artefacts of the world around them (Hajer, 2006). Recent research has suggested that so-called "critical moments", defined as "events that allow negotiation of meanings, formulation or reformulation of dominant discourses" (Yuana et al., 2020, p. 157), provide contexts in which discursive battles are crucial for understanding transition dynamics. By drawing on documents that capture the evolution of a discourse during critical moments, our approach enables a semi-quantitative reconstruction of the temporal and spatial (dis-)alignments of socio-technical configurations. Mapping different actor statements around institutional and technological concepts as relational structures (networks), we are able to depict the emergence of new, as well as shifts in the dominance of existing socio-technical configurations. The qualitative basis of the data, in turn, enables the identification of key mechanisms and actors that drive these reconfiguration processes.

As an illustrative case, we apply STCA to statements made by actors in national newspapers and global industry magazines about how to respond to challenges in the urban water sector. Conceptually, we follow Fünfschilling and Truffer (2014) in depicting socio-technical transitions as shifts in the most highly institutionalized core of an organizational field (DiMaggio and Powell, 1983, Scott, 1991). Actor statements are interpreted as exemplary voices on how to best solve key challenges in a given field. Coherent combinations of such statements – which we will call "storylines" in the following – can be interpreted as proxy measures for currently existing or future imagined socio-technical configurations. We expect that, during critical moments, the configurations that are compatible with a prevailing regime will be more coherent and voiced by more numerous and more powerful actors than newly emerging configurations. Therefore, socio-technical transitions or reconfiguration processes will be mirrored by shifts in the kinds of storylines that actors mobilize in a field's discourse. During and across critical moments, one might expect to see shifts from one (or several) well-aligned configurations to new one(s), mirroring the de- and re-institutionalization of old and novel regime structures over time.

While STCA can be applied to a wide variety of transition dynamics, we will here limit ourselves to presenting an illustrative case: retracing the multi-scalar discursive dynamics before, during, and after a recent critical moment in the evolution of the urban water management (UWM) sector. This sector has historically developed a highly institutionalized and globalized socio-technical regime, which builds on centralized treatment and bulk transports of water through sewers and water pipes and a state- or market- based governance model dominated by large utilities (Fuenfschilling and Binz, 2018, Larsen et al., 2016). In face of increasing environmental pressures like droughts and flooding in several places around the world, decentralized, modular and community-based solutions have been promoted as a potentially more sustainable alternative (Hoffmann et al., 2020, Larsen et al., 2016). Yet, the uptake of these new socio-technical configurations is still limited in most places and has shown great spatial variation (Heiberg et al., 2020). We will apply STCA to a selection of 576 articles drawn from 70 national and international newspapers during an eight year period from 2011-2018, covering major drought and flood events, which we interpret as critical moments for the UWM sector. This enables the mapping of ongoing (dis-)alignment processes around technological and institutional concepts related to centralized and modular water infrastructures. From this analysis, we identify transition potentials in different countries, derive spatially differentiated development pathways and discuss implications of the approach for policy and industry strategies. Furthermore, by retracing shifts in international expert discourses, we may check whether the national transformations are mirrored by changes in the "global socio-technical regime" (Fuenfschilling and Binz, 2018) or whether they largely remain local/national phenomena.

The paper is organized as follows. Section 2 outlines the conceptualization of transitions as spatially and temporally differentiated (dis-)alignments of alternative socio-technical configurations, and elaborates how discourses can be used for retracing the corresponding dynamics. Section 3 introduces the STCA methodology and illustrates how it can be used for retracing socio-technical reconfigurations over time and space. Section 4 illustrates the application of STCA to our empirical case in the UWM sector. Section 5 discusses the implications of our findings and outlines the contours of a broader research agenda leveraging the full potential of the STCA methodology.

2.2 Mapping and measuring the (dis-)alignment of socio-technical configurations through a discursive lens

In transition studies, the structural transformation of sectors is essentially conceptualized as the "destabilization or de-institutionalization of existing socio-technical configurations and the creation and diffusion, hence institutionalization, of new ones" (Fuenfschilling, 2019: 2). Transitions occur when well-aligned and stable socio-technical configurations - the combination of technologies, actor networks, and institutions that have co-evolved and stabilized over long periods of time - start to get supplanted by one or several alternative configuration(s) with new core values and technologies. The electricity sector, for example, faces a transition from centralized fossil and nuclear power generation and long-distance power grids towards decentralized smart-grid connected renewable energy technologies. Typically, these transformations are accompanied by major shifts in the underlying rule sets – also called the 'regime', 'grammar' or 'deep structure', which guide the practices of actors in a field (Geels, 2002). To understand a transition, one has to explain how regime shifts come about, i.e. how certain institutional and technical elements get re-aligned or displaced by new ones to converge into new socio-technical configurations that work. This contribution aims at formulating a new methodological approach for mapping and measuring such reconfiguration processes. To do so, we first have to elaborate on how to conceptualize the relevant dynamics.

2.2.1 Socio-technical configurations as alignments of actors, technologies and institutions in organizational fields

As a conceptual starting point, we adopt a neo-institutional perspective on socio-technical transitions, which understands transitions as reconfigurations in organizational fields (Fuenfschilling, 2019). Fuenfschilling and Truffer (2014), building on Thornton and Ocasio (1999) and DiMaggio and Powell (1983), argued that this perspective enables conceptualizing socio-technical change processes in a less categorical and rigid way than the conventional distinction of regime, niche and landscape structures (Hoogma et al., 2002, Geels, 2002, Rip and Kemp, 1998). Organizational fields are defined as the aggregate of organizations that define "a recognized area of institutional life", as for example an economic sector with competing companies, users, consumers and regulators (DiMaggio and Powell, 1983, p.148). More recently, this definition has been extended to an understanding of fields as relational spaces in which various organizations interact in collective sense making processes around organizational and field level processes (Wooten and Hoffman, 2016). In this context, socio-technical regimes can be understood as the most highly institutionalized elements in an organizational field (Fuenfschilling and Truffer, 2014). Transitions can accordingly be understood as emerging socio-technical configurations, whose social and technical elements get more aligned and institutionalized as they mature and start to reshape previously dominant configurations in the field. Structural change may take a wide variety of forms, from a linear substitution of established regime structures by an upcoming niche configuration (as presented in much of transitions literature), but also all sorts of hybridization dynamics, such as those which Smith and Raven (2012) called stretch-and-transform or fit-and-conform patterns. Our argument thus resonates with recent calls for developing more multi-dimensional and configurational theorizations of transition trajectories (such as Fuenfschilling, 2014, Geels et al., 2016, van Welie et al., 2018).

The institutional view on transitions, furthermore, enables the qualification of regime structures as more or less strongly institutionalized socio-technical alignments at any moment in time (Fuenfschilling and Truffer, 2014, van Welie et al., 2018). Fünfschilling and Truffer (2014) argued that the strength of a regime in guiding actor strategies is, among others, dependent on the number of competing field logics present in the corresponding organizational field. Field logics constitute coherent bundles of institutional logics which are defined as the "socially constructed (…) values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality" (Thornton and Ocasio, 1999, p. 804). A strong regime is characterized by a strongly aligned and deeply institutionalized socio-technical configuration, which responds to a single and largely uncontested prevailing field logic. A weak regime, instead, would be characterized by (several) poorly aligned socio-technical configurations, which have to accommodate several competing field logics (Fuenfschilling and Truffer, 2014). The organizational field as a whole will, in general, hold a variety of more or less strongly aligned and institutionalized socio-technical configurations composed of technological and institutional concepts that get promoted by diverse actor coalitions. The conventional view of a transition playing out between a single dominant regime, getting challenged and ultimately overthrown by a single niche, therefore, represents only one (and arguably a rather special) case among many potentially relevant transition trajectories (van Welie et al., 2018, Geels et al., 2016).

2.2.2 Mapping and measuring re-configuration dynamics through discourses

The empirical assessment of change in socio-technical configurations requires a detailed capturing of the dynamics that lead to the (dis-)alignment of actors, institutions and technologies. In most transition studies so far, socio-technical alignments were identified by tracing reconfiguration processes through in-depth historical and qualitative case studies (Hansmeier et al., 2021). This approach provided deep insights into core mechanisms that drive specific transition processes, but made it rather difficult to generalize findings across different technologies, sectors, time periods or spatial units (Svensson and Nikoleris, 2018, Sorrell, 2018). One of the reasons for the prevalence of this methodological approach is that compared to other realms of innovation studies, -- e.g. those focusing on knowledge dynamics, which can be measured (partially) through global patent and publication databases -- there are no comparable systematic and extensive stocks of data that would enable to map socio-technical (dis-)alignment dynamics with quantitative methods.

In order to overcome these limitations, we here propose a methodological approach, which builds on textual recordings of discourses. Hajer (2006, p.67) defines discourse as the "*ensemble[s] of ideas, concepts and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices"*. Discourses serve as a suitable lens to reconstruct changing configurations because they reflect different actors' arguments for or against the need for change in a given field. Especially in critical moments, actors will be compelled to publicly voice their opinions in order to control for problem definitions, the assumed nature of future challenges, or influence how contradicting values will be considered in future development pathways (Seo and Creed, 2002, Wooten and Hoffman, 2016, Yuana et al., 2020).

Discursive approaches have already been applied to various problems in socio-technical transition studies. They have been used to analyze strategies of transition proponents (Raven et al., 2015, Smith et al., 2014, Smith and Raven, 2012), the building and maintenance of legitimacy for specific technologies (Geels and Verhees, 2011), the semi-coherence of socio-technical regimes (Fuenfschilling and Truffer, 2014), and the formation of socio-technical storylines, e.g. through the translation of landscape pressures in proponents' and opponents' framing activities of different socio-technical concepts (Rosenbloom et al., 2016, Yuana et al., 2020).

Discourses thus provide useful proxy measures for identifying patterns, dynamics and strategies through which socio-technical configurations may develop, align, stabilize or get challenged. We interpret alignments in these configurations as follows: If during a critical moment, a specific concept, say a technology or value, is used in congruence with a large number of other concepts in the larger discourse, we would argue that it has a higher potential to become a highly institutionalized part of the regime. Its congruence with many other concepts indicates compatibility and hence easier alignment with regime structures than more peripheral concepts that are only used in an isolated fashion causing friction with taken-for-granted beliefs. A cluster of closely aligned concepts, may thus be interpreted as a (socio-technical) “configuration that works” (Rip and Kemp, 1998), while loosely connected clusters may be attributed to less mature socio-technical configurations. The more coherently concepts are co-framed positively (or negatively) in actor’s statements, the more strongly aligned the configuration will be.

One key advantage of this methodological approach is that extensive textual databases exist, through which statements about socio-technical concepts can be empirically assessed. Potential databases comprise a wide array of secondary textual media, such as newspapers, conference proceedings, government protocols, online blogs, social media platforms or industry magazines, but also primary data like interview transcripts. Textual data sources that cover different spatial and/or temporal contexts furthermore enable researchers to analyze developments over time and to compare between geographical or sectoral contexts in a systematic way. STCA, in particular, improves our ability to retrace the geography of socio-technical transition processes, since it allows to empirically assess how transition proponents and opponents voice their opinions differently in different arenas or layers of the socio-technical system (Smith et al., 2014, Miörner and Binz, 2021). As an example, we can distinguish conceptually between expert discourses that are forming in the globalized professional expert circles of a sector (i.e. the global regime), and public policy discourses that are carried out by actors embedded in specific national/regional/urban spatial subsystems (Miörner and Binz, 2021). In the global regime layer, internationally operating companies, NGOs, consultants or investors will divergently evaluate certain technical approaches and engage in battles around the directionality of their field at international conferences, trade fairs, as well as in professional industry magazines, blogs, etc. In territorially embedded layers, in contrast, discursive battles will be fought in the context of national, regional or even urban policy arenas. The relevant statements might in turn be staged in local/regional/national newspapers as well as in parliamentary debates, roundtables, policy fora, and the like.

2.3 Socio-technical configuration analysis (STCA)

Based on the above conceptual framing, we will now elaborate the STCA methodology in more detail. We depart from an established method in political sciences, Discourse Network Analysis (DNA, Leifeld, 2009, Leifeld and Haunss, 2012, Leifeld, 2017), which was originally developed to analyze policy debates. The core idea of DNA rests on generating relational data structures that connect actors with different beliefs, arguments or policy stances (Leifeld, 2009, Leifeld, 2017). Based on these relations, DNA can on the one hand be used to study "advocacy coalitions" (Sabatier, 1988), which are operationalized through actor congruence networks, where links between actors are established based on their similar (congruent) statements around a given concept. On the other hand, the same approach can also be used to analyze prevalent "storylines" in a policy discourse. Here, concepts are aggregated into so-called concept congruence networks. If two concepts are uttered in tandem by the same actor(s), this implies some degree of ideological and intrinsic compatibility between them. Congruent supportive or obstructive statements around several concepts can then be interpreted as coherent storylines (for such an operationalization see also Leifeld and Haunss, 2012). The content of these relational data may then either be represented in so-called affiliation or two-mode networks, or in one-mode projections as actor or concept congruence networks.

DNA has already been applied in socio-technical transition studies, mostly to analyze political advocacy coalitions and public policy debates related to sustainability transitions (Schmidt et al., 2019, Schmid et al., 2020). STCA builds on the intuition of these approaches but expands far beyond the realm of policy debates. Rather, similar to Geels and Verhees (2011) and Konrad et al. (2012), it perceives societal, political and professional discourses as a relevant proxy measure that mirrors prevailing socio-technical configurations.

As Geels and Verhees (2011) have shown, the proponents and opponents of a given technological solution do not only evaluate its performance, but also consider its meanings in broader social, political, economic, ecological, or spatial contexts. Hence, STCA captures how individual organizations evaluate technologies, infrastructures, policies, regulations or sectoral paradigms and norms. Drafting actor congruence networks then enables us to map actor coalitions that share certain rules, norms, interests, visions and beliefs about appropriate solutions for a prevalent problem. Concept congruence networks, in turn, enable us to assess how closely different concepts are aligned with each other. The visual inspection of these networks can be complemented with network statistics, which enable to infer the degree of institutionalization of specific concepts and configurations as well as the tracing and comparison of reconfiguration patterns across time and space.

As a prerequisite for such an analysis, the textual data from which the analysis is derived, needs to be a representative sample of the respective socio-technical field's discourse. It is therefore important to make sure that, for example, newspaper articles cover the full diversity of diverging views (and editorial stances) on a certain topic, or that interviewees represent a broad range of perspectives in a specific field. Oftentimes, in socio-technical discourses, researchers will have an expectation regarding important actors and positions. If these do not appear in the data, then the data sources may need to be improved or extended or initial assumptions revised until theoretical saturation is reached (i.e. adding additional data sources does not change the overarching storylines anymore).

In the remainder, we will mostly elaborate on how to interpret concept congruence networks, since they are most useful for analyzing shifting socio-technical configurations. In figure 2.1, three ideal-type constellations are presented, which might be interpreted as shifting socio-technical configurations in an organizational field. At a most basic level, socio-technical configurations are identifiable as sub-networks of technological and institutional concepts, which are more strongly interlinked among themselves than with other concepts. The width of the links between concepts reflects the strength of their mutual alignment. Furthermore, we differentiate shapes and colors of symbols in order to denote attributes of the concepts. Following Fuenfschilling and Truffer (2014), we position concepts in a 'radar plot' in order to differentiate between 'central' and more 'peripheral' concepts.

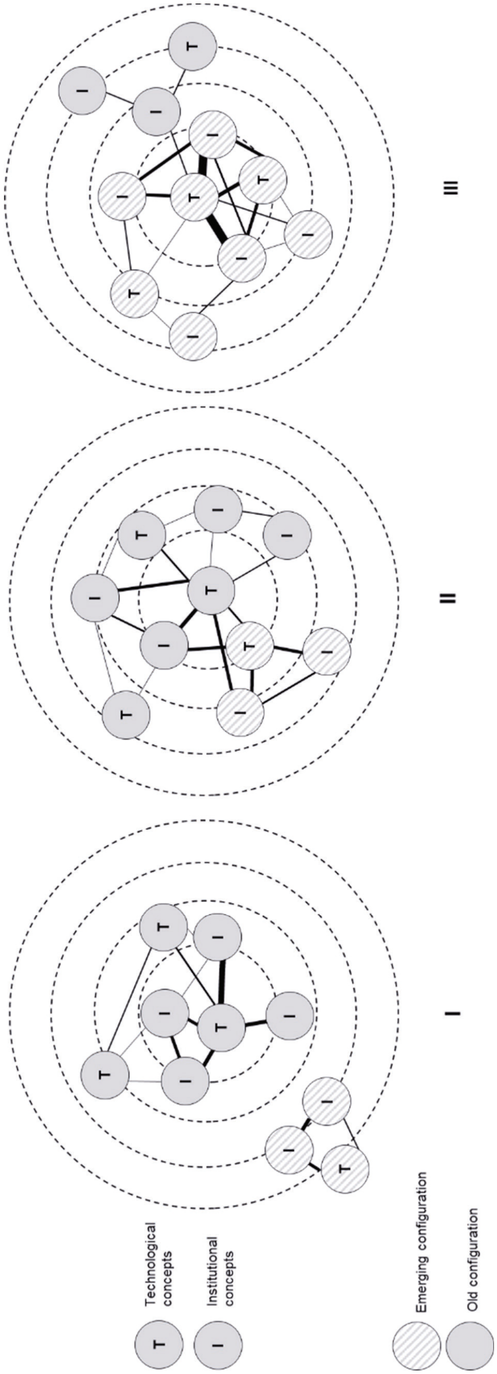

Fig. 2.1: Socio-technical configurations as alignments of technological and institutional concepts. Own illustration.

Radar plot I depicts a configuration with strongly aligned technologies and institutional concepts (solid filled nodes), which can be interpreted as representing a socio-technical regime. The pattern-filled, more peripheral cluster of nodes represents a competing socio-technical configuration of technologies and institutional concepts that is less aligned with the majority of other concepts and supported by fewer and more peripheral actors. In plot II, concepts of the peripheral configuration are getting partly integrated into the regime structure, which thus becomes hybridized. Plot III, then, shows a reconfigured regime constellation, that resulted from a merger of the formerly distinct configurations.

Equipped with this conceptual intuition, we may now further operationalize the framework with network indicators that allow for a deeper characterization of configurations in concept congruence networks. First, we propose two measures for assessing the **degree of institutionalization** of a given concept: Its degree centrality and the frequency of its use. *Degree centrality* measures the number of other concepts that a concept is linked to in the discourse. In actor networks, a person with a high degree centrality can be interpreted as "a major channel of relational information, […] occupying a central location" (Wasserman and Faust, 1994, p. 179). In concept congruence networks, degree centrality reflects the number of other concepts that have been co-mentioned in a congruent way. A central concept is therefore one, which is used congruently with many other concepts. Visually, a concept's degree centrality score may be represented by its position in a radial centrality layout (Baur, 2008). Concepts in the core of the radar plot thus denote the 'core' of a discourse in a given point in time.

The degree of institutionalization of a certain concept can, however, not solely be read from the position on the radar plot. It also depends on the number of actors who have endorsed it in a given period. The more different actors have used a concept in their statements, the more prevalent that particular concept is. Especially in critical moments, one can assume that concepts that are more prevalent in the discourse also have a higher degree of institutionalization. Visually, the number of actors using a concept is captured by the size of each node.

A given concept's degree of institutionalization can thus be inferred from a combined view on both measures. I.e. a large node (concept used by many different actors) with a high degree centrality (positioned close to the core of the radar plot) arguably has a high degree of institutionalization. A small node (few actors using the concept) with low degree centrality (positioned at the fringe of the radar plot) represents a rather peripheral concept in the overall discourse with a lower degree of institutionalization.

As a second analytical step, we turn the focus to identifying congruent storylines - i.e. clusters of technological and institutional concepts that are strongly aligned with each other, thus representing a coherent socio-technical configuration. The **alignment between concepts** can be operationalized by a normalized edge weight that considers the similarity of two concepts in terms of the organizations that have used them congruently. To this end, we calculate each concept pair's jaccard similarity (Gower and Legendre, 1986). Jaccard similarity (s) is expressed as:

$$s = a/(a + b + c)$$
$$where\, n11 = a,\, n10 = b,\, n01 = c\, and\, n00 = d$$

Where *a* represents the number of organizations that have used both concepts congruently (n11). The sum of *a, b* and *c* represents the number of organizations that have referred to both *and* either one *or* the other of the two concepts (n11 + n10 + n01). *d* represents the case of no joint referral (n00). If s turns 1, then numerator and denominator are the same, meaning that two concepts are always used in congruence, as no organization uses one without also using the other. An s close to 0, instead, indicates two concepts that are only rarely used congruently. Accordingly, a jaccard index of 1 or close to 1 indicates a more coherent storyline than an index value close to 0. We visualize the alignment between concepts accordingly by setting the shading and the width of an edge according to its jaccard index value. This way concept clusters, and hence coherent storylines, may be detected through the visual inspection of the graph. Clustering techniques could further be applied for the quantitative detection of coherent socio-technical configurations.

As a last analytical step, one may turn to the **overall composition of the concept congruence network**, which indicates whether and how strongly different socio-technical configurations in a field are aligned with each other. In some cases, different configurations will be largely isolated from each other, thus hinting at a fragmented or splintered regime structure. In other cases, different configurations may show strong overlaps, hinting to a hybridized polycentric or even monolithic regime structure. We use a combination of aggregate network indicators here. First, *network density* is calculated to assess the proportion of actual links compared to the maximally possible links among all concepts in the network (Wasserman and Faust, 1994). The higher the density, the more connected are the concepts in a graph, hence, the more aligned are the core storylines presented in the discourse during a certain period of time. Second, *average degree* and the *average number of actors per concept* reflect the average alignment of concepts with each other, and the average amount of actors behind concepts. In future research, these measures may be enriched with additional indicators for overall network composition, as e.g. global clustering or cohesion coefficients. As an illustration inspired by our empirical case, figure 2.2 presents a hypothetical concept congruence network in the UWM sector. The blue dots represent a well-aligned socio-technical configuration that connects (here randomly chosen) concepts like key technologies (T), regulations (R), and infrastructure paradigms (P) around centralized water infrastructures. Green dots in turn represent a more emerging configuration around modular water infrastructures. We may now characterize this network in more detail, based on the analytical procedure outlined above.

Infrastructure paradigm P2 (centralized treatment) constitutes the most deeply institutionalized, core concept of the discourse. It is compatible with four other concepts, resulting in a degree of 4, which is clearly above the average degree of the full network (2.286). Its relatively large node size furthermore indicates that a high number of actors have congruently used the concept. Both indicators thus suggest a high degree of institutionalization for P2. When turning to the identification of coherent storylines, the jaccard normalized edge weights indicate strong alignment between concepts related to centralized water infrastructures, especially P2, T4, R1 and T3. The closed triplets P2-T4-T3 and P2-T4-R1 furthermore indicate that a coherent storyline exists among the blue dots. The overall pattern thus indicates that a deeply institutionalized (regime) configuration exists around centralized water infrastructure. Also the overall density of the network (0.381) indicates that over one third of possible connections between nodes are present, hinting to a rather well-connected overall network structure, which is here driven by the core configuration around centralized infrastructures. The P1-T1 configuration around modular water infrastructure, in turn, is less deeply institutionalized and more peripheral to the overall discourse. Even though a strong alignment exists between P1 and T1, the storyline is only loosely connected to the core storyline in the field. In the remainder, we will apply this methodology to the analysis of socio-technical reconfiguration dynamics during a critical moment in the global UWM sector's recent evolution.

2.4 Analyzing and mapping recent transition dynamics in urban water management with STCA

The UWM sector constitutes a well-suited empirical case for illustrating the STCA approach, as it is facing strong transformation pressures globally and boasts a complex global actor structure that can be expected to exhibit relevant activities in different locations and at different spatial scales. With an estimated annual investment volume of 500 billion US dollars in 2014, the sector is dominated by private or public water utilities, as well as large multinational equipment suppliers, engineering consultants and service providers like Suez, GE, Dow, Veolia or Thames Water (Lieberherr and Fuenfschilling, 2016, OECD, 2019, OECD, 2018). Next to public investments, also international development banks, and private investors play an increasingly important role (OECD, 2019).

Scholars and practitioners alike are increasingly highlighting the importance of making UWM practices more sustainable, resilient, and fit-for-purpose (Larsen et al., 2016, Hoffmann et al., 2020). Modular, decentralized treatment technologies combined with community-based values play a key role in the storylines by actors pushing for radical change in UWM. Proponents of this alternative socio-technical configuration typically argue that diffusing the conventional, large-scale infrastructure paradigm to the whole world will be difficult to finance, and socially/ecologically damaging (Sadoff et al., 2015, UN-WWAP, 2015, Eggimann et al., 2018b, Larsen et al., 2021). The promise of modularized and decentralized technologies, in turn, rests on the hope that they can benefit from "economies of unit numbers" rather than economies of scale at the level of the treatment unit, making them cheaper, more flexible, and more efficient in closing local resource cycles (Wilson et al., 2020, Dahlgren et al., 2013, Larsen et al., 2016).

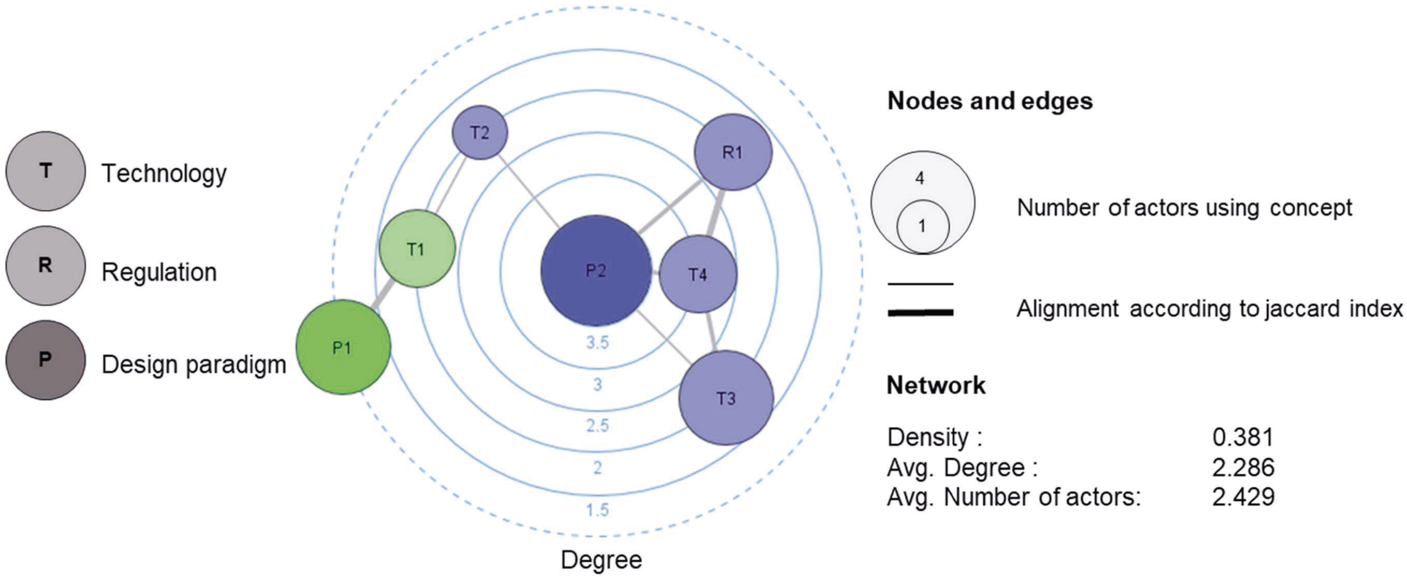

Fig. 2.2: Hypothetical, illustrative concept congruence network in the UWM sector. Colors reflect concepts associated with centralized (blue), or decentralized (green) water infrastructures. Own figure.

In contrast to conventional, centralized UWM solutions, modular and decentralized socio-technical configurations are still nascent in many parts of the world. They are pushed by relatively few industrial actors, and with funding and support mostly originating from philanthropy (especially the Bill and Melinda Gates Foundation – BMGF), NGOs, or research and development agencies (OECD, 2019). Yet, based on the continuing transformation pressures in the water sector, we would expect them to be increasingly raised in discourses during critical moments, such as droughts or floods, as viable alternative to the incumbent regime solutions. Incumbents may in turn be expected to react to these storylines by defending the existing regime or promoting solutions that are more compatible with the status quo (here e.g. seawater desalination or large-scale wastewater recycling schemes) (Fuenfschilling and Truffer, 2016, Williams, 2018, Fuenfschilling and Binz, 2018). Thus, empirically, we expect controversial (and potentially shifting) debates around the best-suited technologies, infrastructure paradigms, policies, regulations, and guiding values for dealing with water challenges that revolve around centralized vs. modular configurations.

2.4.1 Database and methods

Our illustrative application of STCA is based on discursive information collected from global newspaper repositories. We first screened the global repository Nexis Uni for outlets and articles dealing with water problems in various English speaking countries and in international industry magazines during 2011-2018. This period was chosen because it covers critical moments related to severe drought or flooding events in various parts of the world. Well-known examples include the droughts in the South-Western USA between 2011-2017, a major drought crisis in South Africa since 2015, as well as ongoing regional drought and flooding pressures in India (Spinoni et al., 2019, and see A5). A set of 191 outlets classified as quality newspapers and industry magazines by Nexis Uni, plus newspapers from India, South Africa, and Singapore, was filtered with a search query focusing on centralized or modular water technologies. The newspapers and industry magazines were selected in order to cover public discourses in different major cities within the countries analyzed, as well as global sectorial expert discourses in water treatment related sectors such as mining, oil and gas and the chemical industries(for details, see A1). As outlined in A1, our database intentionally covers media outlets with diverging editorial stances (i.e. New York Times, Washington Post, and Christian Science Monitor in the US discourse).

The search query was iteratively built based on the review of secondary literature and interviews with leading technology experts at the authors' home institution, using both general and specific technology terms, to account for potentially changing terms and definitions of configurations used across time and space (for details, see A2). Of initially around 800 articles, 576 articles stemming from 70 outlets were deemed relevant and subsequently coded by two coders with help of DNA-software (Leifeld, 2018). The first author developed and tested a coding scheme (A3) before teaching a second coder in consistently applying it, involving feedback rounds and inter-coder reliability checks. The coding differentiates several innovative water technologies both within the centralized and modular paradigms. Further, we distinguished individual concepts for the centralized vs. modular infrastructure paradigm, and for different types of governance and regulative approaches (i.e. hierarchical utility-based vs. distributed/community-based forms of governance) that actors would mobilize in the context of their statements.

Wherever applicable, direct and indirectly quoted statements by organizations were coded. For each code, an agreement variable specifies if a paradigm, technology, policy etc. was being referred to positively (supportive) or negatively (obstructive). Congruence among concepts may then either emerge from two concepts that have jointly been evaluated positively *or* negatively, as both instances indicate ideological compatibility between the concepts. For example, statements about large-scale desalination and large-scale wastewater reuse might indicate congruence either if they are conjointly rejected by many actors, or if they are conjointly supported by many actors. Eventually, for each code, we captured the dominant spatial scale of the activity of the organization referring to a concept, (i.e. global for multinational companies, (sub-) national for governments or local utilities, etc.), based on separate desk research. Further, we captured the spatial reach of the newspaper/magazine, in which a statement relating to a concept was published (i.e. global for industry magazines, regional/national for newspaper articles, also see A1). Figure 2.3 illustrates how we moved from textual data to coding concept-actor affiliations and finally to the projection of concept congruence networks.

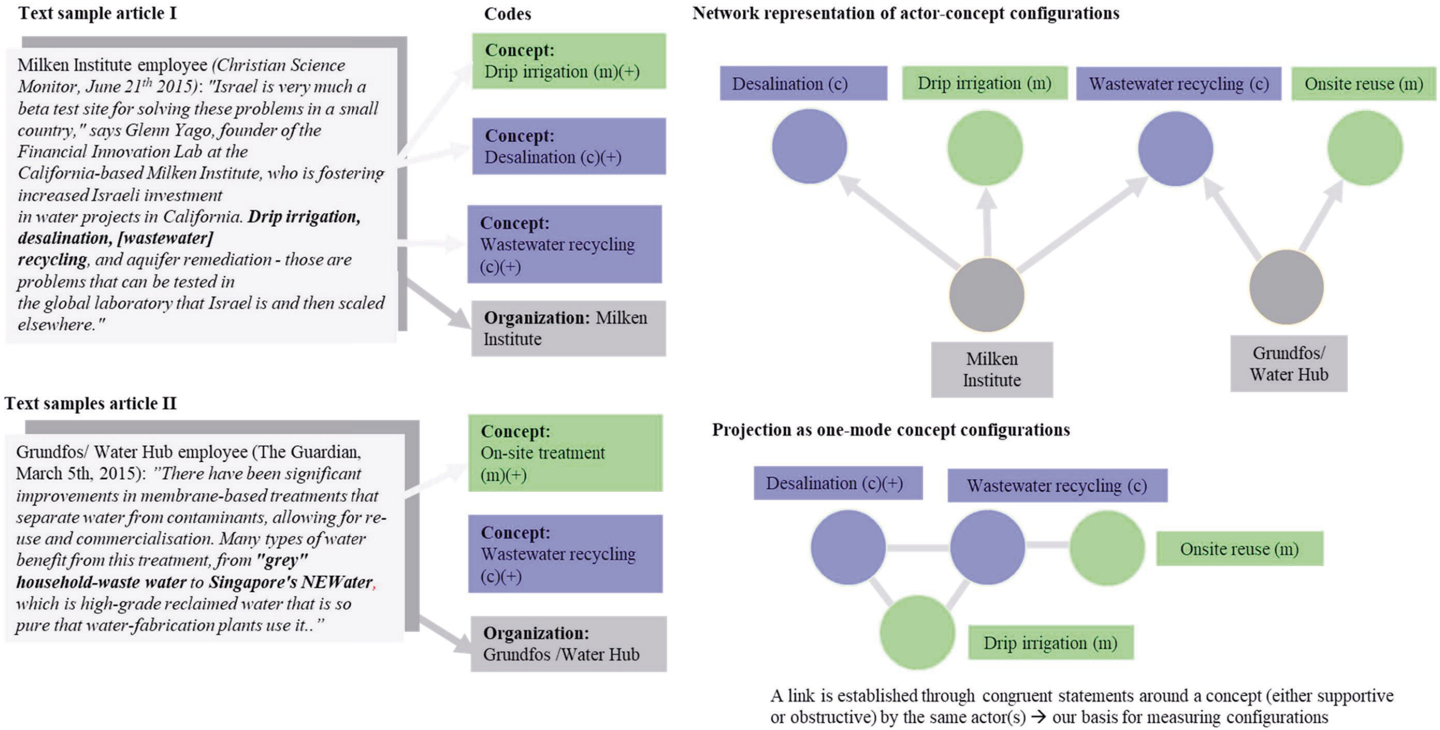

Fig. 2.3: From statements to actor-concept affiliations and further to concept configurations. Own figure

The code-co-occurrence matrices created with DNA software were later filtered with the help of R to calculate jaccard normalized concept congruence networks based on the statements of globally and nationally embedded actors. The networks were divided into three time-slices, reflecting shifts in average global drought patterns around the world: 2011-2013 a dry period, however with precipitation slowly returning to average levels, 2014-2016 accelerating droughts globally, and 2017-2018 a continuation of the droughts (A5). The US, South Africa and India stood out in terms of discursive activity (A4; A5). All three countries experienced particularly severe drought in the observed period, which spurred extensive coverage by public media.

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The relevant concept congruence networks were analyzed with the above described network measures and were visualized with the software package *visone* (Baur, 2008). The underlying relational datasets of these socio-technical alignment dynamics were further analyzed with help of descriptive statistics regarding key actors and actor types. To this end, we identified the organizations behind all *favorable* statements around the modular or the central paradigm (green or blue in our coding scheme). By favorable, we mean the sum of all supportive or positive statements around concepts associated with one paradigm (e.g. modularization), and all obstructive or negative statements around concepts associated with the respective opposite paradigm (e.g. centralization).

In the remainder, we will present the results for socio-technical re-configuration processes by global professional experts, and by actors from the three contrasting country cases. These three countries, taken together, account for half of all statements captured from over 30 countries (see A4).

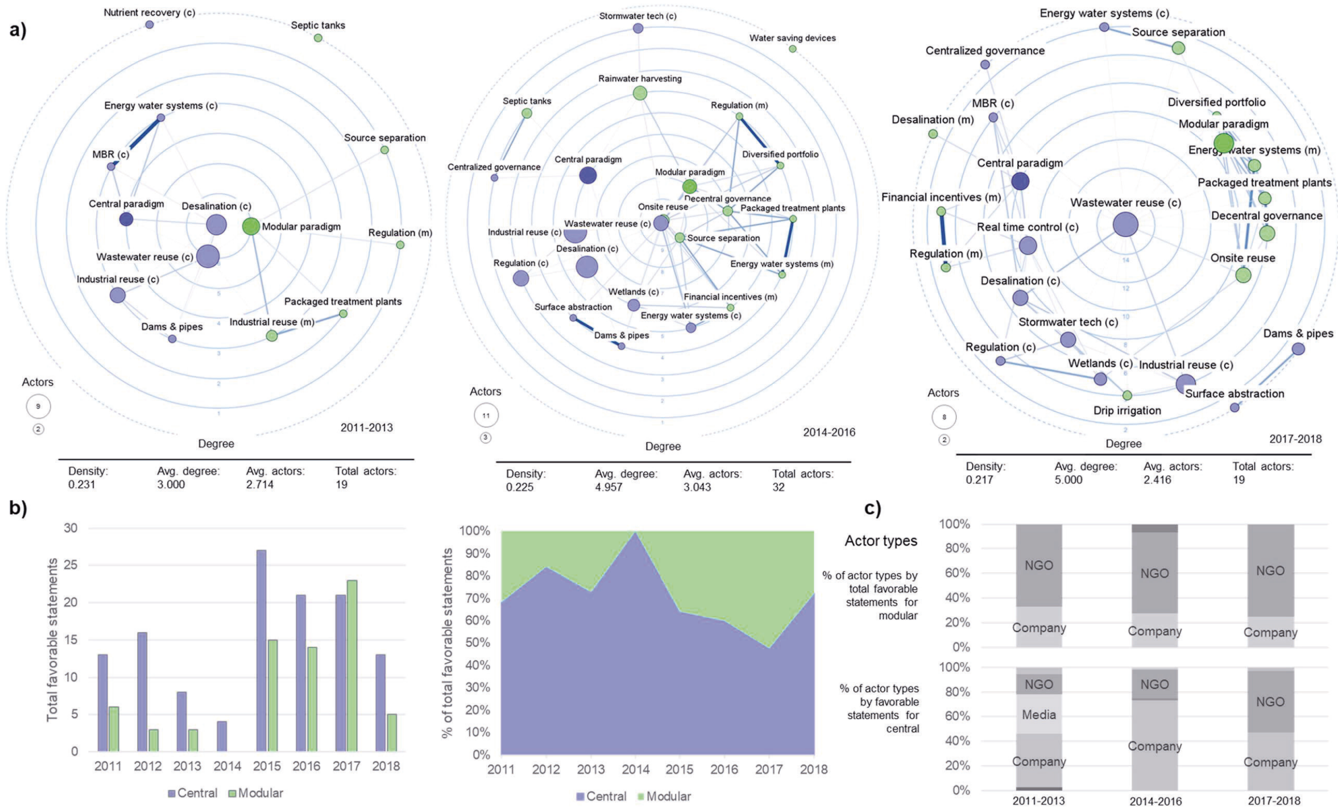


Fig. 2.4: **a)** Dynamics in socio-technical configurations based on global actors' statements, three phases. Blue: Conventional, centralized water systems, Green: Emerging, modular water systems. **b)** Total and % of annual favorable statements for centralized (blue) and modular (green) elements. **c)** Dominant actor types as % of favorable statements, three phases.

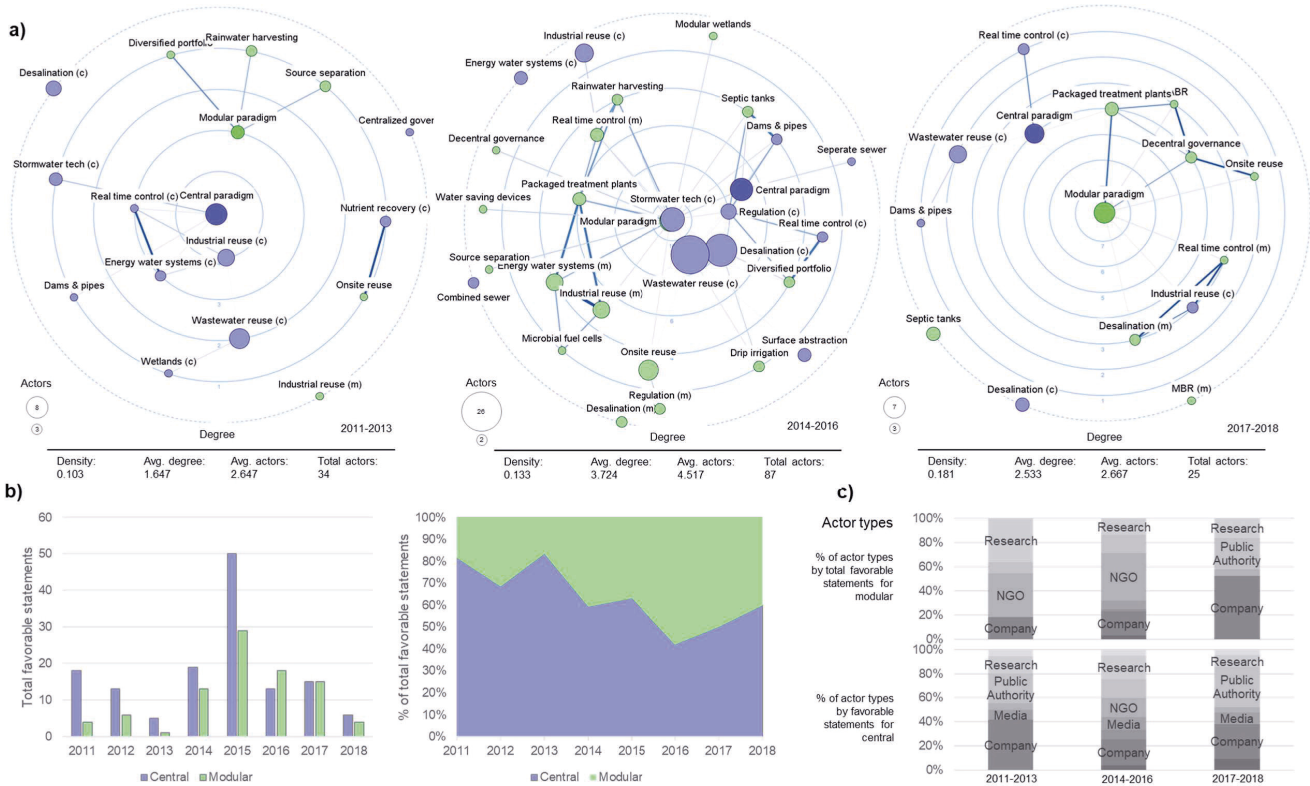


Fig. 2.5: a) Socio-technical configurations based on US actors' statementstatements, three phases. Blue: Conventional, centralized water systems, Green: Emerging, modular water systems. **b)** Total and % of annual favorable statements for centralized (blue) and modular (green) elements. **c)** Dominant actor types as % of favorable statements, three phases.

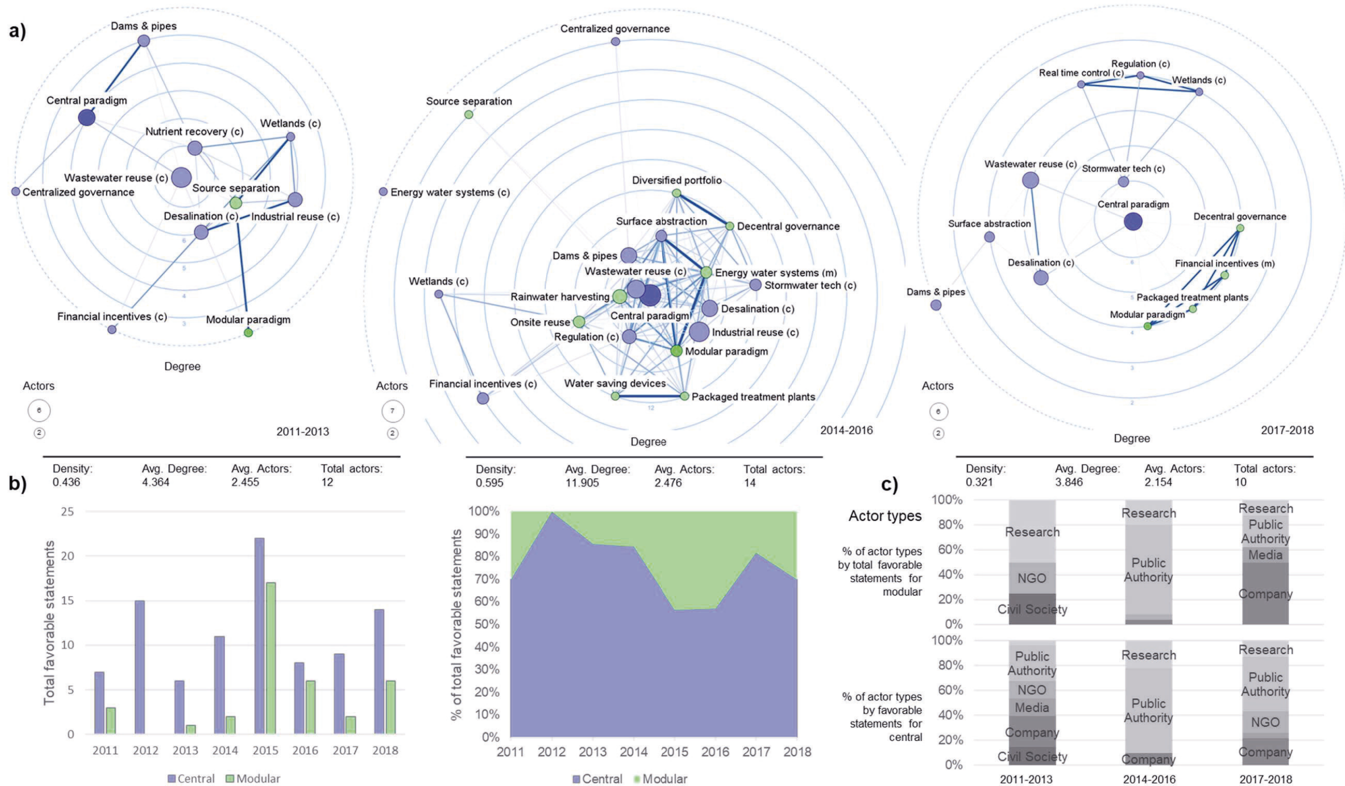


Fig. 2.6: a) Socio-technical configurations based on South African actors' statements, three phases. Blue: Conventional, centralized water systems, Green: Emerging, modular water systems. **b)** Total and % of annual favorable statements for centralized (blue) and modular (green) elements. **c)** Dominant actor types as % of favorable statements, three phases.

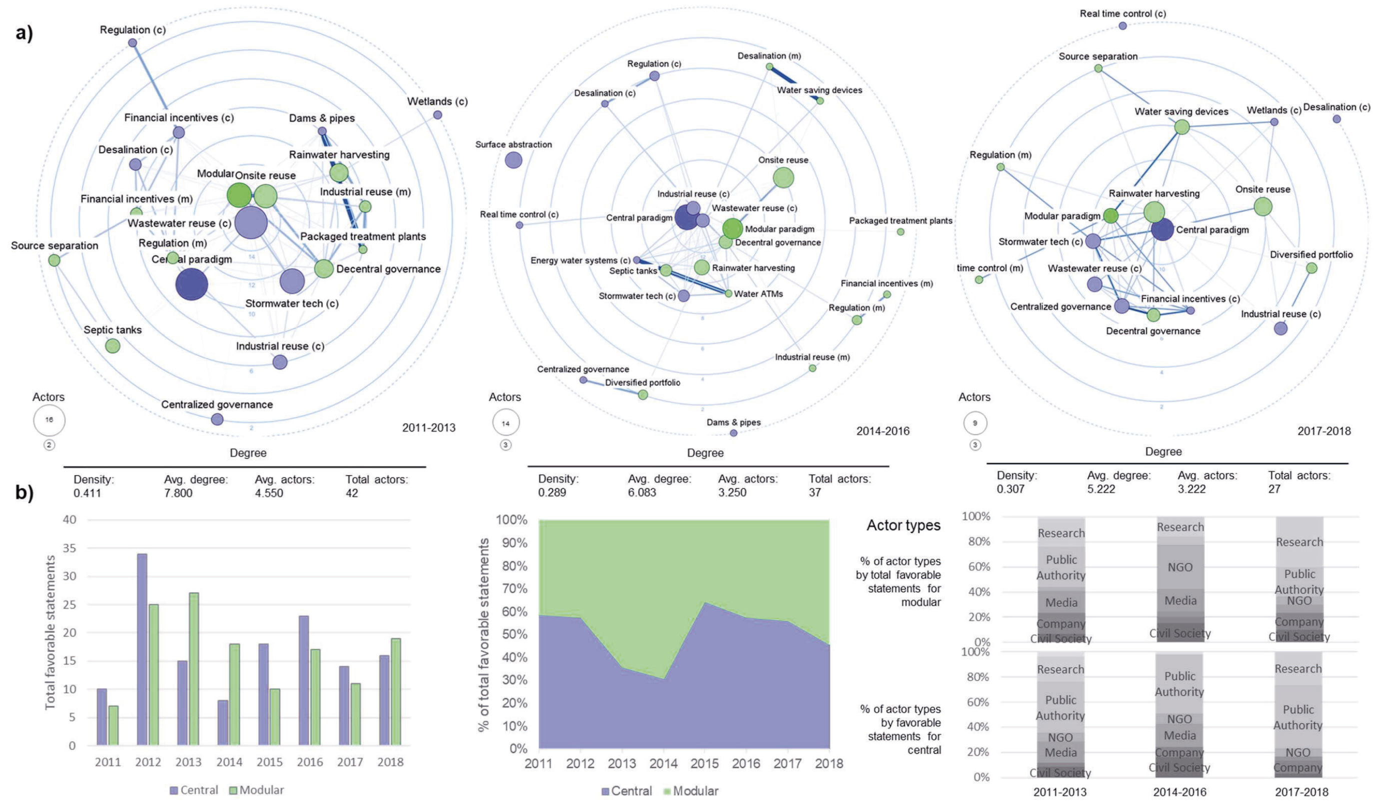


Fig. 2.7a) Socio-technical configurations based on Indian actors' statements, three phases. Blue: Conventional, centralized water systems, Green: Emerging, modular water systems. **b)** Total and % of annual favorable statements for centralized (blue) and modular (green) elements. **c)** Dominant actor types as % of favorable statements, three phases.

2.4.2 Comparing socio-technical reconfiguration dynamics in the global regime for UWM and select national subsystems

The results presented in figures 2.4-2.7 enable to systematically cross-compare transition dynamics in different layers of the socio-technical system[1]. The results reveal particularly interesting differences between statements made by global experts, as well as US, South African and Indian actors. We will start out by characterizing each of these cases along the suggested measures of degree of institutionalization and configurational alignments. We will then move to a discussion of observed differences by drawing on insights from the qualitative content analysis and the contextual information on critical moments that is contained in the analyzed newspaper articles.

Reconfigurations in global-scale actor statements

Our data reveals considerable stability in the socio-technical configurations derived from statements of experts in multinational organizations, among which we would expect to find many proponents of the existing global regime (Fuenfschilling and Binz, 2018). Overall stability is reflected by the combined evaluation of the configurations in the depicted networks, and the density score, which remains stable at around 0.22 across all three periods. In terms of degree of institutionalization, it is striking that large-scale wastewater recycling usually appears at the core of the radar plot, having a high degree centrality, which indicates a strong compatibility with many related concepts. Larger node sizes of the most compatible blue nodes further indicate that conventional, centralized concepts have been congruently used by more actors than the modular ones. The 2011-2013 period shows an almost complete separation between centralized and modularized concepts. During 2014-2016, linkages between these two competing configurations become more evident. As node sizes show, the centralized paradigm remains referred to by more actors than other concepts, but the differences among centralized and modular concepts get less pronounced. In the latest phase, water reuse-oriented concepts show the strongest alignment across modular and centralized concepts. Also the number of actors using each concept is similar across the two configurations. The descriptive statistics also show that favorable statements around modular concepts

[1]Note that edge width and color are calculated individually for each radar plot. Thus, a specific edge width and shading might not reflect the exact same Jaccard value comparing across phases and cases.

become much more prevalent after the 2014 period. An increasing average degree and overall increasing numbers of statements from the 2014-2016 period onwards, indicate that modular concepts are increasingly being promoted at the global regime level. Additionally, statements around modular technologies become more prevalent and alignments across modular and centralized concepts increase. Yet, apart from the increasing institutionalization of water reuse, we see no strong configurational shifts in this layer, even during critical moments in various places around the world. These external shocks seem to only indirectly affect the discourse in the global professional expert circles, by creating growing compatibilities among modular and centralized concepts in the global regime over time.

To further interpret these patterns, we use the qualitative data from the coded newspaper articles and the actor coalitions underlying each configuration (Figure 2.5c). The global expert discourse in our dataset is populated with statements made by the largest multi-national water technology companies in the world (Dow, GE, Veolia, Kemira, Grundfos, BASF, LG, Lanxess, Hyflux), as well as several larger engineering consultants, international associations like International Water Association, International Desalination Association, and intergovernmental organizations (UN, World Bank, WEF, WarterAid among others). Looking at the dominant global actor types contributing to the discourse (Figure 5c), we can see that the incumbent regime configuration is dominantly maintained by multi-national companies, whereas the emerging modular configuration(s) depend on international NGOs and charities promoting it. Interestingly, aside from International Organizations and NGOs, also incumbent players like Dow (in 2011), Veolia (2016), and GE and BASF (in the latest period) are promoting modular technologies explicitly in their statements. While the evidence is still spurious, this development may indicate an emerging shift in global regime discourse for the period after 2018. The BMGF appears as an important and stable proponent of modular and decentralized UWM approaches from around 2014 onwards, which coincides with the launch of their global “Reinvent the toilet challenge” and other related global lobbying activities (Eckhoff and Wood, 2011, Miörner and Binz, 2021).

Concept reconfigurations based on statements from US actors

Whereas the global expert discourses suggest a pattern of stability and path-dependency, statements by US actors indicate more dynamic reconfigurations. Figure 5 illustrates a strong increase in statements during the 2014-2016 period. This coincides with the major drought in California and other South-Western States (NIDIS, 2018, Spinoni et al., 2019, A5), which found strong resonance in US media. Overall, network density is rather stable between 2.3 and 2.1, showing more separated concept configurations in the earliest phase, reflected by individual solutions proposed by individual actors. This gradually shifts towards more complex configurations in the latest phase. Both in terms of degree centralities and numbers of actors, the centralized paradigm is most institutionalized in the first phase. This changes drastically during the drought period, when alternative, modular concepts gain salience. While concepts related to the centralized paradigm like desalination and large-scale wastewater reuse remain very prevalent, we see a more strongly aligned new configuration around packaged-treatment plants, onsite energy-water systems and rainwater harvesting, which puts the modular paradigm to the center of the discourse. A configuration of various new concepts starts to challenge the dominant configuration around centralized technologies. The modular configuration then remains prevalent and visible also in the latest phase, which indicates that its overall institutionalization has increased in the period of interest. Overall, our data thus suggest a configurational shift away from centralized technologies towards modular approaches in the US.

A look at the actor type distribution (Figure 2.6c), and the qualitative data in the articles confirms this picture. Whereas the actor coalition advocating classic regime concepts (large firms, public authorities, research institutes) remains stable throughout the whole period (only with some smaller deviation during the drought), the actor coalition supporting modular UWM technologies has structurally changed its composition. While in the beginning, NGOs and research institutes dominated the discourse, public authorities and companies gain prominence in later phases. We would interpret this pattern as an increasing maturation of the innovation system around modular water technologies in the US. The qualitative data reveals that while in the beginning the modular configuration is promoted by smaller charities and larger universities (CalTec, Harvard, and Stanford), after 2014 new actors enter the discourse. Especially Californian actors contribute to a big surge in supportive statements around 2015 and 2016 (Figure

2.6a). This is particularly driven by NGOs and research institutes such as the Arid Lands Institute, the Pacific Institute, or Greywater Action, as well as UC Berkeley and Stanford University, who are combining emerging and core configurational concepts in their storylines. At the same time, also political stakeholders, especially from the city of San Francisco, appear as new supporters of modular greywater systems at the building scale (onsite non-potable reuse). Large-scale desalination, a typical regime concept pushed in 2011-2013, gets highly disputed in California during 2014-2016. At the federal level, NGOs like WateReuse or the US Water Alliance, as well as a larger producer of packaged treatment systems (Cambrian Innovation) also gain prominence in the discourse.

Concept reconfigurations based on statements from South African actors

Similar to the US, South Africa was hit by a major drought during 2015 and 2016 (Spinoni et al., 2019, A5), which is similarly reflected by an increasing number of statements coded after 2015. The South African data, however, suggest different reconfiguration dynamics (Fig. 2.6). First of all, overall alignment of the proposed concepts is consistently higher than among US actors and global experts. Density varies strongly but ranges consistently above 0.3, implying that configurations proposed by South African actors are overall slightly more aligned than in the US. During 2011-2013 the network reveals two well-aligned configurations around the centralized paradigm and large-scale reuse and around desalination and industrial reuse. Modular technologies are rarely proposed and if so, then mostly in relation to the two dominant configurations. With increasing drought pressures from 2014 onwards, this pattern gets slightly more blurred. The most institutionalized concepts now revolve around the centralized UWM paradigm but also include modular technologies such as rainwater harvesting and energy-water systems. In the latest phase however, this pattern is reversed, as a more divided regime configuration emerges, in which modular and centralized technologies are not conjointly mentioned anymore. In fact, our alignment measures and node-sizes indicate that modular concepts are only proposed by a very small number of actors whereas the majority of actors continues to support centralized solutions. Thus, unlike US actors and global experts, an increasing institutionalization of modular configurations cannot be observed in South Africa. Our analysis rather suggests that the South African discourse realigns with the dominant global regime configuration.

Prominent proponents of modular concepts in South Africa comprise the Government based in Pretoria, the City of Durban, its local University of KwaZulu Natal and a company with expertise in industrial water treatment. The Government turned towards modular technologies, and especially rainwater harvesting during the 2015-2016 drought, while otherwise heavily investing in large-scale desalination in Cape Town and other places. It fits into the picture that modular rainwater harvesting technologies are most strongly promoted. They require relatively little adjustment of the existing socio-technical regime, since they are relatively low-tech, cheap solutions and are already part of the UWM system in some South African cities (Mwenge Kahinda and Taigbenu, 2011, Hacker and Binz, 2021). The city of Durban and the University of KwaZulu Natal are experimenting with more radical on-site urine diversion technologies, strongly driven by international funding through the BMGF (see also Sutherland et al., 2015).

Concept reconfigurations based on statements of Indian actors

India (Fig. 2.7), finally, exhibits discursive dynamics that again strongly differ from the cases described above. Like in South Africa, overall alignment among concepts is relatively high, with a density again close to or above 0.3 throughout all periods. This comparatively high alignment between configurations is interesting, given the spatially highly variegated distribution of critical moments in the country. Bangalore in the Southern State of Karnataka, for example, has seen constant drought pressure throughout the full 2011-2018 period. Pune in the mid-Western state of Maharashtra, in turn, has been facing extreme rainfalls ever since 2015. The northern capitol region around New Delhi, in turn, was getting into a drought during the 2014-2016 period, which continued into 2017-2018 (A5). Despite this variation, we can see that both centralized and modular concepts occupy central positions in the discourse in all three periods. Actors supporting centralized infrastructures emphasize concepts like the centralized paradigm, large-scale water reuse and centralized stormwater technologies. Actors supporting the modular approach, rather promote concepts like the modular paradigm, decentralized governance, onsite reuse and rainwater harvesting technologies. While alignments among these two groups vary in strength, the general pattern clearly shows a stronger alignment between centralized and modular infrastructure solutions in India than in any of the other cases. This is further emphasized by the continuously high average degree of the overall network structure (between 5.2 and 7.8). Our findings thus imply that the Indian water sector features a polycentric regime structure in which centralized and modular solutions co-exist as highly institutionalized approaches that deliver urban water services to different strata of society (centralized sewers in major metropolitan areas and modular solutions in informal settlements and smaller towns (see also van Welie et al., 2018, Dasgupta et al., 2021)).

Modular technologies are being promoted by a broad range of actors in India, including the Government (Figure 8c). Next to the drought-struck region of New Delhi, some geographical clusters in which modular technologies are frequently framed are Maharashtra in the West (with promoting coalitions in several large cities like Mumbai, Pune, Nagpur) where modular technologies like rainwater harvesting are envisioned to alleviate flooding pressures, and a strong hub in the drought-struck city of Bangalore (Karnataka, see also A5). An important constant proponent is the National Environmental Engineering Institute (NEERI) based in Nagpur.

2.4.3 Discussion

The empirical results presented above imply that recent re-configurations in the UWM field can be conceptualized as a patchwork of change processes that happen both among global experts and inside a variety of national (and even regional) subsystems. How transition trajectories in various countries differ from each other and how they influence (or depend upon) 'global' regime structures could so far only be characterized conceptually or with generic, case-based research designs (Fuenfschilling and Binz, 2018, Lieberherr and Fuenfschilling, 2016, Bauer and Fuenfschilling, 2019). In contrast, the STCA methodology enables a direct mapping of the relevant (dis-)alignment processes at global and (sub-)national levels (see also Heiberg et al., 2020). This allows one to infer why and how transition trajectories differ between contexts despite being exposed to the same global regime structures or even similar external (landscape) pressures. At the same time, our approach enables new explanations on why transitions are more likely to occur in certain contexts (here: the USA / India) than in others (i.e. South Africa) (Heiberg et al., 2020).

Our findings revealed the prevalence of a highly institutionalized configuration around centralized, large-scale water infrastructures both at a global expert level and in most of the analyzed national subsystems. This core configuration remains comparatively stable over time, thus hinting at the existence of a locked-in global socio-technical regime in UWM (Fuenfschilling and Binz, 2018). At the same time, emerging configurations around small-scale, modular UWM are increasingly showing signs of institutionalization in particular spatial subsystems like the USA and India. This finding is in line with recent research showing that landscape factors, such as external shocks, may help transform socio-technical regimes by creating windows of opportunity for reconfiguration processes (Turnheim and Geels, 2013, Rosenbloom et al., 2016). However, the STCA revealed some striking differences in how these reconfiguration processes play out across geographical contexts and whether they prove to be sustainable. While statements in the US suggest that modular water systems may actually have gained legitimacy among national stakeholders, the same dynamic is not evident from the data on South African actors. In India, in turn, the STCA shows that modular and centralized concepts may co-exist for longer periods of time in a stable polycentric regime structure (van Welie et al., 2018). Eventually, in the global expert discourses, specific modular concepts are increasingly recognized as compatible with large-scale municipal wastewater reuse. Wastewater reuse, can thus be seen as a potential 'boundary object', around which future hybridization dynamics of the UWM regime may unfold. Our analysis thus confirms previous findings that critical moments and landscape pressures triggering them can, may lead to major reconfiguration processes, but not necessarily so (Turnheim and Geels, 2013, Yuana et al., 2020).

2.5 Implications and future research

In the present paper, we developed a novel methodology to investigate socio-technical configurations and their development across time and space. While transition scholars have used a discursive lens for analyzing socio-technical transitions before (Geels and

Verhees, 2011, Smith et al., 2014, Raven et al., 2015, Rosenbloom et al., 2016), we maintain that studying shifting socio-technical configurations through textual databases allows for a more systematic understanding of the dynamic and geographically variegated nature of socio-technical transitions. We extended the recently developed discourse networks analysis (DNA) method (Leifeld, 2017) into a methodological approach for mapping and measuring socio-technical reconfiguration dynamics (STCA). This novel approach will enable a new perspective on core transition mechanisms like "motors of innovation" and creative destruction in the context of socio-technical change (Suurs and Hekkert, 2009, Kivimaa and Kern, 2016), strategies of field re-configuration, such as fit-and-conform and stretch-and-transform patterns (Smith and Raven, 2012), as well as incumbent's strategies like regime maintenance or appropriation of new concepts (Turnheim and Geels, 2013, Patala et al., 2019). As outlined in more detail in the empirical part, the methodology furthermore enables the comparison between transition pathways in different spatial and sectoral contexts (Geels and Schot, 2007, Hansen and Coenen, 2015, Murphy, 2015).

The methodology arguably opens up for a novel configurational epistemology for studying transition processes, which encompass a long-term research agenda that combines STCA with other, complementary approaches (Miller, 1986, Furnari et al., 2020). Collecting relational, two-mode network data from textual sources and analyzing them with help of social network analysis enables the visualization and analysis of dynamic relational patterns, for example, among a variety of actors, projects or localities on the one hand, and technological or institutional concepts, on the other hand. Hereby, STCA goes beyond the conventional case narrative approach in transition studies, and will enable a more systematic and rigorous form of configurational theorizing (Furnari et al., 2020, Svensson and Nikoleris, 2018, Weber and Truffer, 2017). As we have demonstrated, the STCA methodology allows for mapping and measuring meso-level structures and processes in an organizational field, without losing the connection to in-depth qualitative information. Our application to an emerging transition in the UWM field could only illustrate the potential and potency of this approach. But it opens up a whole series of potentially highly relevant future lines of investigation.

First, we maintain that the STCA methodology offers a new inroad for exploring key transition mechanisms like early innovation system formation, niche upscaling, directionality or industrial shake outs. As Raven et al. (2015) have shown, emerging socio-technical configurations may not only link up to different types of paradigms but also align with - or contradict - various socio-political agendas like a job creation imperative, a national sustainability strategy, or lead-market and export opportunities. An illustrative example could be the case of Uber entering the Netherlands adhering to a socio-political agenda around more innovative and flexible personal transport, but contradicting a political agenda emphasizing the security of jobs in the Dutch Taxi sector (Pelzer et al., 2019). STCA could provide an interesting methodology to investigate the tensions and interactions between an emerging socio-technical configuration around a newly forming TIS and its wider socio-political context. In this line of research, one could explore the fight among different technologies, paradigms and logics within a TIS before a dominant design has emerged (Yap and Truffer, 2019, Heiberg and Truffer, 2021). For research contexts, in which actual configurational alignments within an organizational field shall be analyzed, and not only their representation through discourses, STCA may be based on interview transcripts or other textual data sources (for a recent implementation, see Heiberg and Truffer, 2021).

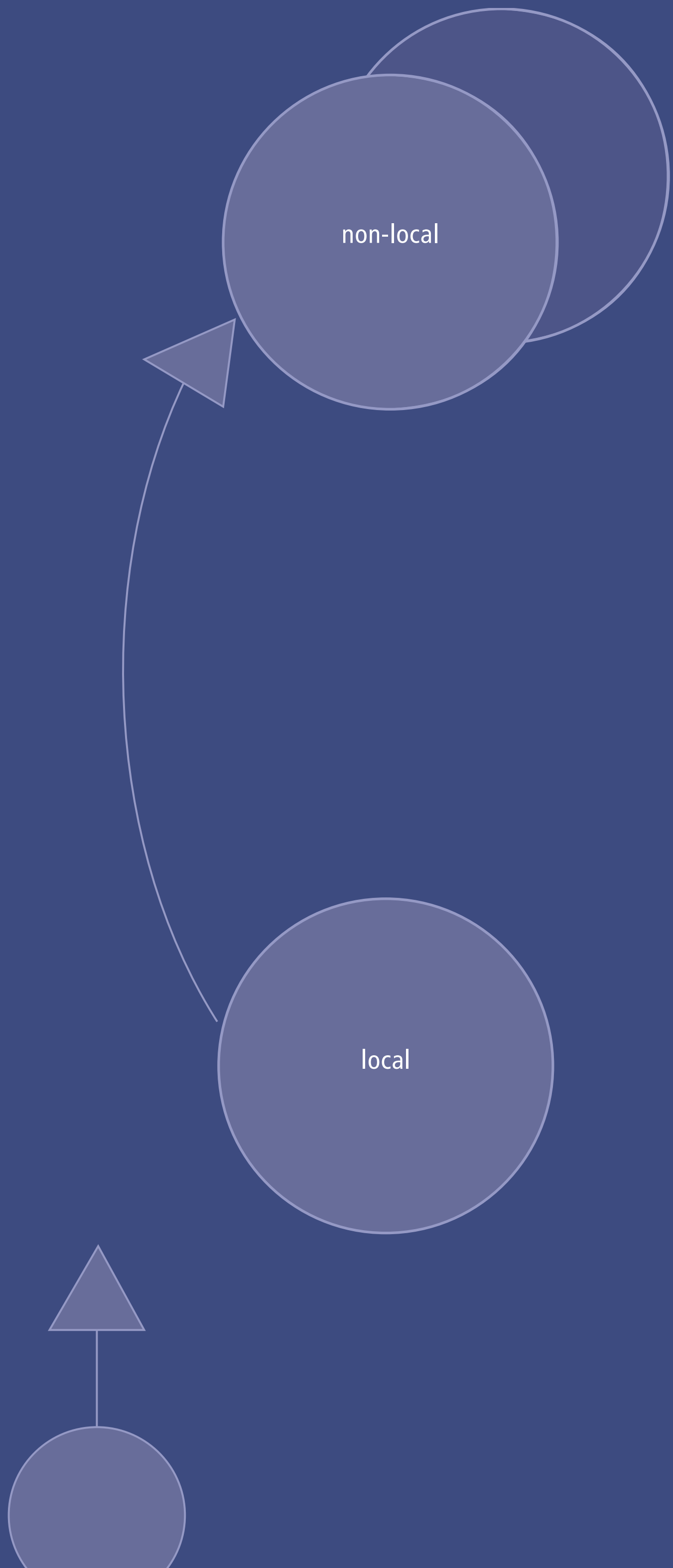
Second, it was beyond the scope of this paper to deeply elaborate on the policy implications that may be derived from an STCA analysis. But it seems clear that for transformation-oriented innovation policy (Weber and Rohracher, 2012) or the identification of effective transformative policy-mixes (Rogge and Reichardt, 2016, Kivimaa and Kern, 2016), it is crucial to understand the dynamic and multi-scalar nature of socio-technical alignment processes. STCA provides a tool for identifying the most important regime-maintaining storylines and logics (and the most powerful / interested actors behind them), which might be weakened by targeted policy interventions. Correspondingly, the methodology may help to identify - and strategically support - certain emerging socio-technical configurations that have the most transformational potential for an organizational field. Mapping who is maintaining dominant regime configurations based on what storylines and at what spatial scale(s) may in turn help to identify the power positions of advocacy coalitions in more targeted ways. In this way, STCA may also provide an interesting tool for scholars investigating the interplay of power and agency in transitions (Avelino et al., 2016) and by this address earlier identified directionality failures (Weber and Rohracher, 2012)

Third, we see a great potential in mobilizing STCA for a deepened exploration of the geographical and sectorial specificities of transition processes. In terms of geographical perspectives, our approach allows for spatially open, comparative research designs, as outlined in the empirical case study of this paper. We only scratched at the surface of the multi-faceted socio-technical alignment processes that take place *at* and spanning *across* various spatial scales (Miörner and Binz, 2021, van Welie et al., 2020). In a next step, one could complement our global mapping with an in-depth investigation of the differences between socio-technical alignment struggles in the US, South African or Indian state-level discourses, while still capturing the various ways of engagement with national-scale and global-scale actors. Such a more regionally embedded STCA analysis could reveal how the storylines and narratives in a region may rest on the absorption of national or global narratives into a regional discourse (Späth and Rohracher, 2012, Heiberg et al., 2020). It would also allow for a more thorough analysis of the actor coalitions maintaining and potentially disrupting specific configurations. STCA could in this sense, become a key methodological contribution to the toolbox of the 'geography of transitions' field (Binz and Truffer, 2017, Gosens et al., 2015, Binz et al., 2014).

Along very similar lines, STCA may help to further tease out and theorize about how transition dynamics differ between sectors as diverse as energy, water, transport, agro-food or healthcare. The relative monolithic regime structure we observed in most countries in the water sector could be compared with polycentric or even fragmented regime configurations one could expect in the urban mobility or public health sectors. Cross-comparing the resulting regime reconfiguration dynamics with STCA could lead to more sector-specific transition concepts, which could, in turn, substantively improve policy advice (Binz and Truffer, 2017). At the same time, STCA could be used to analyze multi-sectoral interactions in transitions (Andersen et al., 2020, Malhotra et al., 2019), or interactions along value chains (van Welie et al., 2019). In particular, using both actor and concept congruence networks the methodology enables a more systematic exploration of how actors from unrelated fields use (discursive) strategies to bridge between - and increasingly align - initially incompatible technologies and institutional elements in transition processes.

Of course, given the novelty of the proposed methodology and the global search lens applied in our illustrative case, STCA could be improved in various ways. Future research should explore in more depth what kind of document stocks are most suitable in capturing socio-technical alignment processes at different scales and in different contexts. While we have attempted to both collect data from global industry magazines and more nationally-bound public newspapers, future applications may want to exclusively focus on more concise transition cases.

Additionally, the various network measures and indicators employed to identify coherent socio-technical configurations could (and should) be further refined, expanded and adapted to the specific needs of a given research question and design. In the mid-term future, we envision that different ideal-type applications of STCA are developed that combine specific databases, network indicators and interpretative schemes to research questions that may revolve around issues as diverse as the maturation of TIS structures, multi-scalar niche-regime interaction, policy battles around transformative innovation or the role of institutional logics and complexity in transition trajectories. All told, we maintain that STCA provides a novel and potentially highly productive methodological approach to strengthen configurational theorizing in transition studies. Through its virtue of representing a semi-quantitative approach, STCA may constructively bridge quantitative and qualitative approaches that have long lived parallel lives in transition studies and the social sciences more broadly. If anything, we believe that we have here only been able to scratch the surface of what could become a very generative perspective for transitions research in the future.


non-local
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Chapter 3

The geography of technology legitimation

How multiscalar institutional dynamics matter for path creation in emerging industries

Abstract

Research in economic geography has recently been challenged to adopt more institutional and multi-scalar perspectives on industrial path development. This paper contributes to this debate by integrating insights from (evolutionary) economic geography, as well as transition and innovation studies into a conceptual framework of how path creation in emerging industries depends on the availability of both knowledge and legitimacy. Unlike the extant literature, we argue here, that not only the former but also the latter may substantially depend on non-local sources. Conceptually, we distinguish between multi-scalar export, attraction and absorption of legitimacy. Coupled with conventional knowledge indicators, this approach enables us to reconstruct how not only external knowledge sourcing but also multi-scalar institutional dynamics contribute to a region or country's ability to leverage its potential for path creation in an emerging industry. Methodologically, we develop legitimation indicators from a global media database, which was built around the case of modular water technologies. Cross-comparing the evidence from six key countries (India, Israel, Singapore, South Africa, UK, USA) with differing path creation constellations for this emerging industry, allows us to hypothesize how multi-scalar legitimation influences a country's prospects for creating a radically new industrial path.

3.1 Introduction

Researchers in economic geography (EG) have recently started developing more institutional and multi-scalar perspectives on industrial path creation and diversification processes (Boschma et al., 2017, MacKinnon et al., 2018, Hassink et al., 2019). Among other efforts, work on institutional agency (Grillitsch and Sotarauta, 2019, Isaksen et al., 2018, Sotarauta and Suvinen, 2018, Dawley, 2014) has conceptualized path creation as a process of mindful deviation not only from technological and knowledge artefacts but also from the relevant institutional structures (Garud and Karnøe, 2001). This line of theorizing has convincingly shown that distributed system building processes, drawing on policy interventions, institutional entrepreneurship and strategic resource mobilization, play a key role for path creation, largely on par with related knowledge and skill sets (Carvalho and Vale, 2018, Binz et al., 2016b, Dawley, 2014, Garud et al., 2010, Garud and Karnoe, 2003).

At the same time, the literature on industrial path creation still has a rather coarse and undifferentiated view on the relevant institutional structures and dynamics that influence why a new path emerges in one region while it fails in another. In particular, the legitimation of radically new industrial paths that diverge from the status quo is not yet well understood. Moreover, the multi-scalar contexts in which the relevant institutional structures develop and change has remained under-researched. This paper addresses these two gaps by asking how path creation potentials in regions are influenced by and dependent upon multi-scalar legitimation dynamics.

To answer this question, we propose combining recent EG perspectives with transition studies, which have conceptualized in depth how the co-evolution of institutional dynamics and technological innovation influence the development potentials of new industrial paths. These studies elaborate how institution-oriented agency can provide breeding grounds for newly emerging socio-technical configurations (Hoogma et al., 2002, Schot and Geels, 2008) and detail what kind of institutional and technological alignment processes have to happen for emerging industries to scale and mainstream (for instance as depicted in the literature on technological innovation systems, see Hekkert, 2007, Bergek et al., 2008a, Markard, 2018). Such processes are closely related to the co-evolution of new technologies and their markets (Quitzow et al., 2014, Dewald and Truffer, 2012, Dewald and Truffer, 2011) or how technology legitimation influences development trajectories of new industries (Bork et al., 2015, Markard et al., 2016b, Binz et al., 2016a).

One of the hallmarks of the transitions literature is the distinction between innovation processes in well-established sectors (socio-technical regimes) and emerging industries that are new to the world (socio-technical niches) (Markard et al., 2012, Geels, 2002). Boschma et al. (2017) recently used this distinction to further conceptualize the institutional dynamics that enable path creation processes in ‘new-to-the-region‘ and ‘new-to-the-world’ industries. Particularly in new-to-the-world industries (emerging industries in the remainder), where technological development, product profiling, and user preferences have to be aligned for the first time, the ability to institutionally embed and thus legitimize an emerging industry becomes a crucial determinant of successful path creation. Related industries are often, but not exclusively, found in the context of infrastructure sectors (e.g. transport, ICT), linked with innovations addressing grand challenges (e.g. renewable energies) or in emerging platform-based industries (e.g. Uber, Airbnb, etc.) (Coenen et al., 2015, Pelzer et al., 2019, Trippl et al., 2020).

In innovation and transition studies, legitimation has been conceptualized as the process by which proponents of a technology attempt to align norms, values and beliefs in favor of their proposed solutions (Markard et al., 2016b, Binz et al., 2016a, Bergek et al., 2008a, Hekkert, 2007). Our framework draws on this interpretation but contests the often implicit assumption that the relevant institutional processes are limited to regional or national boundaries. Recent contributions hint at the multi-scalar nature of legitimation processes for emerging industries, e.g. through the adoption of non-local narratives and policies or the attraction of external investors and industry advocates (Sengers and Raven, 2015, Späth and Rohracher, 2012, Binz et al., 2016b, Crevoisier and Jeannerat, 2009, Quitzow, 2015).

Building on these insights, we propose a set of generic, multi-scalar mechanisms through which industry legitimacy may be generated by drawing on local and/or non-local structures and supportive narratives enacted by actors on different spatial-scales. More specifically, we look at i) genuine *endogenous legitimation* within a region or country,

ii) the mobilization of legitimacy from external sources (*absorption*), iii) the *attraction* of external actors contributing to local legitimation and vi) the *export* of legitimacy by local industry proponents.

The institutional capability of a region or country to leverage these processes may be crucial for its path creation prospects (Malmberg and Maskell, 1997). We will elaborate this argument by developing a typology of different path creation constellations that depend on pre-existing knowledge and capabilities, on the one hand, and active legitimation processes around an emerging industrial path, on the other hand. With the help of our empirical analysis, we show how actors in various countries mobilize legitimacy in the face of different structural preconditions, allowing us to create hypotheses on what sort of multi-scalar legitimation processes may contribute most effectively to path creation in different contexts.

Empirically, we focus on the case of a new industrial path that is currently evolving around modular water technologies (henceforth referred to as "*modular technologies"*). The modular water industry is still in an emerging development phase globally, challenging the widely established regime around conventional, centralized wastewater treatment (referred to as "*conventional technologies*" from now on) (Fuenfschilling and Binz, 2018). To empirically assess the relevant legitimation dynamics, we propose a mixed method approach that builds on a database of newspaper articles (Nexis Uni). Over 180 English-language newspapers and industry magazines were selected in order to identify articles dealing with water and sanitation problems for an eight-year period (2011-2018). The articles selected were coded by means of a socio-technical configuration analysis (STCA, Heiberg et al., 2022) and then analyzed with novel indicators for the relevance of multi-scalar technology legitimation processes. By coupling these legitimation measures with patent data as well as information on path dependencies in built infrastructures, we arrive at a typology of generic path creation constellations. Eventually, we assess to what extent multi-scalar legitimation processes are used in leveraging the potentials of path creation constellations in different countries.

Our results show considerable variation in these constellations. The US, for example, can be characterized as a *lead market constellation*, which combines well-developed local knowledge and capabilities with rather weak institutional path dependencies. With similar knowledge capabilities but facing a locked-in socio-technical regime, Israel and Singapore signify *export- oriented constellations*. India and South Africa, in turn, represent cases with rather weak knowledge and capability stocks, but also weak path dependencies and strong environmental problem pressures, thus exemplifying *challenge-driven path creation constellations*. The UK, eventually, faces a *regime lock-in constellation* associated with a strong regime and only modestly established knowledge and capabilities. In these different constellations and spatial contexts, we find that actors engage in the multi-scalar mobilization of legitimacy to varying degrees, enabling the formulation of hypotheses on how these processes support or hinder industrial path creation more generally.

The argument of the paper will be elaborated in the following steps. Section 3.2 will review the industrial path creation literature and draw on recent insights from transition and innovation studies regarding the multi-scalar nature of industry legitimation. Based on this, we propose an integrated framework of different types of path creation constellations for which multi-scalar legitimation processes may matter. In section 3.3, we apply this framework to the case of path creation around modular water technologies and introduce our methods. The results are presented in section 3.4, comparing six country cases. Section 3.5 discusses our insights into different path creation constellations as well as the conceptual implications and limitations of our research before concluding with an outlook on avenues for future research on the multi-scalar institutional foundations of path creation.

3.2 Multi-scalar legitimation in industrial path creation

The literature on industrial path creation in evolutionary EG and regional studies has paid comparatively little attention to institutional factors such as social, cultural and normative contextual conditions for emerging economic activities (MacKinnon et al., 2009, Hassink et al., 2014, Hassink et al., 2019). Furthermore, attempts to investigate the institutional preconditions to path creation have rather favored macro-level and static approaches, such as that of Boschma and Capone (2015), who apply a Varieties of Capitalism (VoC) lens to study how macro-economic structures in coordinated and liberal market economies lead to different industrial diversification patterns. Critics of this approach have called for a more explicit consideration of process-based and micro-institutional approaches associated with path development trajectories (see e.g. Isaksen et al., 2018, Sotarauta and Suvinen, 2018, Zukauskaite et al., 2017, Dawley, 2014).

The role of distributed and embedded agency in emerging industries was introduced most prominently by Garud and Karnoe (2003). They proposed conceptualizing it as the continuous re-combination of regionally available codified and tacit knowledge stocks by a heterogeneous set of actors, leading to different national innovation trajectories, labeled as science-technology-innovation-based ‘breakthrough’ or doing-using-interaction-based ‘bricolage’.

Carvalho and Vale (2018), in a recent paper, show how the latter process led to unrelated diversification in the biotechnology sector in a peripheral Portuguese region with comparatively weak initial knowledge and skill endowments. They conclude that path creation was not facilitated by technological or knowledge relatedness, but rather by “institutional relatedness” (see also Content and Frenken, 2016). Also Binz et al. (2016b) showed how a new water recycling industry emerged in Beijing through a process of “anchoring and system building”, which allowed local actors to outcompete rival initiatives in other regions that were initially endowed with stronger related variety (Xi’an and Shanghai).

A similar agency-based approach was suggested by Grillitsch and Sotarauta (2019), who argue that change agency for path creation is not limited to technology entrepreneurship but also includes “institutional entrepreneurship” and “place leadership”. While institutional entrepreneurship relates to active processes of institutionalizing new or transforming existing institutions (Battilana et al., 2009), place leadership is more concerned with the alignment of various actors to jointly mobilize resources in favor of a certain path creation trajectory (Gibney et al., 2009).

Despite this increased acknowledgement of the role of institutional dynamics in industrial path creation, the related conceptualizations (around broad notions like institutional thickness, system-level agency or institutional entrepreneurship) have remained somewhat vague as to the relevant factors and mechanisms that condition the emergence of radically novel industries as well as about the multi-scalarity of the relevant institutional change processes. This is why we propose a closer connection to transition studies, which have recently used socio-technical regimes and technology legitimation as heuristics for assessing the institutional dynamics that make an emerging industry comply with existing institutions or cause it to adapt the institutional environment in a region to such a degree that it becomes more supportive of the emerging industrial path (Markard et al., 2016b, Binz et al., 2016a, Geels and Verhees, 2011, Bergek et al., 2008b, Aldrich and Fiol, 1994).

3.2.1 Legitimation as a focal lens to understand institutional dynamics around path creation

An important conceptual aspect in EG is that emerging industries are embedded in two relevant institutional contexts: a regional and a sectorial one (Boschma et al. 2017). While EG is predominantly concerned with the regulative, normative and cultural-cognitive structures in a region that support or hinder innovation, transition research focusses on understanding how inherently multi-scalar socio-technical systems in sectors that fulfill societal functions (energy, water, transport, agro-food) are built, maintained and potentially replaced (Rip and Kemp, 1998). A core of this literature deals with explaining how path dependencies can be assessed through the concept of socio-technical regimes. These are defined as highly institutionalized configurations of knowledge, practices, technologies, products, user needs, regulation, institutions and infrastructures which co-evolve and get aligned over time, thus locking sectors into path-dependent development trajectories over expanded time spans (ibid.). At the same time, transitions scholars have elaborated in great detail how such path dependencies may vary between different regions and be broken up through distributed and system-level agency – as in the technological innovation systems (TIS) framework (Bergek et al., 2008a, Hansen and Coenen, 2015, Markard et al., 2016b) or in socio-technical alignment and scaling processes happening in protective spaces, so-called socio-technical niches (Rip and Kemp, 1998, Geels and Raven, 2006).

Similar to the notions of agency in the path creation literature, transition studies emphasize the importance of collective, more or less coordinated strategies, mobilizing various emerging system resources for successful innovation. Binz et al. (2016b) argue that four key system resources have to be mobilized in a region to enable path creation processes: knowledge, markets, financial investment and legitimacy. The mobilization of legitimacy is arguably of key importance, especially for emerging industries that have no predecessor in the social order (Aldrich and Fiol, 1994; Rao 2002). Legitimacy is commonly defined as “a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions” (Suchman, 1995: 574). It thus denotes a societal assessment of how well an emerging industry is aligned with the relevant regional and sectorial institutional contexts (Markard et al. 2016). If an industry is well-aligned, the relevant audiences will take it for granted and confer resources to its further development, be it in the form of policy support, the installation of test markets, the provision of educational services, venture capital or even through the absence of organized opposition form citizen’s movements.

If it is in conflict, the industry’s proponents will have to engage in active institutional work to change the relevant structures in favor of the new organizational form (Lawrence and Suddaby, 2006). The actor strategies that aim at changing the relevant institutional contexts often comprise rather subtle and discursive interventions in the social order, e.g. through the construction of new identities and norms, changing normative associations or educating relevant audiences about the benefits of a new solution (Lawrence and Suddaby, 2006, Fuenfschilling and Truffer, 2016). Such interventions are ‘embedded’ in the sense that they are both enabled and constrained by the institutional structures that they attempt to influence (Battilana et al., 2009, Garud and Karnoe, 2003). Over time, system resource mobilization and institutional work will adapt the relevant institutional structures to such a degree that legitimacy for the emerging industry is created and/or the legitimacy of the pre-existing path is eroded (Rao, 2004, Battilana et al., 2009, Fuenfschilling and Truffer, 2016, Binz et al., 2016a, Markard et al., 2016b).

Linking such observations back to the path creation and diversification literature, Boschma et al. (2017) have, on the one hand, argued that institutional work and technology legitimation are particularly important in cases of unrelated diversification. To make ‘large jumps’ in the product space (Hidalgo et al., 2007), actors have to engage in a distributed, bricolage-type of agency to overcome place dependencies stemming from the pre-existing (or missing) resources in a region. On the other hand, institutional work and legitimation are crucial, especially for newly emerging industries that have to overcome the path dependency emanating from a deeply institutionalized socio-technical regime in a sector. From a geographical point of view, both overcoming place-dependencies and sectorial path dependency may involve active institutional work at the local level. Yet, in the case of sectorial path dependencies, agency in local contexts will have to be complemented with challenging the dominant regime (which often develops in international networks) through multi-scalar forms of institutional work (Fuenfschilling and Binz, 2018). Following this reasoning, technology legitimation becomes an umbrella term for the variegated types of institutional work that are relevant for industrial path creation and which may be enacted by local or non-local actors on different spatial scales and in different places. We will now turn to elaborating the multi-scalarity of these processes in more detail.

3.2.2 Non-local sources of path creation

The importance of non-local knowledge as a source of path creation and diversification has long been acknowledge in EG, but a focal research agenda around this theme has only formed more recently in the path creation literature (Trippl et al., 2017, Boschma et al., 2017, Neffke et al., 2018, Klement and Strambach, 2019). Already in their seminal article, Martin and Sunley (2006) highlighted that new paths may emerge from the importation of organizational forms, technologies, firms or institutional arrangements from other places. However, it remained unclear how exactly the importation of institutional arrangements would play out and whether and how it resembles the sourcing of non-local knowledge.

In order to tackle this challenge, we build on a more recent framework proposed by Trippl et al. (2018) on how external sources of knowledge can contribute to regional industrial path creation. Their heuristic separates the anchoring of non-local knowledge for path creation into the *attraction* of new actors from outside a region and the *absorption* of non-local knowledge through more intangible linkages. Attraction relates to the inflow of new organizations or individuals, e.g. through labor migration, the resettlement of firms, takeovers, mergers or foreign direct investments (FDI). Absorption does not require actors to relocate but rather relates to formal or informal linkages between organizations or individuals based on different types of non-spatial proximities that facilitate knowledge diffusion (Bathelt et al., 2004, Agrawal et al., 2006).

Building on this differentiation, Trippl et al. (2018) argue that "*the need and attractiveness for exogenous actors/resources as well as the absorptive capacity to turn those into new growth paths*" (p.692) are the most crucial determinants of the importance and role of non-local resources in path creation processes. Attractiveness reflects the capacity of a region to draw in knowledge carriers such as individuals or organizations, e.g. through local assets such as a relevant skills base, education, security, more competitive salaries or other regional amenities. Absorptive capacity, in contrast, reflects the ability of "anchoring" (Crevoisier and Jeannerat, 2009) non-local, mobile knowledge into a locally embedded path.

We propose conceptualizing the non-local relationships that impact legitimacy for an emerging industrial path in a region along similar lines, drawing on recent insights from transition studies. Transition scholars argue that legitimacy in a region may be fueled by trade or collaboration networks, when entrepreneurs absorb success stories from abroad, or when they invite external actors to contribute to solving local problems. The Chinese PV industry, for example, initially almost completely legitimized itself through overseas export successes and listings on international stock exchanges (Binz and Anadon, 2018, Zhang and White, 2016). A study on the global diffusion of Bus Rapid Transport (BRT) systems (Sengers and Raven (2015)) similarly finds that "places" can be mobilized by a global community of actors who use success stories of certain cities to push infrastructure projects in regions far away. Späth and Rohracher (2010, 2012) refer to discourse coalitions in emerging renewable energy paths to show how Austrian actors absorbed national and international narratives purposefully by translating and using them in specific regional contexts. By absorbing non-local narratives, they managed to align other actors' technological choices across various governance levels. These insights suggest that attraction and absorption processes are relevant not only for knowledge, but also legitimation dynamics. Of course, emerging industries may also predominantly draw on legitimacy that is built up endogenously within a regional context, as in the case of the Danish wind turbine industry (Garud and Karnoe 2003). Yet, as recent literature shows, the wind power case is arguably also quite special in that its innovation and institutional embedding processes depended particularly strongly on spatial proximity (Binz and

Truffer, 2017, Huenteler et al., 2016). In other industries, multi-scalar linkages may be much more relevant for the buildup of industry legitimacy. We can therefore conceptualize multi-scalar legitimation interactions in three generic ways (Fig.3.1).

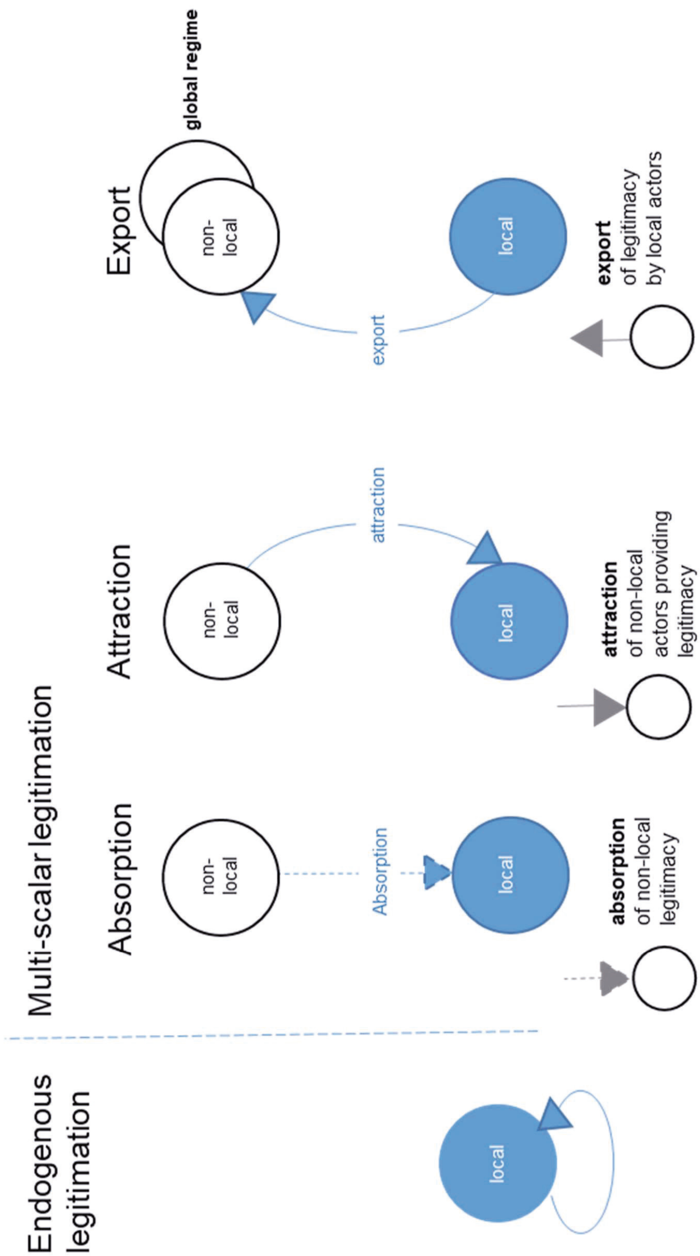

Fig. 3.1: Multi-scalar legitimation processes. Own figure.

“Absorption” relates to a situation in which regional actors internalize legitimacy from other places. This mostly happens through reference to cases of success or failure in other parts of the world. For instance, the early legitimation of bus rapid transport (BRT) systems in several South East Asian cities was strongly driven by the absorption of the emblematic “success case” of Bogota, Colombia (Sengers and Raven, 2015). In this process, supportive narratives were transported between places not only through mobile actors, but by other forms of communication such as the media, expert journals or informal communications at industry events, etc.

“Attraction” refers to legitimacy that is built up by drawing external actors into a region who create favorable market environments for novel products. Attraction can happen rather passively, e.g. when a region presents itself as a promising market for new technologies, or more pro-actively, when local actors try to actively construct favorable institutional framework conditions for external firms to operate in the region. An example of a rather passive strategy is Norway, which strategically developed into the current global lead market in electric vehicles by leveraging strong deployment policies and by mobilizing its energy mix, which is based on almost 100% hydropower (Ryghaug and Skjølsvold, 2019). Both factors helped lay the foundation for the development of a novel industry around battery development, producing in the Agder region (Barbiroglio, 2020). Examples of more proactive attraction strategies abound in the catch-up literature, for instance when latecomer regions proactively attract foreign direct investments or participate in technology transfer programs supported by international organizations (Gosens et al., 2015, Yeung, 2016).

As the mirror image of attraction, we can expect to see legitimation activities that draw on a pronounced export strategy. “Export” refers to a strategy in which legitimacy is not primarily achieved by endogenous institutional embedding, but by serving markets and influencing institutional environments outside the home region. The platform-economy company Uber, which actively attempted to legitimize its service Uber pop in various world cities while simultaneously delegitimizing the existing regulations around taxi laws, constitutes an illustrative example (Pelzer et al., 2019). Export to other regions may at the same time coincide with absorption, i.e. when narratives about export success help to mobilize indigenous resources such as export risk insurance, industrial support policies or local venture capital.

Based on these specifications, we propose conceptualizing the trans-regional flows of legitimacy in similar terms as the trans-regional knowledge flows identified by Trippl et al. (2017), yet with some important qualifications. Most importantly, we have to account for institutional contexts established on different "scales", such as on the regional, national and global scale, while acknowledging that these levels are socially constructed and intrinsically intertwined and imbricated (Brenner, 2001, MacKinnon, 2011). For the case of legitimation, it is particularly important to understand that socio-technical regime structures relate to the dominant institutional structures in sectors, which often reach beyond single regions or countries, up to a global scale (Fünfschilling and Binz, 2018). Regime structures are predominantly developed, maintained and changed by (international) expert networks in a sector and may shape the way national or regional industrial strategies can be carried out, particularly when it comes to radically new approaches. At the same time, the socio-political and cultural legacies in regions and countries lead to strong spatial variation in regimes as global regime structures are only partially or 'creatively' translated back into regional and national settings (ibid.). The challenge of legitimizing emerging industries is thus a dual one in that it requires tackling both the place-dependency in regional/national institutional structures as well as path-dependencies in international sectorial structures (Boschma et al., 2017). We have to acknowledge the multi-layered structure of legitimation strategies beyond the simpler 'local vs. non-local' exchanges that were identified for the knowledge dimension. Moreover, the export of legitimacy can be further differentiated into those activities targeting other national/regional-scale institutional contexts and those activities targeting the 'global' regime.

3.2.3 Analytical framework

On this basis, we propose a typology of path creation constellations which is based on two analytical dimensions (see Tab.3.1). The first dimension describes the strength of related knowledge and capabilities in a region. The second dimension depicts the resistance of the established regime against a newly emerging industry. The strengths of this resistance can be measured on the basis of two conditions: a) the number of alternative regimes currently prevailing in a sector and b) the degree to which the current regime is challenged by emerging alternative industries and /or external conditions. The dominance of the current regime can be measured as a gradient between monolithic and polycentric constellations (van Welie et al., 2018). A highly monolithic, hard to change, regime structure can be found in the electricity sector, which in many places is still dominated by fossil-fuel-based technologies, centralized generation, long distance transport, large utility companies and decentralized consumption (Verbong and Loorbach, 2012). A polycentric, and thus more easily adaptable, regime structure can in turn be found in the transport sector, where several service regimes for alternative mobility solutions co-exist (i.e. around cars, public transport, bicycles, etc.) (Geels et al., 2011). The contestation of a regime can in turn be measured by how strongly its core logic is challenged by social movements, competing technologies and related institutional logics or exogenous 'landscape pressures'.

Tab. 3.1: Path creation constellations in emerging industries

		Institutionalization/ coherence of socio-technical regime: weak	Institutionalization/ coherence of socio-technical regime: strong
Availability of Knowledge and capabilities	high	lead market	export-driven
	low	challenge-driven	regime lock-in

Based on these conceptualizations, we may now distinguish four ideal-type path creation constellations, which depend on the knowledge base and strength of regime structures in a region (Table 3.1). In general, we would expect that the more related knowledge a region provides, the higher its ability to create a new path in a given emerging industry. In terms of institutional contexts, we expect that the stronger and the more unchallenged the incumbent regime in the respective sector is, the more difficult it will be to establish a new path in the region (Boschma et al., 2017). These two structural conditions result in the following path creation constellations.

First, regions hosting high levels of related knowledge and relatively weak regime structures can be characterized as providing a *lead-market constellation*. With easy access to relevant knowledge and a favorable institutional environment, local firms may find it easy to develop new products and services, lobby for supportive policies, to install local niche markets and to find competent partners for raising financial resources. The ensuing path creation dynamics would likely start with local niche formation for a new socio-technical configuration, followed by endogenous build-up of supportive innovation systems, and the gradual establishment of alternative local regime structures. Once the industry is established locally, the export of ready-made solutions may be undertaken and local actors may seek to alter the global regime through targeted institutional work in other regions and on other spatial scales.

A second constellation depicts regions that possess related knowledge capabilities but face strong path-dependencies from the incumbent regime. In this situation, the proponents of the emerging industry will often be forced to gain legitimacy in foreign markets. Successful penetration of foreign markets may subsequently be used to mobilize resources domestically. The related path creation dynamics will typically depend on transnational companies building up markets for technologies far away, without relying on short distance exchange between market formation and technology development. We would thus label this constellation as *export-driven*.

A third constellation relates to regions that lack related knowledge, while facing rather weak path dependencies from existing regimes. The latter may be due to the existence of varying competing service solutions in a place (i.e. in the highly dynamic context of booming mega-cities) or strong landscape pressures for which the novel technology would provide a better solution (e.g. arid areas having to fight with severe water shortages). These regions will depend on external actors providing and promoting alternative solutions, building up corresponding markets, or helping to develop a stronger knowledge base through cooperation with external companies, FDI and/or inward labor mobility. We call this a *challenge driven constellation*.

Finally, regions which lack knowledge and capabilities and face strong path dependencies from incumbent regime structures may be characterized as a *regime lock-in constellation*. This is arguably the most challenging constellation for path creation since regional actors would have to attract or absorb both legitimacy and knowledge from elsewhere. Although instances of successful path creation have been described for such situations (i.e. the example of on-site water reuse in Beijing or of PV panel manufacturing in China), any strategy in this situation will likely face strong barriers and thus need an elaborate, long-term support strategy.

While the typology in Tab. 3.1 depicts ideal-type path creation constellations, the actual strategies of regional policy makers or local companies in real world cases will likely cover the full portfolio of endogenous and external knowledge and legitimacy mobilization patterns, as identified in section 3.2.3. We would, in other words, expect actors in a lead market and export-driven constellation also to be able to engage in the export of legitimacy to other regions and on the global-scale. Attraction and absorption of legitimacy may further occur, to some extent, in all types of configurations, either creating novel (export-driven, regime lock-in) or maintaining existing (challenge-driven, lead-market) institutional environments. Whether or not the potentials of a given constellation will be leveraged, or even what kind of strategies the individual actors will mobilize to overcome resource deficits, remains an empirical question. We will operationalize this generic framework and map the diversity of resource mobilization strategies for an illustrative empirical case in what follows.

3.3 Mapping global legitimation activities for modular water technologies

To illustrate and validate our framework empirically, we will apply it to the case of modular water technologies, which represent a currently emerging, radically novel industrial path in the water sector. The global water sector had an estimated investment volume of over 500 billion US Dollar in 2014, which is only a fourth of the yearly investments needed to fulfil the sustainable development goals by 2030 (OECD, 2018, Hutton and Varughese, 2016, Winpenny, 2015). It is dominated by publicly or privately managed water utilities, which often collaborate with large multinational equipment suppliers, engineering consultants and service providers like Dow, Veolia, Suez or Thames Water (Lieberherr and Fuenfschilling, 2016). Next to public funding, investment in large-scale water infrastructures and technologies increasingly comes from private investors, but also multi- and bi-lateral development banks and philanthropic donors (OECD, 2019).

The sector is confronted with grand challenges like climate change and rapid urbanization, which render the operation and maintenance of large-scale infrastructures increasingly difficult (Sadoff et al., 2015, UN-WWAP, 2015, Eggimann et al., 2018b, OECD, 2019). Small, flexible, modular water technologies are hence increasingly regarded as a promising means of flexibly alleviating water scarcity, supporting cities in becoming more resilient and helping them to implement more sustainable urban water management practices (Larsen et al., 2016, Wong and Brown, 2009). Often applied in small-scale off-grid contexts, modular water technologies can benefit from so-called "economies of unit numbers", bringing them management and cost advantages compared to conventional large-scale water infrastructures (Wilson et al., 2020, Dahlgren et al., 2013).

Given these characteristics, they fundamentally challenge the dominant regime logic in the water sector, which is predisposed to technologies designed for large unit-scale and custom-built water infrastructures (Fuenfschilling and Binz, 2018). In contrast to this highly institutionalized regime, the actor network pushing for modular technologies is still in a rather nascent stage, with limited commercial applications and an actor structure that is dominated by small and medium sized enterprises (OECD, 2019). Funding still mostly originates from grants provided by private foundations and venture philanthropy, like through the Bill and Melinda Gates Foundation (BMGF), but also via NGOs, development agencies and some social impact investors (ibid.).

In light of these specifications, we expect strong legitimation challenges among actors pioneering innovative modular approaches and regime actors defending the centralized paradigm. We further expect a broad range of multi-scalar legitimation activities as the centralized socio-technical regime is globally rather standardized with relatively few regional variations (Fuenfschilling and Binz 2018).

3.3.1 Measuring legitimation and discursive path dependency

To operationalize our framework, we constructed a dataset by means of a semi-qualitative methodology – which we call socio-technical network analysis (STCA) (Heiberg et al., 2022) –, which rests on a discourse and social network analysis tool (Discourse Network

Analyzer) developed in the political sciences (Leifeld, 2017, Leifeld, 2013). Given the global ambition of this study, we do not aim to analyze legitimation through a full-fledged discourse analysis (e.g. Geels and Verhees, 2011), but rather focus on organizations' (positive or negative) evaluations of technologies or related infrastructural and institutional elements in media coverage. For example, newspaper articles are coded for individual statements through which organizations contribute to a specific favorable or obstructive narrative (narrative events in the remainder) around certain technologies or institutions. STNA conceptualizes these narrative events – statements around institutional or technological elements – as an interaction between *actors* that make normative claims about certain *concepts*. The time-referenced and coded data that is retrieved based on qualitative content analysis is subsequently transformed into network matrixes that enable the quantification of various relationships between actors and concepts across time, allowing for the analysis of the alignment and reconfiguration processes associated with changing socio-technical regimes (Heiberg et al., 2022).

In the present paper we aim to investigate the geographical patterns behind the narrative events. We thus capture contributions to legitimizing and de-legitimizing narratives made by actors around technologies as well as institutional elements in the media. For this, we use a binary qualifier variable, which connects each coded excerpt to an either legitimizing or de-legitimizing narrative. This distinction, of course, constitutes a strong simplification of reality. Yet, in light of the fundamentally opposing infrastructural logics associated with conventional and modular water technologies, it was usually easy to identify whether an actor framed a concept in a favorable or obstructive way.

Further, a valid operationalization of our framework requires the identification of the spatiality and scalarity of the coded narrative events. To this end, we coded three types of spatial variables associated with each code. First, actors – mostly organizations in our case – are assigned to a specific location where they carry out most of their activities (*actor location*). Here, we distinguished roughly between national and global actors, which refers to the scale where most of their activities take place. Global-scale organizations (such as TNCs, NGOs, industry associations, etc.) are defined by being active in various locations around the world. If necessary, and not encompassed by our textual sources, the assignment to scales is based on supplementary desk research[2].

Second, we identify whether the narrative an organization contributed to includes a spatial reference to a specific case or activity somewhere abroad (*narrative location*). Typical examples involve reference to companies or global NGOs that promote specific technologies abroad or reporting on the success or failure of specific projects from other geographical contexts. For instance, in Israeli newspapers, a recurrent narrative promoting the local modular industry hinted at a huge market for these technologies emerging in China and made reference to Israeli companies' successful involvement in experimental projects in several Chinese regions. For such narratives, we would code China as the 'narrative location'.

The third locational variable denotes the geographical places and scales of the audience which articles are targeting (*audience location*). This assumes that a media article always wants to inform some geographically specified readership. The audiences addressed are either predominantly (sub-) national-scale public audiences, e.g. for nationally or regionally distributed newspapers like the Times of India, The Guardian or the Washington Post, or global-scale expert audiences, as in sector-based global magazines like Chemical Week or Business Monitor Online. In national legitimation processes, media articles capture the interplay of different value perspectives in policy contexts within clearly delimited territorial boundaries. Global-scale outlets, by contrast, capture the (dis-)agreements on certain infrastructure solutions among global experts with academic, business or financial backgrounds.

As will be elaborated in section 3.3.3, capturing these three variables will allow us to build indicators that measure endogenous legitimation, attraction, absorption and export for several focal cases.

3.3.2 Data sources

To characterize different countries' generic path creation constellations, we select indicators for both the availability of place-based knowledge related to water technologies and for the strength of the incumbent socio-technical regime. To identify existing national

[2] E.g. on sources like Bloomberg.com

knowledge and capabilities, we access innovation performance indicators from the OECD.stat database, which are based on PATSTAT data on patent family filings that were filtered for water technologies[3]. To assess regime strength, we collect centralized sewerage connection rates from the WHO/Unicef Joint Monitoring Project (JMP) on water supply, sanitation and hygiene and combine them with the degree of discursive path dependency evident in the media, based on our own dataset (see 3.3.1). To identify legitimation activities globally, over 180 English-speaking newspapers covering most OECD countries plus India, South Africa, China and Singapore, as well as selected global expert magazines, were accessed through the online newspaper repository LexisNexis. The outlets were filtered for articles dealing with solutions to solve water problems during 2011-2018[4]. The source base was built around "Major World Publication" sources that contained a selection of the world's major English-speaking newspapers, industry magazines and trade publications, which "are held in high esteem for their content reliability" (LexisNexis, 2018)[5]. The base was further manually extended for media coverage in world regions that were only sparsely or not at all represented by the initial assemblage (i.e. India, African countries). We only included outlets that were covered over the whole time period and that were considered of national or international importance by LexisNexis[6].

A search query was then formulated[7] to filter articles published between 2011 and 2018 from the source base. Of initially about 800 articles, 563 where deemed relevant and subsequently coded by a single coder with help of DNA-software (Leifeld, 2018). The first author developed and tested a coding scheme (for details see also appendix A3 and Heiberg et al., 2022) before a second coder was educated in consistently applying it through several coding runs with test data involving feedback rounds and inter-coder reliability checks.

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[3] See B1. We use patent data as in indicator to compare the creation of knowledge and capabilities across countries due to its availability over long time-spans and comparability, especially at the country level (Archibugi & Planta, 1996). While we are aware that not all innovations in the water sector may be patented, previous investigations of innovation activities in the water sector have shown its general applicability for the sector (e.g. Moro et al 2018; OECD, 2019). Note that the appendix is available only.

[4] see B2 for the technological specification of modular versus centralized systems

[5] The LexisNexis Academic database was updated in spring 2019. Its successor LexisUni does not provide source assemblages like "Major World Newspapers" anymore

[6] see B3 for a full list

[7] see B4

Due to the structure of our databases, we will focus our remaining analysis mostly on national and global scales. An expansion of the analysis to sub-national scales would in principle be easily possible by applying the same method to media and patent databases that contain more fine-grained information on regional and local newspaper coverage and inventor data.

3.3.3 Indicators for discursive regime strength and multi-scalar legitimation processes

The narrative events captured from our databse enable us to disentangle the endogenous and multi-scalar dimensions of legitimation as concepualized in section 3.2. In a first step, we identify geographical hot spots of legitimation activities. This is achieved by mapping the frequencies of narrative events at the level of national audiences.

For each country case, the absolute numbers of legitimizing and de-legitimizing narrative events per year are subsequently taken to construct a **favorable narrative share** (Fig. 3.2, I). It is defined by the sum of narrative events that legitimize modular technologies or de-legitimize conventional technologies divided by the sum of all narrative events in a specific country. The higher the measure, the more challenged the regime is. Together with the connection rate to centralized water infrastructures, this indicator measures the degree of institutionalization of the conventional socio-technical regime in a given country.

We then ask how prevalent processes of endogenous legitimation, absorption, attraction, and export of legitimacy are in select hotspot countries. This enables us to assess the importance of multi-scalar legitimation processes in countries with differing path creation constellations.To assess the prevalence of multi-scalar legitimation processes, we develop four indicators.[8]

[8] For a detailed description of each indicator and its calculations, see B5

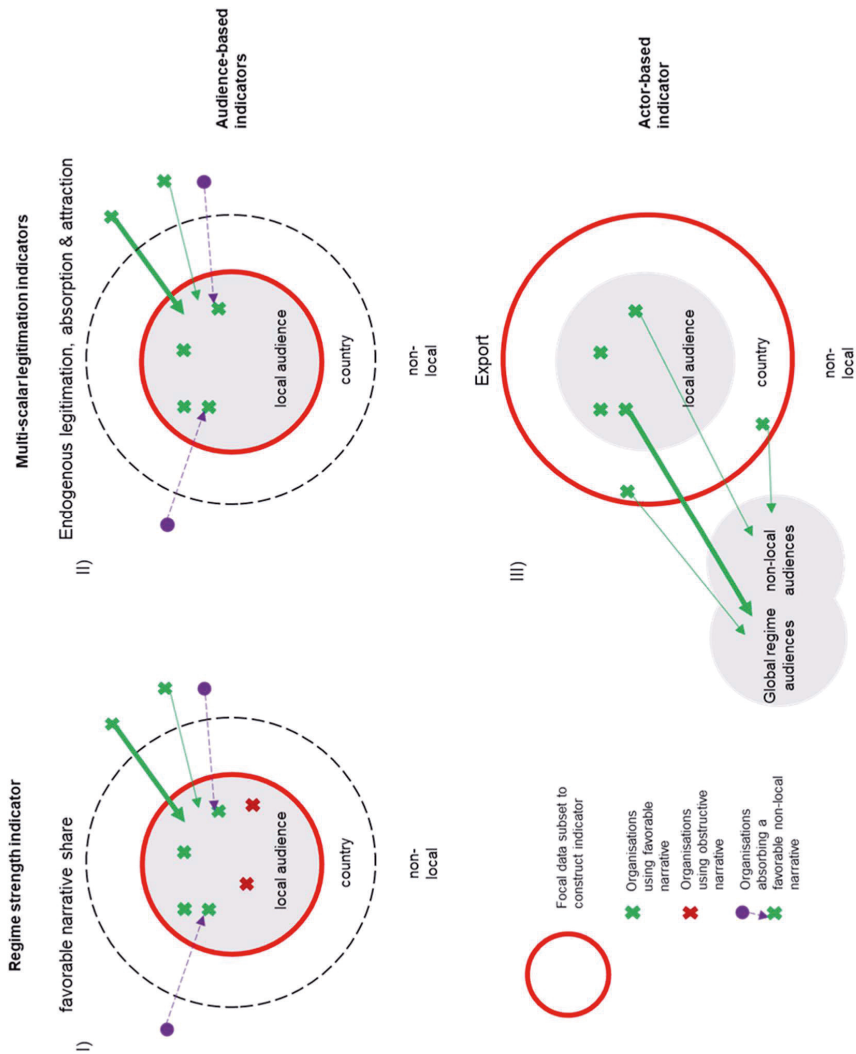


Fig. 3.2: Data subsets to calculate indicators for regime strength and multiscalar legitimation processes.

The relative importance of endogenous legitimation inside a country is given by the **endogenous legitimation** indicator (Fig. 3.2, II). It measures the share of favorable narrative events by local actors among all favorable narrative events in a country. The importance of attraction processes is captured by the **attraction** indicator (Fig. 3.2, II). It is given by the share of favorable narrative events by non-local organizations among all favorable narrative events in a country. Finally, the **absorption** indicator (Fig. 3.2, II) represents the share of narrative events that absorb success stories from elsewhere among all favorable narrative events in a country. Unlike attraction, absorption is operationalized as an inherently transnational process because success or failure cases that can be absorbed are necessarily associated with stories from distinct other countries or regions.

While endogenous legitimation, import and absorption can be calculated based on narrative events addressing an audience in a specific country (*audience-based*), the **export** indicator follows a slightly different logic since it is calculated using the share of favorable narrative events by local actors addressing the global-scale or another countries' audience (Fig. 3.2, III). The export indicator is hence *actor-based*. Fig. 3.2 illustrates the logic behind the different indicators and their respective data subsets.

3.4 Results

The main descriptive statistics of our analysis can be obtained from Tab. 3.2. Roughly 2/3 of all the narrative events captured legitimize the existing regime and conventional industry. The remaining third of events are favorable to the emerging modular industry. We capture data from 6 countries (the rest of the world being clustered in larger world regions) plus the global-scale regime audiences (adding up to 16 audience locations). Most narrative events can be identified in India, the USA, Singapore, South Africa, the UK and in Israel, as well as on the global scale. Narrative events addressing these major national and global-scale audiences account for over 78 percent of all legitimation activities in the dataset (Tab.3.2).

Tab. 3.2: Dataset.

Narrative events after duplicates/document cleared:	1435	
Narrative events favorable to conventional technologies	911	
Narrative events favorable to modular technologies	524	
STCA Variables:		
Organisations:	566	
Organisation types:	8	
Concept codes (referred to in narratives):	51	
Actor locations:	20	
Narrative locations:	19	
Audience locations:	16	
Overall narrative events per country (or clustered in supra-national regions):	count	% of subtotal
India	280	21.93
USA	199	15.58
Singapore	150	11.75
South Africa	138	10.81
UK	104	8.14
Israel	96	7.52
East Africa	66	5.17
East Asia	53	4.15
Southern Africa	50	3.92
Oceania	45	3.52
Canada	41	3.21
Europe	30	2.35
Central and West Africa	14	1.1
Other Africa	6	0.47
China	5	0.39
subtotal	1277	100
% of subtotal (top-6 countries)	967	75.72
Overall narrative events in global-scale expert discourse:	count	% of total
Global-scale	158	11.01
% of Global-scale and top-5 countries		78.4
Total	1435	100

The analysis of path creation constellations (visualized in Fig. 3.3 and Tab. 3.3) shows that in India, a higher favorable narrative share for modular technologies coincides with a weak regime in centralized infrastructures. Combined with low knowledge and capabilities, this reflects a challenge-driven path creation constellation. In Singapore, in contrast, high patenting in water technologies and a 100-percent connection rate to centralized infrastructures go hand-in-hand with a strong regime orientation, thus indicating an export-driven constellation. Israel, a leading innovator in the water field, combines strong patenting with a moderately strong favorable narrative share and a complete lock-in to centralized infrastructures, thus resulting in an export-driven constellation. South Africa, in turn, has a very weakly established centralized infrastructure regime, resulting in a more challenge-driven constellation. The US constitutes an intermediate case, thus representing a potential lead-market constellation. Finally, the UK constitutes a case with weak to moderate patenting activities, a strongly dominant centralized infrastructure regime, which is, however, highly challenged by multiple narratives promoted in public media. Taken together, this results in a regime lock-in constellation.

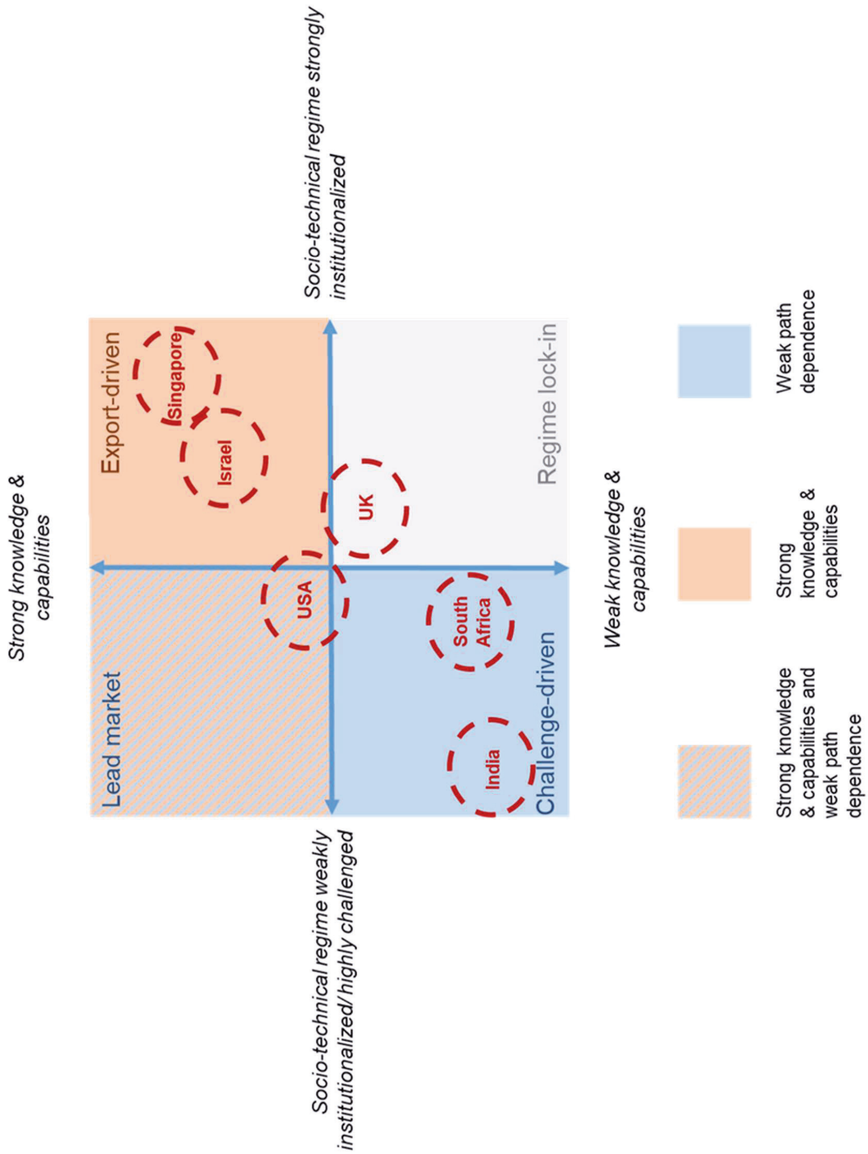


Fig. 3.3: Path creation constellations across countries.

Tab. 3.3 Country-Level Indicators for Path Creation Constellations

Availability of knowledge & capabilities

Knowledge indicators

	Average annual water technology patent family filings 2011-2016, per 1 Mio inhabitants*	Share of water-related patents among all patents
India	0.08	1.30
USA	7.93	1.44
Singapore	11.10	2.45
South Africa	0.30	3.31
UK	4.02	1.85
Israel	9.54	1.50
OECD	7.22	1.70

* PATSTAT data from OECD.stat

Regime strength

Infrastructural indicators

Sanitation service levels 2017, % of households*

	sewered	non-sewered
India	11	89
USA	82	18
Singapore	100	0
South Africa	58	41
UK	97	3
Israel	99	1

* WHO & Unicef data from Joint Monitoring Project on water supply, sanitation and hygiene

Discursive indicators

Narrative events concerning modular water technologies 2011-2018*

	All narrative events	favorable narrative events	favorable narrative share %
India	280	138	49
USA	199	68	34
Singapore	150	20	13
South Africa	138	41	30
UK	104	49	47
Israel	96	40	42

*Own database

3.4.1 Multi-scalar legitimation processes

In what follows, we will review the indicators for multi-scalar legitimation processes introduced in section 3.3.3 to assess their importance in each of the four quadrants of our typology. This enables an assessment of whether certain multi-scalar legitimation processes may be more relevant in certain quadrants than in others. The values of the audience-based attraction, absorption and endogenous legitimation indicators can be obtained from fig. 3.4a. The different scores will be contextualized with additional qualitative information drawn from the text analysis.

Lead market constellation (USA)

The USA constitutes the only country in our dataset that can be connected to a lead-market strategy. For countries in this quadrant, we would not only expect the creation of a favorable environment locally, but also strong potential for exporting legitimacy both to other countries and to the global regime. As Fig. 3.4 clearly indicates, US actors indeed engage more strongly in the export of favorable narratives than actors from most other countries featured in our dataset. The respective US actors involve tech firms in the modular technology field, such as Cambrian Innovation or RWL Water, as well as NGOs, industry associations and several public authorities (especially in arid western states like California or Arizona). Most strikingly, over 16 percent of all favorable narratives by US actors are associated with statements addressing global-scale audiences. Most of these export activities are associated with statements by big universities such as MIT, Caltech and Harvard, as well as individual venture capital firms directed towards international industry and policy audiences. Hence, diverse US actors seem to be able to contribute to dominant narratives among professionals in the global water sector. Directly shaping the prevalent global regime narratives may be a powerful method for big countries, like the US, to positon themselves as global lead-markets since the professional community will disseminate and reproduce these narratives in other parts of the world and hence legitimize the US solutions there. At the same time, professional global networks may also feed legitimacy back into the US and hence strengthen the emerging niche in the long run.

Further, US media coverage is also strongly influenced by attraction and absorption processes, which make up about 40% of all favorable narrative events in the country. Actors legitimizing modular technologies in the US consist of international organizations (like the WHO) as well as tech-firms from Israel (like IDE) and Australia (Aquacell), which see a potential market for modular technologies in the US. The latter has indeed become a key provider of on-site water reuse technologies in Northern California

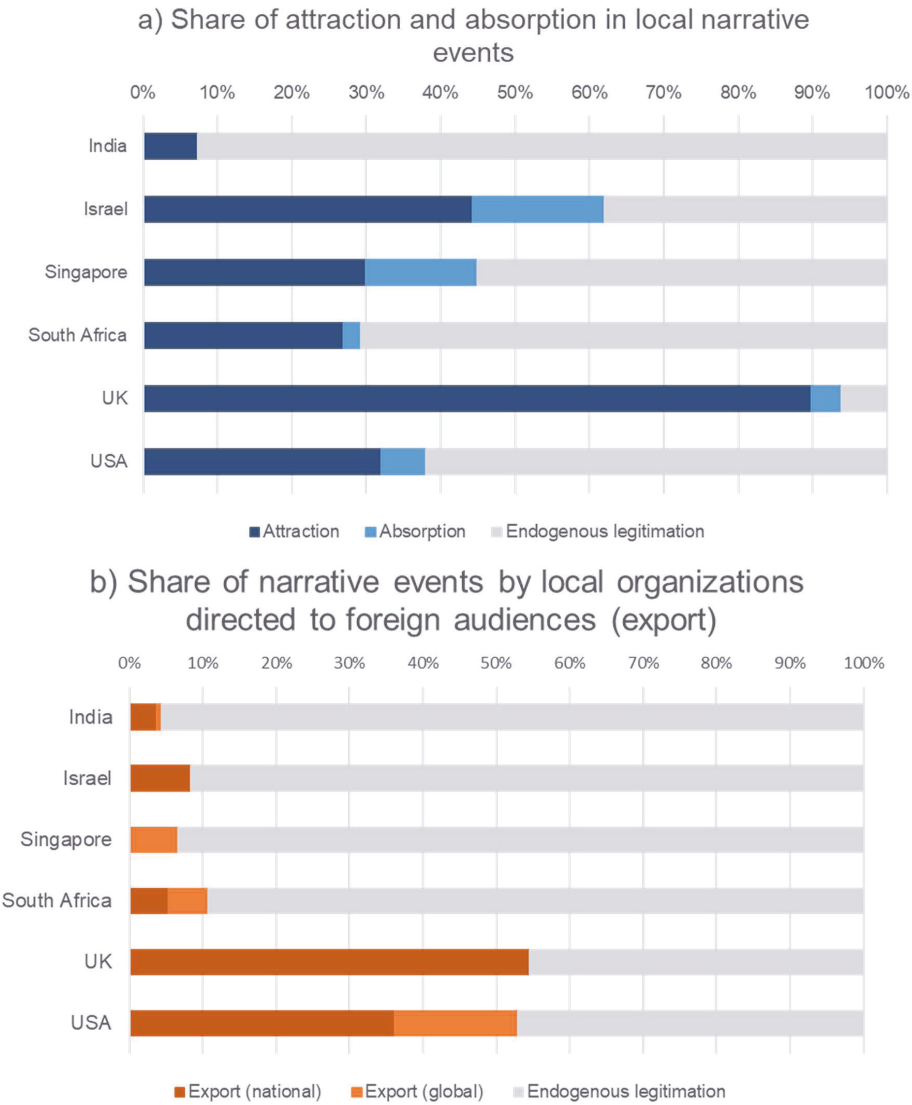


Fig. 3.4:Multi-scalar legitimation processes across countries

recently. Further, international universities (e.g. from Germany, Israel and the UK) are frequently given a voice in the US media. Absorption, in fact, relates to the reporting of successful deployment cases from all other countries investigated in this paper, including the BMGF activities in Durban (South Africa). What's more, deployment cases from Israel, Singapore, India or Australia are often used by universities and NGOs advocating modular technologies.

In addition, the text analysis revealed that the US faced particular regional environmental pressures, e.g. through droughts that hit California and the Western states peaking between 2014 and 2016 (NIDIS, 2018). These events pushed water issues into the public media, which additionally attracted global and transnational experts to legitimize modular solutions locally. Overall, the US context can thus be characterized by a strong export of legitimizing narratives to the global regime as well as by a balanced mix of attraction, absorption and endogenous legitimation activities, which taken together create a supportive institutional environment for industrial path creation, potentially making US actors the forerunners of a wider sectoral transition.

Export-driven constellations (Israel, Singapore)

For countries with strong local knowledge capabilities as well as strong regime structures, we expect analytically distinct legitimation strategies, which depend more on export activities with the subsequent absorption of success stories into the local context. As discussed above, Israel and Singapore can be positioned in this quadrant. Israeli actors conducted about 10% of their narrative events in other countries (Fig. 3.4b). Unlike in the US case, they do not target the global regime but attempt to directly support export markets in other countries, most prominently in the US. At the same time, absorption processes also play a comparatively strong role in that case. Most of the absorbed narratives are built around Israeli companies' (such as Emefcy) successful engagement with modular water technologies in foreign markets, for example in China or the Americas. Additionally, Israel manages to attract European, US and global-scale organizations to co-legitimize the emerging industrial path around modular water technologies in Israeli media outlets. Overall, multi-scalar legitimation processes make up the largest part of all legitimation activities in that case. Fulfilling its potential in an export driven constellation (e.g. targeting markets like the USA), path creation in Israel heavily benefits from multi-scalar legitimation, partly compensating for the lack of an existing domestic market.

Singapore is characterized by a similarly strong deployment of attraction and absorption processes among all favorable narrative events. Unlike Israel, however, the discourse in Singapore remains strongly dominated by narratives around conventional large-scale water technologies (Fig. 3.4a). Moreover, unlike Israel, Singaporean promoters of modular technologies rather target the global regime and not specific countries. An explanation for this pattern may be found in Singapore's strong export orientation in centralized wastewater reuse and desalination, which builds on its 'Four National Taps' water strategy (PUB, 2018). Since the national water technology export activities are already strongly focused on this trajectory, modular technology proponents face strong opposition by export-oriented competitors and rather follow a long-term strategy in changing the global socio-technical regime. While Israel follows a rather classic export-driven legitimation strategy including export and subsequent absorption processes, in Singapore regime resistance cannot be overcome yet, hence actors focus on legitimizing niches on the global-scale. Overall, the data from Israel and Singapore suggests that the success of an export-driven path creation constellation depends on actor strategies that effectively mobilize non-local legitimacy.

Challenge-driven constellation (India, South Africa)

Countries that largely lack knowledge and capabilities, but at the same time represent potentially favorable institutional environments due to strong challenges to the regime, may in turn provide an attractive environment for foreign actors and hence depend more heavily on attraction processes than the other cases. In our dataset, India and South Africa exemplify this path creation constellation. Legitimation patterns within both countries are strongly dominated by a combination of endogenous legitimation and attraction processes. Export to other countries and the global regime remain low, and absorption from other countries is virtually non-existent.

South African actors appear to influence the global regime in a few instances, yet much less strongly than US or Singaporean actors. Where it occurs, it is driven by the University of KwaZulu Natal and Durban municipality, which are also the most prominent proponents domestically, having a long-standing record of experimenting with and implementing modular technologies in informal settlements (Sutherland et al., 2015). Apart from these, we also find the government promoting modular solutions in response to severe droughts in 2015/16 (Baudoin et al., 2017). These pressures also attracted international organizations like the International Water Association (IWA) and the UN to legitimize modular solutions in South Africa. Further, the qualitative data suggests that modular water technologies are already an institutionalized part of many Indian and South African cities since decentralized and modular sanitation is a widely diffused practice in both countries (Ulrich et al., 2018, Schellenberg et al., 2020).

India, in particular, has a long history in the application of modular water infrastructures. Narratives by Indian actors thus often revolve around these pre-existing modular water infrastructures, which are promoted by a large variety of actors ranging from public authorities to NGOs and companies. Regional discursive hubs can be identified, in particular, in the southern states of Tamil Nadu, Karnataka and Maharashtra as well as in some Northern States such as Uttar Pradesh and Himachal Pradesh. Local environmental problems, like overly polluted rivers and sewerage overflow, often lead regional organizations to suggest an increased use of modular technologies for greywater reuse, rainwater harvesting or on-site wastewater treatment. Overall, we may expect challenge-driven countries to create legitimacy endogenously building on existing institutional templates and in reaction to landscape pressures. While these cases often provide institutional windows of opportunity for path creation, the lack of knowledge capabilities may require the absorption and attraction of knowledge from beyond the region. A feasible strategy in this constellation would thus involve attracting capable foreign firms and experts based on the strategic promotion of local markets and legitimation trajectories.

Regime lock-in constellation (UK)

Regime lock-in constellations, finally, are the hardest to tackle, even with multi-scalar legitimation strategies, due to the lack of local knowledge capabilities and strong regime structures. To create a domestic path, local actors may thus have to engage in a diversity of legitimation strategies in parallel, such as developing an export-driven trajectory (similar to the Israeli case), while also attracting foreign firms to both transplant external knowledge and discursively challenge the domestic regime. The UK constitutes an illustrative case in this regard since almost all legitimation activities in domestic media coverage are based on attraction processes. There are two reasons for this. On the one hand, there have been frequent reports about the Californian drought between 2014-2016, especially in the Guardian, giving a voice to US entrepreneurs in the UK's small, modular technology field. On the other hand, the BMGF, which funds various British research partners in the context of their 'reinvent the toilet challenge', frequently pushes their ideas in British media.

Thus, while British infrastructures and endogenous legitimation is strongly focused on the centralized regime, British media also provides a platform for external industry proponents to promote their ideas about modular water technologies, effectively challenging the socio-technical regime. International actors, like BMGF, may find the UK an attractive location to legitimize modular technologies in order to gain attention from investors based in London or powerful British companies. At the same time, British industry proponents themselves mostly target foreign markets in the rest of the English speaking world. Hence, for the UK, we may observe a combined strategy of attracting foreign legitimizers to the otherwise strongly path dependent institutional environment, with British industry proponents seeking their luck in export-markets. The British case thus illustrates how an internationally well-connected country, despite facing a regime lock-in constellation, may become a hub for transnational legitimation flows and even generate opportunities for path creation thanks to the attraction of foreign legitimizers.

3.5 Discussion & conclusions

The goal of the present paper was to address the question of how path creation potentials in regions are influenced by and dependent upon multi-scalar legitimation dynamics by developing a conceptual and empirical means of disentangling multi-scalar legitimation processes in new industrial path creation. We have demonstrated how regional path creation constellations differ according to their existing knowledge and capabilities and with respect to the institutionalization of the socio-technical regime relative to the emerging industry. We have then shown how, within these varying structural constellations, multi-scalar legitimation processes can be empirically identified through the analysis of narrative events in public media. In light of the findings presented, our research brings to the fore several aspects that may enrich future work on non-local sources of industrial path creation within the discipline of EG and beyond.

While recent research on path creation has focused mostly on regional and national institutional dynamics (Gong and Hassink, 2019, Miörner and Trippl, 2018), our work is innovative in proposing a more global and multi-scalar perspective on institutional dynamics. Our results show how multi-scalar legitimation processes may shape a region's ability to create industrial paths in emerging industries. In particular, we illustrated the importance of non-local sources of legitimacy for regional path creation in conjunction with non-local sources of knowledge (Trippl et al., 2018). Our results indicate that an explicit consideration of multi-scalar flows of legitimacy is crucial for identifying potential strategies of regional actors. Integrating these insights with recent understandings of multi-scalar knowledge flows, it is possible to formulate a number of original hypotheses which shed light on success conditions of path creation processes (see Tab. 3.4).

In a lead-market constellation, knowledge and legitimacy can be developed endogenously. In this case, actors will likely engage in the export of both knowledge and legitimacy in order to shape supportive institutional environments, both in the sector's global regime as well as in other regions. Lead market countries like the US, may additionally benefit from non-local sources of legitimacy in a similar manner as organizationally thick and diversified regions benefit from absorptive capacity and attractiveness in the anchoring of extra-regional knowledge resources (Trippl et al., 2018). In an export-driven constellation, the lack of a favorable institutional environment needs to be compensated by active export activity, absorption as well as attraction of legitimacy, which can be facilitated through (experimental) commercial activities abroad. Put differently, in an export-driven constellation, multi-scalar legitimation processes serve to mobilize a path potential that could not be created or maintained in the local context alone (see also Kwak and Yoon, 2020).

A challenge-driven constellation, in turn, has ample opportunities to build up legitimacy endogenously, while depending on knowledge and other missing system resources that must be attracted from abroad. This situation may be best compared to an organizationally thin or peripheral region in which actors face the greatest difficulties, yet can nonetheless reap the largest benefits from absorbing extra-regional knowledge and other resources (Trippl et al., 2018). Finally, in a regime lock-in constellation, resources need to be almost entirely drawn in from non-local sources or be developed from scratch domestically. Since the latter often proves difficult, actors in a regime lock-in constellation may chose a legitimation strategy that builds strongly on extra-regional legitimacy. A regime lock-in constellation may e.g. relate to old industrial regions, for which empirical studies have suggested that multi-scalar institutional interventions may matter just as much as the absorption of non-local knowledge (Dawley, 2014, Dawley et al., 2015, Trippl et al., 2018, Hassink et al., 2019).

As apparent from these hypotheses, our results point to the importance of interactions between regional entities and global socio-technical regime structures (Fuenfschilling and Binz, 2018) that may substantially affect the path creation prospects of a region. Beyond only looking at institutional environments *on* different spatial scales, mostly referring to regulation and policy processes (Martin, 2010, MacKinnon et al., 2019b), we have shown that these institutional environments may be affected by processes that run *across* different spatial scales. The transnational absorption of legitimacy through narratives around foreign success cases, or the attraction and export of legitimacy from and to a global-scale community of experts that reproduces the global socio-technical regime, reveal that new windows of opportunity for paths in emerging industries may develop in contexts that existing theorizing would not have suggested (as the cases of Israel and the UK illustrate). Hence, merely looking at endogenous institutional work for an emerging industry or at static layers of institutions that affect path creation regionally blind researchers to the diverse ways through which industry proponents may influence relevant institutional environments in and across spatial scales.

We began this paper with the ambition to analyze the importance of multi-scalar institutional dynamics for regional industrial path creation. However, our actual framework has focused on legitimation processes. A more encompassing perspective would additionally have to consider other relevant system resource formation processes, such as market formation and the mobilization of financial investment (Binz et al., 2016b). Furthermore, the method proposed could be further improved. Since we only capture legitimacy generated through articles in selected media outlets, we cannot make

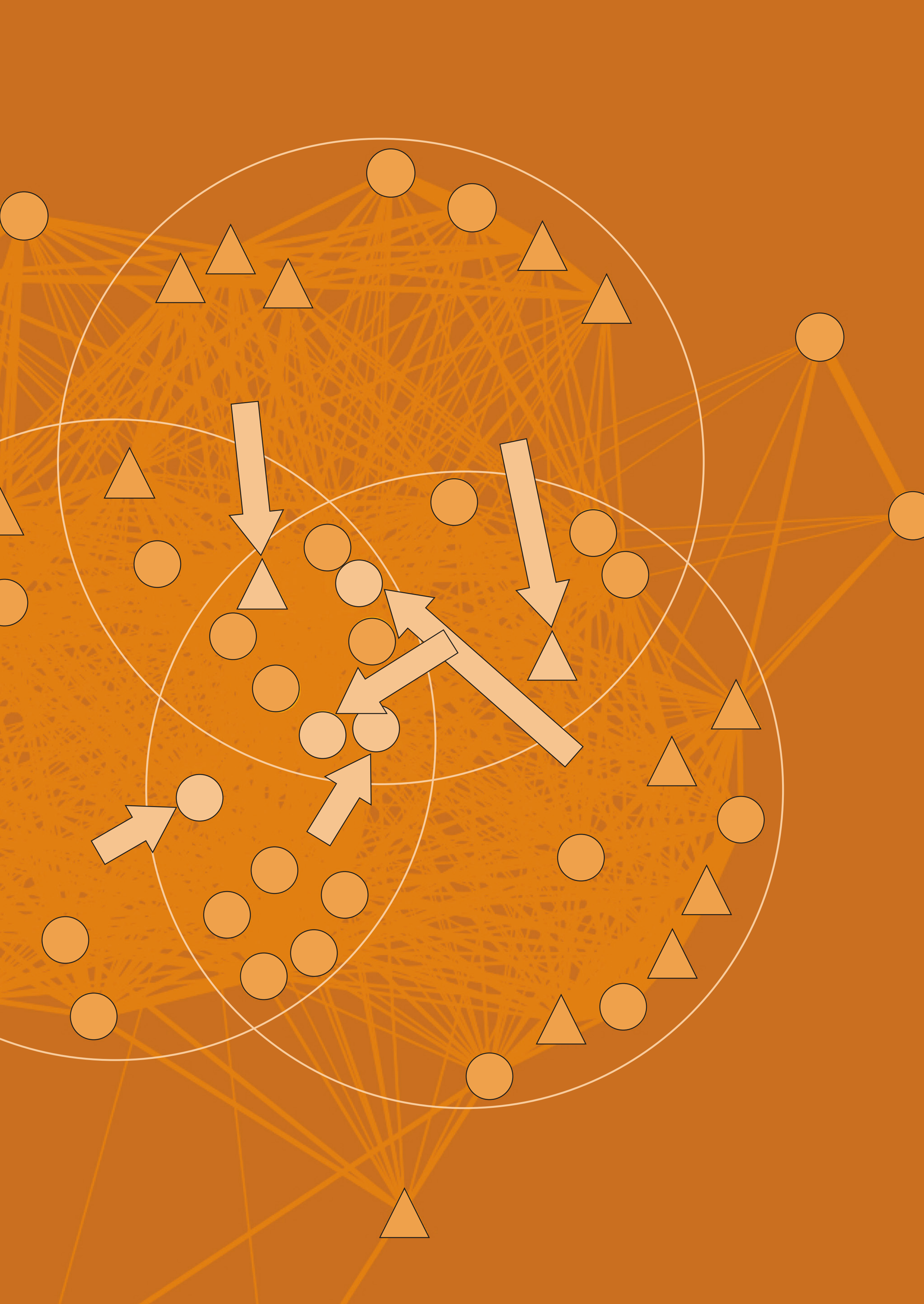
Tab. 3.4: Relevance of multi-scalar ressource formation strategies in different path creation constellations

		Lead market	**Export-driven**	**Challenge - driven**	**Regime lock-in**
Knowledge	Endogenous	++		-	
	Attraction & Absorption	+		++	
	Export	++		-	
Legitimacy	Endogenous	++	-	++	-
	Attraction	+	+	+	++
	Absorption	+	++	-	++
	Export	++	++	-	-

++ high relevance
\+ intermediate relevance
\- lower relevance

any claims about legitimacy conveyed through more tangible actions, such as investment decisions or presentations at trade fairs or conferences (Bork et al., 2015). Future research should thus venture to identify broader valuation concerns, which may require the triangulation of data generated by means of a variety of databases/methods. As discussed above, our method could be applied to more detailed analyses at the regional level to gain more in-depth insights into the sub-national validity and specificity of the processes studied in this paper. Eventually, an analysis of the role of multi-scalar legitimation processes in more traditional and established sectors could provide important insights beyond the case of an emerging (cleantech) industry as analyzed herein.

In summary, we maintain that the conceptual framework, method and databases presented open an important new inroad to understanding the systemic interplay between novel technologies, institutions and knowledge in a globalizing innovation and industry formation race. Contextualizing the contribution of this paper in a wider conceptual perspective will enable economic geographers and transition scholars to combine the exploration of productive trading zones with theorizing in other disciplines, such as neo-institutional sociology or the literatures on institutional work and entrepreneurship. Embracing and expanding on these theoretical insights constitute the topical horizon for geographers and transition scholars alike, particularly in light of increased efforts to understand path creation in emerging or green industries (Trippl et al., 2020).



Chapter 4

Overcoming the harmony fallacy

How values shape the course of innovation systems

Abstract

The technological innovation systems (TIS) framework is one of the dominant perspectives in transitions studies to analyze success conditions and system failures of newly emerging technologies and industries. So far, TIS studies mostly adopted a rather harmonious view on the values of actors and by this were unable to address competition, conflicts and, in particular, battles over diverging directionalities within the system. To empirically assess this potential "harmony fallacy", we identify values as part of underlying institutional logics of major organizations in the field of modular water technologies in Switzerland by means of 26 expert interviews. We show how logics may condition collaboration patterns and technological preferences. This analysis enables to inspire key conceptual tasks of innovation system analysis, like the identification of system failures, the setting of appropriate system boundaries and the formulation of better policy implications.

4.1 Introduction

Over the past decades, research in innovation studies has informed innovation policy based on different rationales. While prior innovation studies research focused on fixing market failures to foster economic growth, from the 1980s on, the analytical perspective broadened to account for weaknesses of innovation system structures to explain competitiveness and innovative performance at the level of countries, regions or specific technological fields (Woolthuis et al., 2005, Edquist, 2005, Weber and Truffer, 2017, Schot and Steinmueller, 2018). Policy advice was then mostly oriented at overcoming of diagnosed “system failures” such as deficiencies in capabilities of actors, coordination deficits among actors or mismatches with extant institutional structures (De Oliveira et al., 2020, Chaminade and Edquist, 2010, Wieczorek and Hekkert, 2012). In transition studies, this second generation of innovation policies primarily gained prominence through the technological innovation system (TIS) framework (Bergek et al., 2008a, Hekkert, 2007) as applied to green technology and industry dynamics. More recently the innovation system perspective got criticized for being too knowledge and technology focused, too “naïve” in terms of power relationships and politics, and thus unable to address grand challenges which would be required for a more transformation-orientation innovation policy (Weber and Rohracher, 2012, Schot and Steinmueller, 2018, Markard et al., 2015).

Tackling this problem notably requires to embrace diverging value orientations of actors, associated interests, and conflicts (Stirling, 2009, Wirth et al., 2013, Kern, 2015, Jeannerat and Kebir, 2016, Weber and Truffer, 2017). The currently dominant view in most TIS studies implicitly assumes that relationships among actors in a new technological field derive from a rather homogenous set of shared goals and interests (Kern, 2015), which engender largely harmonious relationships inside the TIS. Conflicts and competition are assumed to mostly occur in relation to the incumbent technological systems (Bergek et al., 2015). Even though values have not been fully absent in the TIS framework, they are mostly subsumed under the “function” of legitimation (Bergek et al., 2008b). Recent transitions research has made considerable progress in conceptualizing technology legitimation (Fuenfschilling and Truffer, 2016, Binz et al., 2016a, Markard et al., 2016a, Heiberg et al., 2020, MacKinnon et al., 2021, Rohe and Chlebna, 2021 among others). However, these studies still mostly focused on the overall societal legitimation of a novel technology, not elaborating on diverging value orientations within a TIS (for exeptions see Yap and Truffer, 2019, Yang et al., 2020).

As a consequence of this rather knowledge focused approach, lacking innovation success is often explained by a rather technical understanding of system failures: Coordination deficits are often framed as stemming from lacking awareness among actors, implying a need for more efficient forms of exchange (e.g. through intermediaries, conferences, research programs). Similarly, capability failures result from insufficient technical knowledge and expertise, which can be remedied by providing platforms for mutual learning or building up regional educational programs. Thirdly, institutional failures are assumed to stem from prevailing sectoral norms, rules and regulations that limit the further development of the TIS. Policy advice stemming from these TIS studies has therefore mostly revolved around mobilizing external support, overcoming external hindering conditions and providing better conditions for internal knowledge exchange. Little room is left for conflicts and competition among different actors within the technological field and hence internal battles over directionality (Stirling, 2009).

Hence, we diagnose a potential “harmony fallacy” in much of innovation systems research. This fallacy is likely to over-estimate the potential of policies that aim for creating synergies among innovating actors in a technological field, assuming that lack of knowledge and other resources represent the main impediment for innovation success. On the other hand side, the focus on harmonious relationships carries the risk of trying to prematurely close in on seemingly successful technological trajectories instead of supporting the competition among alternative designs. A better understanding of value positions is therefore key for assessing directionality failures and by this being able to reflect how innovation systems may contribute to tackling grand societal challenges. While, we will not be able to solve this entire puzzle in a single article, we aim at providing some first stepping stones by asking the following research questions: how does a value-sensitive perspective enrich or alter the existing innovation system framework in terms of the study of system failures, the handling of directionality choices, and in terms of setting appropriate system boundaries?

To do so, we conceptualize value orientations of actors by drawing on the concept of prevalent institutional logics in a technology field (Friedland and Alford, 1991, Thornton and Ocasio, 1999, Fuenfschilling and Truffer, 2014). Institutional logics denote specific “coherent” combinations of values, visions, beliefs and rules that guide actor behavior and which provide rationales for specific actor groups to rationalize their actions (Thornton and Ocasio, 1999, Kooijman et al., 2017, Kieft et al., 2020). Conflict and competition in a TIS may therefore result from diverging visions, values and technology preferences different actors rally around. The institutional logics lens enables to group the different actors in terms of “value-based proximities” and from this to derive an overall assessment of the degree of harmony (or conflict) in the technological field. We assume that value-based proximities may help explain TIS- internal institutional failures, collaboration patterns, and competing directionalities.

We apply this value perspective to recent innovation system dynamics in the field of modular water technologies in Switzerland, during the past two decades (2000-2020). Various types of modular water technologies have been proposed as sustainable additions, or even alternatives, to the globally dominant urban water management regime, which builds on large-scale centralized water infrastructures (Fuenfschilling and Binz, 2018). Modular technologies may be more resilient to challenges of climate change and rapid urbanization (Larsen et al., 2016, Hoffmann et al., 2020) by allowing to close water and resource cycles near to the point of use and by this dispense of expensive sewer networks. Due to economies of scale of mass production, cost competitiveness with current centralized treatment technologies could improve rapidly (Dahlgren et al., 2013, Wilson et al., 2020) promoting a transition in the urban water management sector (Eggimann et al., 2018a, Eggimann et al., 2016). Switzerland constitutes an interesting case to study the emerging technological field due to the presence of top-notch research institutes with expertise in both conventional and modular water technologies (Hoffmann et al., 2020).

The empirical case study builds on 26 semi-structured interviews with diverse experts (companies, consultants, user organizations, researchers) engaged in the development or deployment of modular water technologies in Switzerland, and the analysis of supplementary documents, like project homepages, reports, and media coverage. The experts were asked to elaborate on the most important organizations that had been active in the field over the last decade and to assess their strategies, motivations and technology preferences. Based on these expert judgements, we identify portfolios of basic institutional logics for 57 of overall 88 organizations that were mentioned. These value portfolios were further aggregated by applying the recently proposed method of socio-technical configuration analysis (STCA)(Heiberg et al., 2022), which enables to reconstruct networks from associations of actors and values. This enables to "measure" proximities among actors in terms of value positions and to identify overarching "field logics". The proximity measure may be used to explain the presence or absence of collaboration patterns among different actor groups and their spatial reach. Furthermore, it enables revisiting characteristics of system failures, delimit geographical system boundaries, as well as identify alternative directionalities that actors might pursue in the future in modular water technology development and implementation in Switzerland.

In the following section (4.2), we will elaborate the theoretical foundations of this paper building on work on innovation system failures, institutional logics and proximities. Section 4.3 introduces the methodological approach. Section 4.4 presents the results of the Swiss case study. Section 4.5 discusses implications for system failures, system boundaries and policy implications for the Swiss case. Eventually, section 4.6 concludes drawing broader conceptual implications, elaborating limitations of the chosen approach, and proposing avenues for future research.

4.2 Considering values in technological innovation systems

One of the major reasons for implicitly assuming harmonious relationships within a TIS might stem from the fact that most of the studies were conducted in particular countries

(Markard et al., 2012) with the aim of informing national industrial policy makers (Hekkert et al., 2007). At the level of national industrial policy, interests, values and goals could be considered as rather uniform due to shared overall policy visions, industrial structures and regulations, as well as homogenous language and culture. This assumption matches with lessons from economic geography, that spatial proximity can be an important condition for innovation success generating high potentials of interaction, a specialized labor market or focused and coherent policy strategies leading to regional hotbeds of innovation like silicon valley, Terza Italia or Southern Germany (Saxenian, 1994, Malmberg and Maskell, 2002). However, scholars have early noted that in face of the increasing globalization of innovation and production, spatial proximity may not be a necessary condition for reaping systemic synergies (Carlsson et al., 2002, Bathelt et al., 2004, Saxenian, 2006).

In the following, we will revisit the harmonious view on system failures, and whether and how they coincide with a given spatial system boundary by means of the concept of institutional logics which accounts for value orientations of distinct groups of actors in innovation systems. The institutional logics approach states that value orientations do not exist as individual combinations of idiosyncratic preferences of each individual actor, but rather that values typically come in coherent configurations aligned with the requirements of specific societal realms such as the state, the organization, the market, the profession, the community or the family (Friedland and Alford, 1991). Depending on how individual actors relate to and combine these different institutional logics, collaborations can be more or less easily established also over long geographical distances or lead to system failures and resource conflicts even within countries. This sets clear limits on how national policy may support the growth and maturation of TISs.

4.2.1 An overly harmonious view on system failures

One of the core assumptions of innovation system thinking is that resources for successful innovation do not only reside at the level of individual actors, such as innovating companies. Especially, more radical innovations require competencies and resources that only emerge out of the interaction of a wide variety of actors, like companies, users, government departments, associations, media or academic research (Weber and Truffer, 2017). Compared to conventional approaches in economics or political sciences, which would side either for state or market failures to explain lacking innovation success, systemic approaches emphasize “system failures” providing more powerful explanations (Bergek et al., 2008a, Woolthuis et al., 2005, Wieczorek and Hekkert, 2012). System failures consist of deficiencies in interaction or coordination among different actors (Edquist, 2005, Lundvall, 1992 , Carlsson and Stankiewicz, 1991), mismatches between rules and regulations of the emerging technology and the established sectoral context (institutional failures), or lacking appropriate capabilities (capability failures).

Network and interaction failures may come in strong or weak form (Carlsson and Jacobsson, 1997). Weak network failures reflect that innovating actors might be insufficiently aware or each other while building up similar or complementary technological assets. This may hamper innovation success by slowing down learning and knowledge diffusion, and by missing out on potential synergies. Strong network failures, on the other hand, point to the opposite problem of existing networks overly restraining the search for new solutions, which may lead to path-dependencies and an insufficient exploration of promising alternative technological opportunities (ibid., see also Granovetter, 1973, Granovetter, 1983, Burt, 1992). Thus, there seems to be a trade-off between “not enough” and “too much” coordination of actors (Boschma, 2005). Therefore, network and interaction or – as we will call them – coordination failures were mostly understood as a lacking awareness about knowledge stocks among the key actors in an innovation system. Equally related to the knowledge dimension of innovation systems, capability failure points to a mismatch between existing expertise and the requirements of further developing a focal technology. As a consequence, policy is called to promote the exchange of knowledge through platforms, workshops and conferences. In a similar vein, institutional failures were often seen as resulting from a mismatch between the set of rules and norms that actors working on more radical innovations agree on, and those rules that prevail in established sectors, mostly favoring more incremental innovations. All told, we state that innovation system thinking has mostly assumed to portray socio-technical innovation dynamics as a battle between a homogenous set of new actors, technologies, visions and interests against an equally homogenous incumbent socio-technical system (Smith et al., 2005, Smith, 2007).

The harmonious view on innovation systems resonates well with early work on the geography of innovation, which were dominated by different forms of territorial innovation system concepts (Lundvall, 1992 , Asheim and Gertler, 2005). The core assumption of this work was that spatial proximity would enable actor collaboration due to short travel distance, or a shared cultural, educational and industrial background, it is a small step to assume that the boundary of technological innovation systems will often coincide with the jurisdictional boundaries of industrial or environmental policy making. This fact may explain why most transition research delimited their scope of analysis to specific countries or regions (Hansen and Coenen, 2015). This national focus is all the more remarkable as the founders of the TIS concept Carlsson and Stankiewicz (1991) had originally criticized the national and regional innovation system framework for taking territorial boundaries for granted and not following the networks wherever they would take the analysis (Coenen et al., 2012, Binz et al., 2014).

Boschma (2005) provided a major contribution to resolve this contradiction by arguing that spatial proximity was only one possible condition to enhance innovative collaboration and learning, especially through related knowledge, which is hard to codify and requires personal interactions and learning (Martin and Moodysson, 2013). However, cooperation may also be enabled above and beyond spatial nearness by other forms of proximity, like similar educational backgrounds (cognitive), working in a same organization (organizational), shared friendship ties (social), or similar behavioral rules and regulations (institutional proximity).

We take from this discussion, that different forms of proximities between actors may exist, which enable or impede collaboration and the emergence of systemic resources. Depending on the actual distribution of such proximities, we may determine how harmonious or conflictual a technological field is at a certain point in time and how to best delimit an innovation system in spatial and technological terms.

4.2.2 Measuring harmony and conflict from an institutional logics perspective

To arrive at a more coherent conceptual framing of these different forms of proximity, we draw on insights from organizational studies and their reception in innovation and transitions studies (Fuenfschilling and Truffer, 2014, Turner et al., 2016, Kooijman et al., 2017, Binz et al., 2016a, Yap and Truffer, 2019, Kieft et al., 2020, Yang et al., 2020, Wittmayer et al., 2021). Cognitive, organizational, social and institutional proximities can be seen as stemming from different institutional logics that actors subscribe to (Friedland and Alford, 1991, Thornton and Ocasio, 1999). Institutional logics have been defined as "the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality" (Thornton and Ocasio, 1999, p. 804). Society is seen as composed of different basic logics, which individuals or organizations draw on, and that guide their actions and rationalizations. Typical examples of these basic logics encompass i) the market logic which is aligned with the goal of profit or utility maximization; ii) the state logic defined by constitutions, regulations and law, mostly aiming for justice; iii) the family or community logic, which defines interactions based on loyalty, love, mutuality and solidarity; and iv) the logics of religion and science to, who seek to find truth (Friedland and Alford, 1991). More recent studies have also considered various professional logics that shape interactions in different professions (Thornton and Ocasio, 1999) and a sustainability or ecology logic that embraces the protection of natural resources (see e.g. Runhaar et al., 2020).

In a given technological field, actors will typically have to more or less coherently combine basic logics for being able to operate coherently. Departing from these concepts we can define "value-based proximity" by how similar two actors are in terms of the different basic logics they adhere to. Similarity and dissimilarity in terms of basic logics then indicate harmony or conflict among two actors in the field. Specific combinations of basic logics which are shared by substantial groups of actors and therefore may potentially determine the further development of the technological field can be interpreted as field logics. Depending on the power base of actors subscribing to the different field logics, collaboration and exchange among actors might be easier or competition and conflict may be prevalent (DiMaggio and Powell, 1983, Thornton and Ocasio, 1999, Fuenfschilling and Truffer, 2014). We can therefore conceptualize the “degree of harmony or conflict” in a technological field by the diversity of prevailing field logics.

These conceptual elaborations provide a theoretically grounded definition of “value-based proximities”. Actors subscribing to different field logics may find it difficult to coordinate and share knowledge or resources, due to conflicting visions of legitimate types of knowledge, preferred modes of upscaling, roles of specific actors or ways to use natural resources. For instance, Fuenfschilling and Truffer (2014)’s study identified three field logics in the Australian water sector building on earlier findings in the US publishing industry identified by Thornton and Ocasio (1999) (see table 4.1): i) Utilities and public authorities were mostly subscribing to a “hydraulic” field logic combining the basic professional engineering logic and the state logic. It proposed rather technocratic vision of achieving security of water supply through large-scale infrastructure investments like dams and pipelines, building primarily on engineering knowledge, where users were not foreseen to have an active role and nature being seen as a resource to be technically managed. Consultancies and multi-national companies adhered to a “water-market” field logic, which encompasses primarily elements of the basic market and the corporate logic. For these actors, the vision of the future sector structure mostly revolved around installing an efficient water market that would treat users as consumers and the choice of technologies would be determined by cost-benefit calculus. iii) A third group of actors, mostly environmental engineers and activists, rallied around a “water sensitive” field logic, building primarily on elements of the basic logics of community and professional engineering. They envisioned a more sustainable sector that would take environmental and societal concerns more seriously and would build on more decentralized, small-scale water recycling technologies as part of integrated water management. Knowledge generation, here, was more interactive, based on practical experiences and trial and error.

4.2.3 Harmony, conflict and directionality

Based on these characterizations of field logics, one may identify the degree of harmony (conflict) in the field by checking for how compatible or reconcilable (conflict prone) values, visions, types of knowledge and as well as the perception of users and nature are. At the level of the whole field, we may assess how much tension is likely to emerge between different actor groups in terms of these dimensions. Low conflict will be expected in a situation of one or a few distinguishable field logics, which are largely reconcilable, and which are endorsed by the most powerful actors in the field. High levels of conflict will result from fundamentally incompatible value positions, which are supported by different powerful actor coalitions. Actors with disagreements along the core value dimensions might perceive each other as competitors for resources like funding, legitimacy or public attention.

Depending on the technological preferences that are associated with the different field logics, we may furthermore identify whether conflict s over the future directionality of the field are likely to emerge and how specific policies may support the development of one trajectory at the expense of another, more (or less) sustainable one, for instance (Yap and Truffer, 2019). As a result, different actor coalitions and collaboration patterns will emerge in the field with more or less potential for creating synergies and forming a harmonious TIS. Adopting this value based view, the remediation of system failures may mean many different things. Coordination failures might primarily be due to diverging value orientations and merely offering information exchange platforms will not be effective to make actors join forces. Institutional failures might be more due to disagreements about joint rules and moral orientations within the field. And capability failures will emerge because of diverging overall goals and specific preferences relating to technologies and knowledge.

Tab. 4.1: Conflict dimensions among water sector field logics. Own table, building on Fuenfschilling & Truffer, 2014

	Core values	Vision for transforming the sector	Legitimate knowledge	Role of users	Perception of nature
Hydraulic field logic	Securtiy of supply, national welfare, social equity	Continue to produce safe and hygienic water for drinking, irrigation and energy production	Analytical & synthetic knowledge	Test persons and Trial users	Nature can be managed (technocratic view)
Water market field logic	Economic efficiency, rationalization	Transform the water sector into a water market	organizational, marketing and market knowledge	Consumers	Nature is an externality of an otherwise independent market (capitalist view)
Water sensitive field logic	Environmental sustainability, liveability	Uptake of technology through like-minded organizations or groups. Wider diffusion not necessarily the goal	Tacit/symbolic & synthetic knowledge	Adopters and innovators	All technologies need to adhere to the laws of nature (ecologist view)

Diversity and conflict might however not only be a bad thing for the development of a technological field. A field hosting a wide diversity conflictual field logics will typically enable a variety of potential development pathways. Regarding sustainability transitions, this may be important if the actual sustainability of a technology is debated and if potential rebound effects might develop. Then a premature dominant design might lock-in the technology on rather unsustainable tracks. On the other side, agreement on the directionality of a field will be important to create the critical mass for reaping economies of scale and eventually substitute incumbent technological systems. The actual directionality resulting from the interplay of different actor constellations, institutional logics and technological designs will therefore depend on how different actors can mobilize resources, how they can bridge diverse field logics, and how external pressures will support or hinder particular pathways. Our proposed approach therefore enables to address the broader question of how technological dynamics may lead to sectoral transitions without having to adopt politically naïve assumptions.

This leads us to a final set of implications for formulating policy recommendations. For national or regional policy makers, a technology field hosting strong conflicts will require a differentiated approach that goes beyond providing platforms of knowledge exchange. Actors might oppose to be forced into collaborations at the national level, because they can access critical resources more efficiently though international networks building on value-based proximities. Setting the analytical system boundaries at a national or regional level will, therefore, essentially misrepresent the core processes and structures in the TIS and the resulting policy advice will likely be inappropriate. Thus, we posit that policy recommendations will be improved if value-based proximities are considered. It enables, in particular, to assess the potential directionality of a TIS aiming at resolvinggrand challenges (Weber and Rohracher, 2012).

4.3 Methodological approach

We will proceed the empirical analysis of value-based proximities and the degree of harmony/conflict in the field of modular water technologies in Switzerland in three steps: i) setting the system boundary for collecting data, ii) conducting qualitative content analysis of the collected data regarding TIS structure, collaboration networks, technological preferences and institutional logics, and iii) applying the STCA methodology to operationalize and measure value-based proximities and the degree of harmony in the field by means of a network representation of actor-value associations.

4.3.1 System delineation and data collection

We delineate the empirical system by including all national and foreign organizations working on or collaborating in the field of modular water innovations in Switzerland. Despite the earlier stated critique of taking the national system boundary for granted, we take it as a starting point to inquire whether we can actually identify a coherent TIS within Switzerland. Following the standard procedure in TIS analyses (Bergek et al., 2008a, Hekkert, 2007), we further guide the selection of relevant organizations by the definition of the focal technology. “Modular water technologies” are defined as technologies for the treatment of separated or non-separated water and wastewater streams, which do not need to be connected to a centralized sewer system and can work off-grid. Starting from expert interviews with key researchers from the leading research institute Eawag (the Swiss Federal Institute of Aquatic Science and Technology) further experts were identified via snowballing (Bergek et al., 2008a), asking each interviewee to name their formal and informal collaborators as well as other actors they were aware of that had an influence on the potential formation of an innovation system in Switzerland. Formal collaborations are here defined as contractual collaborations within projects. Informal collaborations relate to regular informal exchanges among organizations regarding technological questions, funding, legal issues or the like. Overall data collection involved 26 interviews that were conducted with representatives of companies, consultancies, research institutes, as well as representatives of civil society organizations (see C1 for an anonymized list of interviewees). Interviews were subsequently transcribed by the first author and detailed interview notes were collected for all interviews. All data was entered into the qualitative content analysis software Nvivo12 and additional attributes for actors, projects and collaborations were collected based on desk research.

4.3.2 Qualitative content analysis: identifying system structures and value orientations of actors

The objective of the qualitative content analysis was, first, to provide a comprehensive overview over all important structural features of the emerging innovation system, that is all relevant organizations and projects, as well their evolution over time. Second, for each organization, technology preferences, as well as collaboration partners (both formal and informal) were derived from the statements of the interviewed experts. Third, statements indicating that organizations endorsed a specific basic institutional logics were coded. The coding started by deductively deriving basic logics common in industrial and technological fields form the literature (relying on Thornton and Ocasio, 1999, Fuenfschilling and Truffer, 2014), and inductively making smaller adjustments to the coding scheme according to the empirical evidence presented by the case. Basic logics were identified in the interview transcripts through expert statements about interests, goals and strategies of the identified key organizations in the field. Thus, we did not ask directly about values, but rather derived the basic logics from the narratives of the interviewed experts about specific organizations. As a result, each organization could potentially be associated with multiple basic logics. Figure 4.1 provides an exemplary representation of the coding, interpretation, and the resulting association between organization and basic institutional logic.

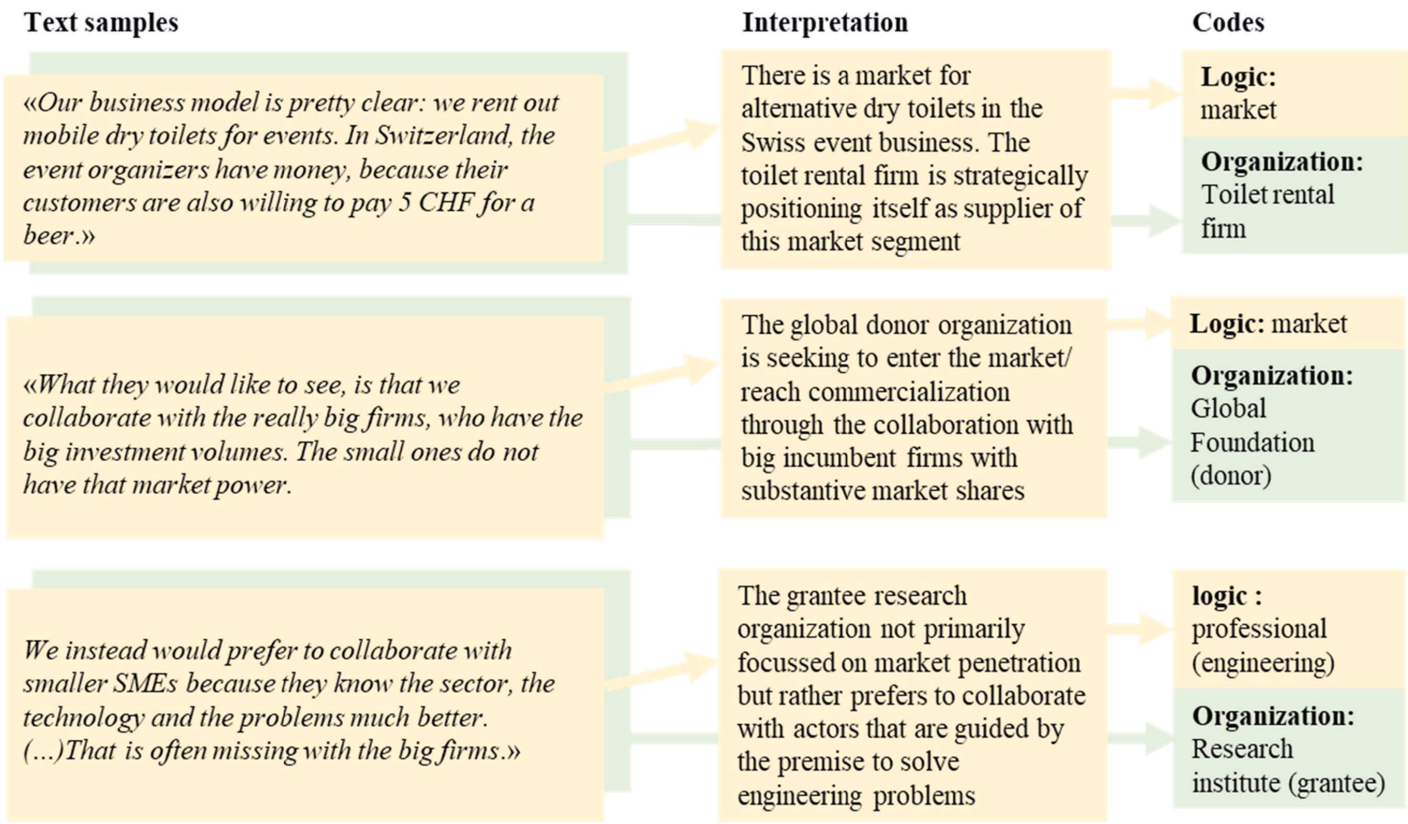


Fig. 4.1: STCA, coding process for associating different organizations with basic institutional logics.

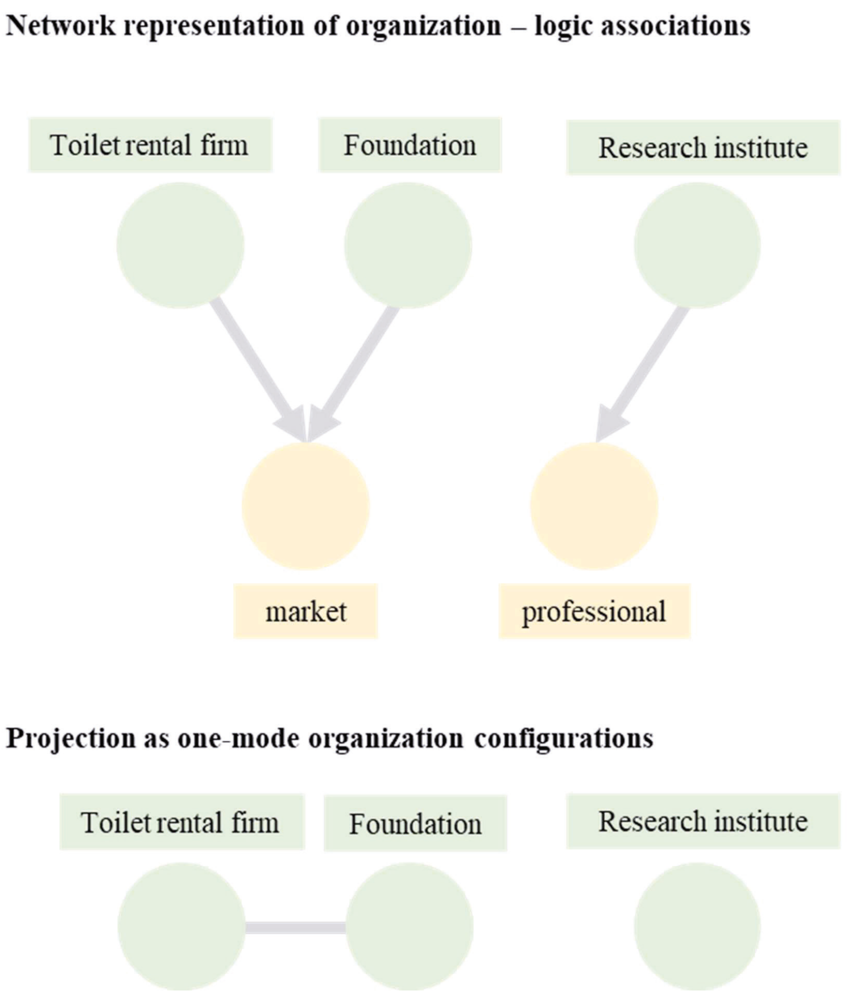


Fig. 4.2: Types of one-mode network relationships among organizations following the STCA approach. The toilet rental firm and the foundation both adhering to the market logics will result in a direct link between the two organizations in the one-.mode representation. The research institute only endorsing the professional basic logic will instead stay unconnected to the other two organizations in the one-mode network.

In order to further analyze these associations by means of social network analysis (SNA) methods, we constructed an unweighted two-mode matrix, where each row represents an organization and each column represents a basic logic. To identify value-based proximities among organizations, we transform this two- mode matrix into a "one-mode" matrix among organizations, where cells represent overlaps in terms of institutional logics (see figure 4.2 for an intuition for how the two-mode relationships can be translated into one-mode networks). Unlike more classical SNA applications (Wasserman and Faust, 1994), links between organizations do not represent jointly attended events or material collaborations, but rather the similarity in terms of portfolios of basic logics.

Similarity among actors in terms of their portfolio of endorsed basic logics may be measured by the relative overlap between their respective portfolios. A very widely adopted measure is provided by the Jaccard index (following Gower and Legendre, 1986), which is calculated as follows:

$$s = a/(a + b + c)$$
$$where\ n11 = a,\ n10 = b,\ n01 = c\ and\ n00 = d$$

n11 *(a)* represents the number of basic logics that both organizations endorse. n10 (*b*) and n01 (*c*) represent the number logics of that one of the organizations endorsed but not the other. n00 (*d*) reflects the number of basic logics that were not endorsed by either actor. Thus, the similarity measure *s* takes the value of 1 in a situation where two organizations have a complete match in their portfolio of basic logics. It will be 0 in the case where basic logics do not overlap at all. Values between 0 and 1 denote the relative overlap of the portfolios of basics logics of the two organizations. Fig. 4.3 illustrates the calculation of value based proximity for the exemplary toilet rental firm and the foundation, assuming that apart from the market logic the toilet rental firm has also been coded adhering to an ecology logic, and the foundation is additionally adhering to a legal logic. The two organizations in this example, therefore, are weakly similar as they share one basic logic but differ in terms of two other ones.

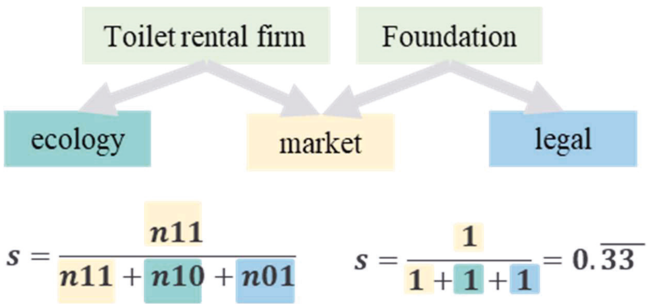


Fig. 4.3: Jaccard similarity calculation example.

The *s* values for each pair of organizations provides a measure for their bilateral value based proximity. In order to assess overarching field logics, we aggregate organizations into groups which exhibit high proximities within but differ strongly with other groups. This is a typical application case for clustering methods. Cluster identification aims at identifying coherent subgroups within a larger population by minimizing differences within clusters and maximizing differences among clusters based on a specific characteristics. In our case, the core characteristic for differentiating clusters is the similarity measure *s*. Field logics may be considered as stemming from coherent combinations of basic logics endorsed by specific actors groups sharing similar basic logics portfolios (Fuenfschilling and Truffer, 2014). Hence, applying clustering algorithms to the one-mode organization matrix will provide a bottom-up measure for field logics. More specifically, we chose the Ward's method, an agglomerative clustering algorithm, which starts from each node as a cluster and then iteratively merges organizations into higher level clusters by minimizing the squared distance of any point within a newly merged cluster from the centroid of the cluster, compared to the squared distances from the centroid of any other potential cluster merger (see Murtagh and Legendre, 2014 for its implementation in R). The procedure is repeated until all actors end up in one cluster. This iterative construction of clusters results in a hierarchical tree of alternative groupings of the field between one and N clusters (N representing the actual number of organizations). The analyst may then choose the number of clusters that provides an "optimal" differentiation in terms of minimal within and maximal across distance between the respective clusters. A simple way of judging the coherence of each cluster is by comparing overall network density with each cluster subgraphs' density. Density is defined as the "proportion of possible lines that are actually present in the graph" (Wasserman and Faust, 1994, p. 101).

Once, an optimal set of distinct field logic clusters is identified, one may proceed to characterize these groups according to the basic institutional logics that actors within the cluster endorse. Basic logics that are particularly salient in each cluster, i.e. endorsed by a high percentage of organizations within the cluster, may be used to label the cluster. In a second step, the analyst may check whether these field logics correlate with actual collaborations, technology preferences or other characteristics.

4.4 Value-based proximities in the field of Swiss modular water technologies

The empirical analysis splits up into three sub-sections. First, we reconstruct the development of the innovation system over the past 20 years, the key organizations and activities, as well as their geography and technological foci. Second, we reconstruct the major field logics based on value-based proximities among actors, and examine whether and how these logics influence actual collaborations and technology preferences of actors. Third, we will assess the major potential conflict lines and the overall degree of harmony/conflict in the field. Eventually, we will use the contextual knowledge from the interviews to reflect on historical field-level and organizational level dynamics that might shape the future directionality of the field.

4.4.1 Evolution of the technological field in Switzerland over the past two decades

In Europe, research and experimentation with modular water technologies started in the 1990s mainly in Sweden and Germany, where pioneers experimented with on-site blackwater treatment as well as dry toilets and composting of urine and feces at household and district scale (Larsen et al., 2013). In Switzerland, the modular water technology field had its inception with an early publication by Larsen and Gujer (1996) at Eawag, laying the foundations for so-called urine-separation systems separating urine and feces in the toilet, to more efficiently recycle resources like phosphorous or nitrate. After this early research phase, the emergence of the field in Switzerland can split up in three phases (Fig. 4.4).

In the “inception phase” starting around 2000, the Novaquatis project at Eawag included the first experimental-scale demonstration project of modular urine separation technologies in Switzerland. The experimental technologies were temporarily installed in three public and a private cooperative buildings. Collaborating with the two pioneering urine-separation toilet manufacturers from Sweden, BB Innovation and Wostman, as well as the German firm Roediger (Larsen and Lienert, 2007), the project helped improve the technology substantially. Lessons were learned about toilet acceptance, but the project also led to some frustration especially among the cooperative, who had to replace the toilets after a series of failures within the first two years after installation (In6). In parallel to these developments at Eawag, an architectural firm from Fribourg and another cooperative from Geneva started using dry toilets and composting technologies in an office building and a cooperative-housing block in the French-speaking, Western part of Switzerland from around 2007 (In15, In10; "Western-part" will henceforth be used to denominate the French-speaking part of Switzerland). Despite the legal obligation to connect to the sewerage system, public authorities in both cities soon found arrangements to allow for unconventional solutions to be implemented, partly because water stress in both cities is more severe than in other places in Switzerland (Interviews In15, In10).

In the second, the "internationalization phase", starting around 2009, the Seattle-based Bill and Melinda Gates Foundation (BMGF), a powerful, globally-active donor organization entered the Swiss modular water field. It provided major resources in terms of funding various technology development projects at Eawag and other Swiss research institutes in the context of their "Reinvented toilet" challenge. But it also set clear boundary conditions on the kind of systems to be researched on (Interviews In5, In21, In16). Rooted in its strong corporate culture based in software engineering (Schurman, 2018), the BMGF approached its core grantee, Eawag, with a clear framing to solve the problem through a high-tech pathway (for example fully integrated systems based on supercritical water oxidation), challenging Eawag's civil engineering based culture of developing urine separation toilets and separate urine treatment. The application case was set to situations with a lack of access to safe water, sanitation and electricity in the global south. Other grantees or collaborating institutions during this phase included the universities of applied sciences (FHNW), a former nuclear research institute (PSI), as well as Swiss multinational chemical firms (Firmenich), all of which are based in German-speaking part of Switzerland (Interviews In21, In16, In3). Collaborations within BMGF projects was very internationally oriented, often involving the establishment of sounding boards including Swiss and foreign technology firms, which were expected to commercialize the technologies at some point, in the future (Interviews In21, In16, In5, In20, In3).

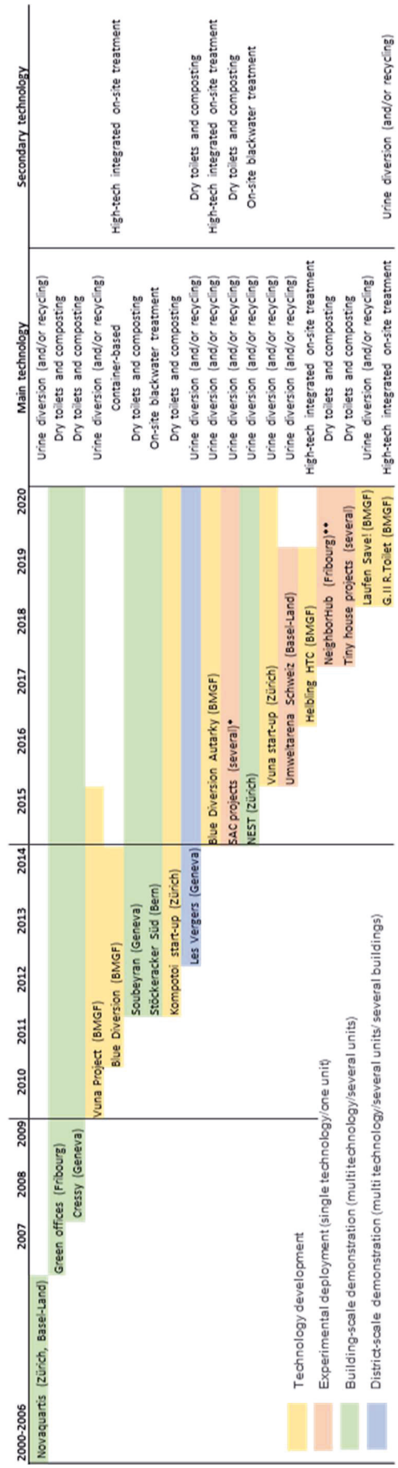


Fig. 4.4: Timeline of major projects in the Swiss innovation system.

In parallel to these developments around the BMGF, the Western-Swiss cooperative Equilibre developed two more demonstration sites in Geneva implementing comparatively low-tech, dry toilet and composting systems (Interviews In10, In7, In24). In contrast, implementation attempts of similar technologies by cooperatives in the German-speaking part largely failed due to technological challenges as well because of a lack of capabilities and push back from public authorities and utilities (Interviews In6, In9, In7). As an exception, Kompotoi, a start-up renting out mobile dry toilets for events was founded in Zürich, and the city of Bern started developing a district with a more advanced on-site blackwater treatment system (Interviews In2, In8, In26). These developments were mostly driven by different actors lacking any serious connection.

This, however, started changing gradually in the "consolidation phase" starting from around 2014. BMGF accepted to embrace urine diversion in their funding strategy (Interview In21, In16). One of the BMGF-funded projects at Eawag led to a spin-off (Vuna) in 2015, to commercialize urine recycling technology. Another BMGF-funded collaboration between Laufen Bathrooms and Austrian design firm EOOS led to the commercialization of a design-improved urine-diversion toilet in 2018 (Interviews In5, In25). BMGF funded projects were increasingly diversifying their technological focus by embracing the urine-diversion technology, which proved an interface technology compatible with both low and high-tech configurations. Urine diversion was also taken up by the Geneva cooperative by implementing the Laufen toilet in their latest development projects. More recently, a newly founded cooperative (La Bistoquette) took-up these ideas and started a spin-off to further commercialize composting, dry toilet and urine-diversion technologies (Interviews In10, In7, In24). In parallel, the Fribourg-based public-private partnership utility SINEF decided to develop a whole district using modular water technologies (Interview In15), including both low- and high-tech solutions. While collaborations of these projects in the Western part of Switzerland were more localized than in the BMGF networks, early pioneers had strong linkages to dry toilet pioneers in France (Interview In10, In7). In recent years, informal collaborations between actors from the French and the German speaking parts of Switzerland was facilitated by the establishment of a technology test platform, the "NEST", at Eawag starting in 2015 (Interviews In12, In10), and by Vuna's activities in market segments like mountain huts all over the country (Interviews In22, In12). Thus, we see a complex geography unfolding in the technological field, with a mix of regional, national and global actors, relationships and activities. Whether this technological field increasingly developed into a nationally delimited TIS, however remains an open question.

4.4.2 Identifying field logics through value-based proximity

Through the interviews, we identified 118 organizations that either directly engaged in modular water technology projects or were mentioned as collaborators regarding the development or deployment of modular water technologies. 60% of all identified organizations (71) originate from Switzerland, 40% from abroad (47). The left hand graph in figure 4.5 shows the one-mode actor network based on the Jaccard-normalized relations among the subset of 57 organizations[9] for which our interviews provided sufficient evidence for the basic logics that have guided actors' engagement in modular water technology projects. The graph layout is a stress minimization algorithm (Multi-Dimensional Scaling) that places those organization nodes closer to one another, that share a higher value-based proximity (see Brandes and Pich, 2009 for the layout method). To strengthen the visual interpretation, we chose to set the link width proportional to the jaccard similarity between two organizations. Based on these data, the Ward clustering identified three groups with similar value dispositions: cluster *A* consisting of 18 organizations, cluster *B* of 19 and cluster *C* of 20. *A* and *C* show a larger subgraph density (>0.900) than the overall network (0.568). *B* is more densely connected than the overall network but only marginally (0.617). So, *A* and *C* are more coherent in terms of sharing at least one basic logics, whereas *B* is less clearly distinguishable.[10]

[9] Including all important organizations involved in the projects in figure 4.3

[10] We also explored the cluster tree at higher cut-off values to better understand the diversity within the clusters. At a value of 8, we find that the professional cluster splits up into clusters of different professions (engineering, architecture, design), the socio-ecological logic cluster splits into two subgroups of pure ecology and ecology-engineering. For simplicities sake, we finally decided to restrict the presentation to three groups and allowed for heterogeneity where it seemed suitable (like among different professions).

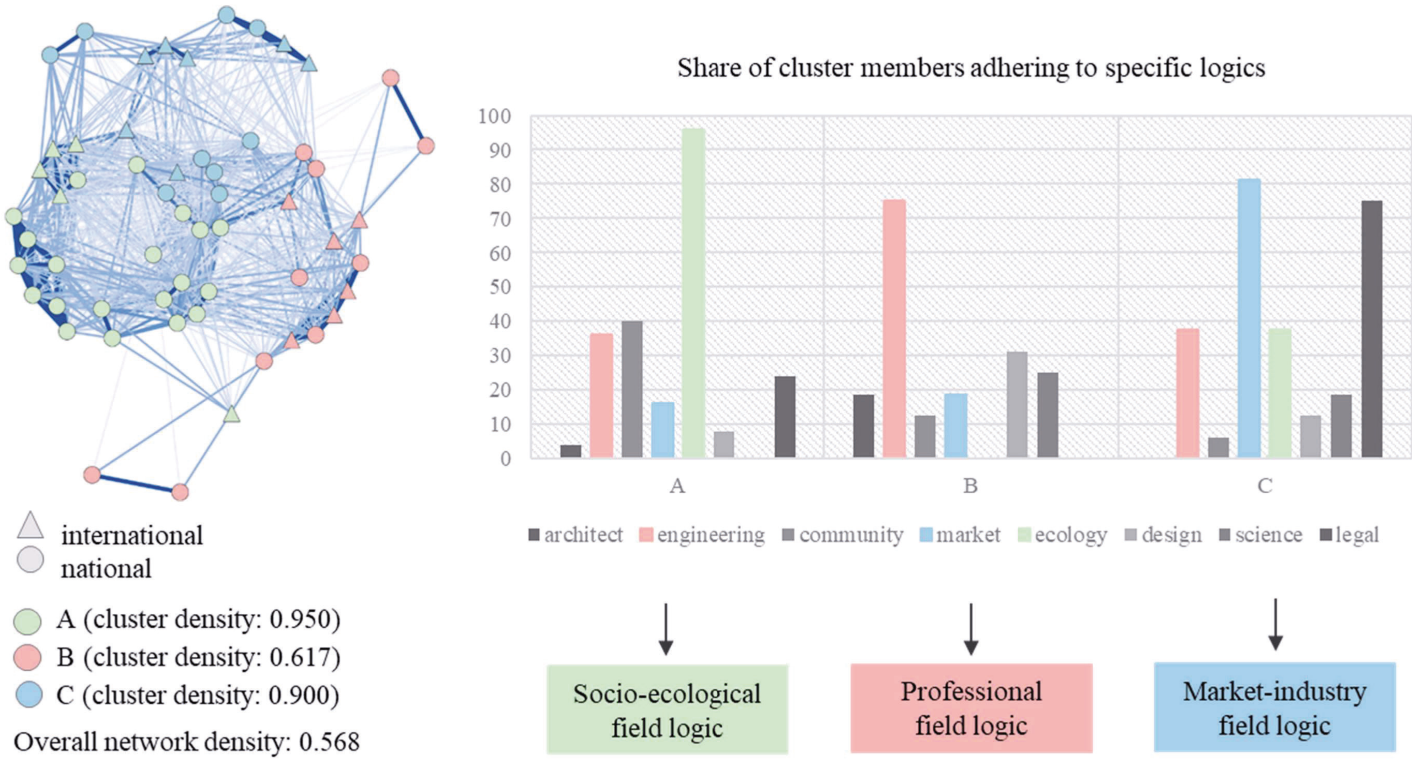


Fig. 4.5: Network graph of institutional proximity, modularity cluster, and within cluster composition of institutional sector logics.

Analyzing the distribution of basic logics in each of these clusters in terms of the share of cluster members that follows specific basic logics (see bar chart at the right hand of Figure 4.5), enables to identify three aggregated field logics. Cluster A seems to be dominated by organizations following what we would call a **socio-ecological** field logic, dominated by the ecology logic but also comprising smaller elements of the professional engineering, legal and community logic. Cluster B may be characterized by a semi-coherent **professional** field logic dominated by the logic of professional engineering but also encompassing architect, designer, academic, and community logics. Cluster C represents a field logic dominated by elements of the market logic and the legal logic which reflects actors' involvement in a global industrial ISO-standardization process. We may therefor speak of a **market-industry** field logic**.** Both the network topology and the clustering algorithm identify rather clearly distinct groups of actors, which depict rather homogenous internal profiles in terms of basic logics. Furthermore, from the network graph, a rather clear center-periphery structure emerges with a center populated by actors following a broad range of basic logics, whereas most of the actors are located in rather peripheral realms of the graph, indicating adherence to more specific basic logics.

4.4.3 How value orientations shape collaboration patterns and technology preferences

In order to assess whether value-based proximities shape preferences for collaborations among actors, we have to analyze the actual collaboration networks. The network graph in figure 4.6 shows the formal and informal collaborations of 88 organizations that we identified through the interviews, including the 53 organizations, which we analyzed in the previous part. To more solidly ground the interpretations of the visual patterns, we derived different network statistics based on three guiding questions around coordination failures, the degree of harmony and conflict, as well as the role of geography.

First, we want to understand the propensity of collaboration of actors within specific field logics, assuming that the higher the collaborations, the more interested in (or dependent on) the existence of system level resources these actors are. The assumption is that the higher the average number of collaborations of each actor in the network, the lower the probability that we will find coordination failures. The second question asks whether adherence to a specific field logic limits the ability to collaborate with actors holding different value positions. Here, we assume that the more open actors are for collaborations across field logics, the lower the potential degree of value conflicts and hence the more harmonious the innovation system. And third, we want to know how strongly value-based and spatial proximities are correlated, and what implications this has for drawing appropriate system boundaries.

To answer these questions we will report the following network statistics (I1-I5) derived for the whole network and the different sub-networks of field logic clusters. For answering the first question, we report the indicator of the "average degree" (I1) of organizations in each field logic cluster. It counts how many collaborations each organization in a given field logic cluster has on average. To answer the second question, we introduce two complementary indicators. One measures the intensity of collaborations among organizations of the same field logic, compared to the intensity of the technological field as a whole. We use the statistics of "network density" (I2) within each field logic related subgraph for this purpose. The opposite indicator reports on how frequently organizations of a specific field logic collaborate with organizations form other field logics. This is expressed as a percentage share of these collaborations compared to all collaborations in the whole field (I3). Regarding the third question, we apply one indicator to measure the propensity of organizations from a given field logic to collaborate with international partners. It is given as a percentage share of connections of organizations from a specific logic to organizations from outside their home country compared to all collaborations (I4). The second indicator reports cross-regional collaborations inside Switzerland as a percentage share of collaborations of Swiss organizations that are crossing the "Rösti-trench"[11] compared to all collaborations within Switzerland.

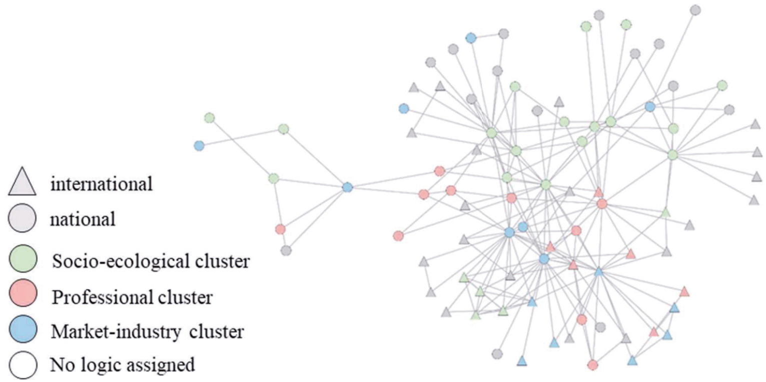
With these statistical indicators, we may now answer the three questions. The average degree indicator shows that members of the market-industry and socio-ecological field

[11] The Rösti-trench is a popular denomination of the cultural differences between the German and French speaking parts of Switzerland, called after the German name for the signature dish of hash browns, which is more popular in the German than in the French speaking parts.

logic tend to have more collaborators (>6) than members of the professional field logic (~4). This might indicate that organizations adhering to the professional field logic have more potential to find synergies with other organizations. Regarding the openness of organizations adhering to different field logics, higher density scores of the market-industry cluster and the socio-ecological cluster may imply that these two cluster are more inward oriented and that value-based proximities play a more important role (0.152 for both). Members of the professional field logic cluster (0.117) instead seem to be more open and able to connect to different value positions. As emerges from the qualitative material, the market-industry field logic was strongly reinforced through the engagement of the BMGF, which encouraged collaborations between Swiss grantees and firm actors in order to commercialize modular technologies through particular terms of reference in the funding scheme (Interviews In21, In16, In18). Members of the socio-ecological cluster started out as rather inward looking local initiatives mostly in the western part of the country. More recently, however, they started to reach out more proactively beyond their project contexts, even envisioning the foundation of a national association (Interview In24). A second indicator for the openness of the field logics relates to trans-logic collaborations. It shows that within field logics collaborations are much more common among the socio-ecological cluster than for the other two. The socio-ecological field logic cluster only entertains 22 % collaborations with other field logic members. This is substantially lower than for the professional (55 %) and the market-industry cluster (77 %). Thus, the socio-ecological field logic seems to be most inward oriented, while the organizations from a market-industry logic entertain a more open approach, however, under very clear conditions regarding the enforcement of the market logic. The engineering cluster, too, is more versatile and potentially able to bridge different value orientations.

Finally, assessing the geographical reach of collaborations indicates that members of the market-industry (50%) as well as the professional cluster (47 %) are strongly internationally oriented, whereas the socio-ecological cluster members show clearly a more local orientation (17 %). Again, this can be explained by the origins of both organization configurations. The BMGF with its international network, is a prominent initiator of the market-industry field logic. Instead, international collaborations among the socio-ecological and professional cluster members are less frequent. Notable exceptions are the participation of companies like Kompotoi and Vuna in the French and German industry association for off-grid sanitation (Interviews In2, In22). The latter company also frequently collaborates with French companies. The Western Swiss cooperative- and public authority-driven movements, instead, had privileged local and regional collaborations in the beginning (Interview In10, In24, In15). More recently, the socio-ecological field logic members have started to engage more actively in national-scale networks (38 % vs. < 7 %), as also the cross-Rösti-trench collaboration indicator illustrates. Especially, the Geneva cooperatives Equilibre and La Bistoquette have become active in promoting their ideas in the German-speaking part (Interview In10, In24, In9, In7) but also Vuna, and more recently Eawag have engaged in cross-regional networking (In22, In10, In12, In9)

We may now ask whether and how the value-based proximities and the identified field logics have implications on the likely direction of innovation activities different organizations prefer. The bar chart to the right of figure 5 summarizes the preferences for specific technological designs among the field logics groups. It clearly shows, in line with the low-tech vs. high-tech divide elaborated above, that low-tech solutions are more prevalent among proponents of the socio-ecological field logic, whereas high-tech is only important among the market-industry configuration members. In contrast, urine diversion technologies that were recently picked up both by socio-ecologists in the Western part and by the BMGF are supported across all logic clusters.



	n	Average degree	Density	Trans-logic collaboration	Trans-national collaboration	Trans-regional collaboration
overall	88	4.41	0.051	66.97	40.37	19.81
professional	19	**4.05**	**0.117**	54.84	47.17	6.67
market-legal	15	**6.87**	**0.152**	**76.67**	**50.00**	**5.88**
socio-ecological	24	6.31	**0.152**	**22.22**	**16.98**	**38.24**

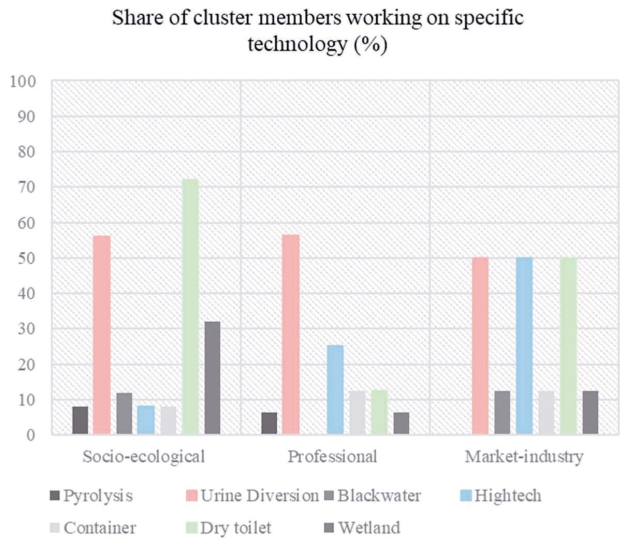


Fig. 4.6: Analysis of collaboration networks and technological foci at the level of cluster members.

4.4.4 Assessing the impact of harmony/conflict in the field on future development trajectories

Mapping out these topologies of value positions among groups of organizations might be largely inconsequential if they just represent different motivations, rationales and mobilizing visions that guide a diversity of organiaztions to contribute to a shared overarching goal, namely the development of a new technology. The socio-technical systems literature has shown time and again how relevant such complementary resource stocks are for further developing a new technological system. The key question is, however, how we may assess the actual degree of harmony among these different groups of organizations and whether substantial conflicts emerge when organizations attempt to collaborate across different institutional logics. Hence, we will proceed to a systematic analysis of potential value based conflict lines building on the theoretical assumptions presented in section 4.2, table 4.1. Tab. 4.2 summarizes these for the Swiss technological field.

Most fundamentally, members of different field logics share different visions of the end-state of technological development and typically also different appropriate ways of upscaling modular water technologies. Members of the socio-ecological cluster, for instance, reject the capitalist growth orientation of market-industry cluster: "*They are not my friends (…). What is their motivation? It's advertisement, product placement, finance and most of all, sales" (*engineering consultant belonging to socio-ecological cluster). They are also wary of large multi-nationals who could steal and capitalize on their inventions: *"Folks sorry, but we do not really want to share with you what were are doing (…) We don't want to share all our secrets with you so you can make a patent, for which we will have to pay in the end"* (cooperative member belonging to socio-ecological cluster). Members of the market-industry logic, in turn, criticize the grassroots oriented innovators from the socio-ecological cluster for being too risk-and marketing-averse: "*I do not see anything happening. Nothing. (…) Someone would have to invest in this, put it into a box, which you can put in your basement.* (Engineering consultant from an MNC belonging to the market-industry cluster).

Tab 4.2: Conflict dimensions among Swiss modular water field logics. Own figure

	Core values	Vision for upscaling	Legitimate knowledge	Role of users	Perception of nature
Professional field logic	Scientific method, security of supply and health	Scientific discovery, demonstration and teaching at universities	Scientific knowledge	Passive adopters	Technocratic
Market-legal field logic	Economic efficiency, rationalization	Risk investment by large players and increasing consumer demand	Design, market, scientific knowledge	Consumers	Capitalist
Socio-ecological Field logic	Environmental sustainability, liveability	Word-of-mouth propaganda and interactions among friends and other grassroots initiatives	Practical/ synthetic, symbolic knowledge	Active adopters, innovators, producers	Ecological

Conflicts among the professional and the socio-ecological cluster are most clearly identified through mismatches in the knowledge dimension: While the academic engineers from the professional cluster follow a strictly analytical knowledge base focused on scientific publications and lab-based prototypes, members of the ecological field logic engage much more strongly in an interactive mode of innovation rooted in practical experiences and trial and error experiments, leading an applied research biologist from the socio-ecological cluster to suggest: "*I think we have never had collaborations. (…) The worlds are really rather different. (…) They are all about science and publications. Why would they be interested in our [applied] work here?"* when talking about a major research institute in the field. In turn, members of the professional cluster and the socio-ecological cluster are united in their critique of the market-industry field logic in reducing users to mere consumers, which according to their critique won't work when diffusing modular technologies to global south countries: "*if someone comes and asks: «how can I implement this in my village in the global south?» All you need to give him is know-how! And not sell him some product. (…) You do not need to produce something high-tech "(socio-ecological cluster entrepreneur).* This also reflects the discrepancies in terms of high versus low-tech solutions, as well as modes of knowledge generation. Eventually, these statements further reflect different philosophical stances to nature, which are far from being easily compatible: a technocratic (technology-fix) view among the professional cluster members, an externality or marketing problem among the market-industry cluster members, and an ecologist view among the socio-ecological cluster members.

4.4.5 Field level and organizational dynamics

While the present study represents merely a snap-shot of the most recent constellations of actor constellations and field logics, the content analysis of the interview transcripts further provides insights on potential development trends in the field. In terms of the technology portfolio, certain technological components might be able to bridge between alternative trajectories, as the case of the Laufen Save! urine diversion toilet shows. Only after the Eawag engineers started to collaborate with the design company EOOS in order to propose a much improved toilet design, BMGF endorsed the commercial potential of the urine diversion path and started to co-fund urine related research, due to its compatibility with high-tech back-end treatment (Interviews In20, In21, In16). It subsequently also became an attractive option for the ecology-oriented actors due to its compatibility with the "low-tech" back-end of composting fecal matter (Interviews In4, In5, In2, In10, In24). This enabled the more professional-logic oriented actors to increasingly mediate between the opposing camps of the market-industry and socio-ecological field logic.

Also actors may change positions in the field. We had already identified that some actors are positioned more in the center of the value-based networks, while others are positioned at the peripheries. Circles in Fig. 4.7 encompass organizations that subscribe to the three basic logics of ecology (green), market (blue) and professional engineering (red). Overlap areas depict exactly those organizations that combine two or even all three of these basic logics.[12] The central realm where all circles overlap identifies those organizations that could potentially serve as intermediaries in the field because they endorse all three basic logics that are instrumental in charactering the overarching field logics. Drawing on individual history of core organizations, we retraced their repositioning in terms of adherence to different logics in the field (see Fig. 4.7).

Equilibre moved from a pure ecological value base to increasingly embracing engineering principles in their three housing projects in Geneva. La Bistoquette started under similar conditions but then further moved towards a market logic when initiating a consultancy business based on the experiences already collected in Geneva. Vuna, the Eawag spin-off from a BMGF funded research project, moved away from a strong professional engineering value base to increasingly embrace elements of an ecology logic. The engineering research department at Eawag learned to increasingly adapt to the market-logic imposed by the BMGF funding terms. Later, they organized several workshops and involved ecology oriented planning consultants into their research projects.

[12] Actually only one actor does not comply with this general rule. It is the Zürich municipal waste cooperation (ERZ) that is positioned in the overlap area a but actually combines a legal and a professional engineering logic.

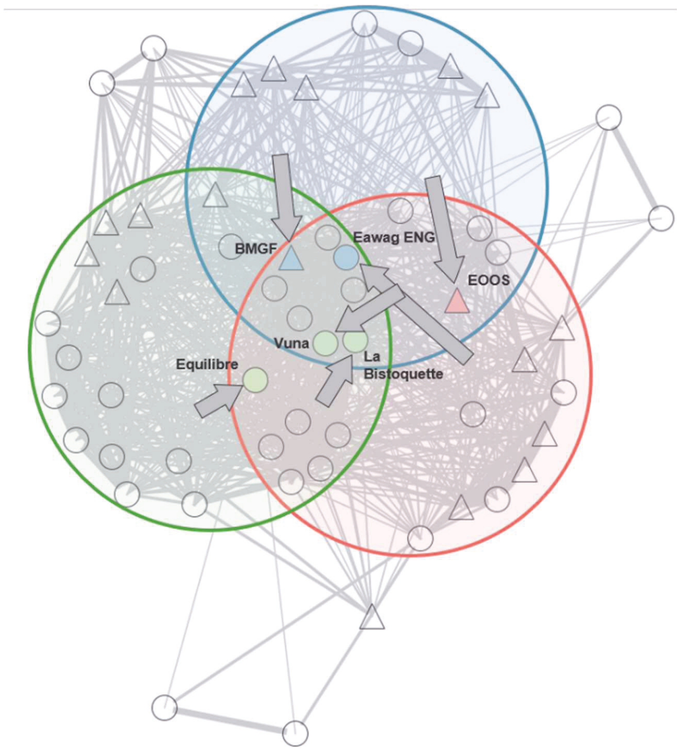


Fig. 4.7: Field level repositioning. Red circle: organizations following basic logic of professional engineering, green circle: organizations following basic logic of ecology, blue circle: organizations following basic logic of market. Node colors of highlighted nodes: field logic cluster membership. Arrows indicate moves of actors in the value field during the time of analysis.

The major funder of recent initiatives, the BMGF started out from a very strong market logic, based on the corporate culture of managing innovations as software engineers. They approached the toilet business and wastewater engineering by primarily adding a philanthropy perspective to their usual market based approach. But ultimately, they agreed to endorse more and more elements of the professional engineering logic. Finally, EOOS, a product-design firm increasingly oriented itself to achieving socio-ecological goals in development contexts.

These exemplary re-positioning processes of individual organizations show that some consolidation and bridging activities took place in the technological field. Nevertheless, value-based conflict lines still persist and it remains open, which of the logics and directionalities will prevail in the near future, and which form of modular water system will eventually contribute to a sustainability transition of the urban water management sector.

4.5 Discussion

What implications can be derived from the empirical analysis of value orientations in the Swiss modular water technology field in terms of system failures, system boundaries and directionality? Will it develop towards a well-aligned national TIS or will it splinter up into diverse initiatives where actors establish collaborations and mobilize resources mostly following field logics, regionally or outside the national borders? The analysis of the Swiss modular water technology field illustrates that the implicit assumption of harmonious relationships inside the national container does not necessarily hold (Coenen, 2015). The different value-based proximities may give rise to manifold conflicts among actors, which might enable novel development trajectories but also stand in the way of further consolidating a "Swiss" TIS . This has implications for how to frame system failures, how to set adequate geographical system boundaries, and ultimately, for how to assess potential directionality failures.

The analysis of value-based proximities among the actors in the Swiss field shows that value considerations had strong impacts on how actors engage in collaborative activities, what kind of technological development pathways they prefer, how they perceive the role of end-users and even what kind of knowledge they consider legitimate. This leads to fundamental challenges in terms of agreeing on rules, norms and visions across actor groups in a future nationally bounded TIS. At least initially, the different proponents of modular technologies followed rather diverse technological avenues depending on the field logic they adhered to (low-tech dry toilets vs. high-tech fully integrated systems). This limited interactions and synergies among each other. The field is therefore confronted with very tricky questions of directionality. Depending on whether these different interests can be overcome, the field may either develop into a well-aligned TIS or the field will splinter into irreconcilable promotional factions.

In terms of geographical system boundaries, the Swiss technology field is constituted by complex geographies. We had witnessed a high diversity of sub-national activities, following cultural fault lines (the Rösti-trench!) and depending on very local agency to generate early innovation activities. Developments started to get a bit coordinated at the national level only since a couple of years and were not the result of a coordinated strategic plan but rather based on accidental encounters and opportunities. At the same time, we saw that transnational actors, networks and resource flows played a key role in the formation of innovation networks and processes and that the different actor groups still entertain and even extend their own transnational co-operations. Hence, it is hard to conclude whether a real "Swiss TIS" is emerging or whether the national context only represents one among many contexts for occasional encounters and for raising specific resources. Beyond todays value orientation patterns, much is likely to depend on the direction in which intermediary organizations are strategically positioning themselves, on technological developments, and on agency through which the various organizations involved may attempt to alter the institutional structure of the field

This has further implications for guidance and directionality of the emergent field. National industrial policy-making needs to consider the different field logics that co-exist in field, or it will run the risks of enforcing collaborations among actors against their proper values and interests. Furthermore, the different logics clusters may defend fundamentally different transition pathways, which may lead to what Weber and Rohracher (2012) have called "directionality failures" of policy. In the Swiss case, we see at least two opposing trajectories: one policy option might be to support comparatively low-tech, dry toilet and brown water treatment solutions, which might benefit from a strengthening of localized actor networks. A challenge of this avenue will be to accommodate for the value-based conflicts, which might occur when pushing towards market-based diffusion of the new solutions. A second policy trajectory might be to support high-tech modular technologies, which would require national policy makers to engage with potent multi-national companies and global actors like the BMGF. A major risk of this path is certainly the lack of social and institutional embedding of these technologies in Switzerland. Rather than solving local water and resource issues, policy would then potentially be perceived as supporting industry formation for global markets and thus spending tax-payers' money for non-local benefits.

4.6 Conclusion

We started this paper by diagnosing a flagrant neglect of actors' value positions in the innovation system literature and stated that the scholarly field is suffering from an implicit harmony fallacy. We showed the shortcomings emerging from this neglect related to several core analytical tasks in empirical TIS analyses: i) a possible misrepresentation of system failures, ii) a potential misidentification of an appropriate system boundary, either in technological or in spatial terms, and iii) a potentially misleading formulation of policy recommendations related to the directionality of the system. With the development of a value-based proximity measure, we were able to identify actor groups holding similar value orientations, which we identified as field logics, and which coincide with distinct technology preferences, visions and conceptions of users and nature. This structuring enabled the identification of potential value-based conflict lines and by this to assess the degree of harmony or conflict in a technological field.

The general implications of this approach relate first to how system failures have to be conceptualized when addressing value positions explicitly. The most obvious extension is that coordination failures will not be limited to overcoming problems of ignorance of other actors' knowledge stocks or a lack of resources. Value considerations, mismatches in goals and visions, or differences in preferred development trajectories might seriously impact the willingness of actors to cooperate. Conventional approaches to overcoming coordination failures through organizing joint workshops, conferences or matchmaking may therefore fail because more basic agreements about more fundamental questions cannot be achieved. This might even impact capability failures, because typically actors following different logics also differ in the specific types of expertise they deem relevant for solving the original problem. And finally, institutional failures may also occur among the TIS actors if they cannot agree on shared visions, standards and ways to proceed, which will hamper their ability to build up systemic resources or access resources from "outside" the TIS in the form of government funding, legitimacy in public discourses, or user acceptance (Bergek et al., 2015). Ultimately, these failures are intimately connected to differences about the preferred directionality of the field and might prevent it from developing into a proper innovation system.

A second major conclusion relates to how system boundaries should be set, which is one of the key methodological steps of any TIS analysis (Bergek et al., 2008a). As elaborated above, differences in value positions may give rise to fundamentally different technological trajectories. If joint system resources cannot be built up within a given region or country, actors are likely to mobilize them from outside (Binz and Truffer, 2017). This may lead to a situation, where different TISs coexist in a specific region with little interaction among each other. We saw such a situation between the French- and the German- speaking parts of Switzerland, which exhibited strongly diverging technologies, visions and knowledge strategies, at least in the beginning. The different actor groups might then still aim at building up TIS structures. But they will primarily have to look for them outside their home country or region. Setting the system boundaries in technological and spatial terms therefore becomes a key question where value positions have to be considered (van Welie et al., 2019) .

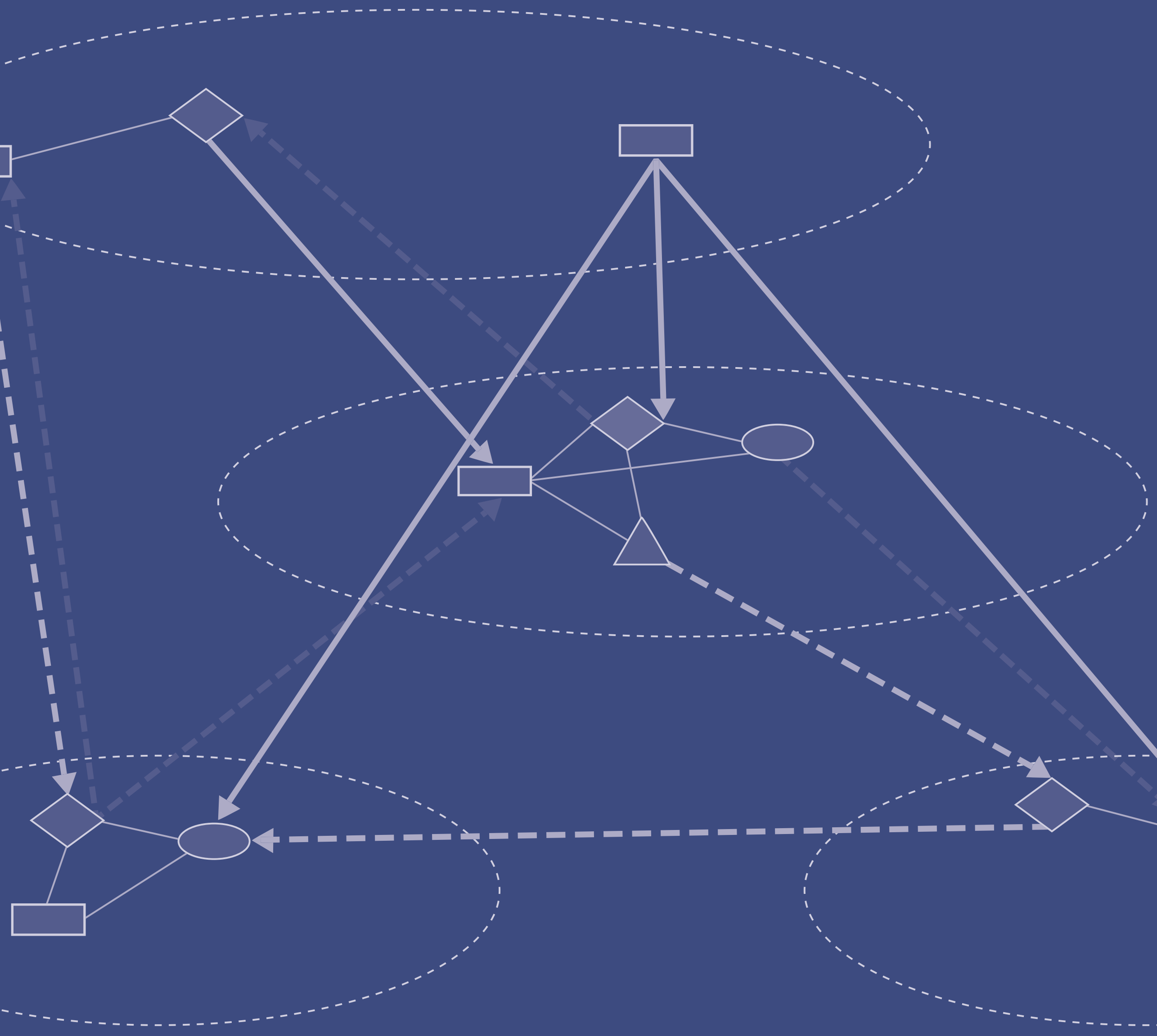
In a sense, we re-iterate insights that were already provided by Boschma's (2005) proximity framework. However, we maintain that be defining value-based proximities by means of different field logics, we are able to arrive at providing an conceptual base for Boschma's non-spatial proximities, which represent a rather intuitively plausible list : organizational proximities typically coincide with the basic logic of the organizational hierarchy, social proximity can easily be seen as some form of community or family logic, and finally, Boschma's "institutional proximity" coincides very much with specific state or legal logics. By means of the field logics concept, we are furthermore able to provide further arguments on how certain combinations of basic logics may enable or impede collaboration and exchange. The question of how spatial proximity relates to all these forms of value-based proximities remains largely an empirical question. Spatial proximity will be strong, if many of the field logics based proximities overlap in a territory without generating too strong conflicts.

Third and finally, all these considerations have implications on what policy makers can do to promote innovation success, especially in terms of how they will contribute to the tackling grand challenges. This is the problem that Weber and Rohracher (2012) identified as the “directionality failure” in transformative policy making, or what Schot and Steinmueller (2018) see as the core of the third generation of innovation policies. Considering value-based proximities therefore promises to better connect innovation system research to socio-technical transition processes and therefore increases the synergies between different sustainability transitions frameworks (Markard and Truffer, 2008).

Of course, the empirical, methodological and conceptual approach presented in this paper has various limitations. Empirically, the case of an early technology field on modular water technologies in Switzerland, was suitable for our analysis due the prevailing uncertainties about a dominant technological design and associated battles around directionality. However, future research will have to explore how value-orientations affect the course of more mature technological fields or already established TISs, and in other empirical sectors. Methodologically, applying STCA on a set of expert interviews proved to be suitable approach due to the limited size of the field, which allowed covering the whole field through a manageable interview campaign. This approach, however, might not be feasible when studying value-based proximities in larger fields. Here, researchers may want to draw on other textual databases as an input to derive organization-logic associations, such as media articles (Heiberg et al., 2022). Either way, the qualitative assignment of institutional logics to different organizations in a field remains a challenge and needs further be systematized.

One aspect that this study could only touch upon, was that the deeper dynamics and in particular the processes of value creation could not be addressed. Elucidating value-based proximities at different points in time might further enable to bridge between innovation studies and valuation studies (Boltanski and Thévenot, 2006, Thévenot et al., 2000). The latter has a long tradition in studying different orders of worth, i.e. modes of evaluation which actor draw on in justifying their actions, which strongly resonates with the institutional logics perspective applied in this work. This implies a move from focusing on the development and diffusion of technology towards the co-creation of values in addressing grand challenges (Huguenin and Jeannerat, 2017). Future investigations might therefor bridge over to valuation studies by studying value-based proximities of actors in a field at different points in time.

Despite these limitations, we see the presented approach as very promising for informing future transitions research not the least also because of the chosen methodological approach. Analyzing socio-technical alignments and field structures by means of network topologies enables to better understand the alignments but also misalignments that may emerge among system elements. This type of analysis coincides very naturally with configurational theorizing, which is mandatory in innovation and socio-technical systems research (Furnari et al., 2020, Weber and Truffer, 2017).



Chapter 5

The emergence of a global innovation system

A case study from the water sector

Abstract

Innovation studies is increasingly acknowledging the multi-scalar nature of the systemic contexts, in which innovations are being developed and deployed. This paper builds on and further develops a recently proposed framework for studying global innovation systems (GIS). It aims at explaining the emergence of a GIS by outlining the specific local resource-related conditions that lead to the creation of structural couplings, i.e. actors, networks and institutions that allow for multi-scalar resource flows. Deploying a qualitative case study, the paper investigates eight demonstration sites for an innovative wastewater treatment technology in North-Western Europe. It shows how resource-related deficits lead actors to draw on resources generated outside of their local context. The paper contributes to the literature on the Geography of Transitions by highlighting the importance of resource complementarities among different local contexts, as well as the crucial role of translocal systemic intermediaries in shaping emergent GIS.

5.1 Introduction

The globalization of innovation activities is one of the well-established facts in innovation studies of the past decades (Archibugi et al., 1999, Carlsson et al., 2002, Carlsson, 2006). Especially in the quest for tackling grand societal challenges, like climate change, urbanization, inequality and migration, harnessing resources from translocal networks will be important for innovation success (Coenen et al., 2012, Truffer and Coenen, 2012). Accordingly, innovation- and transition studies have increasingly recognized that socio-technical transformation processes are not limited by the boundaries of specific countries, but often span across places and even scales (Carlsson and Stankiewicz, 1991, Oinas and Malecki, 2002, Coenen et al., 2012, Dewald and Fromhold-Eisebith, 2015, Gosens et al., 2015, Sengers and Raven, 2015, Fuenfschilling and Binz, 2018). The dominant approach in transition studies to understand emerging clean tech industries – the framework of technological innovation system (TIS), however, had a strong if not implicit focus on national system boundaries (Bergek et al., 2008a), which got increasingly problematized in recent years (Bergek et al. 2015; Coenen et al. 2012). Scholars started to reformulate the framework to embrace multi-scalar or even global structures in socio-technical innovation dynamics (Binz et al., 2014, Wieczorek et al., 2015, Sengers and Raven, 2015, Binz and Truffer, 2017). Binz and Truffer (2017) argued that in order to conceptualize multi-scalar or even "global" innovation systems (GIS) two assumptions had to be introduced. First, systemic synergies in the built-up of resources could emerge among bundles of actor networks or institutions in particular spatial contexts (cities, regions or countries), which constitute partial subsystems. Second, for an overall (global or multi-scalar) innovation system to function properly, these place-bound resource formation processes have to be "structurally coupled", i.e. specific actors, networks or institutions (Binz & Truffer, 2017, p. 1285) have to enable the flow of these resources between the relevant subsystems (henceforth related to as "structural couplings"). Innovation processes within or across such subsystems are assumed to contribute to the generation of four key resources, according to Binz and Truffer (2017): knowledge, legitimacy, market structures and financial capital.

While research in economic geography has a long tradition in explaining how spatial or other proximities matter in the diffusion of different types of knowledge for innovation processes (Bathelt et al., 2004, Martin and Moodysson, 2013, Boschma, 2005), scholars are only starting to understand the underpinnings of translocal couplings in the co-creation and diffusion of market structures, capital and legitimacy (e.g. Binz et al., 2014, Chaminade and Plechero, 2015, Yeung and Coe, 2015, Binz et al., 2016b, Heiberg et al., 2020, Gong, 2020). Some scholars have elaborated how GIS may differ along the value chain of a specific innovation (Rohe, 2020, Hipp and Binz, 2020, Malhotra et al., 2019). Others identified how multi-scalar development trajectories differ between sectors (Binz et al., 2020b). The mechanisms behind the emergence of new multi-scalar GIS structures have, however, not yet been addressed. What are the conditions that drive innovating actors to build networks and learn from other experiences gained outside of their urban, regional and national networks? And how can systemic synergies be generated in translocal networks? These are the leading questions which the present paper aims at answering.

We assume that actors can contribute to building up resources for innovation success like new knowledge, early market structures, specific promotional support, or legitimizing narratives, for example through R&D, networking, investments, or institutional work (Hekkert et al., 2007, Musiolik and Markard, 2011, Binz et al., 2016b). Their local contexts may be conducive to these activities by providing portfolios of resources, by hosting pre-existing local networks, infrastructures, funding opportunities, or related knowledge. However, a lack of resources or the inability to build them up locally may represent barriers for the further development and maturation of the innovation. In the extant literature, these barriers are typically conceptualized as system failures (Woolthuis et al., 2005, Weber and Rohracher, 2012, De Oliveira et al., 2020), which have to be proactively addressed by joint activities in the innovation system. For instance, innovators in a region with plentiful related industries, a differentiated labor market and matching universities will more easily be able to build up knowledge stocks that are critical for innovation success (Jaffe et al., 1993, Audretsch and Feldman, 1996). Other regions may host a population, with a high awareness for environmental challenges and a higher willingness to support and adopt new, seemingly more sustainable technologies and products (Jeannerat and Kebir, 2016, Binz et al., 2016b). Hence, actors in this latter region may be more easily able to mobilize legitimacy and engage in early market formation, even if the related knowledge base is not well established. Depending on the stage of maturity of an emerging innovation system and its spatial context, specific "motors" of innovation may be at work, leading to different resource constellations in a local context (Suurs and Hekkert, 2012, Suurs and Hekkert, 2009). Therefore, in many emerging systems, we may witness only a partial establishment of an innovation system, generating specific resources, while being confronted with barriers for further progress. If unable to mobilize resources within the local context, actors will start to look for exchanges with other places based on other forms of proximities, such as for example similar formal or informal institutional set-ups (Boschma, 2005, Content and Frenken, 2016, Carvalho and Vale, 2018, Heiberg and Truffer, 2021).

Based on these considerations, we conceptualize how resources get mobilized in spatially distant subsystems and ultimately give rise to a multi-scalar, global innovation system. In explaining these developments, we identify resource stocks and associated barriers of local innovation sites. The actors associated with these sites may try to establish structural couplings with initiatives in other places and potentially complementary resource portfolios. Another signal for a GIS to take shape is when structural couplings are managed by systemic intermediaries, which coordinate translocal activities and resource flows among previously unconnected spatial contexts. With this, the GIS perspective opens up for a wider set of spatial development trajectories compared to the linear pathway often implicitly assumed in TIS studies, in which a TIS starts to form in one particular place, where it matures by mobilizing all relevant resources locally, before the innovation gradually diffuses to other places. Rather, development pathways may start at a global scale and then diffuse to different regions, or early mover regions may lose leadership along the way, while other regions catch up.

Empirically, we explore an emerging translocally connected set of demonstration sites, which emerged in the field of onsite blackwater treatment and vacuum sewerage in North-western Europe over the past decade. Initiatives with alternative, often decentralized, water treatment technologies have emerged in many cities across the world as a means to

counter impacts from climate change on urban water management like flooding and droughts (Larsen et al., 2016). Mostly, these initiatives remain isolated as different cities, regions or countries try to find local solutions to such global problems. These specific places often lack critical resources to scale and mature solutions and, therefore, their contribution to overall transitions remains limited. In the case of blackwater treatment, we observe an increasing interconnection of experiments in different sites and the emergence of translocal system resources and structural couplings across North-Western Europe. We, therefore, hypothesize that this technological field of blackwater treatment has the potential to develop into a translocal innovation system and is likely to exhibit core processes that we would expect in the emergence of a GIS. We trace the evolution of this network of local experiments as well as the mechanisms behind local and translocal resource mobilization processes over the past 20 years from the origins around individual research groups in Norway and Germany to a current wave of investment, technology deployment and translocal coordination across the Netherlands, Belgium and Sweden.
Methodologically, we base our case study on the analysis of transcripts of twenty expert interviews with actors involved in individual blackwater development and deployment experiments across North-Western Europe, as well as drawing on supplementary documents (Yin, 1994). These data, allow for a detailed reconstruction of initial local resource endowments, degrees of partial subsystem maturity, and spatial scales of resource mobilization that can be linked to the emergence of multi-scalar innovation system.

The article is organized as follows. Section 5.2 introduces existing conceptualizations of innovation system resources and barriers, typical resource constellations during maturation phases of innovation system, and the role of intermediaries in facilitating resource mobilization, leading to GIS emergence. Section 5.3 introduces the empirical case around a blackwater treatment technology and elaborates the methods. Section 5.4 present the results along three phases of development before section 5.5 discusses the results in light of our conceptual approach. We conclude with conceptual lessons and future research avenues in terms of further conceptualizing general GIS dynamics.

5.2 Perspectives on Innovation system formation

To formulate a dynamic understanding of GIS emergence, we will elaborate how core system resources get built up through strategies of different actors depending on the specific development stage of their demonstration site and, potentially, its local systemic context. In a second step, we will extended this understanding in order to explain the establishment of structural couplings across spatial contexts.

5.2.1 Resources and barriers for innovation system formation

Innovation studies has established that success of innovations is often best explained by adopting a systemic perspective, especially when radical innovations or those that are supposed to respond to grand societal challenges are at stake. Instead of solely depending on actor-internal capabilities, strategies and resources, innovation success often depends on the strategies of and interactions among a wide set of actors, such as companies, academic research, industry associations, government offices, and even users and NGOs. This perspective was most prominently spelled out by the well-established family of innovation systems frameworks, which gained strong resonance both in academic and in policy circles over the past three decades (Edquist, 2005, Sharif, 2006, Chaminade and Edquist, 2010, Weber and Truffer, 2017). In the context of sustainability transitions research, the approach of technological innovation systems (TIS) gained most prominence, by focusing on the emergent industry dynamics in clean tech sectors such as photovoltaics, wind, biogas, organic food, electric cars or urban water (Carlsson and Stankiewicz, 1991, Bergek et al., 2008a, Negro et al., 2012). Scholars proposed that innovation systems could first of all be described by their structural characteristics, i.e. the different types of actors, their networks and the rules and regulations that they developed for their coordination (Jacobsson and Bergek, 2004, Carlsson and Jacobsson, 1997). A complementary description of the system was later proposed through identifying the core activities, processes or "functions" that these actors engaged in: knowledge creation, entrepreneurial experimentation, market formation, capital mobilization, guidance of the search and legitimation (Bergek et al., 2008a, Hekkert, 2007). The conceptual added value of looking at innovation success through a systemic lens is that it emphasizes the joint construction of key resources through cumulative causation or what authors have coined “virtuous circles” (Jacobsson and Bergek, 2004, Carlsson and Jacobsson, 1997). Despite having highlighted the relevance of these cumulative processes, innovation systems approaches have repeatedly been criticized of being primarily descriptive and lacking explanatory power (Weber and Truffer, 2017).

To counter these limitations, Binz et al. (2016a) and Binz and Truffer (2017) proposed to interpret these seven functions as activities to build up four core resource stocks, which they identified as knowledge, financial capital, market structures and legitimacy. Knowledge is mostly related to expertise in technology, manufacturing, operation and maintenance, which are needed in the course of the development, diffusion, and deployment of new technologies. It can be differentiated in codified knowledge, which can be easily reproduced and mobilized through information and communication technologies, and tacit knowledge, which is spatially sticky and can only be learned through face-to-face interactions and on-site learning (Jensen et al., 2007). Knowledge is the one resource, which has gained most attention in innovation studies and much of economic geography (Hassink et al., 2019). For instance, in their seminal paper, Carlsson and Stankiewicz (1991, p.111) defined technological systems as the “knowledge and competence networks” of actors working in a specific field and under a specific institutional infrastructure. However, success of innovation will also strongly depend on how new products, technologies or services will interact with existing value concerns in society: Will options be perceived as providing added value to customers compared to existing product alternatives? How will these relate to pre-existing regulations and will they mobilize any sort of support or opposition by broader societal circles?

Binz and Truffer (2017), therefore, hypothesized another three resource stocks to be decisive for innovation success, and which denote value-related aspects of innovation: market structures, financial capital, and legitimacy. Market structures represent regularized exchange relations with users which stabilize income flows for the innovating companies. However, especially in early phases of innovation, market relations do not yet exist and have to be built up conjointly by different actors. Value chains will have to be built up, market segments with users interested in this option have to be addressed, particular value propositions and corresponding business models have to be defined and implemented. Hence, actors pushing for radical innovations typically have to engage in building up market structures (Dewald and Truffer, 2011, Dewald and Truffer, 2017, Boon and Edler, 2018, van der Loos et al., 2020). The same holds true for financial capital. Financial investment is crucial to provide the means to fund activities in the absence of income streams from established markets (Karltorp, 2016, Geddes and Schmidt, 2020). Early innovation activities, however, are associated with high uncertainties in terms of functionality, cost structures and actual consumer segments. Innovating actors, therefore, have to establish a specific resource stock consisting of a basic understanding of and trustful relationships with creditors like banks, venture capital firms, and other private investors. The same holds for political actors and public authorities prepared to support R&D, experimentation and demonstration projects (Hekkert, 2007, Binz et al., 2016b). Finally, legitimacy for an emerging technology needs to be actively created to raise positive expectations among different actors, and help align regulation in policy in favor of the novel technology (Aldrich and Fiol, 1994, Bergek et al., 2008b, Binz et al., 2016a). The accumulation of such knowledge- and value-related resources is necessary for innovation system formation and, hence, their absence has been labelled as blocking mechanisms, system failures or systemic barriers (Jacobsson and Bergek, 2004, Woolthuis et al., 2005, Bergek et al., 2008a, Wieczorek and Hekkert, 2012, De Oliveira et al., 2020).

The focus on resources enables to identify causal mechanisms connecting innovation system structures with innovation success through the intermediate concepts of key processes and resource stocks (see figure 1). The causal connection between the three dimensions can be summarized as follows: Actors typically first draw on their internally available resources (e.g. capabilities, capitals and networks) to manage their in-house innovation processes. Especially, for radical innovations or those that respond to grand challenges, however, many of the critical resources may not be in the ownership of individual organizations. Innovators, therefore, have to access them by teaming up with other actors. As an example, positive expectations about the prospects of a new technology or product are key to raise funds and build up markets. An individual company's activities on its own behalf will, however, quickly run the risk of being perceived as a mere marketing and lobbying. A more effective form of creating positive expectations will be achieved by engaging in processes of technology legitimation jointly with other actors (Aldrich and Fiol, 1994). Technology legitimacy is a resource, which is hard to create by any individual actor and, therefore, the coordinated actions of different organizations in networks and the proactive institutional work for influencing normative or cognitive institutions becomes a collective challenge (Yap and Truffer, 2019). Legitimacy is a systemic resource because it cannot be fully controlled by any of the specific actors alone, while all actors will ultimately profit from its existence (Binz et al., 2016a, Markard et al., 2016b). The literature has converged on a list of core processes or functions through which actors co-produce systemic resources as the ones listed above (Bergek et al., 2008a, Hekkert, 2007). Causal mechanisms, therefore, connect structures (actors, networks and institutions) through their activities and strategies (processes or functions) to create the four systemic resources stocks, which are essential for innovation success. Lacking or insufficient resource stocks will lead to system failures or represent barriers, which hamper the further maturation and scaling of the respective product, technology or service (see figure 5.1 for a schematic representation).

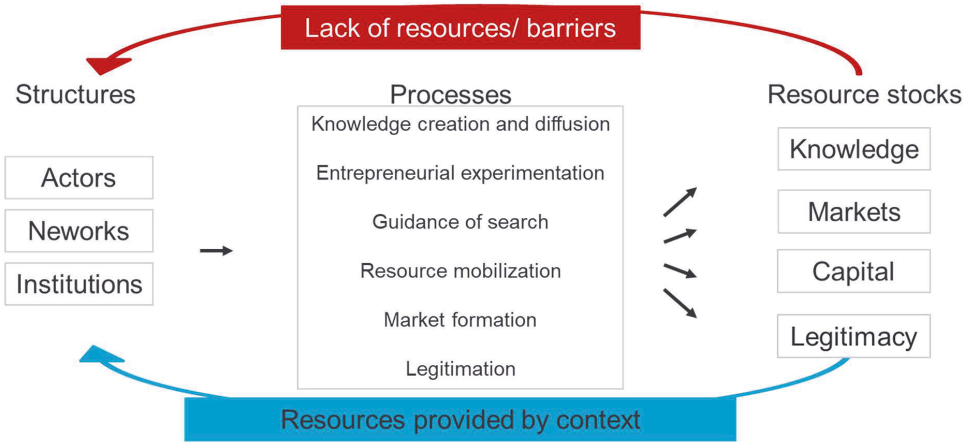


Fig. 5.1: Causal scheme of innovation system build up based on Hekkert (2007), Bergek et al. (2008a), Binz et al. (2016b)

5.2.2 Multi-scalar processes of resource mobilization

The origins of relevant resources for innovation success are not restricted to those within companies or co-produced within an emerging innovation system. A third origin can be from different contexts in which an innovation system is embedded (see figure 5.1 bottom arrow) (Bergek et al., 2015). Most obviously, actors will try to draw on resources that are available in their specific social or geographical context. Specific localities, such as regions may host particular knowledge stocks, which are critical for solving the technological innovation challenges, a fact that is well-established in evolutionary economic geography (Frenken and Boschma, 2007, Hidalgo et al., 2007, Kogler et al., 2013). Or, the region might be the home of special cultural communities or institutional setups, which facilitate the mobilization of resources for early test markets (Dawley, 2014, Content and Frenken, 2016, Carvalho and Vale, 2018).

However, local resource stocks might not be available for all possible resource scarcities. In that case, actors may try to import them from elsewhere (Coenen et al., 2012, Binz et al., 2014, Gosens et al., 2015, Wieczorek et al., 2015, Trippl et al., 2018, Heiberg et al., 2020, Gong, 2020). Binz and Truffer (2017), therefore, proposed to study innovation systems as multi-scalar constructs, so-called global innovation systems (GIS) to account both for spatially contextual resources as well as interconnections that span across regions, nations or even at the global scale. Depending on the technological and value-related characteristics of an industry or sector, different geographical layouts of GISs are likely to emerge. For instance, footloose innovation systems, like solar photovoltaics, which draw strongly on codified knowledge are likely to see their manufacturing activities quickly moving to low-cost regions and establish globalized knowledge networks, markets, financing, and legitimacy, whereas in spatially sticky systems, like wind energy, local knowledge creation and valuation will lead to a GIS where certain manufacturing regions will maintain strong positions in the global industry (Binz and Truffer, 2017).

The GIS framework posits that, in addition to the usual structures, processes and resources of an innovation system, we have to differentiate (spatially defined) sub-systems in which particular resources will be developed. In order for the innovation to develop and mature, it is important that these different subsystems get interconnected through so-called structural couplings, i.e. actors, networks and institutions (Bergek et al., 2015), which span over different spatial scales and which enable the flow of specific resources among the relevant regions. At the actor level, a multinational firm or NGO might represent a structural coupling by actively liaising between system formation processes in different countries or regions. Regular international trade fares or conferences might represent opportunities to connect actors from different regions through networking. And institutions may also function as structural couplings, when global industry standards or professional cultures enable the flow of resources among different places (Binz and Truffer, 2017, Fuenfschilling and Binz, 2018). A fully functional GIS, will, in general, consist of several localized initiative contexts engaging with knowledge or value-related activities, and a set of structural couplings to complement the overall resource stocks necessary for the development and maturation of this innovation.

Fig. 2 exemplifies a specific constellation of resource endowments captured in subsystems at the regional, national and transnational scale. We depict subsystems with their prevailing resource stock constellation (grey blocks in the middle of fig. 5.2). A low score on any of the three resource stocks suggests that actors would have to engage in corresponding activities to correct for this deficiency. In our generic example, region #1 shows weak knowledge, almost no market structures, but high levels of legitimacy for the emerging innovation. To further promote the innovation in region #1, actors' might try to import these resources from elsewhere, like accessing expertise from the transnational level in fig. 5.2.

Previous research in evolutionary economic geography showed that transnational transfer and regional embedding of knowledge and legitimacy might operate through the *attraction* of specific individuals to a specific region or country, or through the *absorption* of resources by actors with the relevant capabilities (Binz et al., 2014, Trippl et al., 2018, Heiberg et al., 2020). The other way round, resources might also be consciously *exported* elsewhere, e.g. through foreign direct investments or knowledge embodied in tradeable goods. Thus, we would expect multi-scalar resource mobilization to be instantiated by actors, networks and institutions that span across spatial subsystems with *complementary* knowledge and/or value-related resources. We posit that complementary resource stocks may be a necessary condition for the establishment of multi-scalar resource mobilization structures. However, they are not sufficient. Actors still have to identify their existing resource constellation, find out about potentially complementary resource stocks elsewhere, and finally establish the structural couplings necessary to tap into these resource stocks (Wieczorek et al., 2015). In this light, coordination and reflexivity become crucial dimensions of GIS emergence.

When one can meaningfully speak of a GIS and what differentiates it from mere translocal linkages among individual actors, might then crucially depend on the ability of the system to self-coordinate and maintain its activities at the translocal scale. In this context, a central aspect may be the establishment of 'systemic intermediaries' (van Lente et al., 2003, Klerkx and Leeuwis, 2009). Systemic intermediaries are by definition actors operating at the system level in activities related to addressing systemic barriers and connecting the "different components of international, national, sectoral and/or regional innovation systems" (Klerkx and Leeuwis, 2009, p.850). Indeed, van Welie et al. (2020) found in the context of a GIS around sustainable sanitation solutions in the Global South that systemic intermediaries might be a crucial element for facilitating the development of networks for the mobilization of knowledge and legitimacy for subsystems during their formative phase, and for the guidance of search and resource mobilization within and across subsystems during their growth phase. While not a sufficient condition, we, therefore, argue along the lines of van Lente et al. (2003, p.30) that "the efforts of systemic intermediaries in encompassing systemic innovations are (…) probably necessary". These intermediaries may originate from or be embedded in any subsystem context at any specific spatial scale. In Fig. 5.2 the exemplary systemic intermediary is a national industry association that also coordinates activities among subsystems. In other cases, systemic intermediaries might equally originate from the global scale, like the global membership based association for sustainable sanitation innovations in the global south identified by van Welie et al. (2020), or from the regional-scale like, for example, grassroots network hubs that coordinate a network of localized transition town movements (Feola and Nunes, 2014).

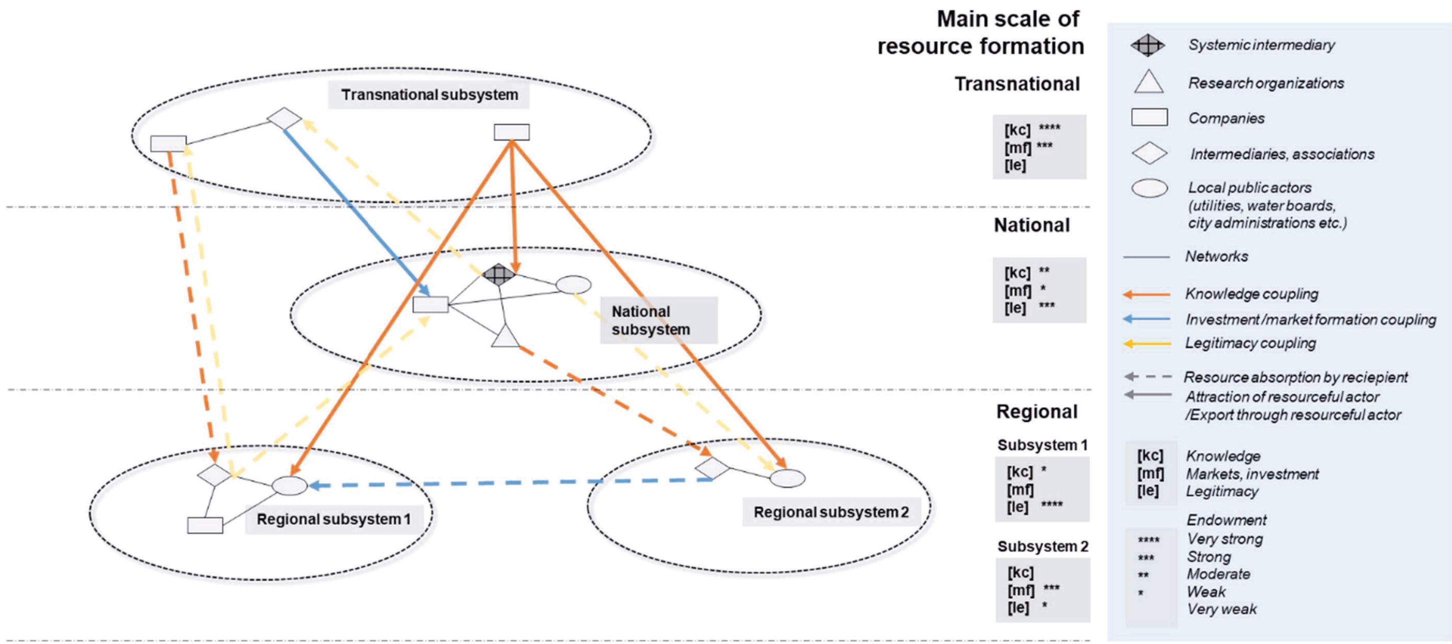


Fig. 5.2: GIS structure with different resource stocks in subsystems at different spatial scales. Own figure based on Binz and Truffer (2017).

Hence, we can assume that along with resource complementarities and the necessary capabilities for multi-scalar resource mobilization, an indicator of the emergence of a GIS is the presence of one or more systemic intermediaries that coordinate systemic activities and facilitate the creation of structural couplings among several individual subsystems. Departing from these static, structural features of GIS, we will now formulate a framework, which captures the dynamic interplay of the different causal mechanisms in a multi-scalar context and which may ultimately give rise to a fully-fledged GIS.

5.2.3 Mechanisms of global innovation system emergence

TIS scholars established early on that innovation systems are likely to develop through different stages of maturity. Especially for emerging industries a formative phase can be distinguished from a growth phase (Bergek et al., 2008a). The formative phase involves a high degree of uncertainty, lacking institutional structures such as markets or standards and many companies entering and leaving the field. The growth phase is characterized by the establishment of a dominant design, rapid market expansion and technology diffusion. Already Suurs and Hekkert (2009, 2012) claimed that the explanatory power of TIS analyses was in dire need for improvement. They proposed to analyze how the profiles of salient functions – so-called motors of innovation – shifted over the course of system maturation phases. During the *formative phase,* knowledge-related activities as well as legitimation and the creation of positive expectations by promoting actors mattered very strongly. Although initial financial resources need to be mobilized, market formation is still largely absent. In the subsequent *system building phase*, market formation needs to be tackled more proactively, e.g. by active strategies of the state, community based organizations or by pioneering companies themselves, and legitimation and knowledge creation remain equally important. While funding and the provision of human capital is crucial throughout system development, these processes are mostly driven by the legitimation activities of proponents to secure research and innovation grants during earlier stages. During later stages, financial resources are increasingly available as a result of market formation and demand articulation. In the latest phase, *the growth phase*, legitimation is less important, since market formation, the mobilization of financial resources and the knowledge creation have been institutionalized. While in reality, deviations from these patterns may be rather the rule than an exception, we take from these elaborations that different constellations of activities may prevail in different phases of system development. In our interpretation, these processes relate to the buildup of specific resources, which are critical at each development stage.

Fig. 5.3 combines these insights in a joint framework. On the Y-axis it differentiates between subsystems at different spatial scales: regional, national and transnational. They X-axis (P1-3) represent phases in the development of the overall GIS, independent from the maturity of its individual subsystems. The symbol shadings, in turn, differentiate the maturity of a subsystem in formative, system building and growth phase. Eventually, the symbol shapes differentiate four different combinations in the presence or absence of specific resources at the level of individual subsystems. In the exemplary illustration in Fig. 3, two regional subsystems (S1 and S2) coexist in their formative phase. S1 is more advanced in terms of local knowledge endowments, so S2 can absorb knowledge from it. During the second phase, S1 and S2 enter the system building phase, during which market structures and capital investment become much more important. S1 is still specialized on producing local knowledge and has been able to draw on networks at the national scale. Investment can now be attracted form the regional subsystem S2, which has specialized on value-related resources. A third, rather weakly-endowed subsystem is entering the field in a different region, benefitting from the anchoring of knowledge and legitimacy crucial during its formative phase. In the third phase, S1 and S2 institutionalize their exchange and mature further, as a transnational donor organization (SI) with a strong interest in the focal technology enters the field, providing continued funding for all subsystems and coordinating resource exchanges at the trans-national scale. As such, SI fulfills the role of a systemic intermediary maintaining and further developing the systems. The interconnected set of distanced innovation activities may now be characterized as a newly formed GIS, represented by the dotted line around the whole system.

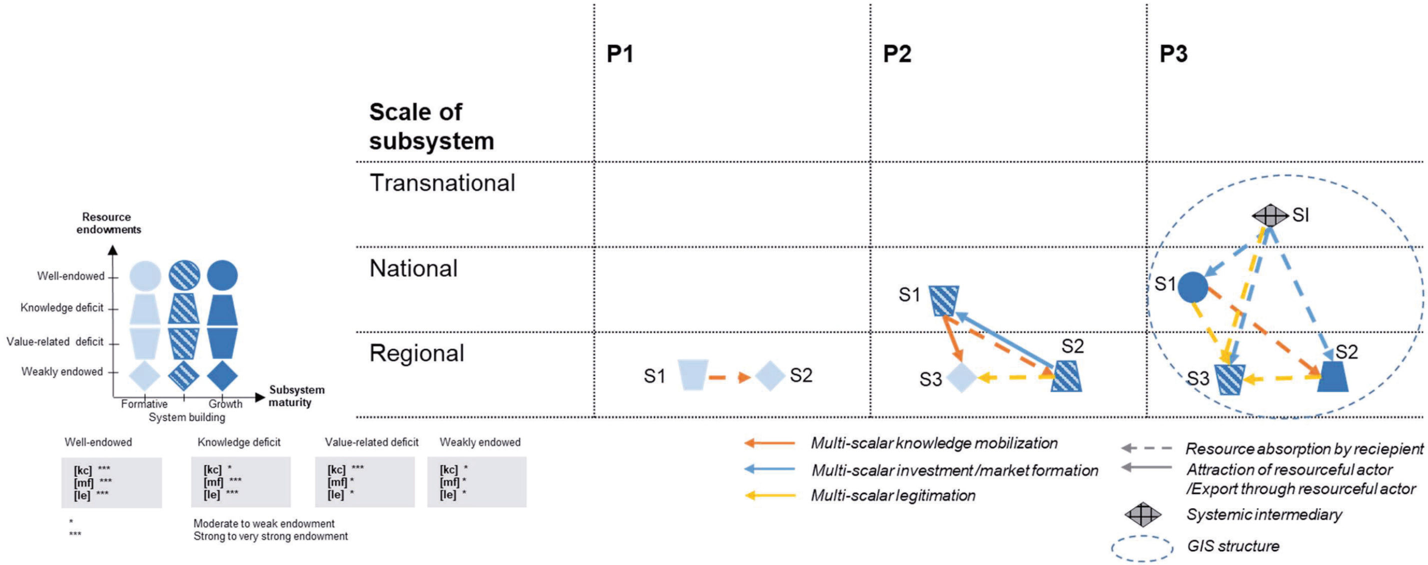


Fig. 5.3: Multi-scalar resource mobilization and intermediation during different phases in the emergence of a hypothetical GIS . Own figure.

To answer our focal research questions, when and why multi-scalar resource mobilization processes do emerge, it is, therefore, instrumental to study resource endowments that emerge in different spatial contexts, resource complementarities among these contexts, as well as the coordination of multi-scalar resource exchanges among them, over time. In the following, we will outline our methods and introduce the particular empirical context through which we will reconstruct the emergence of a GIS for the district-scale blackwater treatment technology in Northwestern Europe.

5.3 Empirical cases and methodology

Empirically, we study a set of international innovation processes around blackwater treatment and vacuum toilets in North-Western Europe over the past 20 years. Vacuum toilets represent a mature technology already widely adopted in cruise ships and trains. Blackwater treatment technologies in turn have so far rarely been applied to on-site wastewater treatment in urban contexts. This novel combination of blackwater treatment with vacuum toilets has evolved as one of several source-separating alternatives to conventional centralized wastewaster treatment. It might help alleviate environmental and economic pressures on the centralized sewerage system in the future (Larsen et al., 2016) as it allows to treat the blackwater on-site. The less diluted water is treated by an anaerobic reactor. Often it is combined with a separate treatment unit for greywater from the kitchen, washing machines and showers, where heat and energy might be recovered at the source. Also different methods to recover resources like nitrogen and phosphorus from the wastewater are being developed in the context of this configuration, as well as the additional production of biogas. Early research experiments around this configuration or individual parts of it took place during the late 1990s at Wageningen University, in the Netherlands, at TUHH, in Hamburg, Germany, and at the Norwegian University of Life Sciences NMBU in Olso (Larsen et al., 2013). Since then, a couple of demonstration and deployment cases have popped up in Northwestern Europe suggesting the development innovation system dynamics in and across different localities. The sites and organizations for our study were selected based on prior desk research and through references from earlier research campaigns (de Mul, 2020) . Interviewees were selected in order to be able to reconstruct resource mobilization processes contributing to the realization of demonstration projects situated in different geographical contexts.

The first author conducted twenty interviews with organizations involved in eight major demonstration sites for blackwater treatment technologies in five North-Western European countries (see D1). We asked the interviewees about the emergence of different project sites, about the ways resources were mobilized, and about context-specific resources and barriers to the development of their demonstration projects. The interviews were transcribed and coded with help of the qualitative content analysis software Nvivo12. A coding scheme was abductively developed differentiating codes for local resource drivers and local barriers related to three core resource mobilization realms of the GIS framework: knowledge & capabilities, market structures & capital, and legitimacy & institutions. We chose to combine market structures and capital since market structures usually exclusively involved investments associated with the stimulation for demand around niche markets.

For each demonstration project, we generated a resource profile based on the presence of resources and associated barriers, counting any resource or barrier detected as 1. Resources were identified, if interviewees explicitly mentioned the availability of a resource or the capability to produce it in the local context during the planning and implementation of their respective projects. Barriers were identified through references to specific problems that related to a lack of knowledge, markets and capital, or legitimacy. Subsequently, an index was calculated subtracting the share of barriers present from the share of resources present in each of the three resource realms. For example, eight institutional resources were detected throughout the whole dataset and four institutional barriers. A demonstration project, for which three out of eight institutional resources were present (0.375) and three out of four institutional barriers (0.750) would receive an index score of (0.375) - (0.750) = (-0.375), indicating a prevalence of barriers within this realm. The index, which can take values between -1 and 1, was subsequently classified into five equally distributed classes ranging from very strong resource endowments to very weak resource endowments. This way, we derived a basic index score for each project site regarding resource availability/scarcity during the planning and implementation phase of each project. Importantly, the time during which planning and implementation was executed varied strongly across the cases. Therefore, for each project site the starting year of planning and implementation was captured to orient the project sites in a timeline.

Additionally, any evidence of multi-scalar resource mobilization was coded in the transcripts according to its resource realm and type, as absorption or attraction/export. The results of individual resource profiles and multi-scalar mobilization processes were mapped over three periods of time, differentiating between the starting years of the individual demonstration projects. The phases were chosen to differentiate the early mover projects and dynamics (1990s and 2000s) from the more recent ones (2010s), and from the developments, which are unfolding during the interview campaign (2020s). Each projects' resource score, as well as the individual case narratives emerging from the interviews were drawn upon in order to explain the differentiated patterns of multi-scalar resource mobilization observed.

5.4 Results

The results will be presented by first introducing the individual demonstration sites, and discussing the subsystem resource endowment indicators. Second, we will elaborate the resource complementarities, and the evolution of multi-scalar resource mobilization processes among the sites and their respective subsystems, as well as the presence of potential systemic intermediaries during different phases of GIS structure development. Third, we will link all of these evidences back to the proposed conceptualization to discuss how and why subsystems have co-evolved into a larger GIS structure.

The first sites, in which actors had implemented blackwater systems are Oslo in Norway and Wageningen in the Netherlands. The efforts of these two sites date back to the end of the late 1990s. Later, in the 2000s, Sneek in the Netherlands and Hamburg in Germany became demonstration sites. In the 2010s Helsingborg (Sweden) and Ghent (Belgium) developed major demonstration sites. Visby and Stockholm in Sweden, eventually entered the planning stage of demonstration projects more recently, for implementation in the 2020s.

Tab. 5.1a shows the share of resources present and barriers within each of the three resource realms in each major demonstration locality during their respective planning and implementation phases. Tab. 5.1b shows the resource index scores for all project sites. As can be seen from Tab. 5.1b, demonstration sites had different starting dates and local resource endowments based on our interviewees elaborations. The two last projects, Stockholm and Visby, are still in the planning process, while all other projects have at least concluded parts of their demonstration sites. In terms of strong resources, Sneek and Ghent had better knowledge and capability endowments than all other localities, while Ghent and Helsingborg stood out in terms of stronger local market formation and funding. In terms of institutional and legitimacy related conditions, Visby, Ghent and Sneek had slightly better conditions than the other localities. Additionally, project contexts lack resources to varying degrees. While most localities have only moderate knowledge and capability endowments, Oslo, Sneek and Visby were especially lacking market structures and capital investments. Institutional and legitimacy problems were most prevalent in Oslo, Hamburg and Helsingborg. With this general description of the local context conditions of different demonstration project sites at time of their initialization and implementation, we can now turn to the specific multi-scalar resource mobilization processes that have emerged around them over time. Further, we will draw on the qualitative information from the interviews to elaborate mechanisms linking local resource endowments to the emergence of multi-scalar resource mobilization, i.e. a GIS structure. We will elaborate on the emergence of the GIS following the three phases, which will be labeled ‘inception phase’, ‘coordination phase’, and ‘expansion phase’.

Tab. 5.1a Local resource and barrier scores. Share of overall resources/barriers present within each category.

	knowledge & capabiity	Market structures & capital	Legitimacy & institutional	Knowledge & capability barriers	Market structures and capital barriers	Legitimacy & institutional barriers
Oslo	0.67	0.00	0.25	0.50	1.00	0.50
Wageningen	0.00	0.00	0.25	0.00	0.00	0.25
Sneek	0.33	0.00	0.50	0.00	0.33	0.00
Hamburg	0.00	0.50	0.25	0.00	0.33	0.75
Helsingborg	0.00	0.50	0.50	0.00	0.00	1.00
Ghent	0.33	1.00	0.50	0.00	0.33	0.25
Stockholm	0.33	0.00	0.38	0.50	0.00	0.50
Visby	0.33	0.00	0.63	0.50	0.33	0.00

Tab. 5.1b Local resource score. Resource present minus barrier score for each resource category. Symmetric local resource scores from very strong to very weak.

	Decision year	knowledge & capabilities	market structures & capital	legitimacy & institutions
Oslo	App. 1998	0.17	-1.00	-0.25
Wageningen	App. 1998	0.00	0.00	0.00
Sneek	2003	0.33	-0.33	0.50
Hamburg	2008	0.00	0.17	-0.50
Helsingborg	2012	0.00	0.50	-0.50
Ghent	2014	0.33	0.67	0.25
Stockholm	2018	-0.17	0.00	-0.13
Visby	2020	-0.17	-0.33	0.63

>= 0.60 <= 1.00 : very strong	****
>= 0.20 < 0.60 : strong	***
>= -0.20 < 0.20 : moderate	**
>= -0.60 < -0.20: weak	*
>= -1.00 < -0.60: very weak	

5.4.1 Inception phase: late 1990s to 2000s

The inception phase was characterized by the initial uptake of the blackwater configuration by Wageningen University during the second half of the 1990s, marked by the publication of a series of seminal papers like Lettinga et al. (1997). Researchers had already developed a treatment technology for blackwater but needed a more concentrated waste stream than usually received from toilets. To this end, they were looking for practical experiences with low-flush, or ideally, vacuum toilets. In the late 1990s, they visited Lübeck Flintenbreite, where researchers of Technical University Hamburg-Harburg (TUHH) had implemented vacuum sewerage in a small ecovillage already in the 1990s (In10). Exchanges with TUHH helped generate confidence that a combination of the Dutch UASB reactor and vacuum toilets could actually become a useful technology in the Netherlands. Technological knowledge was thus absorbed from the Lübeck experiences, as well as legitimacy. Another conducive factor was that the national institute for applied water research (STOWA) was looking for ways to make the Dutch Water sector more resilient against shocks. STOWA helped the researchers connect to individual water boards (mostly in Friesland), as well as regional municipalities and water professionals. In this way, STOWA clearly fulfilled the function of a systemic intermediary in the Dutch national context. Eventually, this led to the implementation of the first larger demonstration site covering 24 homes in ***Sneek***, starting from around 2003 (In10 & In14).

Parallel to these developments in the Netherlands, researchers at the Norwegian University of Life Sciences, NMBU, started developing knowledge around blackwater treatment with vacuum sewerage, collaborating with the vacuum toilet producer Jets that is mostly producing for the maritime sector (In16). The technology was applied in a demonstration project in a dormitory in ***Oslo***. All of these developments were rather isolated, research-driven activities, reflecting a very formative phase of system development. During this phase, a translocal structural couplings emerged through site visits of Dutch engineers to Hamburg, which provided knowledge and potentially legitimacy, contributing to the Dutch subsystem's formative phase (Fig. 5.4).

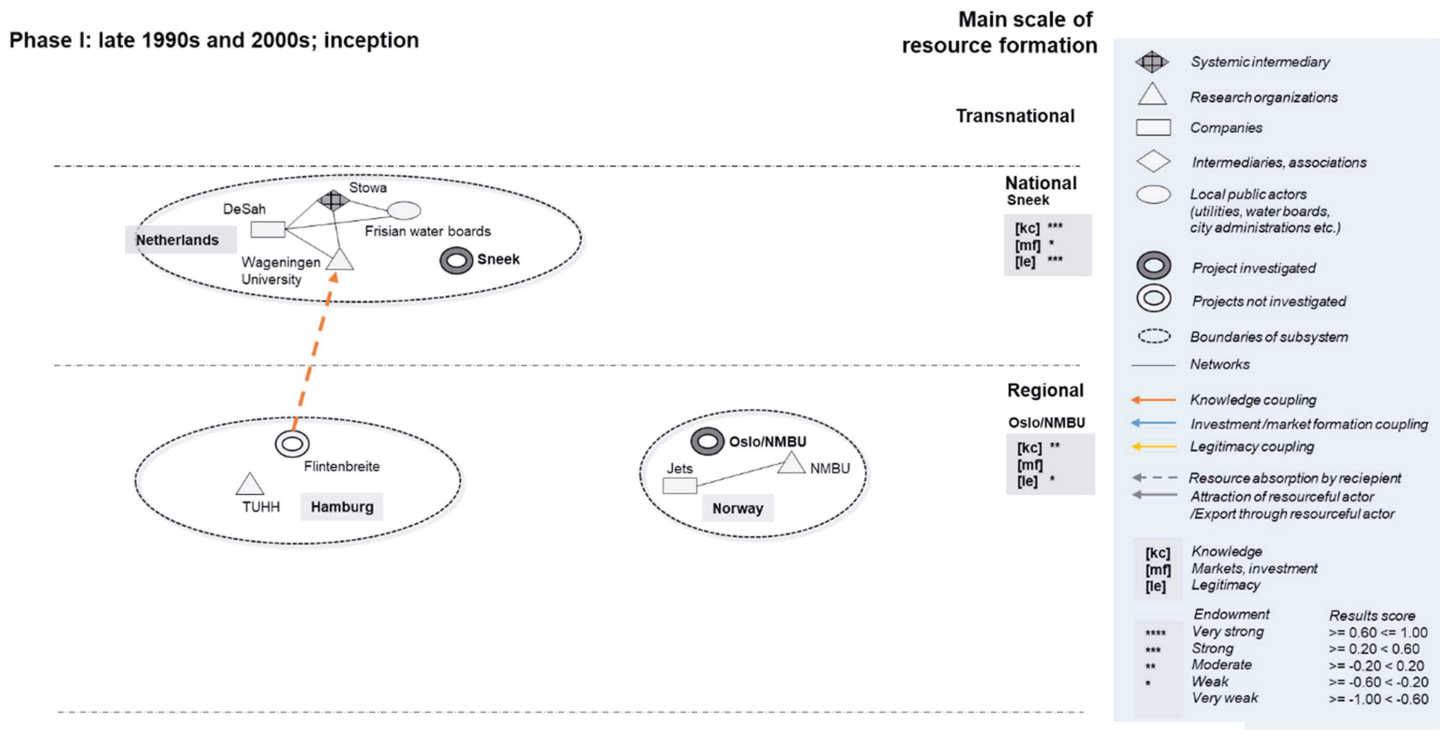


Fig. 5.4: Inception phase of GIS structure emergence. Own drawing.

5.4.2 Coordination phase: 2010s-2020

Beginning around the turn of the 2010s, several new projects emerged in different countries building on variegated sets of local resources. In the Netherlands, ***Sneek***'s succeful application of the technology secured local legitimacy for continued experimentation. A spin-off firm, Desah, as well as an engineering consultancy, LeAF BV, were created by individuals from Wageningen University to commercialize and further develop and diffuse the technology, allowing for more demonstration projects in Venlo and Kerkrade. Thus, legitimation and knowledge creation were developed locally during this phase. However, market formation and access to financial resources were rather scarce and fluctuating. Major influx of financial support during this phase came through the support by funding schemes of the European Commission, like through the participation of Dutch actors in a Horizon2020-funded project called Run4life from 2017 onwards (In10, 11). Without these external funding sources, the Dutch innovation system might not have been sustained during this period (In11). On the vacuum toilet end of the technology, however, knowledge was channeled to the Netherlands through a collaboration with the Dutch branch of Jets. Thus, while legitimation was generated local, knowledge for specific components, and funding were mobilized from outside of the Dutch national subsystem mainly through Jets and the EU.

In ***Hamburg***, the local water utility decided to implement the technology in an urban neighborhood already as early as 2008 (Augustin et al., 2013, In17). Being sole supplier of water and wastewater services in the city, they actively engaged in market formation themselves. Knowledge and capabilities were built by an internal innovation team, which drew inspiration from TUHH's previous research projects at Flintenbreite and a Fraunhofer project, DEUS21 that had been running near Stuttgart between 2003 and 2010. They also collaborated with various German research institutes and universities (In17). Major barriers were related to local environmental legislation and legitimacy, which needed a lot of local institutional work by the utility and which resulted in compromises around the specific technological variants chosen (In17, In15). Resources were mobilized from abroad to address some of these shortcomings. A major factor was also being funded via the EU's Life+ program (In17). Funding from the EU-level, helped legitimize the technology locally and provided important funding to execute research and development in-house at the utility. Both big international vacuum producers, Roediger, from Germany, and Jets, from Norway, were contracted for parts of the piping and vacuum installations, however it was Roediger who was chosen as the main supplier due to their progress made with vacuum noise reduction (In17). External knowledge was further absorbed from Sneek but also made available for interested parties from other sites due to the public character of the utility (In17). Thus, in Hamburg, multi-scalar resource mobilization took place through the absorption or attraction of capital and legitimacy from the EU-level, and of knowledge from multinational vacuum toilet producers and exchange with other sites. These helped address shortcomings in terms of knowledge and legitimation.

In ***Helsingborg,*** the decision to go for the technology dated back to 2013 (In15). A waterfront district was subsequently developed, partly using the blackwater treatment & vacuum technology. Niche market formation was actively stimulated, and resources were made available by the local utility and the city itself to apply for additional external funding at the national scale. Especially, the city provided a clear vision and guidance for the project to be realized. At the same time, and similar to Hamburg, the implementation faced a number of institutional hurdles in the beginning, related to national water legislation, and getting environmental permits for the production of potable water and pelletized fertilizer (In9, In12, In15)(Lennartsson et al., 2019). Also technological knowledge was missing in the beginning. An important template for how to deal with institutional and organizational issues was found in Hamburg, which was visited by the municipality and the utility during the early phase of the project (In15). The mobilization of institutional resources from outside the subsystem was further intensified through the participation in the EU's Run4life project from 2017 onwards. While Hamburg was instrumental as a source of legitimacy, technological knowledge was mostly absorbed from Sneek, which also led to the contracting of Dutch technology provider Desah for the Helsingborg plant (In15). Thus, in Helsingborg structural couplings were very instrumental in providing knowledge and legitimacy, while market formation and funding were mostly mobilized regionally or nationally (Fig. 5.5).

Building on progress made in Sneek, Hamburg and Helsingborg, another project started in the Belgium city of ***Ghent*** around 2014 (In18). The city of Ghent had a strong interest to lower the environmental footprint of newly built districts, and already in 2011, an investment fund (Clean Energy Projects) and three real estate companies were chosen to develop the Nieuwe Docken area in the greater Ghent area, as a lighthouse sustainable district. Together with more investors, including the municipalities drinking water utility Farys, these companies formed a cooperative company called DeCoop in 2014 that explored different technological alternatives in the realms of energy and water, especially absorbing technological knowledge and inspiration from study visits to Sneek (In18). Also the municipalities' solid waste company, the Flemish Environmental Agency that grants environmental permits, and the local University were involved in the development of DeCoop from early on (Ampe et al., 2021). This way, the project not only secured funding but also generated an enabling environment for the implementation of the blackwater technology. The treatment plant was finally built by a local firm specialized in on-site industrial treatment (Pantarein). However, on the knowledge side, additional inputs were attracted through the contractual involvement of transnational vacuum producer Roediger. This was despite early inspirations for the vaccum technology of Jets, who had co-developed the installations at Sneek, and who DuCoop was collaborating with in the Run4Life project (In18). A study visit to Hamburg as part of the EU-project, led to the contracting of Roediger, whose technology was more convincing and suitable to DuCoop's engineers (In18). Thus, in Ghent, it was mostly technological knowledge that was mobilized from outside the subsystem. While these knowledge spillovers were also key to the participation in the EU-project, market formation, funding and legitimacy were strongly developed locally.

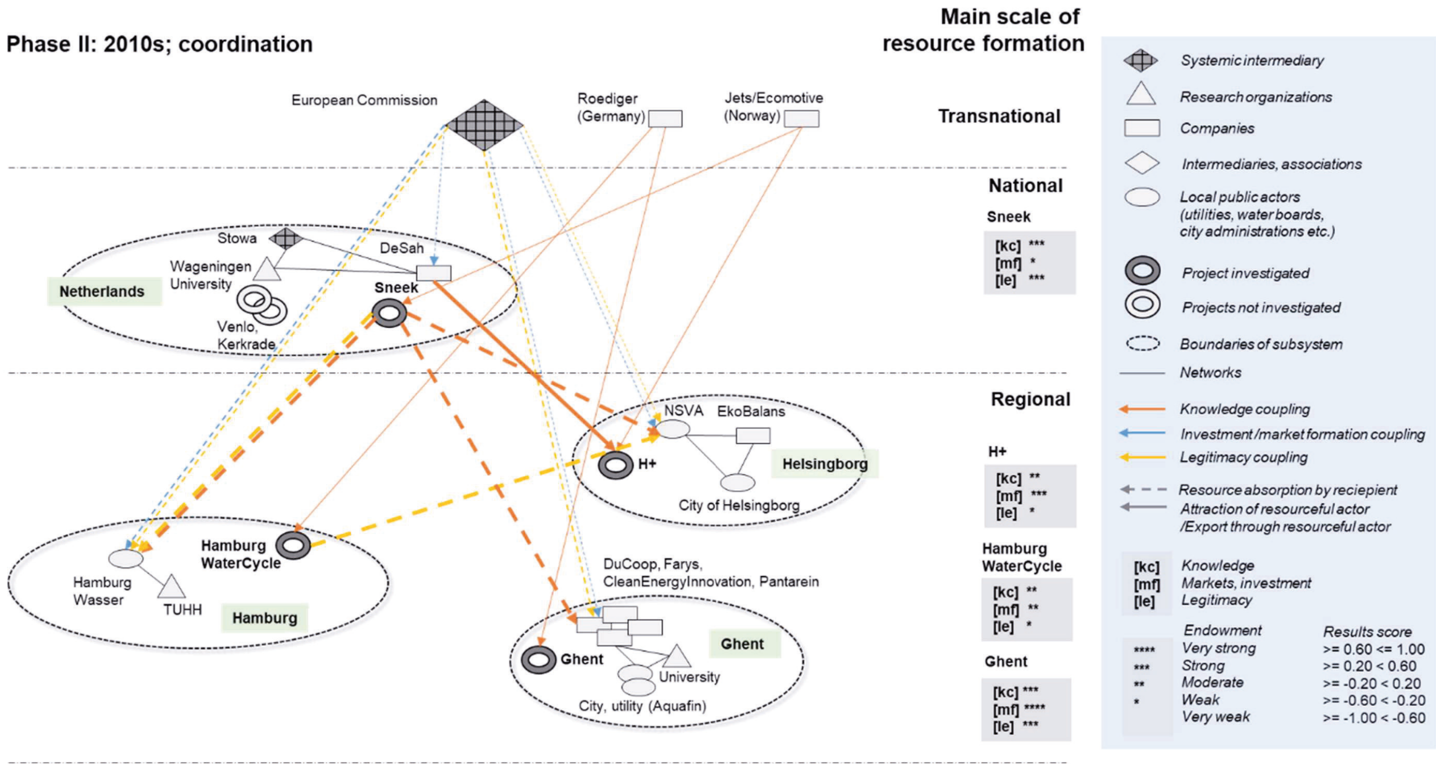


Fig. 5.5: Coordination phase of GIS structure emergence. Own drawing.

As is evident from these case descriptions, the EU Commission became a central systemic intermediary through the funding provided by the Life+ and H2020 funding schemes, which members from different sites selectively drew upon for the purpose of absorbing legitimacy, capital or technological knowledge, as well as to build and maintain networks among the different sites. Especially, the Run4Life project (2017-2021), which had a dedicated project manager, formalized this coordinating role. We, therefore, identify the emergence of GIS, albeit on that is still rather weakly coordinated.

5.4.3 Multi-scalar expansion phase: 2020- looking forward

In the very recent years, most of the emergent GIS structure remained stable but a new expansion dynamic is evolving in Sweden. Two additional cities have decided to develop districts with the blackwater technology: Stockholm and Visby on Gotland. While these encompass varying starting conditions and resource portfolios, this suggests the formation of new Swedish national subsystem in the blackwater treatment field. At the "global level" of the emerging GIS, the Run4Life project coordinated many activities in the late 2010s. However, it ended in 2021. During the more recent years, there have been attempts to re-activate EU-level funding and outreach by actors from Sweden. For example, actors on Gotland are exploring options for continued funding for their blackwater treatment demonstration site at the EU-level (In19).

In ***Stockholm***, the idea to implement the technology was already vivid since the early 2010s, when it was included in the development plan for the Royal Seaport area (In9) (Lennartsson et al., 2019). In the following 10 years, the project has, however, been stuck in an investigation phase due to internal budget allocation procedures at the city level and lack of legitimacy among crucial stakeholders in the utility (In9). It was only in 2018, when there had been some changes in staff of the utility, when the city started collaborating with the cities of Helsingborg and Visby in a national research project (MACRO) on on-site wastewater treatment funded and coordinated by the innovation agency, Vinnova, and when there was a political shift in the city parliament towards greener parties, that the utility was convinced to explore and develop the novel technology. Thus, Vinnova now assumed the role of a systemic intermediary in bringing together all three major Swedish project sites. Both knowledge and legitimacy were then absorbed in field visits to Hamburg and Sneek, were the technological configurations were found to be convincing (In9). It was only after the water engineers of the utility had talked to their peers in Hamburg and Sneek that they were fully convinced to further drive the development of the demonstration site. So, again, resources from outside the systems were instrumental in this formative phase of the Stockholm Royal Seaport case.

In ***Visby***, on Gotland, a much smaller city than Stockholm, the story still unfolded in a very similar vein. Here it is the public authorities, the municipality and the region that have pushed for the implementation of a blackwater system in a newly developed project. Legitimacy, too, was anchored from Helsingborg, and to lesser extent from hearing stories about Hamburg and Sneek. By now an investment decision has been made to develop the site and implement the technology. It is planned that the local utility will develop the technology but absorb knowledge from the other implemented cases in Northwestern Europe. As other actors before, the driving regional authority is hoping to draw on funding and legitimacy as well as access to networks from the EU level (In19).
To summarize, the emergence of demonstration projects in Sweden, is characterized by connections of projects at the national scale (e.g. through the MACRO project) on one hand, and through the mobilization of, in particular, knowledge, and to some extent legitimacy, from abroad on the other hand (Fig. 5.6).

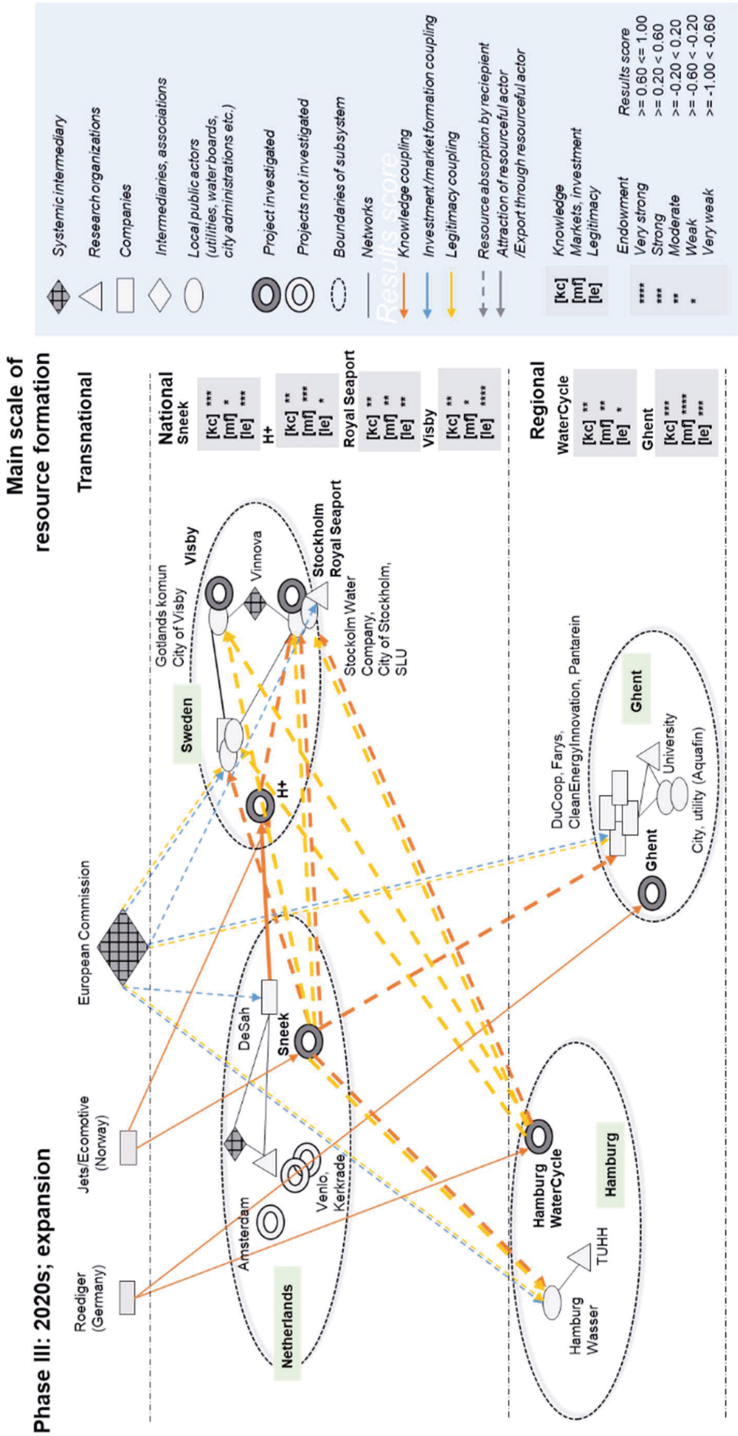


Fig. 5.6: Multi-scalar growth phase of GIS structure emergence. Own drawing.

5.5 Discussion

Reflecting on the patterns observed in the empirical analysis conceptually, we are witnessing maturation processes in various subsystems at regional and national-scales, in which crucial resources are drawn from non-local sources. Furthermore, we observe the emergence of systemic intermediaries at the level of the Netherlands and Sweden, enabling the formation of national TISs, but also the increasing role of the joint management of translocal activities through the EU. Hence, we would claim that an actual GIS has emerged and that the system is starting to operate as an integrated set of innovation activities.

Fig. 5.7 summarizes how subsystems have evolved in terms of their spatial scale and multi-scalar resource mobilization over the different phases of GIS formation. As can be seen from this stylized representation of the observed dynamics, the inception phase was characterized by individual subsystems, all in their formative phase, showing loose connections among them. In the coordination phase, translocal resource flows intensify and the EU enters the scene as a provider of resources offering new structural couplings. The Dutch subsystem, coordinated by the systemic intermediary STOWA, has been a first mover in terms of local innovation activities, became a core source of technological knowledge, for a newly emerging formative subsystems in Ghent, and in Helsingborg. Since Hamburg and the Netherlands enter their local system building phase during the 2010s, they require additional financial investments, which they absorb from the transnational scale through the European Commission's Life+ and H2020 programs. The two multinationals Jets and Roediger, both already established firms in the vacuum toilet industry, became key transnational technology providers for the different subsystems during this period, we labelled coordination phase. Eventually, in the expansion phase, the knowledge dimension was more firmly established, allowing the Dutch subsystem to move into a growth phase, with Dutch technology experts exporting their knowledge to various other subsystems, and legitimizing deployments both locally and abroad.

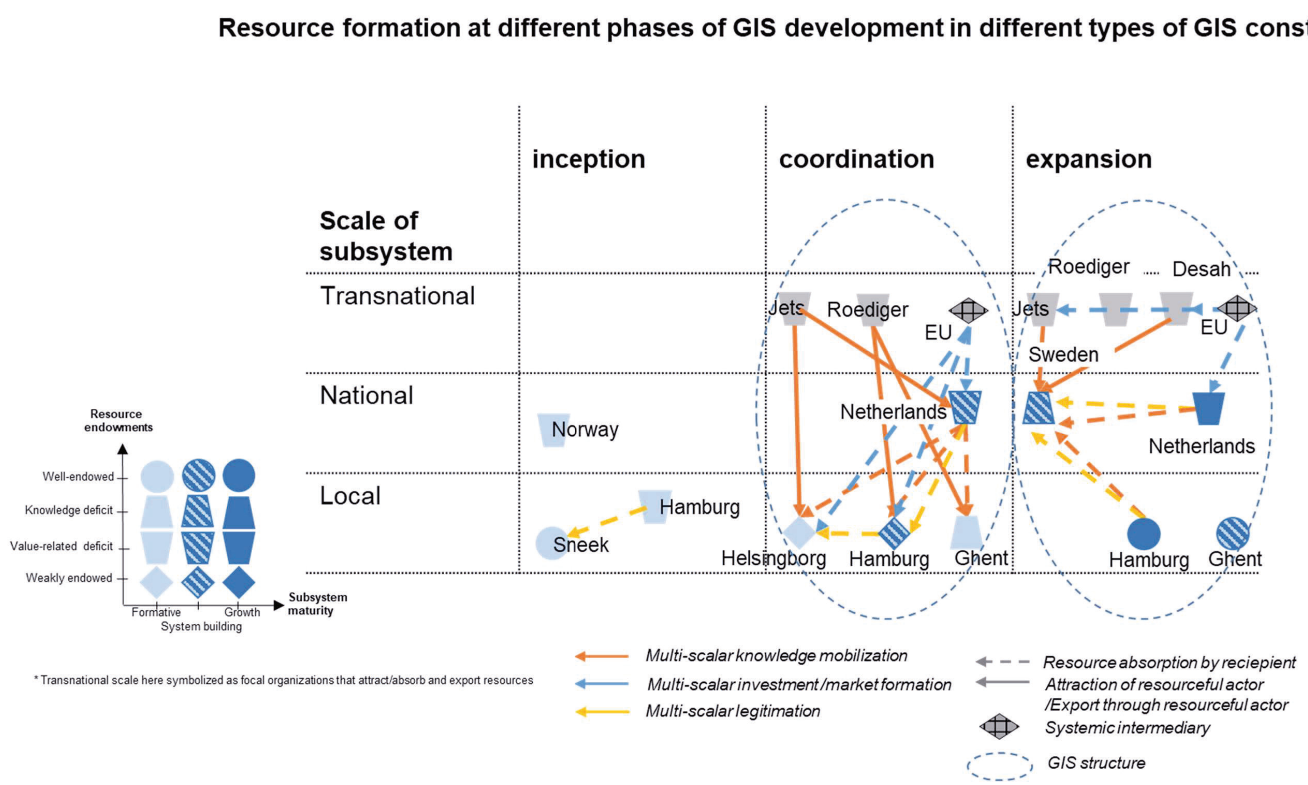


Fig. 5.7: Multi-scalar resource mobilization through phases of GIS emergence. Own figure.

The newly emerging Swedish subsystem, built around the Swedish Innovation Agency Vinnova and the national-scale MACRO project, enters its system building phase well embedded into the established GIS structure, absorbing initial legitimacy, but more importantly, most of the technological knowledge from abroad. Hence, systemic intermediaries emerged as coordinating actors at the national scale but only after the EU entered the scene and incentivized transnational coordination a GIS structure developed and stabilized. However, it remains to be seen for how long this will be the case, and who will take the lead in coordinating translocal resource mobilization in the future. The fact that Swedish actors are now actively reaching out to absorb knowledge, legitimacy and funding from abroad might indicate that the GIS structure will indeed prevail also in this decade. However, even if it does not, the structural couplings of the 2010s have been instrumental to help create various regional and national subsystems, which at least remain loosely coordinated.

In the medium-term future, one might expect other regional or national subsystems to follow the example of Sweden and enter the field by providing legitimacy, market structures and funding primarily internally, and absorbing or attracting the knowledge and capabilities from abroad. The Dutch subsystem became the leading knowledge producer around the treatment technology, and value-related activities started to take place in different subsystems at different scales (EU, Sweden, other urban, regional subsystems around the world). However, a core question will be whether and how the EU will continue to assume its role as systemic intermediary, or who will take this place in the future.

What do these elaborations imply for our initial question, when and why a GIS emerges? First of all, multi-scalar resource mobilization can be conceptualized as a local response to resource barriers or lack of internal resources. This implies, that GIS might emerge out of one local subsystem, which successfully mobilizes knowledge and value-related resources locally, or several subsystems, which are complementary in mobilizing different types of resources. As such, we might see subsystems entering an existing GIS although they lack key local innovation resources (like Ghent), or value-related resources (Netherlands), or both (Hamburg, Helsingborg). In fact, a spatially linear diffusion trajectory might be rather unlikely for a GIS since it would require a single subsystem to host the relevant knowledge and value-related resources to gain a first-mover advantage, as well one or several powerful systemic intermediaries to oversee the diffusion. Instead, other trajectories might be imagined as our case study suggests. For example, two subsystems with complementary resources might engage in resource flows out of a mutual interest, coordinated through an intermediary organization originating from within one of the subsystems. However, it might also be that an external intermediary, not belonging to any subsystem, enables the creation of structural couplings among subsystems. Arguably, in our case, we witness a combination of the latter two, rather than a simple diffusion story. At first, exchanges among the Dutch and the Hamburg subsystem were self-coordinated and mutual. Later the EU was mobilized as an external, transnational intermediary that facilitated couplings among various subsystems. In the future, translocal exchanges might be coordinated by a strong national or regional intermediary, for example from the emerging Swedish subsystem. Other subsystems, like Oslo, have disappeared, or might only be further developed at the regional scale, like in Germany, where potentials for a German subsystem have not been harnessed beyond the Hamburg region.

5.6 Conclusion

The goal of this paper was to elaborate when and why the mobilization of non-local resources occurs in different spatial subsystems that enter a field with different resource endowments at different points in time, and to explore how this leads to the emergence of an integrated GIS among them.

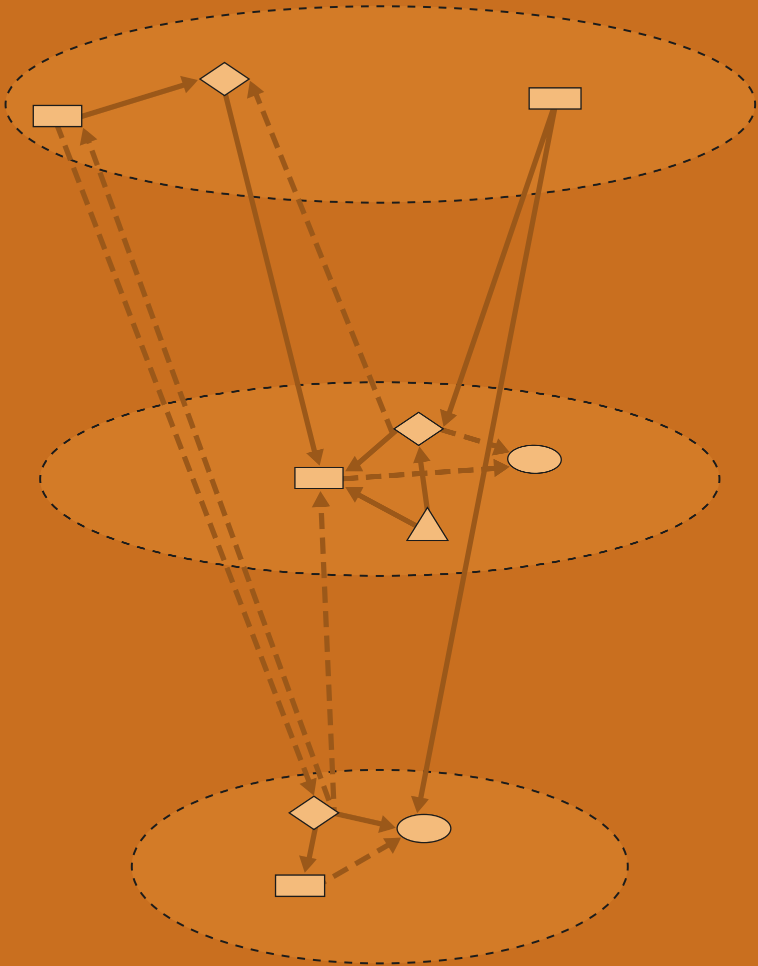
While previous research has hinted at the importance of sectoral differences (Binz and Truffer, 2017), of different value chain segments (Rohe, 2020, Hipp and Binz, 2020), and of local absorptive capacities (Binz and Anadon, 2018) in shaping the scalar dynamics of emerging GIS structures, our contribution adds to these perspectives a temporal dimension. It shows that especially in newly emerging fields, resource complementarities among different subsystems with different degrees of maturity might be crucial in providing the breeding ground for a GIS to be established. Importantly, however, the emergence of an enduring GIS structure may be dependent on the presence of translocal systemic intermediaries.

Our case generated relevant insights in this respect. It suggests, that subsystems may develop and diffuse complementary resources in order to enter a novel technological field. Additionally, mobilizing resources absent in the local context from non-local sources may help subsystems move from formative to growth phases. Eventually, first mover advantages might be available to localities that enter a technological field early, be is as a first mover or in coordination with others. In our case, the early pioneering sites in the Netherlands and Hamburg became important sources of knowledge and legitimacy, for late-mover subsystems like in Sweden or in Ghent. The Norwegian case, additionally, shows how the specialization in a specific knowledge field may create business opportunities abroad, even if there is no local subsystem emerging.

These findings have several implications for future research in innovation and transitions studies. They point to the ability of local actors to absorb or attract resources from other contexts and to actively embed the subsystem into more transnational GIS structures (Crevoisier and Jeannerat, 2009, Binz et al., 2016b, Binz and Anadon, 2018, Heiberg et al., 2020). The article illustrates how a GIS may develop by mobilizing resources locally and by compensating for local resource barriers through complementarities with subsystems at different spatial scales and at different stages of maturity. At the same time, local capabilities and translocal resource complementarities alone are not sufficient for the emergence of a GIS structure. Systemic intermediaries prove to be crucial system builders without which multi-scalar resource flows may not be developed or maintained (Musiolik et al., 2018, van Welie et al., 2020).

Additional insights may be important for a policy perspective. The fact that actors from different regional demonstration sites in Sweden draw on resources from other Western-European contexts very selectively depending on their specific starting conditions, illustrates that a pure national promotion policy for the Swedish innovation system would likely have failed in mobilizing the resources necessary for the innovation system to materialize (Coenen, 2015, Heiberg and Truffer, 2021). Our work shows that innovation and industrial policy should also take into account the facilitation of vertical and horizontal resource mobilization processes, as well as the strategic creation of transnational systemic intermediaries in overcoming such failures (Binz and Anadon, 2018, Binz and Truffer, 2021). Thus, future research could further explore implications for policymaking since policy usually seeks to address systemic and transformational failures within a specific national or regional spatial jurisdiction (Weber and Rohracher, 2012). In our specific case, instead, the directionality and coordination imposed by the EU level was a distinct facilitator of creating an at least temporarily lasting GIS structure.

Conceptually, the present article has bridged research on the geography of transitions (Coenen et al., 2012) and innovation system dynamics (Hekkert, 2007, Suurs and Hekkert, 2009) by both taking into account the temporal dimension of innovation system formation, as well as the spatial relations into which it is embedded. So far, this research could only provide some first indications on how and when resources are being mobilized from outside the local subsystem, and on the emergence of a GIS. Future research should further test these findings, for example by exploring the different local resource portfolios, the presence of systemic intermediaries, and other place-dependent factors that may lead to the multi-scalar mobilization of resources, and the emergence of a GIS.



Chapter 6 Conclusion

What new insights has this thesis generated in terms of the mechanisms through which geography matters in institutionalization processes of novel or altered socio-technical configurations in sectors and industries? What are the conceptual and methodological lessons learned? What are limitations of the approaches chosen in this thesis? What can we learn from a policy and practice point of view? Starting with a summary of the core finding of this thesis in light of the focal research questions, the concluding chapter will address these questions and will broaden the perspective towards discussing the wider implications of this work.

6.1 Summary – bringing together the relational and the configurational

As the contributions in this thesis show, different conceptual and disciplinary angles may illuminate the question through which mechanisms geography conditions sectoral or industrial re-configuration processes around modular water technologies.

In chapter three, we drew on a scalar-relational perspective and elaborated how industrial path creation, especially in emerging clean-tech industries do not only depend upon local knowledge and capabilities but equally on the local institutionalization of the socio-technical regime against which they need to be legitimized. Depending on the specific preconditions for innovation and institutionalization in a spatial context, actors might depend on non-local resources. The novelty of our findings is that we could show how analogous to trans-local knowledge flows multi-scalar processes of attraction, absorption and export of legitimacy may contribute to the institutionalization of a novel configuration. Actors might reference successful technology implementation cases abroad, or attract resourceful actors to support the local legitimation of a new industrial path.

But when and why do individual actors actually start to engage in mobilizing non-local resources? Chapter five addresses these questions taking an explanatory and dynamic angle on the scalar-relational processes introduced in chapter three. While chapter three has identified multi-scalar processes of institutionalization and innovation through which industrial path creation is facilitated in different countries around the globe, chapter five looked at the emergence of these multi-scalar innovation system structures, tracing the development of resource flows among Western-European experimentation sites in the modular water technology field. In chapter three, we looked at national and global-scale structural preconditions for path creation during a specific time-window. In chapter five, in turn, we follow the emergence of a multi-scalar innovation system around a specific modular wastewater treatment technology from its inception through three phases of development. We found that the complementarity among existing resource formation processes in different localities, as well as the coordinating presence of multi-scalar systemic intermediaries, led actors to mobilize non-local resources. In our case, several local innovation systems around the on-site blackwater technology became interdependent, complementing one another at different stages of maturation. The EU played a central role as a systemic intermediary in coordinating and maintaining the system through continuous funding and the appointment of a coordination manager for a transnational project.

The contributions of chapter three and five, in this sense, illustrate how spatial proximity might not be necessary for a novel configurations around an emerging industry or technological field to emerge, if actors in various spatial context are able to uncover and mobilize complementarities among their localized activities. Hence, innovation and institutionalization processes may not only unfold in localized contexts but may require the active mobilization of resources through networks that stretch beyond the immediate locality. This requires a spatially open approach that follows the networks wherever they may lead. Chapter three and five have implemented such an approach, looking at how the *scalar-relational* matters in the early formative phase of novel socio-technical configurations.

The second conceptual advancement of this thesis has been to study industrial and sectoral change from a *configurational* perspective. This implies making explicit the relationships among diverse socio-technical elements, such actors, technologies and institutions that jointly constitute configurations. The focus of chapter two has, therefore, been on how configurations of socio-technical elements and their structural changes can be captured in time and space.

The central contribution of chapter two is the introduction of STCA as a semi-qualitative network methodology to explore socio-technical configurations. Chapter two indeed, looks into the black box of the configurations and their re-configuration processes. Using the same dataset as in chapter three allows maintaining the merit of comparability across countries and scales, but contrary to chapter three, chapter two consciously takes the scalar-relational nature of the re-configurations as given. By focusing on the underlying re-configuration processes instead, chapter two is able to illustrate how regime configurations are reproduced at the global scale of water industry experts and in various countries (Fuenfschilling and Binz, 2018). Further, it reveals how alternative configurations are evolving along different trajectories in either merging with the socio-technical regime into a more hybridized structure (at the global scale or in India), or contradicting and even potentially re-configuring the regime towards a new configuration (USA), mirroring the different discursive strategies of actors proposing novel technologies (Smith and Raven, 2012).

In chapter four, we bring together the scalar-relational and the configurational by focusing on how institutional field logics affect actors' collaboration patterns and their preferences of directionality for an emerging innovation system around modular water technologies in Switzerland. The analysis shows that value-based proximities and the overall degree of harmony or conflict in a field might strongly influence the directionality of an emerging innovation system and equally the geographical boundaries of the system. It indicates that value-based proximities might reflect different types of non-spatial proximities such as cognitive, organizational, social, and institutional proximity (Boschma, 2005)

To summarize, this thesis has brought to the surface different aspects of how geography matters for re-configuration processes by combining a scalar-relational with a configurational perspectives. This has been achieved by combining the scalar-relational processes at work during the emergence of novel configurations (chapter three and five), by mapping and measuring re-configurations of whole socio-technical systems at different spatial scales (chapter two) and by linking institutional configurations of a technological field to scalar-relational processes (chapter four). This work confirms previous work, showing that spatial proximity may be overcome by other types of proximity in re-configuration processes of sectors and industries. It extends beyond this literature, however, taking more explicitly into account processes of institutionalization.

It further introduces a methodological-mix of qualitative and mixed-method approaches that is able to both account for the scalar-relational nature of actor networks and the configurational nature of socio-technical transformations. The following chapter will discuss the implications of the associated methodology, STCA, for research in transitions, EEG and at their interface, on the geography of transitions.

6.2 Making explicit the *configurational* in sustainability transitions

Having elaborated how the four individual contributions of this thesis complement one another with regard to answering the focal research question, the implications of the methodological question (RQ2) require more elaboration. How exactly does STCA contribute to answering questions on the scalar-relational and configurational, and why is this important for understanding the geography of transitions? To discuss the benefit of the STCA methodology to the study of socio-technical transformations, the following chapter will go back to the origins of the *configurational* perspective in socio-technical theories and operationalize it methodologically consistent with a critical realist ontology and epistemology.

Any empirically grounded and – in the spirit of critical realism – explanatory theory of the geography of socio-technical transitions should aspire at both capturing and explaining the dynamics of rule-sets, as well as of the associated alignments of elements that result in the formation and diffusion of new configurations. However, theories of technological change are difficult to construct due to the non-linear and context specific nature of re-configuration processes, and the limitation of having to study transitions through historical case studies ex-post. As already Rip and Kemp (1998, p.359) noted: *"(...) explanations of the eventual shape of technology tend to be glosses on specific case studies (...). Much more may not be possible, given the complexities of technological development and its co-evolution with societal developments"*. Nevertheless, they noted that a more realistic objective for transition scholarship was the mapping and explanation of “(…) formative moments, critical junctures, and the reasons for the emergence of periods of relative stability (…)” (p.360). Despite this early ambition of transition studies, the dominant historical case-study and narrative-explanation based approach chosen by large parts of the scholarship has failed to create generic explanatory theories (Svensson and Nikoleris, 2018, Sorrell, 2018). While it might be too far-fetched to address this gap, this thesis may still contribute to more explanatory theorizations by improving our ability to map and measure socio-technical configurations and the scalar relations of associated actors.

Mapping configurational shifts requires capturing the construction and de-construction of socio-technical linkages among various entities and artifacts that conjointly form a socio-technical system. As Sorrell (2018) notes based on a critical realist ontology of social structures by Archer (1982), emergent properties of a socio-technical system only emerge from the relations of its various entities, and not from any individual entity alone. Svensson and Nikoleris (2018) add along these lines that relations of entities, i.e. socio-technical linkages, are fundamentally mediated by other systemic factors, such as power and space. This means that mapping configurations of entities, their degrees of alignment, coherence, and the relational space into which they are embedded becomes a crucial prerequisite for understanding the emergent properties of socio-technical systems.

The STCA methodology takes an explicit step towards fulfilling this prerequisite by allowing to empirically study configurations as bundles of entities related through socio-technical linkages. It requires the researcher to make explicit the crucial entities, like actors, technologies, types of infrastructures, modes of governance and management, and institutions, as well as the linkages among them and the strength of theses linkages at different points in time and in different spatial and scalar contexts. This is achieved not as part of a historical narrative, but as part of an empirical analysis that derives configurations from textual data, that may ideally be time- and/or geo-referenced. This of course poses a methodological challenge. How can we know about something as complex as the entities of a socio-technical system, their linkages, and dynamics over time and space?

STCA seeks to address this problem in deriving the actual of socio-technical linkages, configurations and their dynamics, from the empirical of their manifestation in different sorts of textual media. Thus, translated to socio-technical configurations and their transformation processes one has to ask: how do socio-technical configurations actualize? What is the empirical domain with regard to re-configuration processes? Moreover, which part of the actual can we infer by studying the empirical? STCA assumes that the socio-technical configuration may actualize through their *articulation* by actors involved in the socio-technical system or by third parties. Configurations may be articulated in interviews or surveys with experts who know the system well. Configurations may be articulated by journalists or commentators who observe the system and write about it in media articles. Or they may be articulated by the system actors themselves, through their articulation in project descriptions, in press releases, media appearances, on social media or through particular types of activities that can be empirically observed. Hence, the sources of the empirical for STCA are similar to any other qualitative research methodology. In choosing any particular textual data source, the task for the researcher is then to ask: which part of the actual does this medium of articulation potentially cover? In chapter two, we draw on specific critical moments, e.g. environmental hazards, during which we assumed configurational shifts did actualize in media discourses based on previous knowledge related to transition discourses. In chapter four, we claim to map field logic configurations in their entirety by studying a sufficiently small field (a newly emerging technological field in Switzerland) talking to a variety of field actors, from whose statements we infer underlying institutional logics that various actors in the field adhere to. Depending on the research question, the data sources and the specific method of data generation may vary. The defining feature of STCA is the representation of configurations and their internal linkages. This representation is achieved, for example, by constructing networks of actors and socio-technical elements, e.g. technologies, infrastructures, institutions (as in chapter two), or among field-logic configurations composed of institutional logics as in chapter four. What STCA researchers are then most interested in, are the shifts in configurations across space and time, which can be studied in the projection of networks of socio-technical elements.

A crucial question that needs to be answered in constructing these "empirical" socio-technical networks relates to the definition of the linkages. Studying configurations from discursive statements, for example, in line with the discourse network analysis (DNA) method, linkages are constituted by ideational congruence, i.e. the joint utilization of two concepts by the same actor(s) (Leifeld and Haunss, 2012, Leifeld, 2009). If an actor utilizes two concepts congruently, e.g. supports the idea of both autonomous vehicles and electric vehicles, the researcher may infer that both technologies will not contradict one another ideationally. Ideational congruence – as the empirical that can be observed – is a proxy for the underlying configuration that it represents. In the example, autonomous vehicles and electric engines may form a configuration that works. In other applications, linkages may rest on other forms of compatibility or alignment. What then is the benefit of the approach compared with classical qualitative case studies and narrative explanation?

STCA allows for a network-theoretic operationalization of socio-technical configurations. It allows for the identification of patterns of institutionalization, of coherence and stability that develop as emergent properties, and can only be understood through their role within larger configurations. While STCA cannot explain socio-technical change on its own, it leverages a novel methodological approach, which extends beyond the traditional case study approach. As shown in chapter two, this may allow for more comparative analyses across cases, sites, regions or countries. Or it may enable a more elaborate understanding of the rules-sets and logics that govern socio-technical change, as in chapter four. In combination with other methodologies, like interviews, qualitative comparative analysis or process tracing, STCA may ultimately allow for more explanatory mixed method research designs (Furnari et al., 2020, Misangyi et al., 2017). These, in turn, may be more applicable to studying transitions from a critical realist perspective (Nikoleris, 2018, Svensson and Nikoleris, 2018) and more coherent with sociological conceptualization of socio-technical regimes (Fuenfschilling, 2014).

The actual value of this contribution has yet to be explored. As shown in chapter four, STCA may be able to situate intermediary organizations in a field based on their ability to mediate between different field logics. In this direction, STCA could be a tool to shed new light on current transition debates on intermediation strategies (Kivimaa et al., 2019). Another application could be looking at transition dynamics within a specific sector, comparing across different countries, but rather comparing across different sectors (Andersen et al., 2020). Similarly, STCA may help explore re-configuration processes that do not primarily involve technological, but rather social or institutional innovations including shifts towards alternative societal paradigms beyond varieties of capitalism

(Feola, 2019). For example, STCA may be a suitable tool to understand re-configuration processes around social, organizational and institutional elements, associated with the rise of the sharing economy (Frenken and Schor, 2017, Frenken et al., 2020, Grabher and van Tuijl, 2020). Of course, the realm of applications within the GeoST field (Binz et al., 2020a) is by far not exhausted by the two applications presented in this thesis. Researcher might be interested in applying STCA in order to understand the translation and reproduction of socio-technical regimes across spatial scales (Miörner and Binz, 2021). A recent paper, co-authored by the author of this thesis, for example, looks at how global regime rationalities diffuse into a local public discourses, impeding a potential sustainability transitions, despite the availability of local resources (Miörner et al., 2021).

Eventually, STCA is not dependent upon operationalizing the core, established analytical frameworks of transitions studies, namely TIS and the socio-technical regime concepts, as has been done in this thesis. Instead, STCA might provide an inroad to studying transformation processes from other theoretical and disciplinary backgrounds, such as for example sociology or human geography more broadly (Hopkins et al., 2020). In this vein, and to elaborate one example in detail, the next chapter will be concerned with outlining the potential added-value of a configurational perspective studying re-configuration processes in the field of EEG.

6.3 Moving towards engaged pluralism by introducing the *configurational* to (E)EG:

Having elaborated the contribution to transitions research, the present chapter will turn towards how the configurational perspective might help consolidate relational, institutional, and evolutionary approaches to economic geography. It will do so, in particular, by alluding to its contribution regarding three conceptual problems frequently highlighted by EEG scholars. These are, (i) a more differentiated institutional approach to EEG (Hassink et al., 2019, MacKinnon et al., 2019a) (ii) the emergence of new regional industrial paths in clean-tech industries which often require unrelated diversification (Trippl et al., 2020, Neffke et al., 2018, Dawley, 2014), and (iii) the multi-scalar and relational processes that may be required for this (Binz et al., 2014, Binz et al., 2016b).

Regarding the first point, research on regional innovation systems and path creation has engaged with the role of institutions as promoting or hindering factors for radically new industrial paths to emerge, for example through the notion of institutional thickness (Trippl et al., 2020, Zukauskaite et al., 2017). Baumgartinger-Seiringer et al. (2021) argue that such an isolated perspective of institutions as an isolated category along with actors and networks fails represent the role of structural conditions for industrial change in regions. Like this thesis, they suggest EEG to draw more heavily on organizational studies, and specifically an understanding of systems as organizational fields (DiMaggio and Powell, 1983). They do so by introducing the concepts of institutional infrastructures (Hinings et al., 2017) and institutional complexity (Greenwood et al., 2011) which direct attention to the degree of institutionalization of different structural elements and the degree to which they reinforce one another in enabling or impeding industrial change. As elaborated in chapter two, STCA operationalizes the degree of institutionalization as well as the coherence of socio-technical elements in organizational fields as properties of a network. STCA might then be a valuable tool to empirically explore and compare the dynamic changes of institutional infrastructures in different RIS. As for transitions studies, also research in EEG, and in particular, research on the structural underpinnings of unrelated diversification and specific regional institutional infrastructures might, therefore, benefit from applying STCA, allowing to trace the “co-evolution of technologies, industries structures and supporting institutions” (Nelson, 1994) into “new combination[s]” (Schumpeter, 1934), or more broadly speaking, configurations that work.

Another contribution to EEG relates to the notion of different types of proximities and their relationship to the diffusion of knowledge through networks in space. Different proximities, such as cognitive (sharing similar knowledge), institutional (sharing similar laws, regulations, norms or values), geographical (being co-located), social (being friends), or organizational (being embedded in the same organizational hierarchy) may drive or impede network formation among organizations and the diffusion knowledge in space (Boschma, 2005, Breschi and Lissoni, 2009, Boschma and Frenken, 2010). In chapter four, we have reframed the notion of proximities into value-based and spatial proximities. We show how adherence to different logics may actually reflect different types of non-spatial proximities among organizations. For example, cognitive proximity rests on water engineers sharing the same synthetic engineering knowledge, which is associated with very particular values reproduced in the professional culture or logic of engineers. Organizational proximity might be translated into the logic of the corporation or the state, which is shared among organizations in the public or private sector respectively. Social proximity might rest on the logic of the community. A translation of non-spatial proximities into institutional logics is not one on one. Nevertheless, it may provide an avenue for further research on a better understanding of proximities. If institutional proximity is everything from shared formal institutions to shared values, then conceptual overlaps and problems of distinction from other types of proximity are inevitable. As we show in chapter four, the logic-based view may allow for a more differentiated perspective on why extra-regional linkages may emerge or not, showing how new paths might emerge despite previously unrelated regional assets.

Eventually, this work, and especially the contributions in chapter three and five, add to a more differentiated understanding of how relations at multiple spatial scales are created, maintained and harnessed in the context of spatial innovation systems. Adding to other contributions in this direction (e.g. Binz and Truffer, 2017, Binz et al., 2014, Binz et al., 2016b), the ambition was to create a better understanding of how and why actors start engaging in the mobilization of resources that they cannot access in their local environment. Chapter three added to this research agenda, by showing how multi-scalar legitimation may strongly resemble the processes of attraction, abortion and export already identified for trans-local networks of knowledge diffusion (Trippl et al., 2018). Additionally, it indicates how a combined perspective on the scalar-relational and the configurational may lead to new hypothesis about different routes and regional strategies to path development in face of lack of related knowledge and capabilities. Chapter five, eventually, takes a dynamic perspective on the early emergence of multi-scalar innovation systems around novel technologies taking both local as well as non-local assets into account. Thus, taken together, these contributions shed light on how and when path dependency (Garud et al., 2010) may be overcome by actors embedded into networks at multiple spatial scales in the creation of global innovation systems (Binz and Truffer, 2017).

With this, it may be that the configurational perspective can provide a vehicle for combining relational and institutional approaches to EEG in an "engaged pluralism" (Hassink et al., 2014, Barnes and Sheppard, 2010). As Sunley (2008) argues in his critique of relational economic geography along the lines of Thelen (2004), what would be needed in EG research is an approach that marries the institutional and the relational in understanding network relations as the mirror image of the rule sets, which are reproduced by various coalitions of actors:

"economic [...] relations are not just capricious network trails, but reproductions [...] of sets of rules and conventions. A properly institutionalist and relational approach in economic geography would give central attention to how coalitions of interest groups [...] shape the evolution of these generative rules" (p.19).

STCA – that allows tracing both scalar-relational actor networks as well as associated reconfiguration processes – may indeed not only resonate with, but also stimulate a dialogue among the seemingly diverging ontological and epistemological traditions of relational, institutional and evolutionary economic geography. In this way, it might be a step towards a novel epistemological paradigm around 'configurational economic geography'.

6.4 Limitations and need for further research

Of course, the conceptual and methodological approaches chosen to study the geography of transitions in this thesis exhibit limitations of different sorts. This final chapter will discuss some of these limitations, and propose research avenues that might help address them subsequently.

One important limitation of this thesis and of the transitions literature more broadly is that the definition of what constitutes a socio-technical regime is not uniformly accepted among transition scholars (Sorrell, 2018). While this thesis clearly follows the traditional rule-based understanding of the socio-technical regime (Geels, 2002), later work has defined it as a duality of structure and agency, hence, potentially including actors and material structures (Geels, 2011). Relatedly, it is still debated whether underlying rules or logics, should be considered merely as institutions, and accordingly, as part of the socio-technical system, or a separate force with emergent properties (Fuenfschilling and Truffer, 2014). No matter how such – arguably ontological – issues are solved, STCA might allow for meaningful analyses form either perspective. In this thesis, choosing to understand logics, i.e. rules, as separate entities allowed to explore them as mirror image of the actual actor networks (and as such of the socio-technical system structures) in chapter four. In Chapter two, configurations include institutional and other elements. Here, the rule-sets are operationalized as infrastructure paradigms that align with different technologies into coherent configurations. Therefore, while the rule-based view has been criticized of reducing reality unduly, STCA may help overcome this issue by explicating relationships between rules and the system without conflating them as one.

Nevertheless, the methodology is still in its infancy and various open questions regarding its boundaries and scope, its differentiation from related methods, and its practical implementation remain. Thus far, the applications of STCA have been limited to media analyses and interview data. Future research will have to explore its applicability and feasibility for studying socio-technical configurations based on other document stocks. A core challenge is accessing these documents. Potential document types beyond newspapers include, for example, press releases, industry magazines, parliamentary hearing protocols, textual data from archives, or transcripts of documentary material. The choice of source data obviously limits the extent to which socio-technical configurations are actualized and can be observed. Another limiting factor is that for many of the temporally and spatially-sensitive research questions, the source data needs to be time, and or geo-referenced. As media data is a predestined source fulfilling these requirements, one may ask whether STCA is not actually only studying the discourse and not re-configuration processes. In this context, STCA's relationship to Discourse network analysis (DNA) may need to be further discussed. Technically the two mixed-method approaches are much alike. The researcher extracts associations of actors and concepts and explores each mode (of a network) with help of tools established by classical social network analysis (SNA) methods. The difference is that DNA is empirically interested in actor-concept associations that rest on actors' statements made around specific policy proposals or political positions uttered in a policy discourse. DNA then reveals advocacy coalitions of actors clustering around a set of opinions towards different policy proposals, or discourse coalitions with actors choosing their side on the pro- or con- storylines around one specific policy proposal (Leifeld, 2009, Leifeld, 2013). As recent applications show, DNA may be a useful tool to study the congruence, and coherence of specific coalitions around transition processes that are discussed widely in public and political discourse arenas (Schmidt et al., 2019, Brugger and Henry, 2021, Markard et al., 2021). STCA, in contrast, is not primarily interested in the discourse, and also not limited to the coding of actor-concept associations based on statements made in the media. Rather, in line with more open qualitative methodologies like historical event analysis (Hekkert, 2007), innovation biographies (Butzin and Widmaier, 2016), or transition topologies (Strambach and Pflitsch, 2020), STCA seeks to identify a much broader set of association among actors and different types of socio-technical elements. Since the character of alignments between socio-technical elements may be manifold, the nature of associations needs to be clearly defined a-priory, and the coding requires the researcher to regularly check for the consistency of the coding process. All of this might be more time consuming than for DNA, where storylines or concepts are usually known to the researcher, at least partly, and statements are more easily identified. A clear limitation is that the diffusion of the relevant practical knowledge to apply the methodology has been limited to local method workshops so far. A codified guidebook to STCA is however being prepared as an online learning resource (Heiberg and Miörner, 2021).

Another limitation is that STCA has yet to be deployed in more explanatory research designs, which is one of the core goals of applying configurational theorizing (Furnari et al., 2020) and a critical realist ontology (Sayer, 1992, Sorrell, 2018). As recently highlighted by several authors, moving towards configurational theorizing may not only be relevant to the study of transitions, but equally for economic geography (Rutten, 2020, Gong and Hassink, 2020). Future research in both fields, should therefor explore more explanatory mixed method research designs (Creswell, 2014) that involve both STCA or DNA as tools to study re-configuration processes or transition discourses, for example in combination with interviews, Qualitative Comparative Analysis (QCA)(Rutten, 2020), and/or process tracing (Williams and Gemperle, 2017). For example, researchers could use QCA to explore how certain configurations of elements have benefited certain transition outcomes or not.

A last limitation also remains the methodological operationalization of both the scalar-relational and the configurational perspective in a single approach. STCA may well incorporate a geographical dimension (e.g. by capturing the geography of specific actors or socio-technical elements). While chapter two and three already provide some ideas into how the geographical dimension of an STCA may be used for more relational purposes, future research will have to explore in how far it may be used beyond the delineation of geographical boundaries when applying the configurational perspective. For EEG scholars interested in regional path creation, who approach their data with clearly demarcated regional boundaries, the filtering of data according to spatial boundaries will already be very useful. In addition, EEG researchers might find STCA useful in order to improve their sampling rationale for cases to compare in later, more in-depth types of analysis.

Overall, this thesis could only identify the contours of an interesting novel methodological approach to studying the geography of transitions and industrial path development. As such, it seeks to motivate transition researchers and geographers alike to deploy more innovative, and eventually, more explanatory research designs.

6.5 Implications for policy and practice

This short concluding section will allude to potential policy implications that may be derived from the insights gained in the four individual chapters.

First of all, it is not the intention of this thesis to formulate policy advice in a more narrow sense. The purpose of this thesis was *understanding* processes and mechanisms related to the role of geography in major re-configuration processes of industries and sectors. Understanding how, why and when re-configuration processes unfold, however, is crucial for policy makers and other private, public or societal stakeholders engaged in an industry or a broader transition. Research like this may help identifying more or less powerful leverage points, hinting to where, when and how interventions in transition and re-configuration processes might be meaningful and effective (Abson et al., 2017). From this point of view, several aspects of the investigations presented in this thesis may be of relevance to practitioners and policy makers.

For early stage, radical innovation, this thesis has drawn attention to the importance of the coordination of resource mobilization processes at the transnational scale (Binz and Truffer, 2021). As the case of the emerging GIS structure around vacuum-toilets and blackwater treatment in chapter five shows, the installation of targeted funding and a coordinating systemic intermediary may be crucial to stabilize the development and diffusion of a technology overall.

Another role for intermediation emerges from the discussion of chapter four. Here, we discovered that specific actors, who were bridging structural holes (Burt, 1992) in collaboration networks, were often also crucial in mediating and combining different field logics and directionalities. Policy-makers might, therefore, consider to more explicitly screen value-based proximities in organizational or technological fields, in order to make themselves and practitioners become more reflexive of their own role in the field (to avoid reflexivity failure), and of the directionality in which they are moving the field by supporting specific initiatives (Weber and Rohracher, 2012). In fact, an interesting feedback by interviewees on the findings from chapter four was that it allowed them to reflect better on their role in the field, which allowed them to plan and structure intervention in a more targeted way. Analyses like the one in chapter four might equally serve as an aid for policy to make difficult decisions, e.g. related to picking a the specific type of technology or configuration, and the underlying actor network to subsidize in the long run. In contrast to more technical screenings of technological or knowledge related compatibilities among technologies, STCA may help to identify and communicate more value-based and other non-technical compatibilities relevant to the promotion of specific technological trajectories.

This leads to a further aspect related to the presentation of research findings to diverse audiences. Here, a crucially important but yet undiscussed aspect of applying STCA comes to the fore, namely, the role of network visualizations as visual representations of socio-technical configurations, socio-technical storylines or emergent field logics. Network visualizations of re-configuration processes or even actor coalitions might help practitioners understand important relationships and their own role in reproducing the same. At the same time, network visualizations can quickly be misused or misinterpreted. Thorough elaborations of the underlying network associations, the underlying sources, and the methodological approach they are based on, are crucial. If all of these aspects are accounted for, then network visualizations as those produced with STCA might be a powerful tool to communicate findings on re-configuration processes to policy and practice.

References

Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., Von Wehrden, H., Abernethy, P., Ives, C. D. & Jager, N. W. 2017. Leverage points for sustainability transformation. *Ambio,* 46 (1): 30-39.

Agrawal, A., Cockburn, I. & McHale, J. 2006. Gone but not forgotten: knowledge flows, labor mobility, and enduring social relationships. *Journal of Economic Geography,* 6 (5): 571-591.

Aldrich, H. E. & Fiol, C. M. 1994. Fools Rush in? The Institutional Context of Industry Creation. *Academy of Management Review,* 19 (4): 645-670.

Alkemade, F. 2019. Sustainable innovation research methods. *In:* Boons, F. & McMeekin, A. (eds.) *Handbook of Sustainable Innovation.* Cheltenham: Edward Elgar Publishing, 299-309.

Allen, L., O'Connell, A. & Kiermer, V. 2019. How can we ensure visibility and diversity in research contributions? How the Contributor Role Taxonomy (CRediT) is helping the shift from authorship to contributorship. *Learned Publishing,* 32 (1): 71-74.

Ampe, K., Paredis, E., Asveld, L., Osseweijer, P. & Block, T. 2021. Incumbents' enabling role in niche-innovation: Power dynamics in a wastewater project. *Environmental Innovation and Societal Transitions,* 39: 73-85.

Andersen, A. D., Steen, M., Mäkitie, T., Hanson, J., Thune, T. M. & Soppe, B. 2020. The role of inter-sectoral dynamics in sustainability transitions: A comment on the transitions research agenda. *Environmental Innovation and Societal Transitions,* 34: 348-351.

Archer, M. S. 1982. Morphogenesis versus Structuration: On Combining Structure and Action. *The British Journal of Sociology,* 33 (4): 455-483.

Archibugi, D., Howells, J. & Michie, J. 1999. Innovation Systems in a Global Economy. *Technology Analysis & Strategic Management,* 11 (4): 527-539.

Archibugi, D. & Planta, M. 1996. Measuring technological change through patents and innovation surveys. *Technovation,* 16 (9): 451-519.

Asheim, B. & Gertler, M. S. 2005. The Geography of Innovation. *In:* Fagerberg, J., Mowery, D. C. & Nelson, R. R. (eds.) *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, 291-317.

Audretsch, D. B. & Feldman, M. P. 1996. R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review,* 86 (3): 630-640.

Augustin, K., Skambraks, A.-K., Li, Z., Giese, T., Rakelmann, U., Meinzinger, F., Schonlau, H. & Günner, C. 2013. Towards sustainable sanitation – the HAMBURG WATER Cycle in the settlement Jenfelder Au. *Water Supply,* 14 (1): 13-21.

Avelino, F., Grin, J., Pel, B. & Jhagroe, S. 2016. The politics of sustainability transitions. *Journal of Environmental Policy & Planning,* 18 (5): 557-567.

Barbiroglio, E. 2020. A New 32GWh Gigafactory Will Build Sustainable Batteries In Norway. *Forbes*.

Barnes, T. J. & Sheppard, E. 2010. 'Nothing includes everything': towards engaged pluralism in Anglophone economic geography. *Progress in Human Geography,* 34 (2): 193-214.

Bathelt, H. & Glückler, J. 2003. Toward a relational economic geography. *Journal of Economic Geography,* 3 (2): 117-144.

Bathelt, H., Malmberg, A. & Maskell, P. 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography,* 28 (1): 31-56.

Battilana, J., Leca, B. & Boxenbaum, E. 2009. How Actors Change Institutions: Towards a Theory of Institutional Entrepreneurship. *Academy of Management Annals,* 3 (1): 65-107.

Baudoin, M.-A., Vogel, C., Nortje, K. & Naik, M. 2017. Living with drought in South Africa: lessons learnt from the recent El Niño drought period. *International Journal of Disaster Risk Reduction,* 23: 128-137.

Bauer, F. & Fuenfschilling, L. 2019. Local initiatives and global regimes – Multi-scalar transition dynamics in the chemical industry. *Journal of Cleaner Production,* 216: 172-183.

Baumgartinger-Seiringer, S., Fuenfschilling, L., Miörner, J. & Trippl, M. 2021. Reconsidering regional structural conditions for industrial renewal. *Regional Studies*: 1-13.

Baur, M. 2008. *Software for the Analysis and Visualization of Social Networks.* PhD, Fridericiana University Karlsruhe

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B. & Truffer, B. 2015. Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. *Environmental Innovation and Societal Transitions,* 16: 51-64.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A. 2008a. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy,* 37 (3): 407-429.

Bergek, A., Jacobsson, S. & Sandén, B. A. 2008b. 'Legitimation' and 'development of positive externalities': two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management,* 20 (5): 575-592.

Bhaskar, R. 1975. *A Realist Theory of Science,* Leeds, Leeds Books.

Bhaskar, R. 1998. General introduction. *In:* Archer, M., Bhaskar, R., Collier, A., Lawson, T. & Norrie, A. (eds.) *Critical Realism: Essential Readings.* London: Routledge, ix-xxiv.

Bijker, W. E., Hughes, T. P. & Pinch, T. 1987. *The social construction of technological systems,* Camebridge, Massachusetts, MIT Press.

Binz, C. & Anadon, L. D. 2018. Unrelated diversification in latecomer contexts: Emergence of the Chinese solar photovoltaics industry. *Environmental Innovation and Societal Transitions,* 28: 14-34.

Binz, C., Coenen, L., Murphy, J. T. & Truffer, B. 2020a. Geographies of transition—From topical concerns to theoretical engagement: A comment on the transitions research agenda. *Environmental Innovation and Societal Transitions,* 34: 1-3.

Binz, C., Gosens, J., Yap, X.-S. & Yu, Z. 2020b. Catch-up dynamics in early industry lifecycle stages—a typology and comparative case studies in four clean-tech industries. *Industrial and Corporate Change,* 29 (5): 1257-1275.

Binz, C., Harris-Lovett, S., Kiparsky, M., Sedlak, D. L. & Truffer, B. 2016a. The thorny road to technology legitimation — Institutional work for potable water reuse in California. *Technological Forecasting and Social Change,* 103: 249-263.

Binz, C. & Truffer, B. 2017. Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. *Research Policy,* 46 (7): 1284-1298.

Binz, C. & Truffer, B. 2021. The Governance of Global Innovation Systems: Putting knowledge in context. *In:* Glückler, J., Herrigel, G. & Handke, M. (eds.) *Knowledge for Governance.* Basel: Springer International Publishing, 466.

Binz, C., Truffer, B. & Coenen, L. 2014. Why space matters in technological innovation systems - Mapping global knowledge dynamics of membrane bioreactor technology. *Research Policy,* 43 (1): 138-155.

Binz, C., Truffer, B. & Coenen, L. 2016b. Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. *Economic Geography,* vol. 92 (no. 2): 172-200.

Boggs, J. S. & Rantisi, N. M. 2003. The 'relational turn' in economic geography. *Journal of Economic Geography,* 3 (2): 109-116.

Boltanski, L. & Thévenot, L. 2006. *On justification. Economies of worth* Princeton; Oxford, Princeton University Press.

Boon, W. & Edler, J. 2018. Demand, challenges, and innovation. Making sense of new trends in innovation policy. *Science and Public Policy,* 45 (4): 435-447.
Bork, S., Schoormans, J. P. L., Silvester, S. & Joore, P. 2015. How actors can influence the legitimation of new consumer product categories: A theoretical framework. *Environmental Innovation and Societal Transitions,* 16: 38-50.
Boschma, R. 2005. Proximity and Innovation: A Critical Assessment. *Regional Studies,* 39 (1): 61-74.
Boschma, R. & Capone, G. 2015. Institutions and diversification: Related versus unrelated diversification in a varieties of capitalism framework. *Research Policy,* 44 (10): 1902-1914.
Boschma, R., Coenen, L., Frenken, K. & Truffer, B. 2017. Towards a theory of regional diversification. *Regional Studies,* accepted.
Boschma, R. & Frenken, K. 2010. The Spatial Evolution of Innovation Networks. A Proximity Perspective. *In:* Boschma, R. & Martin, R. (eds.) *Handbook on Evolutionary Economic Geography.* Cheltenham: Edward Elgar, 120–135.
Boschma, R. & Frenken, K. 2018. Evolutionary Economic Geography. *In:* Clark, G. L., Feldman, M. P., Gertler, M. S. & Wojcik, G. (eds.) *The New Oxford Handbook of Economic Geography.* Oxford: Oxford University Press, 213-229.
Boschma, R. A. & Frenken, K. 2006. Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography,* 6 (3): 273-302.
Brandes, U. & Pich, C. An Experimental Study on Distance-Based Graph Drawing. 2009 Berlin, Heidelberg. Springer Berlin Heidelberg, 218-229.
Brenner, N. 1998. Between Fixity and Motion: Accumulation, Territorial Organization and the Historical Geography of Spatial Scales. *Environment and Planning D: Society and Space,* 16 (4): 459-481.
Brenner, N. 2001. The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography,* 25 (4): 591-614.
Breschi, S. & Lissoni, F. 2009. Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. *Journal of Economic Geography,* 9 (4): 439-468.
Brugger, H. & Henry, A. D. 2021. Influence of policy discourse networks on local energy transitions. *Environmental Innovation and Societal Transitions,* 39: 141-154.
Burt, R. S. 1992. *Structural Holes*, Harvard University Press.
Butzin, A. & Widmaier, B. 2016. Exploring Territorial Knowledge Dynamics through Innovation Biographies. *Regional Studies,* 50 (2): 220-232.
Carlsson, B. 2006. Internationalization of innovation systems: A survey of the literature. *Research Policy,* 35 (1): 56-67.
Carlsson, B. & Jacobsson, S. 1997. In Search of Useful Public Policies — Key Lessons and Issues for Policy Makers. *In:* Carlsson, B. (ed.) *Technological Systems and Industrial Dynamics.* Boston, MA: Springer US, 299-315.
Carlsson, B., Jacobsson, S., Holmén, M. & Rickne, A. 2002. Innovation systems: analytical and methodological issues. *Research Policy,* 31 (2): 233-245.
Carlsson, B. & Stankiewicz, R. 1991. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics,* 1 (2): 93-118.
Carvalho, L. & Vale, M. 2018. Biotech by bricolage? Agency, institutional relatedness and new path development in peripheral regions. *Cambridge Journal of Regions, Economy and Society,* 11 (2): 275-295.
Chaminade, C. & Edquist, C. 2010. Rationales for Public Policy Intervention in the Innovation Process: Systems of Innovation Approach *In:* Smits, R. E., Kuhlmann, S. & Shapira, P. (eds.) *The Theory and Practice of Innovation Policy.* Edward Elgar Publishing.

Chaminade, C. & Plechero, M. 2015. Do Regions Make a Difference? Regional Innovation Systems and Global Innovation Networks in the ICT Industry. *European Planning Studies,* 23 (2): 215-237.

Coenen, L. 2015. Engaging with changing spatial realities in TIS research. *Environmental Innovation and Societal Transitions,* 16: 70-72.

Coenen, L., Asheim, B., Bugge, M. M. & Herstad, S. J. 2016. Advancing regional innovation systems: What does evolutionary economic geography bring to the policy table? *Environment and Planning C: Politics and Space,* 35 (4): 600-620.

Coenen, L., Benneworth, P. & Truffer, B. 2012. Toward a spatial perspective on sustainability transitions. *Research Policy,* 41 (6): 968-979.

Coenen, L., Hansen, T. & Rekers, J. V. 2015. Innovation Policy for Grand Challenges. An Economic Geography Perspective. *Geography Compass,* vol. 9 (no. 9): 483-496.

Content, J. & Frenken, K. 2016. Related variety and economic development: a literature review. *European Planning Studies,* 24 (12): 2097-2112.

Creswell, J. W. 2014. *Research Design. Qualitative, Quantitative, & Mixed Method Approaches,* Los Angeles, Sage Publications, Inc.

Crevoisier, O. & Jeannerat, H. 2009. Territorial Knowledge Dynamics: From the Proximity Paradigm to Multi-location Milieus. *European Planning Studies,* 17 (8): 1223-1241.

Dahlgren, E., Göçmen, C., Lackner, K. & van Ryzin, G. 2013. Small Modular Infrastructure. *The Engineering Economist,* 58 (4): 231-264.

Danermark, B., Ekstrom, M., Jakobsen, L. & Karlsson, J. C. 2001. *Explaining Society: Critical Realism in the Social Sciences*, Psychology Press.

Dasgupta, S., Agarwal, N. & Mukherjee, A. 2021. Moving up the On-Site Sanitation ladder in urban India through better systems and standards. *Journal of Environmental Management,* 280: 111656.

Dawley, S. 2014. Creating New Paths? Offshore Wind, Policy Activism, and Peripheral Region Development. *Economic Geography,* 90 (1): 91-112.

Dawley, S., MacKinnon, D., Cumbers, A. & Pike, A. 2015. Policy activism and regional path creation: the promotion of offshore wind in North East England and Scotland. *Cambridge Journal of Regions, Economy and Society,* 8 (2): 257-272.

de Mul, J. J. 2020. *The development of DESAR technologies in the Netherlands.* MSc, Utrecht University.

De Oliveira, L. G. S., Subtil Lacerda, J. & Negro, S. O. 2020. A mechanism-based explanation for blocking mechanisms in technological innovation systems. *Environmental Innovation and Societal Transitions,* 37: 18-38.

Dewald, U. & Fromhold-Eisebith, M. 2015. Trajectories of sustainability transitions in scale-transcending innovation systems: The case of photovoltaics. *Environmental Innovation and Societal Transitions,* 17 (2015): 110-125.

Dewald, U. & Truffer, B. 2011. Market Formation in Technological Innovation Systems—Diffusion of Photovoltaic Applications in Germany. *Industry and Innovation,* 18 (3): 285-300.

Dewald, U. & Truffer, B. 2012. The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. *European Planning Studies,* 20 (3): 397-420.

Dewald, U. & Truffer, B. 2017. Market formation and innovation systems. *In:* Bathelt, H., Cohendent, P., Henn, S. & Simon, L. (eds.) *Innovation and Knowledge Creation.* Cheltenham (UK): Edward Elgar Publishing Limited, 610-624.

DiMaggio, P. J. & Powell, W. W. 1983. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review,* 48 (2): 147-160.

Dominguez, D., Worch, H., Markard, J., Truffer, B. & Gujer, W. 2009. Closing the Capability Gap: Strategic Planning for the Infrastructure Sector. *California Management Review,* 51 (2): 30-50.

Dosi, G. 1982. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy,* 11 (3): 147-162.

Dosi, G. 1988. Sources, Procedures, and Microeconomic Effects of Innovation. *Journal of Economic Literature,* 26 (3): 1120-1171.

Dubois, V. & Boutin, C. 2018. Comparison of the design criteria of 141 onsite wastewater treatment systems available on the French market. *Journal of Environmental Management,* 216: 299-304.

Eckhoff, P. & Wood, L. 2011. Reinvent the toilet challenge - concept and background. *In:* Ventures, I. (ed.). Bellvue, WA, USA.

Edquist, C. 2005. Systems of Innovation. Perspektives and Challenges. *In:* Fagerberg, J., Mowery, D. C. & Nelson, R. R. (eds.) *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, 181-208.

Eggimann, S., Truffer, B., Feldman, U. & Maurer, M. 2018a. Sustainable transitions in urban water: Screening market potentials for modular infrastructure systems. *submitted*.

Eggimann, S., Truffer, B., Feldmann, U. & Maurer, M. 2018b. Screening European market potentials for small modular wastewater treatment systems – an inroad to sustainability transitions in urban water management? *Land Use Policy,* 78: 711-725.

Eggimann, S., Truffer, B. & Maurer, M. 2016. The cost of hybrid waste water systems: a systematic framework for specifying minimum cost-connection rates. *Water Research,* 103 (15): 472–484.

Feola, G. 2019. Capitalism in sustainability transitions research: Time for a critical turn? *Environmental Innovation and Societal Transitions*.

Feola, G. & Nunes, R. 2014. Success and failure of grassroots innovations for addressing climate change: The case of the Transition Movement. *Global Environmental Change,* 24: 232-250.

Frenken, K. & Boschma, R. A. 2007. A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography,* 7 (5): 635-649.

Frenken, K. & Schor, J. 2017. Putting the sharing economy into perspective. *Environmental Innovation and Societal Transitions,* 23: 3-10.

Frenken, K., Vaskelainen, T., Fünfschilling, L. & Piscicelli, L. 2020. An Institutional Logics Perspective on the Gig Economy. *In:* Indre, M., Johanna, M. & Achim, O. (eds.) *Theorizing the Sharing Economy: Variety and Trajectories of New Forms of Organizing.* Emerald Publishing Limited, 83-105.

Friedland, R. & Alford, R. R. 1991. Bringing Society Back In: Symbols, Practices, and Institutional Contradictions. *In:* DiMaggio, P. & Powell, D. M. (eds.) *The New Institutionalism in Organizational Analysis.* Chicago and London: The University of Chicago Press, 232-263.

Fuenfschilling, L. 2014. *A dynamic model of socio-technical change: Institutions, actors and technologies in interaction.* Doctoral degree, University of Basel.

Fuenfschilling, L. 2019. An institutional perspective on sustainability transitions. *In:* Boons, F. & McMeekin, A. (eds.) *Handbook of sustainable innovation.* Cheltenham: Edward Elgar Publishing, 219-236.

Fuenfschilling, L. & Binz, C. 2018. Global socio-technical regimes. *Research Policy,* 47 (4): 735-749.

Fuenfschilling, L. & Truffer, B. 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Research Policy,* 43 (4): 772-791.
Fuenfschilling, L. & Truffer, B. 2016. The interplay of institutions, actors and technologies in socio-technical systems - An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change,* 103: 298-312.
Furnari, S., Crilly, D., Misangyi, V. F., Greckhamer, T., Fiss, P. C. & Aguilera, R. 2020. Capturing Causal Complexity: Heuristics for Configurational Theorizing. *Academy of Management Review,* 0 (In-press).
Garud, R. & Karnoe, P. 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research Policy,* 32: 277-300.
Garud, R. & Karnøe, P. 2001. Path creation as a process of mindful deviation. *In:* Garud, R. & Karnøe, P. (eds.) *Path dependence and creation.* Mahwah, N.J.: Lawrence Erlbaum Associates, 1-40.
Garud, R., Kumaraswamy, A. & Karnøe, P. 2010. Path Dependence or Path Creation? *Journal of Management Studies,* 47 (4): 760-774.
Geddes, A. & Schmidt, T. S. 2020. Integrating finance into the multi-level perspective: Technology niche-finance regime interactions and financial policy interventions. *Research Policy,* 49 (6): 103985.
Geels, F., Kemp, R., Dudley, G. & Lyons, G. 2011. *Automobility in transition?: A socio-technical analysis of sustainable transport,* New York, Taylor & Francis.
Geels, F. & Raven, R. 2006. Non-linearity and Expectations in Niche-Development Trajectories: Ups and Downs in Dutch Biogas Development (1973–2003). *Technology Analysis & Strategic Management,* 18 (3-4): 375-392.
Geels, F. W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy,* 31 (2002): 1257-1274.
Geels, F. W. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy,* 33 (6): 897-920.
Geels, F. W. 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions,* 1 (1): 24-40.
Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M. & Wassermann, S. 2016. The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). *Research Policy,* 45 (4): 896-913.
Geels, F. W. & Schot, J. 2007. Typology of sociotechnical transition pathways. *Research Policy,* vol. 36 (no. 3): 399-417.
Geels, F. W. & Verhees, B. 2011. Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). *Technological Forecasting and Social Change,* 78 (6): 910-930.
Gehrke, I., Geiser, A. & Somborn-Schulz, A. 2015. Innovations in nanotechnology for water treatment. *Nanotechnology, Science and Applications,* 8: 1-17.
Gertler, M. S. 2010. Rules of the Game: The Place of Institutions in Regional Economic Change. *Regional Studies,* 44 (1): 1-15.
Gibney, J., Copeland, S. & Murie, A. 2009. Toward a `New' Strategic Leadership of Place for the Knowledge-based Economy. *Leadership,* 5 (1): 5-23.
Glückler, J. & Eckhardt, Y. 2021. Illicit innovation and institutional folding: From purity to naturalness in the Bavarian brewing industry. *Journal of Economic Geography*.
Goertz, G. & Mahoney, J. 2012. *A Tale of Two Cultures: Qualitative and Quantitative Research in the Social Sciences,* Princeton, Princeton University Press.
Gong, H. 2020. Multi-scalar legitimation of a contested industry: A case study of the Hamburg video games industry. *Geoforum,* 114: 1-9.

Gong, H. & Hassink, R. 2019. Developing the Shanghai online games industry: A multi-scalar institutional perspective. *Growth and Change,* 0 (0).
Gong, H. & Hassink, R. 2020. Context sensitivity and economic-geographic (re)theorising. *Cambridge Journal of Regions, Economy and Society,* 13 (3): 475-490.
Gosens, J., Lu, Y. & Coenen, L. 2015. The role of transnational dimensions in emerging economy 'Technological Innovation Systems' for clean-tech. *Journal of Cleaner Production,* 86 (2015): 378-388.
Gower, J. C. & Legendre, P. 1986. Metric and Euclidean properties of dissimilarity coefficients. *Journal of Classification,* 3 (1): 5-48.
Grabher, G. & van Tuijl, E. 2020. Uber-production: From global networks to digital platforms. *Environment and Planning A: Economy and Space,* 52 (5): 1005-1016.
Granovetter, M. 1973. The Strength of Weak Ties. *American Journal of Sociology,* 78 (6): 1360-1380.
Granovetter, M. 1983. The Strength of Weak Ties: A Network Theory Revisited. *Sociological Theory,* 1: 201-233.
Greenwood, R., Raynard, M., Kodeih, F., Micelotta, E. R. & Lounsbury, M. 2011. Institutional Complexity and Organizational Responses. *The Academy of Management Annals,* 5 (1): 317-371.
Grillitsch, M. & Sotarauta, M. 2019. Trinity of change agency, regional development paths and opportunity spaces. *Progress in Human Geography*: 0309132519853870.
Grillitsch, M. & Sotarauta, M. 2020. Trinity of change agency, regional development paths and opportunity spaces. *Progress in Human Geography,* 44 (4): 704-723.
Hacker, M. & Binz, C. 2021. Institutional barriers to onsite urban water reuse – A conceptual framework and systematic analysis of literature. *Environmental Science and Technology*.
Hajer, M. 2006. Doing Discourse Analysis: coalitions, practices and meanings. *In:* Brink, M. v. d. & Metze, T. (eds.) *Words matter in policy and planning : discourse theory and method in the social sciences.* Utrecht: Netherlands Graduate School of Urban and Regional Research, p. 65-74.

Hansen, T. & Coenen, L. 2015. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environmental Innovation and Societal Transitions,* 17: 92-109.
Hansmeier, H., Schiller, K. & Rogge, K. S. 2021. Towards methodological diversity in sustainability transitions research? Comparing recent developments (2016-2019) with the past (before 2016). *Environmental Innovation and Societal Transitions,* 38: 169-174.
Haščič, I. & Migotto, M. 2015. Measuring environmental innovation using patent data.
Haščič, I., Silva, J. & Johnstone, N. 2015. The Use of Patent Statistics for International Comparisons and Analysis of Narrow Technological Fields.
Hassink, R., Isaksen, A. & Trippl, M. 2019. Towards a comprehensive understanding of new regional industrial path development. *Regional Studies*: 1-10.
Hassink, R., Klaerding, C. & Marques, P. 2014. Advancing Evolutionary Economic Geography by Engaged Pluralism. *Regional Studies,* 48 (7): 1295-1307.
Heiberg, J., Binz, C. & Truffer, B. 2020. The Geography of Technology Legitimation: How Multiscalar Institutional Dynamics Matter for Path Creation in Emerging Industries. *Economic Geography,* 96 (5): 470-498.
Heiberg, J. & Miörner, J. 2021. STCA guide.
Heiberg, J. & Truffer, B. 2021. Overcoming the harmony fallacy: How values shape the course of innovation systems. *GEIST Working Paper Series,* 2021 (3).
Heiberg, J., Truffer, B. & Binz, C. 2022. Assessing transitions through socio-technical configuration analysis – a methodological framework and a case study in the water sector. *Research Policy,* 51 (1): 104363.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S. & Smits, R. E. H. M. 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change,* 74 (4): 413-432.

Hekkert, M. P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M. 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting & Social Change* 413-432.

Hidalgo, C. A., Klinger, B., Barabási, A. L. & Hausmann, R. 2007. The Product Space Conditions the Development of Nations. *Science,* 317 (5837): 482.

Hinings, C. R., Logue, D. & Zietsma, C. 2017. Fields, Institutional Infrastructure and Governance. *In:* Greenwood, R., Oliver, C., Lawrence, T. B. & Meyer, R. E. (eds.) *The SAGE Handbook of Organizational Institutionalism.* London: SAGE Publications Ltd, 170-197.

Hipp, A. & Binz, C. 2020. Firm survival in complex value chains and global innovation systems: Evidence from solar photovoltaics. *Research Policy,* 49 (1): 103876.

Hoffmann, S., Feldmann, U., Bach, P. M., Binz, C., Farrelly, M., Frantzeskaki, N., Hiessl, H., Inauen, J., Larsen, T. A., Lienert, J., Londong, J., Lüthi, C., Maurer, M., Mitchell, C., Morgenroth, E., Nelson, K. L., Scholten, L., Truffer, B. & Udert, K. M. 2020. A Research Agenda for the Future of Urban Water Management: Exploring the Potential of Nongrid, Small-Grid, and Hybrid Solutions. *Environmental Science & Technology,* 54 (9): 5312-5322.

Hoogma, R., Kemp, R., Schot, J. & Truffer, B. 2002. *Experimenting for Sustainable Transport: The Approach of Strategic Niche Management,* London Routledge

Hopkins, D., Kester, J., Meelen, T. & Schwanen, T. 2020. Not more but different: A comment on the transitions research agenda. *Environmental Innovation and Societal Transitions,* 34: 4-6.

Huenteler, J., Ossenbrink, J., Schmidt, T. S. & Hoffmann, V. H. 2016. How a product's design hierarchy shapes the evolution of technological knowledge—Evidence from patent-citation networks in wind power. *Research Policy,* 45 (6): 1195-1217.

Hughes, T. P. 1983. *Networks of power: electrification in Western society, 1880-1930,* Baltimore, John Hopkins University press.

Hughes, T. P. 1987. *The evolution of technological systems,* Camebridge, Mass., MIT Press.

Huguenin, A. & Jeannerat, H. 2017. Creating change through pilot and demonstration projects: Towards a valuation policy approach. *Research Policy,* 46 (3): 624-635.

Hutton, G. & Varughese, M. 2016. The Costs of Meeting the 2030 Sustainable Development Goal Targets on Drinking Water, Sanitation, and Hygiene. WSP – The World Bank Group.

Isaksen, A., Jakobsen, S.-E., Njøs, R. & Normann, R. 2018. Regional industrial restructuring resulting from individual and system agency. *Innovation: The European Journal of Social Science Research*: 1-18.

Isaksen, A. & Trippl, M. 2016. Path development in different regional innovation systems: A conceptual analysis. *In:* Parrilli, M. D., Dahl Fitjar, R. & Rodriguez-Pose, A. (eds.) *Innovation Drivers and Regional Innovation Strategies.* New York: Routledge, 66-84.

Jacobsson, S. & Bergek, A. 2004. Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change,* 13 (5): 815-849.

Jaffe, A. B., Trajtenberg, M. & Henderson, R. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *The Quarterly Journal of Economics,* 108 (3): 577-598.

Jeannerat, H. & Kebir, L. 2016. Knowledge, Resources and Markets: What Economic System of Valuation? *Regional Studies,* 50 (2): 274-288.

Jensen, M. B., Johnson, B., Lorenz, E. & Lundvall, B. Å. 2007. Forms of knowledge and modes of innovation. *Research Policy,* 36 (5): 680-693.

Karltorp, K. 2016. Challenges in mobilising financial resources for renewable energy—The cases of biomass gasification and offshore wind power. *Environmental Innovation and Societal Transitions,* 19: 96-110.
Kemp, R. 1994. Technology and the transition to environmental sustainability: The problem of technological regime shifts. *Futures,* 26 (10): 1023-1046.
Kern, F. 2015. Engaging with the politics, agency and structures in the technological innovation systems approach. *Environmental Innovation and Societal Transitions,* 16: 67-69.
Kieft, A., Harmsen, R. & Hekkert, M. P. 2020. Problems, solutions, and institutional logics: Insights from Dutch domestic energy-efficiency retrofits. *Energy Research & Social Science,* 60: 101315.
Kiparsky, M., Sedlak, D. L., Thompson, B. H. & Truffer, B. 2013. The innovation deficit in urban water: The need for an integrated perspective on institutions, organizations, and technology. *Environmental Engineering Science,* 30 (8): 395-408.
Kivimaa, P., Boon, W., Hyysalo, S. & Klerkx, L. 2019. Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research Policy,* 48 (4): 1062-1075.
Kivimaa, P. & Kern, F. 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy,* vol. 45 (no. 1): 205-217.
Klerkx, L. & Leeuwis, C. 2009. Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. *Technological Forecasting and Social Change,* 76 (6): 849-860.
Kogler, D. F., Rigby, D. L. & Tucker, I. 2013. Mapping Knowledge Space and Technological Relatedness in US Cities. *European Planning Studies,* 21 (9): 1374-1391.
Konrad, K., Markard, J., Ruef, A. & Truffer, B. 2012. Strategic responses to fuel cell hype and disappointment. *Technological Forecasting and Social Change,* 79 (6): 1084-1098.
Kooijman, M., Hekkert, M. P., van Meer, P. J. K., Moors, E. H. M. & Schellekens, H. 2017. How institutional logics hamper innovation: The case of animal testing. *Technological Forecasting and Social Change,* 118: 70-79.
Kwak, K. & Yoon, H. 2020. Unpacking transnational industry legitimacy dynamics, windows of opportunity, and latecomers' catch-up in complex product systems. *Research Policy,* 49 (4): 103954.
Larsen, T. A., Gruendl, H. & Binz, C. 2021. The potential contribution of urine source separation to the SDG agenda–a review of the progress so far and future development options. *Environmental Science: Water Research & Technology,* 7 (7): 1161-1176.
Larsen, T. A. & Gujer, W. 1996. Separate management of anthropogenic nutrient solutions (human urine). *Water Science and Technology,* 34 (3): 87-94.
Larsen, T. A., Hoffmann, S., Lüthi, C., Truffer, B. & Maurer, M. 2016. Emerging solutions to the water challenges of an urbanizing world. *Science,* 352 (6288): 928-933.
Larsen, T. A. & Lienert, J. 2007. NoMix – A new approach to urban water management. Zürich: Eawag.
Larsen, T. A., Lienert, J. & Udert, K. M. (eds.) 2013. *Source Separation and Decentralization for Wastewater Treatment,* London: IWA Publishing.
Latour, B. 1987. *Science in action,* Milton Keynes, Open University Press.
Lawrence, T. B. & Suddaby, R. 2006. Institutions and Institutional Work. *In:* Clegg, S., Hardy, C., Lawrence, T. B. & Nord, W. (eds.) *Sage Handbook of Organisation Studies.* London: Sage, 215-254.

Lefebvre, H. 1991. *The production of space*, Oxford Blackwell.
Leflaive, X., Krieble, B. & Smythe, H. 2020. Trends in water-related technological innovation.
Leifeld, P. 2009. Die Untersuchung von Diskursnetzwerken mit dem Discourse Network Analyzer (DNA). *In:* Schneider, V., Janning, F., Leifeld, P. & Malang, T. (eds.) *Politiknetzwerke. Modelle, Anwendungen und Visualisierungen.* Berlin: Springer, 391-404.

Leifeld, P. 2013. Reconceptualizing Major Policy Change in the Advocacy Coalition Framework: A Discourse Network Analysis of German Pension Politics. *Policy Studies Journal,* 41 (1): 169-198.

Leifeld, P. 2017. Discourse Network Analysis: Policy Debates as Dynamic Networks. *In:* Victor, J. N., Montgomery, A. H. & Lubell, M. (eds.) *The Oxford Handbook of Political Networks* Oxford: Oxford University Press.

Leifeld, P. 2018. Discourse Network Analyser Manual.

Leifeld, P. & Haunss, S. 2012. Political discourse networks and the conflict over software patents in Europe. *European Journal of Political Research,* 51 (3): 382-409.

Lennartsson, M., McConville, J., Kvarnström, E., Hagman, M. & Kjerstadius, H. 2019. Investments in Innovative Urban Sanitation–Decision-Making Processes in Sweden. *Water Alternatives,* 12 (2): 588-608.

Lettinga, G., Field, J., van Lier, J., Zeeman, G. & Huishoff Pol, L. W. 1997. Advanced anaerobic wastewater treatment in the near future. *Water Science and Technology,* 35 (10): 5-12.

Levinthal, D. A. 1998. The Slow Pace of Rapid Technological Change: Gradualism and Punctuation in Technological Change. *Industrial and Corporate Change,* 7 (2): 217-247.

LexisNexis 2018. Major World Publications. LexisNexis.

Lieberherr, E. & Fuenfschilling, L. 2016. Neoliberalism and sustainable urban water sectors: A critical reflection of sector characteristics and empirical evidence. *Environment and Planning C: Government and Policy,* 34 (8): 1540-1555.

Lucas, R. E. 1988. On the mechanics of economic development. *Journal of Monetary Economics,* 22 (1): 3-42.

Lundvall, B.-Å. 1992 *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.,* London, Pinter Publishers.

MacKinnon, D. 2011. Reconstructing scale: Towards a new scalar politics. *Progress in Human Geography,* 35 (1): 21-36.

MacKinnon, D., Cumbers, A., Pike, A., Birch, K. & McMaster, R. 2009. Evolution in Economic Geography: Institutions, Political Economy, and Adaptation. *Economic Geography,* 85 (2): 129-150.

MacKinnon, D., Dawley, S., Pike, A. & Cumbers, A. 2018. Rethinking Path Creation: A Geographical Political Economy Approach *Papers in Evolutionary Economic Geography.* Utrecht: Utrecht University.

MacKinnon, D., Dawley, S., Pike, A. & Cumbers, A. 2019a. Rethinking Path Creation: A Geographical Political Economy Approach. *Economic Geography*: 1-23.

MacKinnon, D., Dawley, S., Steen, M., Menzel, M.-P., Karlsen, A., Sommer, P., Hansen, G. H. & Normann, H. E. 2019b. Path creation, global production networks and regional development: A comparative international analysis of the offshore wind sector. *Progress in Planning,* 130: 1-32.

MacKinnon, D., Karlsen, A., Dawley, S., Steen, M., Afewerki, S. & Kenzhegaliyeva, A. 2021. Legitimation, institutions and regional path creation: a cross-national study of offshore wind. *Regional Studies*: 1-12.

Makropoulos, C. K. & Butler, D. 2010. Distributed Water Infrastructure for Sustainable Communities. *Water Resources Management,* 24 (11): 2795-2816.

Malerba, F. 2002. Sectoral systems of innovation and production. *Research Policy,* 31 (2): 247-264.

Malhotra, A., Schmidt, T. S. & Huenteler, J. 2019. The role of inter-sectoral learning in knowledge development and diffusion: Case studies on three clean energy technologies. *Technological Forecasting and Social Change,* 146: 464-487.

Malmberg, A. & Maskell, P. 1997. Towards an explanation of regional specialization and industry agglomeration. *European Planning Studies,* 5 (1): 25-41.

Malmberg, A. & Maskell, P. 2002. The Elusive Concept of Localization Economies: Towards a Knowledge-Based Theory of Spatial Clustering. *Environment and Planning A,* 34 (3): 429-449.

Markard, J. 2018. The life cycle of technological innovation systems. *Technological Forecasting and Social Change*.

Markard, J. 2020. The life cycle of technological innovation systems. *Technological Forecasting and Social Change,* 153: 119407.

Markard, J., Hekkert, M. & Jacobsson, S. 2015. The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions,* 16: 76-86.

Markard, J., Raven, R. & Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy,* 41 (6): 955-967.

Markard, J., Rinscheid, A. & Widdel, L. 2021. Analyzing transitions through the lens of discourse networks: Coal phase-out in Germany. *Environmental Innovation and Societal Transitions,* 40: 315-331.

Markard, J., Stadelmann, M. & Truffer, B. 2009. Prospective analysis of technological innovation systems: Identifying technological and organizational development options for biogas in Switzerland. *Research Policy,* 38 (4): 655-667.

Markard, J., Suter, M. & Ingold, K. 2016a. Socio-technical transitions and policy change – Advocacy coalitions in Swiss energy policy. *Environmental Innovation and Societal Transitions,* 18: 215-237.

Markard, J. & Truffer, B. 2008. Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy,* 37 (4): 596-615.

Markard, J., Wirth, S. & Truffer, B. 2016b. Institutional dynamics and technology legitimacy – A framework and a case study on biogas technology. *Research Policy,* 45 (1): 330-344.

Marlow, D. R., Moglia, M., Cook, S. & Beale, D. J. 2013. Towards sustainable urban water management: A critical reassessment. *Water Research,* 47 (20): 7150-7161.

Martin, R. 2010. Roepke Lecture in Economic Geography—Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. *Economic Geography,* 86 (1): 1-27.

Martin, R. & Moodysson, J. 2013. Comparing knowledge bases: on the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden. *European Urban and Regional Studies,* 20 (2): 170-187.

Martin, R. & Sunley, P. 2006. Path dependence and regional economic evolution. *Journal of Economic Geography,* 6 (4): 395-437.

Martinez, C. 2010. Insight into Different Types of Patent Families.

Meelen, T., Truffer, B. & Schwanen, T. 2019. Virtual user communities contributing to upscaling innovations in transitions: The case of electric vehicles. *Environmental Innovation and Societal Transitions,* 31: 96-109.

Miller, D. 1986. Configurations of Strategy and Structure: Towards a Synthesis. *Strategic Management Journal,* 7 (3): 233-249.

Miörner, J. & Binz, C. 2021. Towards a multi-scalar perspective on transition trajectories. *Environmental Innovation and Societal Transitions,* 40: 172-188.

Miörner, J., Heiberg, J. & Binz, C. 2021. Global regime diffusion in space: a missed transition in San Diego's water sector. *GEIST Working Paper Series,* 2021 (8).

Miörner, J. & Trippl, M. 2018. Embracing the future: Path transformation and system reconfiguration for self-driving cars in West Sweden. *Papers in Economic Geography and Innovation Studies* [Online].

Miörner, J. & Trippl, M. 2019. Embracing the future: path transformation and system reconfiguration for self-driving cars in West Sweden. *European Planning Studies,* 27 (11): 2144-2162.

Misa, T. 2003. The Compelling Tangle of Modernity and Technology. *In:* Misa, T. J., Feenberg, A. & Brey, P. (eds.) *Modernity and Technology.* Cambridge, UNITED STATES: MIT Press, 1-30.

Misangyi, V. F., Greckhamer, T., Furnari, S., Fiss, P. C., Crilly, D. & Aguilera, R. 2017. Embracing Causal Complexity: The Emergence of a Neo-Configurational Perspective. *Journal of Management,* 43 (1): 255-282.

Moro, M. A., McKnight, U. S., Smets, B. F., Min, Y. & Andersen, M. M. 2018. The industrial dynamics of water innovation: A comparison between China and Europe. *International Journal of Innovation Studies*.

Murphy, J. T. 2015. Human geography and socio-technical transition studies: Promising intersections. *Environmental Innovation and Societal Transitions,* 17: 73-91.

Murtagh, F. & Legendre, P. 2014. Ward's Hierarchical Agglomerative Clustering Method: Which Algorithms Implement Ward's Criterion? *Journal of Classification,* 31 (3): 274-295.

Musiolik, J. & Markard, J. 2011. Creating and shaping innovation systems: Formal networks in the innovation system for stationary fuel cells in Germany. *Energy Policy,* 39 (4): 1909-1922.

Musiolik, J., Markard, J., Hekkert, M. & Furrer, B. 2018. Creating innovation systems: How resource constellations affect the strategies of system builders. *Technological Forecasting and Social Change*.

Mwenge Kahinda, J. & Taigbenu, A. E. 2011. Rainwater harvesting in South Africa: Challenges and opportunities. *Physics and Chemistry of the Earth, Parts A/B/C,* 36 (14): 968-976.

Neffke, F., Hartog, M., Boschma, R. & Henning, M. 2018. Agents of Structural Change: The Role of Firms and Entrepreneurs in Regional Diversification. *Economic Geography,* 94 (1): 23-48.

Neffke, F., Henning, M. & Boschma, R. 2011. How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography,* 87 (3): 237-265.

Negro, S. O., Alkemade, F. & Hekkert, M. P. 2012. Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews,* 16 (6): 3836-3846.

Nelson, R. R. 1994. The Co-evolution of Technology, Industrial Structure, and Supporting Institutions. *Industrial and Corporate Change,* 3 (1): 47-63.

Nelson, R. R. & Winter, S. G. 1982. *An Evolutionary Theory of Economic Change,* Cambridge, Harvard University Press.

NIDIS. 2018. *National Integrated Drought Information System* [Online]. Available: https://www.drought.gov/drought/states/california. Accessed 20.10.2018].

Nijland, H. & van Meerkerk, J. 2017. Mobility and environmental impacts of car sharing in the Netherlands. *Environmental Innovation and Societal Transitions,* 23: 84-91.

Nikoleris, A. 2018. *On the Role of Envisioned Futures in Sustainability Transitions.* Doctoral, Lund University.

O'Flaherty, B. 2005. *City Economics,* Cambridge, US, Harvard University Press.

OECD 2009. *OECD Patent Statistics Manual*.

OECD 2018. Financing water. *In:* OECD (ed.) *OECD Environment Policy Papers.* Paris.

OECD 2019. *Making Blended Finance Work for Water and Sanitation*.

Oinas, P. & Malecki, E. J. 2002. The Evolution of Technologies in Time and Space: From National and Regional to Spatial Innovation Systems. *International Regional Science Review,* 25 (1): 102-131.

Ozgun, B. & Broekel, T. 2021. The geography of innovation and technology news - An empirical study of the German news media. *Technological Forecasting and Social Change,* 167: 120692.

Pahl-Wostl, C. 2015. Water governance in the face of global change. *Springer International Publishing: Switzerland. doi,* 10: 978-3.

Patala, S., Korpivaara, I., Jalkala, A., Kuitunen, A. & Soppe, B. 2019. Legitimacy Under Institutional Change: How incumbents appropriate clean rhetoric for dirty technologies. *Organization Studies,* 40 (3): 395-419.

Pelzer, P., Frenken, K. & Boon, W. 2019. Institutional entrepreneurship in the platform economy: How Uber tried (and failed) to change the Dutch taxi law. *Environmental Innovation and Societal Transitions,* 33: 1-12.

Pike, A., Birch, K., Cumbers, A., MacKinnon, D. & McMaster, R. 2009. A Geographical Political Economy of Evolution in Economic Geography. *Economic Geography,* 85 (2): 175-182.

PUB 2018. Our Water, Our Future. Singapore: Public Utility Board of Singapore.

Quitzow, R. 2015. Dynamics of a policy-driven market: The co-evolution of technological innovation systems for solar photovoltaics in China and Germany. *Environmental Innovation and Societal Transitions,* 17: 126-148.

Quitzow, R., Walz, R., Köhler, J. & Rennings, K. 2014. The concept of "lead markets" revisited: Contribution to environmental innovation theory. *Environmental Innovation and Societal Transitions,* 10: 4-19.

Rao, H. 2004. Institutional activism in the early American automobile industry. *Journal of Business Venturing,* 19 (3): 359-384.

Raven, R., Kern, F., Verhees, B. & Smith, A. 2015. Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases. *Environmental Innovation and Societal Transitions,* 18: 164-180.

Rip, A. & Kemp, R. 1998. Technological change. *In:* Rayner, S. & Malone, E. L. (eds.) *Human choice and climate change. Vol. II, Resources and Technology.* Battelle Press, 327 - 399.

Rogge, K. S. & Reichardt, K. 2016. Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Research Policy,* vol. 45 (8): 1620-1635.

Rohe, S. 2020. The regional facet of a global innovation system: Exploring the spatiality of resource formation in the value chain for onshore wind energy. *Environmental Innovation and Societal Transitions,* 36: 331-344.

Rohe, S. & Chlebna, C. 2021. A spatial perspective on the legitimacy of a technological innovation system: Regional differences in onshore wind energy. *Energy Policy,* 151: 112193.

Romer, P. M. 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy,* 94 (5): 1002-1037.

Rosenbloom, D., Berton, H. & Meadowcroft, J. 2016. Framing the sun: A discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada. *Research Policy,* 45 (6): 1275-1290.

Runhaar, H., Fünfschilling, L., van den Pol-Van Dasselaar, A., Moors, E. H. M., Temmink, R. & Hekkert, M. 2020. Endogenous regime change: Lessons from transition pathways in Dutch dairy farming. *Environmental Innovation and Societal Transitions,* 36: 137-150.

Rutten, R. 2020. Comparing causal logics: A configurational analysis of proximities using simulated data. *Zeitschrift für Wirtschaftsgeographie,* 64 (3): 134-148.

Ryghaug, M. & Skjølsvold, T. M. 2019. Nurturing a Regime Shift Toward Electro-mobility in Norway. *In:* Finger, M. & Audouin, M. (eds.) *The Governance of Smart Transportation Systems: Towards New Organizational Structures for the Development of Shared, Automated, Eletric and Integrated Mobility.* Cham: Springer International Publishing, 147-165.

Sabatier, P. A. 1988. An advocacy coalition framework of policy change and the role of policy-oriented learning therein. *Policy Sciences,* 21 (2): 129-168.

Sadoff, C. W., Hall, J. W., Grey, D., Aerts, J. C. J. H., Ait-Kadi, M., Brown, C., Cox, A., Dadson, S., Garrick, D., Kelman, J., McCornick, P., Ringler, C., Rosegrant, M., Whittington, D. & Wiberg, D. 2015. Securing Water, Sustaining Growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth. Oxford: University of Oxford.

Saxenian, A. 1994. *Regional Advantage Culture and Competition in Silicon Valley and Route 128,* Camebridge MA, Harvard University Press.

Saxenian, A. 2006. *The New Argonauts: Regional Advantage in a Global Economy,* Harvard, Harvard University Press.
Sayer, A. 2000. *Realism and Social Science,* London, SAGE Publications Ltd.
Sayer, R. A. 1992. *Method in social science: A realist approach,* London, Routledge.
Schellenberg, T., Subramanian, V., Ganeshan, G., Tompkins, D. & Pradeep, R. 2020. Wastewater Discharge Standards in the Evolving Context of Urban Sustainability–The Case of India. *Frontiers in Environmental Science,* 8 (30).
Schippl, J. & Truffer, B. 2020. Directionality of transitions in space: Diverging trajectories of electric mobility and autonomous driving in urban and rural settlement structures. *Environmental Innovation and Societal Transitions,* 37: 345-360.
Schmid, N., Sewerin, S. & Schmidt, T. S. 2020. Explaining Advocacy Coalition Change with Policy Feedback. *Policy Studies Journal,* 48 (4): 1109-1134.
Schmidt, T. S., Schmid, N. & Sewerin, S. 2019. Policy goals, partisanship and paradigmatic change in energy policy – analyzing parliamentary discourse in Germany over 30 years. *Climate Policy*: 1-16.
Schot, J. & Geels, F. W. 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management,* 20 (5): 537-554.
Schot, J. & Steinmueller, W. E. 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy,* 47 (9): 1554-1567.
Schumpeter, J. 1934. *The Theory of Economic Development,* Cambridge, Mass

Harvard

University Press.
Schurman, R. 2018. Micro(soft) managing a 'green revolution' for Africa: The new donor culture and international agricultural development. *World Development,* 112: 180-192.
Scott, W. R. 1991. Unpacking Institutional Arguments. *In:* Powell, W. W. & DiMaggio, P. (eds.) *The New Institutionalism in Organizational Analysis.* Chicago: University of Chicago Press, 164-182.

Sengers, F. & Raven, R. 2015. Toward a spatial perspective on niche development: The case of Bus Rapid Transit. *Environmental Innovation and Societal Transitions,* 17: 166-182.
Seo, M.-G. & Creed, W. E. D. 2002. Institutional Contradictions, Praxis, and Institutional Change: A Dialectical Perspective. *The Academy of Management Review,* 27 (2): 222-247.
Sharif, N. 2006. Emergence and development of the National Innovation Systems concept. *Research Policy,* 35 (5): 745-766.
Sharma, A. K., Tjandraatmadja, G., Cook, S. & Gardner, T. 2013. Decentralised systems – definition and drivers in the current context. *Water Science and Technology,* 67 (9): 2091-2101.
Singh, H., Kazmi, A. A. & Starkl, M. 2015. A review on full-scale decentralised wastewater treatement systems: techno-economical approach. *Water Science & Technology,* 71 (4): 468-478.
Smith, A. 2007. Translating Sustainabilities between Green Niches and Socio-Technical Regimes. *Technology Analysis & Strategic Management,* 19 (4): 427-450.
Smith, A., Kern, F., Raven, R. & Verhees, B. 2014. Spaces for sustainable innovation: Solar photovoltaic electricity in the UK. *Technological Forecasting and Social Change,* 81: 115-130.
Smith, A. & Raven, R. 2012. What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy,* 41 (6): 1025-1036.
Smith, A., Stirling, A. & Berkhout, F. 2005. The governance of sustainable socio-technical transitions. *Research Policy,* 34 (10): 1491-1510.

Smith, A., Voss, J.-P. & Grin, J. 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective, and its challenges. *Research Policy,* 39 (4): 435-448.

Sorrell, S. 2018. Explaining sociotechnical transitions: A critical realist perspective. *Research Policy,* 47 (7): 1267-1282.

Sotarauta, M. & Suvinen, N. 2018. Institutional Agency and Path Creation. Institutional Path From Industrial to Knowledge City. *In:* Isaksen, A., Martin, R. & Trippl, M. (eds.) *New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons.* New York: Springer.

Späth, P. & Rohracher, H. 2010. 'Energy regions': The transformative power of regional discourses on socio-technical futures. *Research Policy,* 39 (4): 449-458.

Späth, P. & Rohracher, H. 2012. Local Demonstrations for Global Transitions—Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability. *European Planning Studies,* 20 (3): 461-479.

Spinoni, J., Barbosa, P., De Jager, A., McCormick, N., Naumann, G., Vogt, J. V., Magni, D., Masante, D. & Mazzeschi, M. 2019. A new global database of meteorological drought events from 1951 to 2016. *Journal of Hydrology: Regional Studies,* 22: 100593.

Stirling, A. 2009. Direction, Distribution and Diversity! Pluralising Progress in Innovation, Sustainability and Development. *In:* Centre, S. (ed.) *STEPS Working Paper* Brighton.

Strambach, S. & Pflitsch, G. 2020. Transition topology: Capturing institutional dynamics in regional development paths to sustainability. *Research Policy,* 49 (7): 104006.

Suchman, M. C. 1995. Managing Legitimacy: Strategic and Institutional Approaches. *Academy of Management Review,* 20 (3): 571-610.

Sunley, P. 2008. Relational Economic Geography: A Partial Understanding or a New Paradigm? *Economic Geography,* 84 (1): 1-26.

Sutherland, C., Scott, D. & Hordijk, M. 2015. Urban Water Governance for More Inclusive Development: A Reflection on the 'Waterscapes' of Durban, South Africa. *The European Journal of Development Research,* 27 (4): 488-504.

Suurs, R. & Hekkert, M. 2012. Motors of Sustainable Innovation: Understanding Transitions from a Technological Innovation System's Perspective: Roald Suurs and Marko Hekkert. *In:* Verbong, G. & Loorbach, D. (eds.) *Governing the Energy Transition.* Routledge, 163-190.

Suurs, R. A. A. & Hekkert, M. P. 2009. Cumulative causation in the formation of a technological innovation system: The case of biofuels in the Netherlands. *Technological Forecasting and Social Change,* 76 (8): 1003-1020.

Svensson, O. & Nikoleris, A. 2018. Structure reconsidered: Towards new foundations of explanatory transitions theory. *Research Policy,* 47 (2): 462-473.

Swyngedouw, E. 2004. Globalisation or 'glocalisation'? Networks, territories and rescaling. *Cambridge Review of International Affairs,* 17 (1): 25-48.

Swyngedouw, E. & Cox, K. 1997. Neither global nor local:'glocalization'and the politics of scale. *Spaces of globalization: Reasserting the power of the local.* Guilford Press, 137-166.

Tanner, A. N. 2014. Regional Branching Reconsidered: Emergence of the Fuel Cell Industry in European Regions. *Economic Geography,* 90 (4): 403-427.

Thelen, K. 2004. *How Institutions Evolve: The Political Economy of Skills in Germany, Britain, the United States, and Japan,* Cambridge, Cambridge University Press.

Thévenot, L., Moody, M. & Lafaye, C. 2000. Forms of valuing nature: arguments and modes of justification in French and American environmental disputes. *In:* Thévenot, L. & Lamont, M. (eds.) *Rethinking Comparative Cultural Sociology: Repertoires of Evaluation in France and the United States.* Cambridge: Cambridge University Press, 229-272.

Thornton, P. H. & Ocasio, W. 1999. Institutional Logics and the Historical Contingency of Power in Organizations: Executive Succession in the Higher Education Publishing Industry, 1958-1990. *American Journal of Sociology,* 105 (3): 801-843.

Tödtling, F. & Trippl, M. 2005. One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy,* vol. 34 (8): 1203-1219.

Trippl, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A. & Rypestøl, J. O. 2020. Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. *Geoforum*.

Trippl, M., Grillitsch, M. & Isaksen, A. 2018. Exogenous sources of regional industrial change:Attraction and absorption of non-local knowledge for new path development. *Progress in Human Geography,* 42 (5): 687-705.

Truffer, B., Binz, C., Gebauer, H. & Störmer, E. 2012. Market success of on-site treatment: a systemic innovation problem. *In:* Larsen, T. A., Udert, K. M., Lienert, J. & (eds.) (eds.) *Wastewater Treatment: Source Separation and Decentralisation.* IWA Publishing, pp. 209 – 223.

Truffer, B. & Coenen, L. 2012. Environmental Innovation and Sustainability Transitions in Regional Studies. *Regional Studies,* 46 (1): 1-21.

Truffer, B., Murphy, J. T. & Raven, R. 2015. The geography of sustainability transitions: Contours of an emerging theme. *Environmental Innovation and Societal Transitions,* 17: 63-72.

Turner, J. A., Klerkx, L., Rijswijk, K., Williams, T. & Barnard, T. 2016. Systemic problems affecting co-innovation in the New Zealand Agricultural Innovation System: Identification of blocking mechanisms and underlying institutional logics. *NJAS - Wageningen Journal of Life Sciences,* 76: 99-112.

Turnheim, B. & Geels, F. W. 2013. The destabilisation of existing regimes: Confronting a multi-dimensional framework with a case study of the British coal industry (1913–1967). *Research Policy,* 42 (10): 1749-1767.

Ulrich, L., Klinger, M., Lüthi, C. & Reymond, P. 2018. How to Sustainably Scale up SmallScale Sanitation in India? Sandec News: Eawag Sandec.

UN-WWAP 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World. . Paris: UNESCO.

van der Loos, H. Z. A., Negro, S. O. & Hekkert, M. P. 2020. International markets and technological innovation systems: The case of offshore wind. *Environmental Innovation and Societal Transitions,* 34: 121-138.

van Lente, H., Hekkert, M., Smits, R. & van Waveren, B. 2003. Roles of Systemic Intermediaries in Transition Processes. *International Journal of Innovation Management,* 07 (03): 247-279.

van Welie, M. J., Boon, W. P. C. & Truffer, B. 2020. Innovation system formation in international development cooperation: The role of intermediaries in urban sanitation. *Science and Public Policy,* 47 (3): 333-347.

van Welie, M. J., Cherunya, P. C., Truffer, B. & Murphy, J. T. 2018. Analysing transition pathways in developing cities: The case of Nairobi's splintered sanitation regime. *Technological Forecasting and Social Change,* 137: 259-271.

van Welie, M. J., Truffer, B. & Yap, X.-S. 2019. Towards sustainable urban basic services in low-income countries: A TIS analysis of sanitation value chains in Nairobi.

Verbong, G. & Loorbach, D. 2012. *Governing the energy transition: reality, illusion or necessity?,* New York, Taylor & Francis.

Wasserman, S. & Faust, K. 1994. *Social Network Analysis: Methods and Applications,* Cambridge, Cambridge University Press.

Weber, K. M. & Rohracher, H. 2012. Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level

perspective in a comprehensive 'failures' framework. *Research Policy,* vol. 41 (no. 6): 1037-1047.
Weber, K. M. & Truffer, B. 2017. Moving innovation systems research to the next level: towards an integrative agenda. *Oxford Review of Economic Policy,* 33 (1): 101-121.
Wenting, R. & Frenken, K. 2011. Firm entry and institutional lock-in: an organizational ecology analysis of the global fashion design industry. *Industrial and Corporate Change,* 20 (4): 1031-1048.
Wieczorek, A. J. & Hekkert, M. P. 2012. Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and Public Policy,* 39 (1): 74-87.
Wieczorek, A. J., Hekkert, M. P., Coenen, L. & Harmsen, R. 2015. Broadening the national focus in technological innovation system analysis: The case of offshore wind. *Environmental Innovation and Societal Transitions,* 14: 128-148.
Williams, J. 2018. Assembling the water factory: Seawater desalination and the techno-politics of water privatisation in the San Diego–Tijuana metropolitan region. *Geoforum,* 93: 32-39.
Williams, T. & Gemperle, S. M. 2017. Sequence will tell! Integrating temporality into set-theoretic multi-method research combining comparative process tracing and qualitative comparative analysis. *International Journal of Social Research Methodology,* 20 (2): 121-135.
Willis, R. M., Stewart, R. A., Giurco, D. P., Talebpour, M. R. & Mousavinejad, A. 2013. End use water consumption in households: impact of socio-demographic factors and efficient devices. *Journal of Cleaner Production,* 60: 107-115.
Wilson, C., Grubler, A., Bento, N., Healey, S., De Stercke, S. & Zimm, C. 2020. Granular technologies to accelerate decarbonization. *Science,* 368 (6486): 36-39.
Winpenny, J. 2015. Water: Fit to Finance? : World Water Council, OECD.
Wirth, S., Markard, J., Truffer, B. & Rohracher, H. 2013. Informal institutions matter: Professional culture and the development of biogas technology. *Environmental Innovation and Societal Transitions,* 8: 20-41.
Wittmayer, J. M., Avelino, F., Pel, B. & Campos, I. 2021. Contributing to sustainable and just energy systems? The mainstreaming of renewable energy prosumerism within and across institutional logics. *Energy Policy,* 149: 112053.
Wong, T. H. F. & Brown, R. R. 2009. The water sensitive city: principles for practice. *Water Science and Technology,* 60 (3): 673-682.
Woolthuis, R. K., Lankhuizen, M. & Gilsing, V. 2005. A system failure framework for innovation policy design. *Technovation,* vol. 25 (no. 6): 609-619.
Wooten, M. & Hoffman, A. J. 2016. Organizational Fields Past, Present and Future. *In:* Greenwood, R., Oliver, C., Lawrence, T. B. & Meyer, R. E. (eds.) *The SAGE Handbook of Organizational Institutionalism.* Newbury Park: Elsevier BV, 55-74.
Yang, K., Schot, J. & Truffer, B. 2020. Shaping the directionality of sustainability transitions: The diverging development pathways of solar PV in two Chinese provinces. *SPRU Working Paper Series,* 2020-14.
Yap, X.-S. & Truffer, B. 2019. Shaping selection environments for industrial catch-up and sustainability transitions: A systemic perspective on endogenizing windows of opportunity. *Research Policy,* 48 (4): 1030-1047.
Yeung, H. W.-c. 2005. Rethinking relational economic geography. *Transactions of the Institute of British Geographers,* 30 (1): 37-51.
Yeung, H. W.-c. 2016. *Strategic Coupling: East Asian Industrial Transformation in the New Global Economy*, Cornell University Press.
Yeung, H. W.-c. & Coe, N. M. 2015. Toward a Dynamic Theory of Global Production Networks. *Economic Geography,* 91 (1): 29-58.
Yin, R. K. 1994. *Case study research: design and methods,* Los Angeles, Sage Publications, Inc.

Yuana, S. L., Sengers, F., Boon, W., Hajer, M. A. & Raven, R. 2020. A dramaturgy of critical moments in transition: Understanding the dynamics of conflict in socio-political change. *Environmental Innovation and Societal Transitions,* 37: 156-170.

Zhang, W. & White, S. 2016. Overcoming the liability of newness: Entrepreneurial action and the emergence of China's private solar photovoltaic firms. *Research Policy,* 45 (3): 604-617.

Zukauskaite, E., Trippl, M. & Plechero, M. 2017. Institutional Thickness Revisited. *Economic Geography,* 93 (4): 325-345.

Appendix A

A1: Outlets screened in Nexis Uni

Source	Count of statements	Scale of audience	City of headquarter	Availability in Nexis Uni	Type of publication
The Times of India (TOI)	279	IND	Dehli	2010-now	daily newspaper
Africa News	219	ZAF +	various	1991-2018	newspapers & newsletters
The Jerusalem Post	113	ISR	Jerusalem	1989-now	daily newspaper
The Guardian(London)	88	GBR	London	1975-now	daily newspaper
The Straits Times (Singapore)	81	SGP	Singapore	1992-now	daily newspaper
Chemical Week	52	GLO	New York	1975-now	global biweekly expert magazine
San Francisco Chronicle	49	USA	San Francisco	1985-now	daily newspaper
The New York Times	44	USA	New York	1980-now	daily newspaper
The Business Times Singapore	41	SGP	Singapore	1992-now	daily newspaper
The Edge Singapore	36	SGP	Singapore	2002-now	weekly newspaper
Mining Magazine	34	GBR	London	1981-now	monthly magazine
New Scientist	33	GBR	London	1998-now	weekly magazine
Tampa Bay Times	31	USA	Tampa	1987-now	daily newspaper
The Christian Science Monitor	31	USA	Boston	1980-now	daily newspaper
The Irish Times	30	IRE	Dublin	1992-now	daily newspaper
Business Day (South Africa)	29	ZAF	Johannesburg	1997-now	daily newspaper
The Herald (Harare)	25	ZIM	Harare	2010-now	daily newspaper
The International Herald Tribune	25	GLO	New York	1991-now	global daily newspaper
New Straits Times (Malaysia)	24	MYS	Kuala Lumpur	1995-now	daily newspaper
Financial Mail (South Africa)	20	ZAF	Johannesburg	1997-now	weekly magazine
The New Times Kigali	19	RWA	Kigali	2009-now	daily newspaper
The Globe and Mail (Canada)	18	CAN	Toronto	1977-now	daily newspaper
The Economic Times	17	IND	Mumbai	2010-now	daily newspaper
The Conversation Africa (Johannesburg)	15	ZAF	Johannesburg	2012-now	newspaper
National Post's Financial Post & FP Investing (Canada)	14	CAN	Toronto	1985-now	daily newspaper
Canberra Times (Australia)	13	AUS	Canberra	1997-now	daily newspaper
Natural Gas Week	13	GLO	Vancouver	2002-now	global weekly expert magazine
The West Australian (Perth)	13	AUS	Perth	2004-now	daily newspaper
BBC Monitoring: International Reports	12	GLO	London	1979-now	daily newspaper

The Washington Post	11	USA	Washington D.C.	1977-now	daily newspaper
BusinessWorld	9	PHL	Manila	1997-now	daily magazine
The Independent (United Kingdom)	9	GBR	London	1988-now	daily newspaper
The Korea Herald	9	KOR	Seoul	1998-now	daily newspaper
The Australian	8	AUS	Sydney	1995-now	daily newspaper
Business Monitor News	7	GLO	London	2004-now	global daily business magazine
The Times of Zambia (Ndola)	7	ZAM	Ndola	2010-now	weekly magazine
The Toronto Star	7	CAN	Toronto	1985-now	daily newspaper
South China Morning Post	6	CHN	Hong Kong	1992-now	daily newspaper
The Namibian (Windhoek)	6	NAM	Windhoek	2010-now	weekly newspaper
Addis Fortune (Addis Ababa)	5	ETH	Addis Ababa	2010-now	weekly newspaper
Investment Week	5	GBR	London	2009-now	daily newspaper
Korea Times	5	KOR	Seoul	1998-now	daily newspaper
New Era (Windhoek)	5	NAM	Windhoek	2010-now	daily newspaper
Nikkei Asian Review	5	JPN	Tokio	1980-now	weekly magazine
USA Today	5	USA	Tysons Corner	1989-now	daily newspaper
Utility Week	5	GBR	London	2005-now	monthly magazine
Inter Press Service (Johannesburg)	4	ZAF	Johannesburg	2010-now	daily newspaper
Sunday Times (South Africa)	4	ZAF	Johannesburg	1997-now	weekly newspaper
The Advertiser/Sunday Mail (Adelaide, South Australia)	4	AUS	Adelaide	1986-now	daily newspaper
The Edge Malaysia	4	MYS	Kuala Lumpur	2001-now	weekly newspaper
The Gazette (Montreal)	4	CAN	Montreal	1991-now	daily newspaper
The Herald (Glasgow)	4	GBR	Glasgow	1992-now	daily newspaper
Mail on Sunday (London)	3	GBR	London	1992-now	daily newspaper
Sunday Age (Melbourne, Australia)	3	AUS	Melbourne	1991-now	daily newspaper
The Nation (Thailand)	3	THA	Bangkok	1997-now	daily newspaper
The Press (Christchurch, New Zealand)	3	NZL	Christchurch	1996-now	daily newspaper
Belfast Telegraph	2	GBR	Belfast	1996-now	daily newspaper
Daily News (New York)	2	USA	New York	1995-now	daily newspaper
Global Capital Euroweek	2	GBR	London	1999-now	daily expert magazine
The Courier Mail/The Sunday Mail (Australia)	2	AUS	Queensland	1985-now	daily newspaper
The Daily Telegraph (London)	2	GBR	London	2000-now	daily newspaper
The Observer(London)	2	GBR	London	1990-now	weekly newspaper
Daily Trust (Abuja)	1	NGA	Abuja	2010-now	daily newspaper

Farmers Weekly	1	GBR	Sutton	1998-2020	weekly expert magazine
Ghanaian Chronicle (Accra)	1	GHA	Accra	2010-now	weekly newspaper
Investors Chronicle - magazine and web content	1	GBR	London	1990-now	weekly newspaper
Sunday Tasmanian (Australia)	1	AUS	Hobart	1887-now	daily newspaper
The Independent (United Kingdom)	1	GBR	London	1988-now	daily newspaper
The New Zealand Herald	1	NZL	Auckland	1998-now	daily newspaper
World Oil	1	GLO	Houston	2001-2018	global monthly expert magazine

Additional outlets in the search base which did not yield any relevant articles to code statements: Accountancy Age (UK), Accounting Today, Advertising Age, ADWEEK, Airline Business, Al Jazeera - English, Audio Week, Australian Financial Review, Automotive News, Baltic News Service, Belfast News Letter, Belfast Telegraph Online, Billboard, Birmingham Evening Mail, Birmingham Post, Brand Strategy, Brisbane News, Builder, Business & Finance Magazine, Campaign, CFO, City A.M., CMP Information, Computer Weekly, Computing, Contract Journal, Control and Instrumentation, Creative Review, Daily Record and Sunday Mail, Daily Variety, Design Engineering, Design Week, Electronics Weekly, Employee Benefits, Estates Gazette, Euromoney, EXE, Financial Adviser, Financial Director, Flight International, Herald Sun/Sunday Herald Sun (Melbourne, Australia), Het Financieele Dagblad (English), Hindustan Times, Hobart Mercury/Sunday Tasmanian (Australia), Industry Week, Insurance Age, International Money Marketing, ITAR-TASS, Korea Herald, Lawyers Weekly, Legal Week, Lianhe Zaobao, Maghreb Confidential, Management Today, Marketing - UK, Marketing Week, Mergers and Acquisitions, The Dealmaker's Journal, Middle East Newsfile (Moneyclips), mirror.co.uk, Mobile Communications Report, Money Marketing, Moscow News, MTI Econews, Music Week, MWP Advanced Manufacturing, New Media Age, New Musical Express, Newsweek, Nikkei Asian Review, Northern Territory News (Australia), Off Licence News, Ottawa Citizen, Plastics News (tm), Platts Energy Business & Technology, Platts Megawatt Daily, Polish News Bulletin, Precision Marketing, Process Engineering, Professional Broking, Retail Week, Revolution, Rubber & Plastics News, Satellite Week, standard.co.uk, Sydney Morning Herald (Australia), TechNews, telegraph.co.uk, The Age (Melbourne, Australia), The Banker, The Daily Mail and Mail on Sunday (London), The Daily Telegraph (Australia), The Deal Pipeline, The Dominion (Wellington), The Dominion Post (Wellington, New Zealand), The Electricity Journal, The Engineer, The Evening Post (Wellington), The Evening Standard (London), The Express, The Grocer, The Investors Chronicle, The Japan News, The Japan Times, The Jerusalem Report, The Lawyer, The Mirror (The Daily Mirror and The Sunday Mirror), The Moscow News (RIA Novosti), The Moscow Times, The New York Times - International Edition, The New Yorker, The People, The Pharma Letter, The Philadelphia Inquirer, The Sunday Herald (Glasgow), The Sunday Telegraph (London), The Weekly Times, Travel Trade Gazette UK & Ireland, Wall Street Journal Abstracts, Waste News, What's new in Industry, Xtreme Information

A2: Search terms and query for article selection in Nexis Uni

Source: Major World Publications;Major World Newspapers; Times of India (TOI);Africa News*
Combined Source: Major World Publications;Major World Newspapers; Times of India (TOI);Africa News*
((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR smart OR distributed OR integrated OR household) PRE/2 (water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR desalination))
OR ((water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/1 (recycling OR reuse OR reclamation OR harvesting OR desalination))
OR (membrane PRE/1 bioreactor)
OR (sequencing PRE/1 batch PRE/1 reactor)
OR (microbial PRE/1 fuel PRE/1 cell)
OR (membrane PRE/1 aerated PRE/1 biofilm PRE/1 reactor)
OR (nano PRE/1 membrane)
OR (nano PRE/1 adsorbent)
OR (nano PRE/1 photocatalyst)
OR (septic PRE/1 tank)
OR (package PRE/1 treatment PRE/1 plant)
OR (point PRE/2 use PRE/1 treatment)
OR ((dry OR composting) PRE/1 toilet)
OR (dual PRE/1 flush PRE/1 (plumb! OR toilet))
OR ((urine OR source) PRE/1 separation)
OR (water PRE/1 saving PRE/1 device)
OR (inlet PRE/1 control)
OR (infiltration PRE/1 measure)
OR (sustainable PRE/1 urban PRE/1 drainage)
OR (NoMix)
OR (jokhasou)
OR (ecosan)
OR (ecological PRE/1 sanitation)
OR (water PRE/1 sensitive PRE/1 cities)
OR (green PRE/1 roof)
OR (water W/7 (resource PRE/1 recovery))
OR (reverse PRE/1 osmosis)
OR (zero PRE/1 liquid PRE/1 discharge)
OR (capacitive PRE/1 deionisation)
OR (desalination)
OR ((direct OR indirect) PRE/2 potable reuse)
OR (real PRE/1 time PRE/1 control)
OR (autonomous PRE/1 housing)
OR (closed PRE/1 water PRE/1 system)
OR (energy PRE/1 water PRE/1 system)
AND HLEAD(water) AND ATLEAST3 (water) & ATLEAST2 (treatment)

The search query was developed in an iterative process by the first author. First research articles were searched that already had defined terms to classify innovative water technologies into categories like modular/decentralized and conventional/centralized. In the end, a rather comprehensive list of terms by Makropoulos and Butler (2010) was complemented with adjustments based on Singh et al. (2015), Gehrke et al. (2015), Marlow et al. (2013), Sharma et al. (2013), Dubois and Boutin (2018), Dahlgren et al. (2013), Willis et al. (2013). Additionally, five interviews were conducted with water and wastewater engineers at the author's home institution, Eawag, to further judge which technology terms were actually part of ongoing discussions, and how they may be called in different geographical contexts. The resulting search query was constructed in order to capture articles covering any of the term combinations connected through OR, as well as primarily dealing with "water", as the last line indicates. Since water technologies, such as seawater desalination, wastewater reuse, stormwater/rainwater harvesting, are generally scalable and can be applied in a decentralized or centralized fashion, searching for general AND specific technological terms for innovative water technologies was very important to avoid a bias in our search. The most important part of the search query is the most generic combination ((water OR wastewater OR …) PRE/1 (recycling OR reuse OR … desalination)). It covers all types of technologies. Many of the other technology-terms are specific but also scalable: e.g. "reverse osmosis", "sequencing batch reactor", "membrane bioreactor" can all be applied in centralized or decentralized systems. The few specific search terms, like "package treatment plant", which is specifically a decentralized niche type of technology, are very rarely used but were included as an optional filter to make the search as specific to our technological focus as possible.

A3:Coding scheme

Central paradigm related evaluations		Modular paradigm related evaluations	
Technologies			
Wastewater Treatment			
MBR (c)	Large-scale applications of membrane bioreactors	**MBR (m)**	Membrane bioreactors primarily for small-scale applications (like industrial waste water treatment)
Real time control (c)	real time control in large-scale treatment/ harvesting units	**Real time control (m)**	real time control for small-scale treatment units
Seperate sewer	large-scale separate sewer systems for stormwater & wastewater (also fits in HT3)	**MABR**	Membrane aerated biofilm reactors for small-scale treatment units
Combined sewer	large-scale combined sewer systems for stormwater & wastewater (also fits in HT3)	**Nanotech (m)**	Novel nano-membranes primarily for small-scale applications
Wetland (c)	customised constructed wetlands (such as zero discharge willow systems)	**Septic tanks**	small-scale septic tanks, cesspits
Nanotech (c)	nano-filtration techniques to improve large-scale infrastructures	**Packaged treatment plants**	Small-scale, modular, on-site, package treatment plants
		Microbial fuel cells	Small-scale, modular, on-site, treatment based on MFC
Water supply			
Desalination (c)	large-scale desalination plants and technology related to improving them (including nano-materials)	**Desalination (m)**	small-scale to plant-scale applications of desalination, incl. Capacitive/ electric deionisation or graphene
Dams and pipes	large-scale water supply dams and pipelines over long distances	**Water saving devices**	small-scale water saving/ point-of use devices
Surface abstraction	Large-scale OR small-scale groundwater or surface abstraction and/ or monitoring of the same	**Drip irrigation**	Modular irrigation systems for agriculture
Real time control (c)	real time control for optimised large-scale water supply networks	**Water ATMs**	Water ATM's with modular, decentralised on-site treatment
Stromwater management			
Stormwater inf. (c)	large-scale stormwater drainage & storage technologies like detention pools	**Rainwater harvesting**	small-scale/ development-scale rainwater harvesting modules (like tanks, pipes etc.)
Wetland (c)	Large-scale OR small-sclae ponds and/or constructed wetlands for stormwater storage and aquifier recharge	**Modular wetlands**	small-scale, scalable wetland modules
Integrated water management			
Energy water systems (c)	large-scale energy water systems	**Energy water systems (m)**	small-scale energy water systems, microbial fuel cells, heat recovery
Wastewater reuse (c)	large-scale sewerage wastewater recycling/ effluent dual reticulation, direct or indirect potable reuse,	**Industrial reuse (m)**	small-scale industrial wastewater reuse/ recycling
Industrial reuse (c)	plant-scale industrial wastewater reuse/ recycling, zero liquid discharge, common effluent treatment plants	**Real time control (m)**	real time control for small-scale wastewater reuse/ recycling
Nutrient recovery (c)	Nutrient recovery and reuse from large-scale wastewater treatment	**Onsite reuse**	small to development scale houshold wastewater reuse/ recycling
		Source separation	on-site sanitation, treatment and reuse via dry or composting toilets
		Autonomous houses	applications of on-site water technologies integrated in fully autonomous housing/buildings

Central paradigm related evaluations		Modular paradigm related evaluations	
Paradigms (Institutions)			
Central paradigm	evaluations highlighting the superiority of centralized, large-scale approaches to wastewater treatment. E.g. calling for efficiency improvements of sewers (leakage minimisation) or enhancement of existing sewage treatment plants enhanced	**Modular paradigm**	evaluations highlighting the benefits of water supply or treatment that organised more locally, making use of resilient and flexible onsite infrastructures replacing or adding on to the existing or new large-scale infrastructures
Policy, governance (Institutions)			
Centralized governance	centralised governance of water treatment, supply, stromwater drainage or recycling operations	**Modular governance**	decentralised governance of water treatement, supply, stormwater drainage or recycling operations
Regulation (c)	regulation promoting or facilitating the implementation of large-scale water infrastrucutre	**Regulation (m)**	regulation promoting small-scale, modular infrastructures
Financial incentives (c)	financial incentives and discounts to encourage water awareness and reduce consumption in centralised systems	**Financial incentives (m)**	financial incentives and discounts promoting small-scale modular infrastructures
		Diversified portfolio	uwm should include all sorts of technologies including modular

A4: Dataset

Years observed:	8
Documents:	576
Framings after duplicates/document cleared:	1589
Framings conducive to conventional technologies	911
Framings conducive to modular technologies	524
Rationality framings	154

DNA Variables:	
Organisations:	568
Organisation types:	8
Concept codes (referred to in narratives):	51

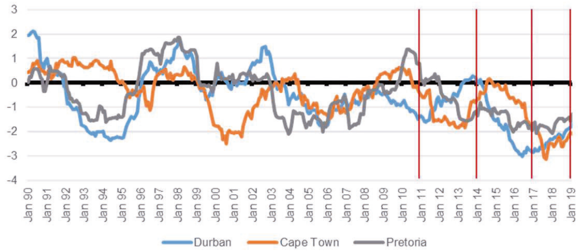
Overall framings per country (or clustered in supra-national regions):	count	% of subtotal
India	286	20.94
USA	260	19.03
South Africa	135	9.88
Singapore	130	9.52
Israel	91	6.66
UK	52	3.81
East Africa	69	5.05
East Asia	46	3.37
Southern Africa	50	3.66
Oceania	55	4.03
Canada	49	3.59
Europe	63	4.61
Central and West Africa	31	2.27
China, Hong Kong, Taiwan	21	1.54
Other Africa	1	0.07
Middle East	23	1.68
Latin America & Carribean	4	0.29
subtotal	1366	100.00
% of subtotal (top-3 countries)	681	49.85

Overall global-scale actor framings:	count	% of total
Global-scale	223	14.03
% of Global-scale and top-3 countries		58.63
Total	1589	100.00

A5 – Droughts and flooding in major cities covered in the dataset. Following the SPEI-36 drought monitor (negative values indicate high drought exposure, positive values indicate high exposure to flooding)

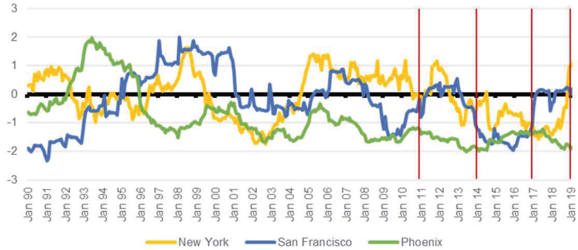
Durban, Cape Town,
Pretoria/Johannesburg region (ZAF)

Major newspapers included :
Business Day, Financial Mail, The Conversation, Sunday Times, Africa News



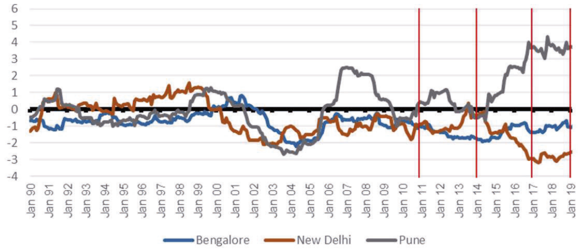
New York, San Francisco, Phoenix (USA)

Major newspapers included:
New York Times, San Francisco Chronicle, Daily News, Washington Post



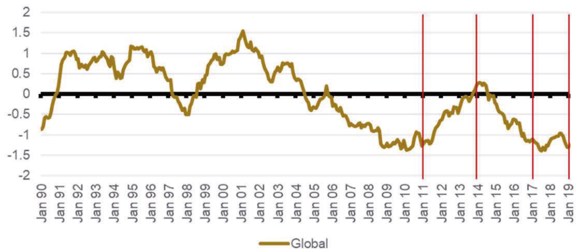
Bengalore, New Dehli, Pune (IND)

Major newspapers included:
Times of India, Economic Times



Global

Major newspapers included :
Business Monitor Online, Chemical News, New York Times International



Appendix B

B1: Search strategy for patent data OECD.stat. The search is built on an adjusted selection of environment-related water technologies (ENV-tech) based on OECD (2009), Martinez (2010), Haščič and Migotto (2015), Haščič et al. (2015) Leflaive et al. (2020) for the identification of technology development based on simple patent families (patent applications protecting the same priority) which can be traced back to individual inventors from individual countries. Since modular technologies cannot be defined easily within the realm of individual patent classes, we assume for reasons of simplicity, that existing knowledge and capabilities in environment-related water technologies reflect the availability for innovative capabilities in the modular technology field.

	Description
	1.2 Water pollution abatement
IPC class	**1.2.1. Water and wastewater treatment**
B63J4	Arrangements of installations for treating waste-water or sewage
C02F	Treatment of water, waste water, sewage or sludge
C09K3/32	Chemistry; Materials for treating liquid pollutants, e.g. oil, gasoline, fat
E03C1/12	Plumbing installations for waste water
E03F	Sewers –Cesspools
IPC class	**1.2.2. Fertilizers from wastewater**
C05F7	Fertilisers from waste water, sewage sludge, sea slime, ooze or similar masses
IPC class	**1.2.3. Oil spill clean-up**
E02B15/04-10	Devices for cleaning or keeping clear the surface of open water from oil or like floating materials by separating or removing these materials
B63B35/32	Vessels or like floating structures adapted for special purposes - for collecting pollution from open water
C09K 3/32	Materials for treating liquid pollutants, e.g. oil, gasoline or fat
	2.1 Demand-side technologies (water conservation)
IPC class	**2.1.1. Indoor water conservation**
	Faucets and showers
F16K21/06-12	Self-closing valves, i.e. closing automatically after operation, in which the closing movement, either retarded or not, starts immediately after opening
F16K 21/16-20	Self-closing valves, i.e. closing automatically after operation, closing after a predetermined quantity of fluid has been delivered

	Aeration of water
F16L 55/07	Arrangement or mounting of devices, e.g. valves, for venting oraerating or draining
F16K 21/16-20	Jet regulators with aerating means
	Sanitation (dual-flush toilets, dry toilets, closed-circuit toilets)
E03D 3/12	Flushing devices discharging variable quantities of water
E03D 1/14	Cisterns discharging variable quantities of water
A47K 11/12	Urinals without flushing
A47K 11/02	Dry closets
E03D13/007	Waterless or low-flush urinals
E03D5/016	Special constructions of flushing devices with recirculation of bowl-cleaning fluid
	Greywater
E03B1/041	Greywater supply systems
	Home appliances
Y02B 40/46	Optimisation of water quantity (for dishwashers)
Y02B 40/56	Optimisation of water quantity(for washing machines)
	Irrigation water conservation
A01G 25/02	watering arrangements located above the soil which make use of perforated pipe-lines or pipe-lines with dispensing fittings, e.g. for drip irrigation
A01G 25/06	Watering arrangements making use of perforated pipe-lines located in the soil
A01G 25/16	Control of watering
C12N15/8273	Mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors, e.g. plasmids, or their isolation, preparation or purification; for drought, cold, salt resistance
	Water conservation in thermoelectric power production
F01K 23/08-10	Combustion heat from one cycle heating the fluid in another cycle
F01D 11	Non-positive-displacement machines or engines, e.g. steam turbines / Preventing or minimizing internal leakage of working fluid, e.g. between stages
	Water distribution
F17D5/02 and E03	Pipe-line systems / Protection or supervision of installations / Preventing, monitoring, or locating loss
F16L55/16 and E03	Devices for covering leaks in pipes or hoses, e.g. hose-menders
	2.1 Supply-side technologies (water availability)
IPC class	**2.2.1 Water collection (rain, surface and ground water)**
	Underground water collection
E03B 5	Use of pumping plants or installations
E03B 3/06-26	Methods or installations for obtaining or collecting drinking water or tap water from underground
	Surface water collection
E03B 9	Methods or installations for drawing-off water

E03B 3/04; 28-38	Methods or installations for obtaining or collecting drinking water or tap water from surface water
	Rainwater water collection
E03B 3/02	Methods or installations for obtaining or collecting drinking water or tap water from rainwater
E03B 3/03	Special vessels for collecting or storing rain-water for use in the household, e.g. water-butts
E03B 3/00	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater
E03B 3/40	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater
	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater
	2.2.2. Water storage
E03B 11	Arrangements or adaptations of tanks for water supply
	2.2.3. Desalination of seawater
E03B 11	Arrangements or adaptations of tanks for water supply
	8. Climate change mitigation technologies related to wastewater treatment or waste management
Y02W10	**8.1 Wastewater treatment**
Y02W 10/00-45	- Biological treatment of water, waste water, or sewage
Y02W 10/00-45	- Sludge processing
Y02W 10/00-45	- Wastewater or sewage treatment systems with climate change mitigation effect characterised by the origin of the energy
	- Valorisation of by-products of wastewater, sewage or sludge processing

B2: Keywords signifying modular water technologies highlighted in red. Specified along the imensions *type of water flow*, *degree of centralisation* & *dominant production logic* (mass-producible vs. custom built), based on Makropoulos and Butler (2010), with adjustments based on Singh et al. (2015), Gehrke et al. (2015), Marlow et al. (2013), Sharma et al. (2013), Dubois and Boutin (2018), Dahlgren et al. (2013), Willis et al. (2013) & own desk research.

Type of water flow	Centralised	Decentralised
Water supply	Water supply reservoirs (dams) Groundwater abstraction Surface water abstraction Large-scale transfer of water resources Raw water treatment Real time control and monitoring (leak detection systems) Desalination (reverse osmosis) Dual supply systems (potable/ non-potable) Direct wastewater reuse (to potable)	Water saving household devices (such as water efficient showerheads, clothes washers, tap flow restrictors etc.) Local/ on-site abstraction On-site desalination (reverse osmosis & capacitive deionisation) Point of use treatment systems (filters, UV disinfection, softening = in-house equipment for water treatment)** Nano-photocatlysts Nano-membranes Nano-adsorbents Microbial fuel cells
Stormwater / drainage	Combined sewers (surface water runoff) Separate storm sewers Underground storage systems (connected to sewers) Combined sewer overflows Surface detention systems Gully pots/inserts Wetlands Sand filters	Inlet control (downpipes, butts, ponding) Swales and filter strips Pervious surfaces Soakaways Infiltration measures Filter drains Ponds (stormwater storage) Constructed wetlands Sand filters Vegetated spaces for stormwater collection and treatment Bioretention basins Sediment basins (*construction*) Built-in storage Evaporative sustainable urban drainage systems
Wastewater & Industrial wastewater	Combined sewer systems Separate sewer systems End-of-pipe wastewater treatment plant Anearobic digester (basic treatement) Phosphorus elimination and denitrification (advanced treatement) Real time control and monitoring Membrane bioreactors (aerobic systems)	Cesspools Septic tank systems (anaerobic treatment) Package treatment plants Reed bed filters Mound systems Constructed/ natural wetlands Sand filters Membrane bioreactors (aerobic systems) Membrane aerated biofilm reactors (aerobic systems) Sequencing batch reactors (aerobic systems)

Sequencing batch reactors (aerobic systems) In-sewer treatment	Sequencing batch reactors (aerobic systems) Living machines (series of emergent vegetation based treatment processes constructed in a greenhouse environment) Small diameter gravity systems Low pressure sewers (for toilet & septic tank) Vacuum toilets Container-based systems Air-displacement toilets Nano-photocatlysts Nano-membranes Nano-adsorbents Microbial fuel cells Real time control and monitoring
Aquifer storage and recovery (storm- or wastewater reuse) Effluent dual reticulation (dual water supply with non-potable supply coming from treated wastewater) (wastewater reuse) Energy-water systems (heat revovery from wastewater)	Rainwater harvesting (stormwater reuse) Green roofs (stormwater reuse) Grey water systems (greywater reuse) Combined rainwater and greywater recycling (storm- and greywater reuse) Dry & composting toilets (ecosan etc.) (wastewater reuse) Urine separation (NoMix) (wastewater reuse) Sewer mining (wastewater reuse) Autonomous housing (storm- and wastewater reuse) Container-based systems Closed water systems (wastewater reuse) Energy-water systems (wastewater reuse) Nano-photocatlysts Nano-membranes Nano-adsorbents Microbial fuel cells Real time control

B3: Full list of newspapers screened in NexisUni.

Africa News	The Sunday Herald (Glasgow)	The Japan News
The Advertiser/Sunday Mail (Adelaide, South Australia)	The Guardian(London)	The Japan Times
Brisbane News	Mining Magazine	Korea Herald
Canberra Times (Australia)	New Scientist	Korea Times
Hobart Mercury/Sunday Tasmanian (Australia)	The Daily Mail and Mail on Sunday (London)	New Straits Times (Malaysia)
Herald Sun/Sunday Herald Sun (Melbourne, Australia)	The Observer(London)	The Edge Malaysia
The Age (Melbourne, Australia)	The Investors Chronicle	New Era (Windhoek)
The West Australian (Perth)	The Independent (United Kingdom)	The Namibian (Windhoek)
Sydney Morning Herald (Australia)	BBC Monitoring: International Reports	Daily Trust (Abuja)
The Australian	The Daily Telegraph (London)	Het Financieele Dagblad (English)

Australian Financial Review	The Engineer	The New Zealand Herald
Northern Territory News (Australia)	The Mirror (The Daily Mirror and The Sunday Mirror)	The Press (Christchurch, New Zealand)
The Courier Mail/The Sunday Mail (Australia)	The Sunday Telegraph (London)	The Dominion (Wellington)
The Daily Telegraph (Australia)	Accountancy Age (UK)	The Dominion Post (Wellington, New Zealand)
The Gazette (Montreal)	Airline Business	The Evening Post (Wellington)
Ottawa Citizen	Marketing - UK	BusinessWorld
National Post's Financial Post & FP Investing (Canada)	mirror.co.uk	Polish News Bulletin
The Globe and Mail (Canada)	standard.co.uk	Sunday Times (South Africa)
The Toronto Star	telegraph.co.uk	GroundUp (Cape Town)
National Post (f/k/a The Financial Post)(Canada)	The Evening Standard (London)	The Conversation Africa (Johannesburg)
South China Morning Post	The Herald (Glasgow)	Business Day (South Africa)
Lianhe Zaobao	Travel Trade Gazette UK & Ireland	Financial Mail (South Africa)
Baltic News Service	Ghanaian Chronicle (Accra)	The Moscow News (RIA Novosti)
Addis Fortune (Addis Ababa)	The Times of India (TOI)	The Moscow Times
Maghreb Confidential	Hindustan Times	Moscow News
Belfast News Letter	The Economic Times	The New Times Kigali
Belfast Telegraph	The Irish Times	The Straits Times (Singapore)
Belfast Telegraph Online	The Jerusalem Post	The Edge Singapore
Birmingham Evening Mail	The Jerusalem Report	The Business Times Singapore
Birmingham Post	Nikkei Asian Review	The Nation (Thailand)

The Christian Science Monitor	Computer Weekly	MTI Econews
The Philadelphia Inquirer	Computing	Music Week
The Philadelphia Inquirer - Most Recent Two Weeks	Contract Journal	MWP Advanced Manufacturing
Advertising Age	Control and Instrumentation	Natural Gas Week
Automotive News	Creative Review	New Media Age
The New York Times	Daily Record and Sunday Mail	New Musical Express
Chemical Week	Daily Variety	Newsweek
The New York Times - International Edition	Design Engineering	Off Licence News
Accounting Today	Design Week	Plastics News (tm)
ADWEEK	Electronics Weekly	Platts Energy Business & Technology
The New Yorker	Employee Benefits	Platts Megawatt Daily
Waste News	Estates Gazette	PR Week
Business Monitor News	Euromoney	Precision Marketing

Tampa Bay Times	EXE	Process Engineering
The Washington Post	Farmers Weekly	Professional Broking
Al Jazeera - English	Financial Adviser	Retail Week
Daily News (New York)	Financial Director	Revolution
Los Angeles Times	Flight International	Rubber & Plastics News
PR Week (US)	Industry Week	Satellite Week
USA Today	Insurance Age	TechNews
The Herald (Harare)	International Money Marketing	The Banker
Audio Week	ITAR-TASS	The Business
Billboard	Lawyers Weekly	The Deal Pipeline
Brand Strategy	Legal Week	The Electricity Journal
Builder	Management Today	The Express
Business & Finance Magazine	Marketing Week	The Grocer
Campaign	Mergers and Acquisitions, The Dealmaker's Journal	The Lawyer
CFO	Middle East Newsfile (Moneyclips)	The People
City A.M.	Mobile Communications Report	The Pharma Letter
CMP Information	Money Marketing	The Weekly Times
Xtreme Information	What's new in Industry	Wall Street Journal Abstracts

B4: Search term query to identify articles.

Terms: (((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR smart OR distributed OR integrated OR household) PRE/2 (water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR desalination)) OR ((water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/1 (recycling OR reuse OR reclamation OR harvesting OR desalination)) OR (membrane PRE/1 bioreactor) OR (sequencing PRE/1 batch PRE/1 reactor) OR (microbial PRE/1 fuel PRE/1 cell) OR (membrane PRE/1 aerated PRE/1 biofilm PRE/1 reactor) OR (nano PRE/1 membrane) OR (nano PRE/1 adsorbent) OR (nano PRE/1 photocatalyst) OR (septic PRE/1 tank) OR (package PRE/1 treatment PRE/1 plant) OR (point PRE/2 use PRE/1 treatment) OR ((dry OR composting) PRE/1 toilet) OR (dual PRE/1 flush PRE/1 (plumb! OR toilet)) OR ((urine OR source) PRE/1 separation) OR (water PRE/1 saving PRE/1 device) OR (inlet PRE/1 control) OR (infiltration PRE/1 measure) OR (sustainable PRE/1 urban PRE/1 drainage) OR (NoMix) OR (jokhasou) OR (ecosan) OR (ecological PRE/1 sanitation) OR (water PRE/1 sensitive PRE/1 cities) OR (green PRE/1 roof) OR (water W/7 (resource PRE/1 recovery)) OR (reverse PRE/1 osmosis) OR (zero PRE/1 liquid PRE/1 discharge) OR (capacitive PRE/1 deionisation) OR (desalination) OR ((direct OR indirect) PRE/2 potable reuse) OR (real PRE/1 time PRE/1 control) OR (autonomous PRE/1 housing) OR (closed PRE/1 water PRE/1 system) OR (energy PRE/1 water PRE/1 system) AND HLEAD(water) AND ATLEAST3 (water) & ATLEAST2 (treatment))

B5: Indicator calculations

Favorable narrative share (discursive indicator for regime strength)

$$x_C^{favorable} = \frac{\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}}}{\sum \boldsymbol{FC}}$$

where $x_C^{conducive\ narrative\ sha}$ denotes the audience-based indicator for the favorable narrative share, which is given by the sum of all legitimising narrative uses towards modular technologies $\boldsymbol{FC_{Lmod}}$ and all de-legitimising narrative uses towards conventional technologies $\boldsymbol{FC_{DLcon}}$ divided by the sum of all narratives uses in the respective discourse.

Attraction indicator

$$\alpha_C^{attraction} = \left(\frac{(\sum \boldsymbol{FC_{Lemod}} + \sum \boldsymbol{FC_{DLecon}})}{(\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}})}\right)$$

where α denotes the audience-based indicator for *attraction*, given by the sum of all narratives by extra-regional actors favorable to modular technologies through legitimation or de-legitimation of conventional technologies $(\sum \boldsymbol{FC_{Lemod}} + \sum \boldsymbol{FC_{DLecon}})$ divided by all narrative uses favorable to modular technologies $(\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}})$ overall in the local media coverage.

Absorption indicator

$$\beta_{AC}^{absorption} = \left(\frac{(\sum \boldsymbol{FAC_{absorbedLmod}} + \sum \boldsymbol{FAC_{absorbedDLcon}})}{(\sum \boldsymbol{FAC_{Lmod}} + \sum \boldsymbol{FAC_{DLcon}})}\right))$$

Where $(\sum \boldsymbol{FAC_{absorbedLmod}} + \sum \boldsymbol{FAC_{absorbedDLcon}})$ refers to all favorable narratives absorbed from abroad by local actors addressing a local audience and $(\sum \boldsymbol{FAC_{Lmod}} + \sum \boldsymbol{FAC_{DLcon}})$ refers to the overall amount of narrative uses by local actors in the local media.

Endogenous legitimation indicator

$$\gamma_{AC}^{endogenous} = 1 - \left(\alpha_C^{attraction} + \beta_{AC}^{absorption}\right)$$

Export indicator

$$\beta_A^{export\ score} = \left(\frac{(\sum \boldsymbol{FA_{Lemod}} + \sum \boldsymbol{FA_{DLecon}})}{(\sum \boldsymbol{FA_{Lmod}} + \sum \boldsymbol{FA_{DLcon}})}\right)$$

Where $(\sum \boldsymbol{FA_{Lemod}} + \sum \boldsymbol{FA_{DLecon}})$ refers to all favorable narratives exported by local actors to non-local audiences and $(\sum \boldsymbol{FA_{Lmod}} + \sum \boldsymbol{FA_{DLcon}})$ refers to the overall amount of favorable narratives used by local actors.

Appendix C

C1: List of Interviews

Organisation	**Code**	**Date**
Research institute	I1	24.06.2019
Technology company	I2	01.07.2019
Research institute	I3	02.07.2019
Technology company	I4	16.07.2019
Research institute	I5	23.07.2019
Cooperative	I6	25.07.2019
Engineering consultancy	I7	29.07.2019
Engineering consultancy	I8	30.07.2019
Cooperative	I9	05.08.2019
Cooperative	I10	06.08.2019
NGO	I11	13.08.2019
Research institute	I12	15.08.2019
Research institute	I13	15.08.2019
Planning consultancy	I14	20.08.2019
Utility	I15	20.08.2019
Research institute	I16	21.08.2019
Technology company	I17	23.08.2019
Research institute	I18	19.09.2019
Research institute	I19	23.09.2019
Engineering consultancy	I20	08.10.2019
Research institute	I21	23.10.2019
Technology company	I22	29.10.2019
Research institute	I23	08.11.2019
Cooperative	I24	12.11.2020
Design consultancy	I25	02.12.2020
Engineering consultancy	I26	10.12.2020

Appendix D

D1: Interviews.

Type	Focus/ Project	Organisation	Code	Date
Research	Source separation (Europe)	Research institute	In1	23.07.2019
Private	Bern (CH)	Engineering consultancy	In2	30.07.2019
Private	Stockholm (SE)	Technology company	In3	08.08.2019
Research	Source separation (Europe)	Research institute	In4	21.08.2019
Research	Source separation (Europe)	Research institute	In5	19.09.2019
Research	**Sneek**, Amsterdam (NL)	Research institute	**In6**	30.09.2019
Research	DEUS21 (DE)	Research institute	In7	11.11.2019
Research	DEUS21 (DE)	Research institute	In8	06.12.2019
Research	**Helsingborg, Stockholm** (SE)	Research institute	**In9**	27.10.2020
Research	**Sneek** (NL)	Research institute	**In10**	04.11.2020
Private	**Sneek** (NL)	Technology company	**In11**	05.11.2020
Public	**Helsingborg** (SE)	Utility	**In12**	06.11.2020
Public	**Stockholm** (SE)	Municipality	**In13**	09.11.2020
Public	**Sneek,** Amsterdam (NL)	Intermediary	**In14**	13.11.2020
Public	Malmö, **Helsingborg** (SE)	Utility	**In15**	17.11.2020
Private	**Oslo** (NO)	Technology company	**In16**	19.11.2020
Public	**Hamburg** (DE)	Utility	**In17**	01.12.2020
Private	**Ghent** (BE)	Consultant	**In18**	03.12.2020
Public	**Visby** (SE)	Municipality	**In19**	07.12.2020
Private	Bern (CH)	Engineering consultancy	In20	10.12.2020

Summary

Today's urban water management infrastructures are reaching their limits during stormwater events and droughts. With climate change related hazards likely increasing globally, this trend is going to perpetuate in the coming decade. The development, production and deployment of technological solutions that help address such grand challenges become of paramount importance to cities, regions and nations. To make more sustainable technologies scale and to make change last, however, institutions and social practices need to change along with technologies. Institutions like socially constructed values, norms and regulations co-shape the direction of technological, industrial and sectorial change. The transformation of less sustainable, resource-intensive infrastructures and modes of production and consumption, therefore, becomes a matter of how both social and technical, henceforth socio-technical, concepts are re-arranged and aligned into more sustainable configurations that work.

The literature on socio-technical transitions has provided a wide range of evidences concerning the transformation of infrastructure sectors and the introduction and scaling of novel technologies and innovations. Socio-technical configurations are considered constellations of social and technical elements that are well aligned, that have been established over long time, and that show strong resistance to change. Their individual parts are compatible with, and do not contradict one another fundamentally. For example, the transition of the personal mobility sector has only very gradually started from fossil fuel driven personal cars towards more shared, service-based, and electrified modes of transport, ideally fueled by renewables. The socio-technical configuration of car manufacturers, automotive suppliers, politicians, laws and regulations, as well as technological applications around the combustion engine shows strong inertia and is only slowly re-configured.

The question of the geography of such transitions is crucial for understanding how re-configuration processes are being enabled or hampered. Intuitively, geography and space constitute focal lenses to understand the emergence of more sustainable socio-technical configurations. One may observe the transition of infrastructural sectors and related industries within specific geographical jurisdictions such as cities, regions, or nations. In a globalized world, transitions may equally rest upon spatial relations that span across

various scales, unfolding both locally and globally. For example, global epistemic communities, multi-national companies, international organizations or NGOs exchange knowledge and other resources for the development and diffusion of technology globally while at the same time being more or less strongly rooted in particular places. This way they condition where socio-technical transformations are more and less likely to take shape. Thus, systemic synergies for novel technologies or social innovations may not exclusively depend on the local context, but they may develop in so-called global innovation systems (GIS). The GIS concept argues that crucial resources necessary for an innovation to develop and mature may develop in subsystems at different spatial scales, from the local to the global, drawing researchers' attention to the organizations and processes (structural couplings) through which resources are transferred across scales. While scholars in economic geography and innovation studies have widely acknowledged and studied such multi-scalar interdependencies in the development and diffusion of novel technological knowledge, it is far less clear how geography conditions processes of institutionalization.

It is, therefore, the ambition of this thesis to answer the question through what mechanisms geography conditions the institutionalization of radically new socio-technical configurations.

It explores this question empirically by studying the case of sustainability transitions and industry formation in the global water sector. The water sector is one of the prime examples of an infrastructural sector, which has to undergo drastic technological and institutional changes to become fit for the challenges of the 21st century. While water and wastewater are usually treated in centralized, large-scale infrastructures, with end-of-pipe treatment facilities in the developed world, the majority of people in the global south are lacking access to safe water and sanitation. Climate change related extreme weather events like droughts or flooding are putting urban water management infrastructures under pressure and are threatening the security of water related services. Responding to these problems, water sector specialists are rushing to develop new technologies to treat water and wastewater more effectively, or to harness new sources of water, like through the reuse of greywater from dishwashers and rainwater tanks. At the same time, valuable resources like nutrients for agriculture or energy for household consumption may be recovered from wastewater onsite. Treating water and wastewater onsite, requires decentralized, modular technologies that come with new business models and modes of governance. Thus, many novel approaches involve a rethinking of the dominant global configuration of treating water and wastewater in centralized facilities controlled by private large multi-national companies or state-owned public utility companies, as well of the its supportive institutions.

The thesis studies the geography of transitions and industry formation in the water sector by addressing different sub-questions and problems.

Firstly, it asks how re-configuration processes in different places are embedded into trans-local resource flows. While trans-local knowledge flows have been well addressed in the literature, it is far less understood how institutional resources, such as legitimacy are being transferred trans-locally. The thesis, therefore, draws attention to multi-scalar processes of technology legitimation that influence transitions in different countries. It analyzes a dataset of water discourses in public media, covering an 8-year period in various major countries and at the global-scale of technology experts. Results show how the dominant configuration of large-scale infrastructures is reproduced at different spatial scales and how transition trajectories may open up during specific critical periods of increased public attention and discursive activity, such as droughts or flooding. The data also suggests that legitimacy may be absorbed or how legitimizing actors are attracted from abroad, contributing to the legitimation of novel industrial paths around modular water technologies in various localities.

Secondly, the thesis explores the local and trans-local conditions for and mechanisms leading to multi-scalar resource flows and the emergence of GIS. This is achieved by exploring the role of values within a network of actors involved in the modular water field in Switzerland in shaping the geography of their collaboration and the directionality of the field overall. This study indicates that values come in coherent packages (so-called field logics). It shows how actors adhering to specific field logics may be more prone to collaborating and linking up with experiences created elsewhere, depending on what we coin value-based proximity. In the last contribution of this thesis, the emergence of a GIS around a specific variant of modular water technologies, namely blackwater treatment with vacuum sewerage, is traced across northwestern Europe over two decades. Results show that a GIS forms based on complementary resource stocks, such as knowledge,

markets, funding, and legitimacy among different local contexts, as well as systemic intermediaries that support resources exchanges across spatial contexts.

For better tackling these processes, the thesis developed an innovative methodological approach, socio-technical configuration analysis (STCA). Alignments of socio-technical elements into coherent configurations are observed through articulations by different actors. The methodology combines qualitative content analysis and social network analysis to study configurations as clusters of socio-technical elements that align through their conjoint articulation by various actors. Its applicability is illustrated in two of the four contributions of the thesis, studying re-configuration processes in the global water sector, and value structures in an emerging the Swiss innovation system around modular water technologies.

In shedding light on the geography of re-configuration processes of the water sector, this thesis contributes to different strands of research in transition studies and evolutionary economic geography (EEG). With STCA, it proposes a novel way to study socio-technical configurations and sheds further light on how both scientific fields may benefit from a combination of a scalar-relational and a configurational perspective. In terms of policy, the thesis draws attention to the institutional and multi-scalar aspects of sectoral transformations and industry formation. Synergies among spatially distributed experimentation and innovation activities may benefit from intermediation across spatial scales. At the same time, within local, regional or national contexts policy needs to take into account the values held by the actors that shape the direction of a technological field at different scales.

Samenvatting

De infrastructuur voor stedelijk water- en afvalbeheer bereikt steeds meer haar grenzen tijdens hevige regenval en droogte. Als gevolg van de klimaatverandering zullen dit soort extreme weersomstandigheden de komende decennia vaker voorkomen. De ontwikkeling, productie en toepassing van technologische oplossingen voor de uitdagingen op het gebied van stedelijk waterbeheer die hieruit voortvloeien, zijn dan ook van het grootste belang voor steden, regio's en landen. Echter, om duurzamere technologieën op te schalen en van blijvende verandering te laten zijn, moeten naast de technologieën ook de instituties en de sociale praktijken veranderen. Instituties, zoals sociaal geconstrueerde waarden, normen en wetten, vormen mede de richting van technologische, industriële en sectorale veranderingen. De transformatie van minder duurzame, grondstof intensieve infrastructuren en productie- en consumptiewijzen hangt daarom nauw samen met de vraag hoe zowel sociale als technische - hierna te noemen socio-technische - concepten en elementen kunnen worden herschikt om duurzamere, "werkende configuraties" tot stand te brengen.

De literatuur over socio-technische transities heeft vele inzichten opgeleverd over de transformatie van infrastructuursectoren en de invoering en het schalen van nieuwe technologieën en innovaties. Socio-technische configuraties worden gezien als constellaties bestaande uit sociale en technische elementen die goed op elkaar zijn afgestemd, over een lange periode tot stand zijn gekomen en in hoge mate weestand bieden tegen verandering. De afzonderlijke delen zijn met elkaar verenigbaar en zijn niet fundamenteel met elkaar in tegenspraak. Zo verloopt bijvoorbeeld de transitie in de mobiliteitssector van auto's die op fossiele brandstoffen rijden naar meer gedeeld, op diensten gebaseerd en geëlektrificeerd vervoer op basis van hernieuwbare energiebronnen, zeer traag. De socio-technische configuratie van autofabrikanten, autotoeleveranciers, beleidsmakers, wet- en regelgeving en technologische toepassingen rond de verbrandingsmotor vertoont sterke inertie en wordt slechts langzaam opnieuw geconfigureerd.

De vraag van de geografie van zulke transities is van cruciaal belang om te begrijpen hoe re-configuratie processen mogelijk worden gemaakt of worden belemmerd. Intuïtief vormen geografie en ruimte categorieën waarin het ontstaan van duurzamere socio-

technische configuraties kan worden gevat en begrepen. Zo kan men bijvoorbeeld de transitie van infrastructuursectoren en van aanverwante industrieën waarnemen binnen specifieke administratieve grenzen zoals steden, regio's of landen. In een geglobaliseerde wereld kunnen transities echter ook gebaseerd zijn op ruimtelijke relaties die verschillende schalen bestrijken en zich zowel lokaal als mondiaal ontvouwen. Zo wisselen bijvoorbeeld wereldwijde beroeps- en onderzoeks-gemeenschappen, multinationale ondernemingen, internationale organisaties of niet-gouvernementele organisaties kennis en andere middelen uit voor de ontwikkeling en verspreiding van technologie over de hele wereld. Tegelijkertijd zijn zij min of meer sterk geworteld in bepaalde plaatsen. Op die manier beïnvloeden zij waar socio-technische transities meer of minder kans krijgen. Systemische synergiën voor nieuwe technologieën of sociale innovaties zijn dus niet uitsluitend afhankelijk van de lokale context, maar kunnen zich ontwikkelen in zogenaamde globale innovatiesystemen (GIS). Het GIS-concept stelt dat de middelen die nodig zijn voor de ontwikkeling en rijping van een innovatie zich kunnen ontwikkelen in subsystemen op verschillende ruimtelijke schalen - van lokaal tot mondiaal. Het vestigt de aandacht op de organisaties en processen (structurele koppelingen) die de middelen tussen verschillende schalen transporteren. Hoewel in economisch geografisch-, en innovatieonderzoek dergelijke multi-scalaire afhankelijkheden bij de ontwikkeling en verspreiding van nieuwe technologische kennis algemeen is erkend en bestudeerd, is het veel minder duidelijk hoe geografie processen van institutionalisering beïnvloed.

Het doel van dit proefschrift is dan ook een antwoord te geven op de vraag via welke mechanismen geografie de institutionalisering van radicaal nieuwe socio-technische configuraties conditioneert.

Deze vraag wordt empirisch onderzocht door duurzaamheidstransities en industrievorming in de mondiale watersector te onderzoeken. De watersector is een van de voornaamste voorbeelden van een infrastructuursector die drastische technologische en institutionele veranderingen moet ondergaan om klaar te zijn voor de uitdagingen van de 21e eeuw. Terwijl water- en afvalwater in geïndustrialiseerde landen gewoonlijk worden behandeld in gecentraliseerde, grootschalige faciliteiten met end-of-pipe-behandelingsmodegelijkheden, heeft de meerderheid van de mensen in het zuidelijk halfrond geen veilige toegang tot schoon drinkwater en sanitaire voorzieningen. De door klimaatverandering veroorzaakte extreme weersomstandigheden, zoals droogte of overstromingen, zetten de stedelijke waterbeheerinfrastructuur onder druk en vormen een bedreiging voor de veiligheid van water- en afvalwater gerelateerde diensten. Als reactie op deze problemen werken professionals uit de watersector aan de ontwikkeling van nieuwe technologieën om water- en afvalwater effectiever te behandelen, of aan de ontwikkeling van nieuwe waterbronnen, bijvoorbeeld hergebruik van grijs water uit vaatwassers en regenwaterreservoirs.

Tegelijkertijd kunnen waardevolle hulpbronnen, zoals voedingsstoffen voor de landbouw of energie voor huishoudelijk gebruik, worden teruggewonnen uit on-site afvalwater. De behandeling van water- en afvalwater on-site vereist gedecentraliseerde, modulaire technologieën die gepaard gaan met nieuwe bedrijfsmodellen en bestuursvormen. Daarom vereisen nieuwe innovatieve aanpakken het heroverwegen van de heersende mondiale configuratie van water- en afvalwaterzuivering in gecentraliseerde faciliteiten die worden gecontroleerd door grote particuliere multinationale ondernemingen of publieke nutsbedrijven.

Het proefschrift onderzoekt de geografie van transities en industrievorming in de watersector door verschillende deelvragen en problemen te behandelen.

Ten eerste wordt nagegaan hoe re-configuratie processen op verschillende plaatsen zijn ingebed in trans-lokale middelenstromen. Terwijl trans-lokale kennisstromen in de literatuur goed zijn bestudeerd, is er veel minder bekend over hoe institutionele middelen, zoals legitimiteit, trans-lokaal worden overgedragen. In dit proefschrift wordt daarom gekeken naar multi-scalaire processen van technologie-legitimatie die van invloed zijn op transities in verschillende landen. Het analyseert een dataset van acht jaar waterdiscoursen in de openbare media, gefocust op verschillende landen en op wereldschaal van technologiedeskundigen. De resultaten laten zien hoe de dominante configuratie van grootschalige infrastructuren op verschillende ruimtelijke schalen wordt gereproduceerd en hoe mogelijkheden voor transities kunnen ontstaan tijdens bepaalde kritieke perioden van verhoogde publieke aandacht en discursieve activiteit, zoals droogteperioden of overstromingen. De gegevens suggereren ook dat legitimiteit kan worden geabsorbeerd of hoe legitimerende actoren uit het buitenland worden aangetrokken, wat bijdraagt tot de legitimering van nieuwe industriële paden rond modulaire watertechnologieën op verschillende locaties.

Ten tweede onderzoekt het proefschrift de lokale en trans-lokale voorwaarden voor en mechanismen die leiden tot multi-scalaire middelenstromen en het ontstaan van GIS. Dit wordt gedaan door de rol te onderzoeken van waarden binnen een netwerk van actoren die betrokken zijn bij modulaire watervoorzieningen in Zwitserland. Er wordt onderzocht hoe de waarden van invloed zijn op de geografie van hun samenwerkingen en de richting van het gehele innovatiesysteem. De studie laat zien dat waarden voorkomen in samenhangende pakketten (zogenaamde veldlogica's). Het laat zien hoe actoren die specifieke veldlogica's aanhangen, meer geneigd zijn samen te werken en voort te bouwen op elders opgedane ervaringen, afhankelijk van wat wij "op waarde gebaseerde nabijheid" noemen. In de laatste bijdrage van dit proefschrift wordt het ontstaan van een GIS rond een specifieke variant van modulaire watertechnologieën, namelijk zwartwaterzuivering met vacuümriolering, in Noordwest-Europa over een periode van twee decennia uiteengezet. Uit de resultaten blijkt dat een GIS zich vormt op basis van complementaire middelen zoals kennis, markten, financiering en legitimiteit tussen verschillende lokale contexten. Ook wordt het belang aangetoond van systemische tussenpersonen die de uitwisseling van middelen tussen ruimtelijke contexten ondersteunen.

Om deze processen beter te begrijpen, heeft dit proefschrift een innovatieve methodologie ontwikkelt, de socio-technische configuratie-analyse (STCA). De afstemming van socio-technische elementen in samenhangende configuraties wordt waargenomen door de articulaties van verschillende actoren. De methodologie combineert kwalitatieve inhoudsanalyse en sociale netwerkanalyse om configuraties te bestuderen als clusters van socio-technische elementen. De toepasbaarheid van de methodologie wordt geïllustreerd in twee van de vier bijdragen van dit proefschrift, waarin re-configuratie processen in de mondiale watersector, en waarde structuren in een opkomend Zwitsers innovatiesysteem rond modulaire watertechnologieën worden bestudeerd.

Door licht te werpen op de geografie van re-configuratie processen in de watersector, draagt dit proefschrift bij aan verschillende onderzoeksgebieden in transitiestudies en evolutionaire economische geografie (EEG). Met STCA stelt het een nieuwe manier voor om socio-technische configuraties te bestuderen en werpt het nieuw licht op hoe beide wetenschapsgebieden voordeel kunnen halen uit een combinatie van een scalair-relationeel en een configurationeel perspectief. Wat betreft beleid vestigt het proefschrift de aandacht op de institutionele en multi-scalaire aspecten van sectorale transformaties en industrievorming. Synergiën tussen ruimtelijk verspreide experimenten en innovatieactiviteiten kunnen profiteren van bemiddeling over ruimtelijke schalen heen. Tegelijkertijd moeten beleidsmakers binnen lokale, regionale of nationale contexten rekening houden met de waarden van de actoren die op verschillende schaalniveaus de richting van een technologisch gebied bepalen.

Resümee

Die Wasser- und Abwasserinfrastrukturen der Welt stoßen bei Starkregenereignissen und Dürreperioden zunehmend an ihre Grenzen. Aufgrund des Klimawandels werden Extremwetterereignisse dieser Art in kommenden Jahrzehnten häufiger werden. Die Entwicklung, Produktion und der Einsatz technologischer Lösungen für die daraus entstehenden Herausforderungen des urbanen Wassermanagments sind für Städte, Regionen und Nationen daher von größter Bedeutung. Damit sich nachhaltigere Technologien jedoch durchsetzen und der Wandel von Dauer ist, müssen sich neben den Technologien auch Institutionen und soziale Praktiken ändern. Institutionen, wie zum Beispiel sozial konstruierte Werte, Normen und Gesetze prägen die Richtung des technologischen, industriellen und sektoralen Wandels. Die Umwandlung weniger-nachhaltiger, ressourcenintensiver Infrastrukturen und Produktions- und Verbrauchsweisen hängt daher stark mit der Frage zusammen, wie sowohl soziale als auch technische - im Folgenden soziotechnische – Konzepte und Elemente neu arrangiert und so nachhaltigere, «funktionierende Konfigurationen» entstehen können.

Die Literatur über soziotechnische Transitionen hat in der Vergangenheit eine Vielzahl von Erkenntnissen über die Transformation von Infrastruktursektoren und die Einführung und Skalierung neuer Technologien und Innovationen geliefert. Soziotechnische Konfigurationen werden als Konstellationen von sozialen und technischen Elementen betrachtet, die gut aufeinander abgestimmt sind, die sich über einen langen Zeitraum hinweg etabliert haben und die eine hohe Widerstandsfähigkeit gegenüber Veränderungen aufweisen. Ihre einzelnen Teile sind miteinander kompatibel und widersprechen sich nicht grundlegend. So vollzieht sich beispielsweise der Wandel im Bereich der individuellen Mobilität weg vom mit fossilen Brennstoffen betriebenen Pkw hin zu mehr gemeinsam genutzten, dienstleistungsbasierten und elektrifizierten Verkehrsmitteln, die mit erneuerbaren Energien betrieben werden, nur sehr langsam. Die sozio-technische Konfiguration von Automobilherstellern, Automobilzulieferern, Politiker*innen, Gesetzen und Vorschriften sowie technologischen Anwendungen rund um den Verbrennungsmotor weist eine starke Trägheit auf und wird nur langsam neu konfiguriert.

Die Frage nach der Geographie ist entscheidend für das Verständnis, wie solche Transitionen ermöglicht oder behindert werden. Geografie und Raum sind bereits intuitiv Kategorien, in denen die Entstehung nachhaltigerer soziotechnischer Konfigurationen erfasst und verstanden werden kann. So kann man etwa den Wandel von Infrastruktursektoren und von verwandten Industrien innerhalb bestimmter administrativer Grenzen wie Städte, Regionen oder Nationen beobachten. In einer globalisierten Welt können Transitionen jedoch auch auf räumlichen Beziehungen beruhen, die sich über verschiedene Skalen hinweg erstrecken und sich sowohl lokal als auch global entfalten. So tauschen beispielsweise globale Fach- und Forschungs-Communities, multinationale Unternehmen, internationale Organisationen oder Nichtregierungsorganisationen Wissen und andere Ressourcen für die Entwicklung und Verbreitung von Technologie weltweit aus. Gleichzeitig mögen sie dabei mehr oder weniger stark an bestimmten Orten verwurzelt sein. Auf diese Weise beinflussen sie, wo sich sozio-technische Transformationen vollziehen werden und wo nicht. Systemische Synergien für neue Technologien oder soziale Innovationen hängen also nicht ausschließlich vom lokalen Kontext ab, sondern können sich in so genannten globalen Innovationssystemen (GIS) entwickeln. Das GIS-Konzept geht davon aus, dass sich die für die Entwicklung und Reifung einer Innovation erforderlichen Ressourcen in Subsystemen auf verschiedenen räumlichen Skalen - von der lokalen bis zur globalen - entwickeln können. Es lenkt die Aufmerksamkeit auf die Organisationen und Prozesse (strukturelle Kopplungen), durch die Ressourcen über Skalen hinweg übertragen werden. Während die Wirtschaftsgeographie und die Innovationsforschung solche multiskalaren Interdependenzen bei der Entwicklung und Verbreitung neuen technologischen Wissens weitgehend anerkannt und untersucht haben, ist weit weniger klar, wie die Geographie Prozesse der Institutionalisierung bedingt.

Daher ist es das Ziel dieser Arbeit, die Frage zu beantworten, durch welche Mechanismen die Geographie die Institutionalisierung radikal neuer sozio-technischer Konfigurationen bedingt.

Diese Frage wird empirisch untersucht, indem Nachhaltigkeitstransitionen und Branchenformierung im globalen Wassersektor untersucht werden. Der Wassersektor ist eines der Paradebeispiele für einen Infrastruktursektor, der drastische technologische und institutionelle Veränderungen durchlaufen muss, um für die Herausforderungen des 21.

Jahrhunderts gerüstet zu sein. Während Wasser und Abwasser in den Industrieländern in der Regel in zentralisierten, groß angelegten Infrastrukturen mit End-of-Pipe-Aufbereitungsanlagen behandelt werden, hat die Mehrheit der Menschen im globalen Süden keinen sicheren Zugang zu sauberem Trinkwasser und sanitären Einrichtungen. Durch den Klimawandel bedingte extreme Wetterereignisse wie Dürren oder Überschwemmungen setzen die Infrastrukturen der städtischen Wasserwirtschaft unter Druck und bedrohen die Sicherheit von wasser- und abwasserbezogenen Dienstleistungen. Als Reaktion auf diese Probleme arbeiten Fachleute im Wassersektor an der Entwicklung neuer Technologien für eine effizientere Wasser- und Abwasseraufbereitung oder an der Erschließung neuer Wasserquellen, etwa durch die Wiederverwendung von Grauwasser aus Geschirrspülern und Regenwassertanks.

Gleichzeitig können aus dem Abwasser vor Ort wertvolle Ressourcen wie Nährstoffe für die Nahrungsmittelproduktion oder Energie für den Haushaltsverbrauch zurückgewonnen werden. Die Behandlung von Wasser und Abwasser vor Ort erfordert dezentralisierte, modulare Technologien, die mit neuen Geschäftsmodellen und Verwaltungsmodellen einhergehen. Viele neuartige Ansätze erfordern daher ein Überdenken der weltweit vorherrschenden Konfiguration der Wasser- und Abwasseraufbereitung in zentralisierten Anlagen, die von privaten multinationalen Großunternehmen oder staatlichen Versorgungsbetrieben kontrolliert werden, sowie der sie unterstützenden Institutionen.

Die Dissertation untersucht die Geographie der Transition und der Branchenbildung im Wassersektor, indem sie verschiedene Teilfragen und Probleme behandelt.

Erstens geht es um die Frage, wie Transitionsprozesse an verschiedenen Orten in translokale Ressourcenströme eingebettet sind. Während ortsübergreifende Wissensflüsse in der Literatur gut untersucht wurden, ist weit weniger bekannt, wie institutionelle Ressourcen, wie z. B. Legitimität, ortsübergreifend transferiert werden. Diese Arbeit befasst sich daher mit multiskalaren Prozessen der Technologielegitimation, die Transitionen in verschiedenen Ländern beeinflussen. Sie analysiert einen Datensatz von Wasserdiskursen in öffentlichen Medien in verschiedenen Ländern und auf der globalen Ebene von Technologieexperten, der einen Zeitraum von acht Jahren abdeckt. Die Ergebnisse zeigen, wie die vorherrschende Konfiguration groß-ausgelegter Infrastrukturen auf verschiedenen räumlichen Ebenen reproduziert wird und wie sich in bestimmten kritischen Perioden erhöhter öffentlicher Aufmerksamkeit und diskursiver Aktivität, z. B. bei Dürren oder Überschwemmungen, Möglichkeiten für Transitionen auftun können. Die Daten deuten auch darauf hin, dass Legitimität absorbiert werden kann oder wie legitimierende Akteure aus dem Ausland angezogen werden, was zur Legitimation neuartiger industrieller Pfade rund um modulare Wassertechnologien an verschiedenen Orten beiträgt.

Zweitens untersucht die Arbeit die lokalen und translokalen Bedingungen für sowie die Mechanismen hinter multiskalaren Ressourcenflüssen und der Entstehung von GIS. Dies geschieht durch die Untersuchung von Werthaltungen innerhalb eines Netzwerks von Akteuren, die im Bereich der modularen Wasserversorgung in der Schweiz tätig sind. Untersucht wird wie diese Werthaltungen sich auf Kollaborationsnetzwerke und die Ausrichtung des gesamten Innovationssystems auswirken. Die Studie zeigt, dass Werte in kohärenten Paketen (sogenannten Feldlogiken) auftreten. Sie zeigt, wie Akteure, die sich an bestimmte Feldlogiken halten, eher dazu neigen, zusammenzuarbeiten und an Erfahrungen anzuknüpfen, die anderswo gemacht wurden. Diese Aktivitäten bauen auf, was wir als eine Form «wertbasierter Nähe» bezeichnen. Im letzten Beitrag dieser Arbeit wird die Entstehung eines GIS rund um eine spezifische Variante modularer Wassertechnologien, nämlich die Schwarzwasserbehandlung mit Vakuumentwässerung, in Nordwesteuropa über zwei Jahrzehnte hinweg nachgezeichnet. Die Ergebnisse zeigen, dass sich ein GIS auf der Grundlage komplementärer Ressourcen wie Wissen, Märkte, Finanzierung und Legitimität zwischen verschiedenen lokalen Kontexten bilden kann. Ausserdem zeigt sich die zentrale Bedeutung systemischer Intermediäre, die den Austausch von Ressourcen über räumliche Kontexte hinweg unterstützen.

Um diese Prozesse besser zu greifen, wurde in dieser Arbeit eine innovative Methodologie entwickelt, die soziotechnische Konfigurationsanalyse (STCA). Die Anordnung sozio-technischer Elemente zu kohärenten Konfigurationen wird dabei über ihre Artikulation durch verschiedene Akteure beobachtet. Die Methodologie kombiniert qualitative Inhaltsanalyse und soziale Netzwerkanalyse um Konfigurationen als Cluster soziotechnischer Elemente zu erfassen. Die Anwendbarkeit der Methodologie wird in zwei der vier Beiträge der Dissertation veranschaulicht, in denen Rekonfigurationsprozesse im globalen Wassersektor und Wertestrukturen in einem entstehenden Schweizer Innovationssystem rund um modulare Wassertechnologien untersucht werden.

Indem sie die Geographie der Rekonfigurationsprozesse im Wassersektor beleuchtet, leistet diese Arbeit einen Beitrag zu verschiedenen Forschungssträngen der Transitionsforschung und der evolutionären Wirtschaftsgeographie (EEG). Mit STCA wird ein neuartiger Ansatz zur Untersuchung sozio-technischer Konfigurationen vorgeschlagen der neues Licht darauf wirft, wie beide Wissenschaftsbereiche von einer Kombination aus einer skalar-relationalen und einer konfigurationalen Perspektive profitieren können. Im Hinblick auf politische Steuerung lenkt die Arbeit die Aufmerksamkeit auf die institutionellen und multiskalaren Aspekte von sektoralen Transformationen und von Industrieformierung. Synergien zwischen räumlich verteilten Experimenten und Innovationsaktivitäten können von der Vermittlung über räumliche Skalen hinweg profitieren. Gleichzeitig muss die Politik in lokalen, regionalen oder nationalen Kontexten die Werthaltungen von Akteuren berücksichtigen, die die Richtung eines technologischen Feldes auf verschiedenen räumlichen Ebenen bestimmen.

Authorship statement

The candidate's share of work in all parts of this dissertation is listed in accordance with the CRediT (Contributor Roles Taxonomy) (Allen et al., 2019).

The candidate conceptualized all four individual articles in collaboration with the supervision team. The candidate was in charge of data curation, formal analysis, investigation, methodology, validation, and all visualizations, as well as writing original drafts. The supervision team has provided support in validation, review, writing and editing, as well provided the organizational context (funding, resources, and network) and has supervised the candidate in all steps of academic publishing.

	PhD candidate	**prof. dr. B Truffer**	**dr. C. Binz**
Chapter 1 - Introduction	Conceptualization, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Resources, Project administration, Funding acquisition	
Chapter 2 - Assessing transitions through socio-technical configuration analysis	Conceptualization, Methodology, Investigation, Formal analysis, Software, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Conceptualization, Writing- Reviewing and Editing, Resources, Project administration, Funding acquisition	Supervision, Conceptualization, Writing- Reviewing and Editing
Chapter 3 - The Geography Of Technology Legitimation	Conceptualization, Methodology, Investigation, Formal analysis, Software, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Conceptualization, Writing- Reviewing and Editing, Resources, Project administration, Funding acquisition	Supervision, Conceptualization, Writing- Reviewing and Editing

Chapter 4 - Overcoming the harmony fallacy	Conceptualization, Methodology, Investigation, Formal analysis, Software, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Conceptualization, Writing- Reviewing and Editing, Resources, Project administration, Funding acquisition	
Chapter 5 - The emergence of a global innovation system	Conceptualization, Methodology, Investigation, Formal analysis, Software, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Conceptualization, Writing- Reviewing and Editing, Resources, Project administration, Funding acquisition	
Chapter 6 - Conclusion	Conceptualization, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization	Supervision, Resources, Project administration, Funding acquisition	

All four articles have been published in peer-reviewed journals. Heiberg & Truffer 2022 (a & b) were published after the deadline for submission of this thesis and include minor improvements that were not yet implemented in this book.

Heiberg, J., Truffer, B. & Binz, C. 2022. Assessing transitions through socio-technical configuration analysis – a methodological framework and a case study in the water sector. Research Policy, 51 (1): 104363.

Heiberg, J., Binz, C. & Truffer, B. 2020. The Geography of Technology Legitimation: How Multiscalar Institutional Dynamics Matter for Path Creation in Emerging Industries. Economic Geography, 96 (5): 470-498.

Heiberg, J. & Truffer, B. 2022a. Overcoming the harmony fallacy: How values shape the course of innovation systems. . Environmental Innovation and Societal Transitions, 42 (2022): 411-428.

Heiberg, J. & Truffer, B. 2022b. The emergence of a global innovation system – a case study from the water sector. Environmental Innovation and Societal Transitions, 43 (2022): 270-288.

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Wentorf bei Hamburg, April 2022

Curriculum Vitae

Jonas Heiberg (Hamburg, Germany, 1992) obtained a BSc degree in Geography (2016) at Philipps-Universität Marburg, Germany, and a MSc degree in Innovation and Spatial Dynamics (2017) at the School of Economic and Management, at Lunds Universitet, Sweden. He has previously lived among the German minority in the Nordschleswig region in Denmark, where he went to high school and to where he returned for his Master thesis, investigating cross-border regional innovation system policies in the German-Danish border region.

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