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Navigating institutional complexity in socio-technical transitions

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ABSTRACT

Transitions from one socio-technical regime configuration to another entail long phases of institutional complexity, where two or more field logics co-exist in a sector and induce incompatibilities and frictions. This paper presents a dynamic phase model, which characterizes the types of institutional complexity that may build up and settle across various phases of a transition, illustrated with a case study from the diffusion of onsite water reuse in San Francisco. Results from semi-structured expert interviews and a focus group demonstrate that different forms of institutional complexity may follow each other in a transition trajectory and that formidable strategic agency is needed by the actors in a field in navigating prolonged phases of competing cultural demands. Gaining a more balanced perspective of both organizational and field-level reconfigurations may help better explain why transitions succeed in some places and fail in others.

1. Introduction

Sustainability transitions are entering a new phase of development in many sectors. Novel socio-technical configurations have diffused widely and reached a level of maturity that makes them directly compete with long-established regimes (Markard, 2018). Relevant transition dynamics (and transition scholars' research interests) are accordingly shifting from the build-up of radical innovation in protective spaces to understanding how regimes are deeply transformed by alternative socio-technical configurations that represent diverging worldviews and core technologies. Several authors have recently argued that connecting transition studies more explicitly with organization studies and neoinstitutional theory could enable a better understanding of the complex (de)institutionalization dynamics that shape sector transformations in this new phase (Fuenfschilling, 2019; Runhaar et al., 2020).

This paper aims at contributing to this debate by exploring the role of institutional complexity in transition trajectories. It draws on the 'institutional perspective on transitions' (Fuenfschilling, 2019), which conceptualizes transitions as shifts from a dominant socio-technical configuration with a deeply institutionalized guiding logic to a new configuration with a transformed underlying field logic (Fuenfschilling and Truffer, 2014; Fuenfschilling, 2019). In transitions between (e.g., fossil-fuel based and renewable) configurations, actors strategically institutionalize new values, beliefs and technologies, while they de-institutionalize existing ones. This process, by definition, is prone to institutional complexity; actors will have to navigate periods in which two or more incompatible field logics co-exist and compete with each other, potentially causing friction and confusion about where the sector is heading.

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Understanding how institutional complexity emerges in transition trajectories and how actors can navigate and collaboratively settle it, is thus of key importance for understanding why transitions succeed in some instances, while they fail in others. The increasing relevance of institutional complexity in understanding transitions is acknowledged, but not (yet) categorically analyzed in transitions literature (Fuenfschilling, 2019).

This paper addresses this gap by explicitly connecting sustainability transitions research with recent theorization on institutional complexity in organizational institutionalism (Raynard, 2016; Greenwood et al., 2011). We address the research question: when and how does institutional complexity emerge in a transition trajectory and how do actors work collectively to reconcile competing demands, expectations, and core values? A conceptual phase model for tracing the buildup and settlement of institutional complexity in transition trajectories is developed and empirically illustrated with a case study in San Francisco's urban water management sector, a case with particularly interesting institutional frictions in the transition process. Based on 25 semi-structured expert interviews and a stakeholder workshop, we trace in detail how institutional complexity emerged in the transition toward on-site water reuse and how local actors re-organized internally and adapted field-level structures to keep the transition moving forward.

Due to water scarcity, repeated droughts and a push for increased resilience, San Francisco has sought to diversify and expand its portfolio of water sources. Since 2015, a local ordinance mandates new, large-scale real estate developments to incorporate on-site water reuse systems (Weiner, 2012). As of 2019, about 90 on-site reuse systems are either installed or in the design and construction phase; such systems capture rainwater or reuse greywater, wastewater, or stormwater for non-potable applications. This approach is a departure from the dominant regime in urban water management (UWM), which traditionally revolves around large-scale, centralized infrastructure and a field logic rooted in the state and the engineering profession (Fuenfschilling and Truffer, 2014). On-site water reuse, in turn, more strongly draws from community and market logics and emphasizes alternative values like environmental and social sustainability, circular economy thinking and the inclusion of building owners, private firms and end user organizations in managing water systems (ibid.).

Using the example of UWM in San Francisco, this paper contributes to a much wider research agenda at the intersection of transition studies and organizational institutionalism (see Fuenfschilling 2019). As we will outline in the remainder, developing a more structured view on institutional complexity is one important step in better understanding and etymologizing the challenges associated with transition trajectories in different (infrastructure) sectors. The identified ideal-type strategies for settling institutional complexity may in turn inform policy makers and practitioners on how to navigate phases of institutional contestation in ongoing transition trajectories.

2. Conceptual framework

2.1. Transitions from an institutional perspective

Transitions denote the long-term structural transformation of socio-technical systems that fulfill basic societal functions like energy, transport, water, or food (Markard et al., 2012). At the core of transitions thinking stands the historic co-evolution of technologies and institutions into cohesive socio-technical configurations 'that work' (Grin et al., 2010; Kemp et al., 1998). In a transition, a sector's core actor networks, values, user practices, and market structures are deeply reorganized and reconfigured, ideally toward increased sustainability. These fundamental transformation processes have been conceptualized as regime shifts, denoting a replacement of the most deeply institutionalized socio-technical configuration in a field with a new one that features structurally different institutional elements, technologies, as well as actor networks (Fuenfschilling, 2019; Geels, 2002). In the past, regimes have been portrayed as rather monolithic structures (Geels, 2002) that align technologies, policies, user preferences, markets, etc. into a dominant configuration that evolves in a path-dependent trajectory over extended periods of time.

In more recent theorizing, institutional theory and organizational institutionalism have increasingly informed the conceptualization of regimes and transition dynamics (Fuenfschilling, 2019). In this paper, we follow the emerging 'institutional perspective on transitions', which characterizes regimes as semi-coherent configurations of field logics with varying degrees of institutionalization (Fuenfschilling and Truffer 2014; van Welie et al., 2018; Fuenfschilling, 2019). In this interpretation, socio-technical regimes denote the most deeply institutionalized ('core') logic in a field, which combines certain technologies, values, organizational forms, etc. into a guiding rationality that locks the system in to a dynamically stable development trajectory. For example, Fuenfschilling and Truffer (2014) illustrated three competing field logics in the (Australian) urban water sector that show diverging levels of structuration. Transitions were accordingly conceptualized as a de-institutionalization of the most deeply taken-for-granted (here: hydraulic) field logic and an institutionalization of one or several competing (here: water market / water sensitive) field logics that draw on different bundles of core values, technologies, and material elements.

This conceptualization has triggered highly productive lines of research. Scholars have applied an institutional perspective on transitions to explore how socio-technical systems transform in urban or regional contexts (Frantzeskaki et al., 2017; Strambach and Pflitsch, 2020), how taken-for-granted regime structures are de-institutionalized (Kungl and Geels, 2018; Rosenbloom and Rinscheid, 2020), or how 'niche' actors may strategically institutionalize a competing rationality through collective institutional work (Binz et al., 2016a; Fuenfschilling and Truffer, 2016). At the same time, the institutional perspective is still a relatively new addition to transition studies, which needs to be further specified in various respects. One key theme that has not received ample attention is how transitioning from one dominant socio-technical configuration to another implies, by definition, that institutional complexity is generated in a field, which then has to be settled through both organizational and system-level change processes. Improving our understanding of what happens in prolonged phases of institutional complexity in a transition process could help address fundamental questions around how niche-regime interactions play out, why transitions succeed in some instances, while they fail in others, or how actors may pro-actively reconcile incompatible cultural demands in 'hot' phases of contestation (Rosenbloom and Rinscheid, 2020; Yuana et al., 2020).

Exploring this theoretical interface represents a relevant frontier to transitions thinking (Fuenfschilling, 2019; Runhaar et al., 2020). At the same time, integrating and bridging insights from institutional organizationalism and transition studies is not straightforward, since fundamental differences exist in the basic ontologies, epistemologies, and empirical foci of both fields. In particular, organizational institutionalism to date has remained mostly concerned with understanding how institutional logics are enacted at micro- to macro levels and how single organizations may strategically navigate competing moral expectations stemming from incompatible logics (Greenwood et al., 2017; Fuenfschilling, 2019). Transition studies are in turn more interested in understanding factors explaining long-term stability and change in macro- to meso-level structures and also how actors might strategically alter field/sector level structures through collective agency (Markard et al., 2012; Binz et al., 2016a; Fuenfschilling and Truffer, 2014).

Since a deep elaboration of the contradictions and complementarities that exist between these literatures lies beyond the scope of this paper,[1] we will focus on a narrower conceptual question, namely how institutional complexity co-evolves with socio-technical system reconfiguration in a transition process. While the salience of this question is acknowledged in transitions literature (see Fuenfschilling 2019), analytical frameworks for assessing the relevant dynamics remain missing. In the remainder, we will develop a first step toward such a conceptualization by reviewing recent literature on institutional complexity in organizational institutionalism and connecting it to transitions thinking in a phase model of the evolution of institutional complexity in socio-technical transitions.

2.2. Institutional complexity

A most basic definition for institutional complexity is the presence of "incompatible prescriptions from multiple institutional logics" (Greenwood et al., 2011, 317). Institutional logics denote "the socially constructed, historical patterns of cultural symbols and material practices that direct attention toward particular stimuli, specify criteria for legitimacy, and define what constitutes appropriate behavior" (Thornton et al., 2012, 2). Organizations tend to follow these principles because compliance equips them with societal legitimacy (Greenwood et al., 2011; Johnson et al., 2006). An important distinction exists between institutional sector logics and field logics. Institutional sector logics originated with Friedland and Alford (1991), who described Western society as an inter-institutional system of generic logics, which revolve around macro-level structures like the capitalist market, bureaucratic state, democracy, nuclear family, or Christian religion. Field logics, in turn, denote bundles of these foundational sector logics that structure practices in an organizational field (Thornton et al., 2012). For example in the water sector, three guiding field logics (i.e. 'hydraulic', 'water market' and 'water-sensitive') have been identified in past research, which partly contradict each other and which are institutionalized to varying degrees (Fuenfschilling and Truffer, 2014). Original literature on institutional logics has ascribed specific sector logics to actors, however recent work emphasizes that actors often enact and mobilize multiple field logics in their agency within an organization (McPherson and Sauder, 2013; Smets et al., 2014). As such, we do not necessarily focus on attributing specific types of logics to actors, but rather, focus on where different field logics overlap in transition processes.

According to organizational institutionalism, the number of competing logics and their degree of incompatibility are two key elements that influence the speed, disruptiveness, and volatility of a structural transformation. A shift between two relatively compatible logics that overlap in their basic moral assumptions may happen in a relatively incremental, 'fit and conform' type of transition trajectory, as seen in the transition from cesspool to sewer systems in the Netherlands (Geels, 2006). In contrast, transitioning between a deeply institutionalized field logic and one (or several) competing logics that are inherently incompatible will induce a long phase of insecurity and 'stretch and transform' type of contestation and re-configuration in the affected sector (ibid.), as seen in the energy transition in Germany (Geels et al., 2016). In addition, Greenwood et al. (2011) argue that the more specific a field logic is, the less room there is for discretionary action (e.g. decoupling or 'greenwashing' strategies) by the affected organizations.

To systematize the different forms of complexity that may arise in a field, Raynard (2016) proposes an analytical framework emphasizing three critical factors: (1) "the extent to which the prescriptive demands of logics are incompatible (incompatibility), (2) whether there is a widely accepted prioritization of logics within the field (prioritization), and (3) the degree to which the jurisdictions of the logics overlap (jurisdictional overlap)" (Raynard, 2016, 315). (In)compatibility of logics addresses the question whether the normative foundations of two logics are compatible or not (Greenwood et al., 2011). For example, logics adhering to a science versus religion rationality are often hard to reconcile, while the sector logic of the market and corporation are rather compatible. Two logics are often not inherently incompatible at all levels, but rather have the potential to "peacefully coexist, compete, supersede each other, or settle upon a temporary truce" (Meyer and Höllerer, 2010, 1251). The prioritization of logics sets precedence for which logic is treated with priority when actors in a field experience incompatibility between the demands of multiple logics. If priorities are clearly set, competing logics may co-exist without creating conflicts or frictions. Jurisdictional overlap, finally, occurs when "prescriptive demands of logics target the same jurisdictional spaces – be they industries, professions, organizations, or practices" (Raynard, 2016, 8). Here, academia provides an illustrative example, as it is confronted with the incompatible logics of science, the market, and the state, which all overlap in the same jurisdiction - universities or research institutes (ibid). In some sectors, this overlap can be reduced through spatial segregation (e.g. the financial industries in Boston and New York following distinct field logics (Raynard, 2016)), in other cases by creating organizational sub-divisions, like technology transfer offices in universities (Greenwood et al., 2011).

The relationship between compatibility, prioritization and jurisdictional overlap determines what sort of complexity exists in a

[1] And others have done this much more eloquently, see e.g. Fuenfschilling (2019).

field how organizations may best react to it. Raynard (2016) introduced four types of complexity based on various combinations of these three factors: segregated, volatile, restrained, and aligned complexity (Fig. 1). First, multiple logics might be incompatible and competing for priority, but without jurisdictional overlap (segregated complexity). In that case, logics compete 'at a distance'. Restrained complexity represents competing logics that overlap in the same jurisdiction with incompatible demands, yet with a clear prioritization, which makes the dominant logic supersede any competing demands. Aligned complexity represents compatible logics with jurisdictional overlap and an unclear prioritization. In this case, several logics may co-exist in the same jurisdiction, yet their inherent compatibility will reduce the potential for conflicts and contestation. Finally, volatile complexity denotes the most complex scenario, in which incompatible logics are at odds with each other in the same jurisdiction and without clear prioritization.

Organizations may respond to and navigate these different forms of complexity with adapted strategies (Raynard, 2016; Jancsary et al., 2017). In the case of segregated complexity, they may respond by creating structurally compartmentalized organizational units (ibid.). In the case of restrained complexity, organizations typically implicitly resist the dominant logic with de-coupling strategies (e.g. affirming a logic while still diverting from it in concrete actions) (Greenwood et al., 2011). In the case of aligned complexity, they can in turn adopt 'blended' hybrid structures, which accommodate different demands and try to profit from their compatibilities (Raynard, 2016). Overall, this line of reasoning has spurred a wave of follow up studies in organization studies, which has however not yet been taken up widely in transition studies.

One reason for this lack of integration is that (as outlined in Section 2.1) the epistemology and analytical foci of organizational institutionalism and transition studies diverge to some degree. Concepts like institutional complexity can thus not be transposed between these literatures one-to-one but provide promising boundary objects for more integrative theorizing (Fuenfschilling, 2019). In the next section, we will thus bridge between both lines of thinking when developing a dynamic phase model on how complexity is built up in transition trajectories and how organizational and system-level agency may help to navigate and settle different forms of complexity in regime change processes.

2.3. Analytical framework: toward a phase model of the evolution of institutional complexity in socio-technical transitions

Institutional complexity poses a key challenge to the actors involved in ongoing transition trajectories. Periods with increased institutional complexity subject a sector to power battles, planning insecurities and in some cases even increased costs or temporarily lowered quality of service provision. These perturbations may significantly reduce the legitimacy of emerging innovations, slow down the transformation of incumbent regime structures or in the worst case even bring the transition trajectory to a halt. From a transitions perspective, a key question then presents itself: How can actors in a socio-technical system successfully navigate prolonged periods of

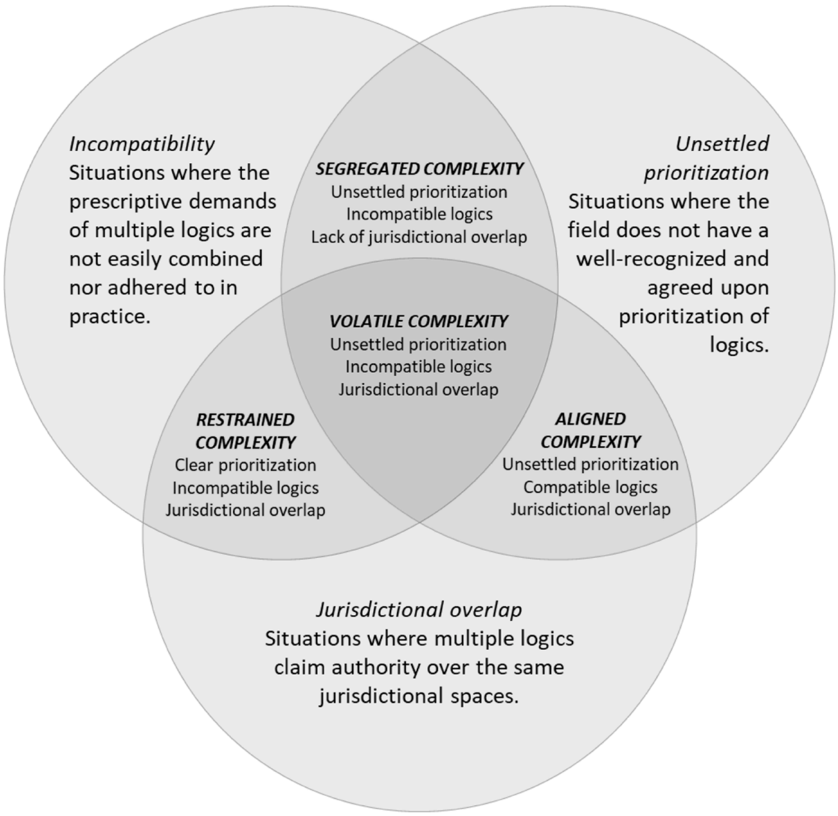

Fig. 1. Analytical model of the components and configurations of institutional complexity (reproduced with permission from Raynard 2016).

institutional complexity and pro-actively clarify the prioritization, reduce jurisdictional overlaps, and/or overcome the incompatibility between incumbent and newly emerging field logics during a transition process?

To characterize potential strategies for navigating institutional complexity in a transition in more detail, we propose a dynamic phase model of the build-up, contestation, and settlement of institutional complexity, which bridges between insights from transition studies and organizational institutionalism (Johnson et al., 2006; Suchman, 1995; Markard et al., 2016; Binz et al., 2016a). Transition studies have traditionally distinguished four phases in transition processes (Geels et al., 2017; Geels, 2005). In a first phase, experiments with transformative innovation emerge in small, protected spaces, based on fragile networks of innovators that push for radical design alternatives with low overall functionality. In a second phase, the innovation enters first market niches, which provide opportunities for further learning-by-doing, technology development and the formation of a dominant design. In a third phase, the innovation breaks out of niche contexts, starts to challenge the regime more directly and creates various frictions with well-established technologies and ways of doing things in a sector. In the last phase, the old regime is transformed by the new solution, leading to far-reaching reconfigurations of core infrastructures, policies, user preferences, industries, etc.

The institutional change processes implied in this generic phase model can be complemented with recent work in organizational institutionalism (Johnson et al., 2006) and the literature on technology legitimation (Markard et al., 2016; Binz et al., 2016a). This literature conceptualizes the relevant (de-)institutionalization processes to occur through four phases that follow each other in a cumulative, yet non-deterministic pattern: (1) a *preformation* phase, denoting the structural preconditions before a transition occurs. (2) A *local innovation and validation* phase where new socio-technical configurations emerge, and an alternative guiding field logic is constructed. (3) *Diffusion* of the new configuration, where uptake becomes more widespread and active contestation between the incumbent regime logic and alternative (niche) logic(s) emerges, requiring active mitigation of institutional complexity by key stakeholders in the system. (4) *General validation*, in which a new field-level settlement is reached, and the new socio-technical configuration and its defining logic(s) become taken-for-granted. We summarize these four phases in the following section and in Fig. 2 below.

In the first phase (*preformation*), the field is structured by a historically grown, deeply institutionalized, settlement (i.e., socio-technical regime). The specific features of this settlement influences – yet does not predetermine – the sort of transition trajectory that is most likely to materialize. We roughly distinguish between three generic structural preconditions: a monolithic regime (with one coherent, dominant logic), a polycentric regime (two or more incompatible logics co-existing in a stable field-level settlement), or a fragmented/splintered regime (various competing logics co-existing, without a stable field level settlement) (van Welie et al., 2018).

In the second phase (*local innovation/validation*), a new socio-technical configuration and defining field logic emerge in protected spaces (Kemp et al., 1998; Smith and Raven, 2012), largely shielded from the selection pressures of the dominant regime. In the early innovation process, emerging actor networks align social and technical elements to a new socio-technical configuration, which either draws on weakly institutionalized technologies and values or imports them from related fields (Fuenfschilling and Truffer, 2016). Due to its emergent status, the new field logic may develop for some time without invoking any targeted response by regime actors. Eventually, the new socio-technical configuration will experience local validation through pilot/demonstration projects or small-scale adoption. In this phase, potential frictions of the new field logic(s) with the established regime logic gains visibility, calling attention to the type of institutional complexity that may arise in a transition.

In a third phase (*diffusion*), the alternative socio-technical configuration and its defining field logic increasingly gain traction, directly challenging taken-for-granted beliefs in the socio-technical system. With incumbents' position in direct proximity to new guiding rationalities, institutional complexity is likely to become a key feature within the transition trajectory. Active contestation, power battles and experiments with new field-level settlements will quickly follow each other in this phase. The socio-technical system structurally transforms with new actors entering, regime incumbents adjusting their roles, and new values, technologies and organizational forms being institutionalized, while old ones are getting de-institutionalized. In this phase, collective action for mitigating institutional complexity is arguably of crucial importance.

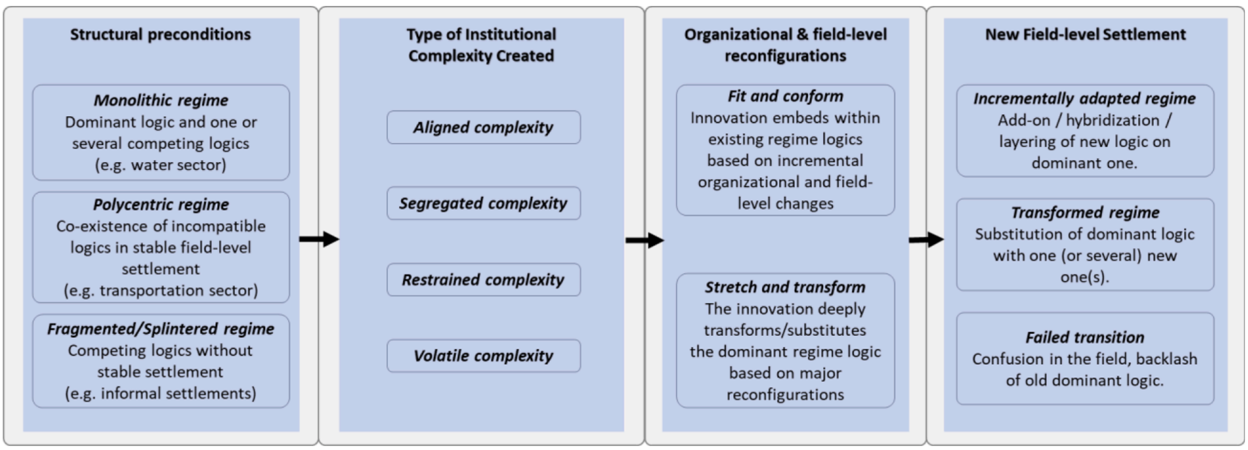

Fig. 2. Generic transition trajectories and sequences of institutional complexity.

Finally, as demands and priorities are clarified, jurisdictional overlap is reduced, and/or a new hierarchy of competing logics is defined, the socio-technical system transitions into the *general validation* phase, settling into a new, stable socio-technical configuration, taking on regime-like properties in a structurally transformed institutional arrangement. In many cases, the new settlement will not be a complete departure from prior situations, but rather "field-level compromises between multiple logics that are crystallized into institutionalized organizational forms […] that permit the co-existence of organizational principles and practices cohering to different logics" (Schildt and Perkmann, 2017, 140). Another potential outcome in this phase is that the transition fails, and the socio-technical system reverts to its prior settlement without any fundamental structural changes.

As outlined in Fig. 2, we distinguish between three structural preconditions, the four types of institutional complexity by Raynard (2016), two types of organizational and field-level responses and three types of field-level settlement. Based on this framework, various ideal-type trajectories for the build-up and settlement of institutional complexity in transitions can be derived.

First, a field might move from a monolithic regime structure to aligned complexity (compatible logics) to an incrementally adapted regime. In this arguably least disruptive trajectory, the field is moving from a relatively stable initial socio-technical configuration to a new one in an incremental process of add-on and layering of the new configuration and its key field logics, which are largely compatible with the existing regime (Smith and Raven, 2012). As mentioned above, an illustrative case of such a 'fit and conform' trajectory is presented in the transition from cesspools to sewers in the Netherlands (Geels and Schot, 2007).

Second, a sector might move from a monolithic or polycentric regime to segregated or restrained complexity *(incompatible logics)* to a structurally transformed regime. This second case exemplifies the 'classic' transition trajectory often emphasized in MLP-based studies, in which one deeply institutionalized socio-technical configuration is substituted by another one in a long-term 'stretch and transform' trajectory (Smith and Raven, 2012). In this case, the respective actor networks, technologies, and institutional structures are deeply reconfigured with incumbents losing their dominant position and newcomers taking on a more central role in the field. Again, the emblematic examples of this type of trajectory is the transition from fossil to renewable energy in Germany and other European countries (Geels et al., 2016; Kungl and Geels, 2018).

Third, moves from all three structural pre-condition to volatile complexity to a deeply transformed regime are also conceivable. In this most disruptive transition trajectory, the field enters a phase with maximal institutional complexity. Since various competing logics overlap and are in conflict with each other with unclear prioritization, the field will enter a phase of turmoil (Geels et al., 2016). Outcomes are either a deeply transformed socio-technical regime with radically novel actor types and field logics, while the incumbents are completely pushed out, or a failed transition and backlash of the old settlement. Instances of this trajectory can arguably be seen in recent case studies analyzing the ascent of platform economy firms like Uber or Lyft in urban transportation (Koen, 2017; Pelzer et al., 2019).

Finally, it is important to note that this framework is not deterministic and transition trajectories will not necessarily involve only one type of institutional complexity that is then gradually settled. A field might as well first move into one type of complexity, which is then partly settled or transformed into another type of complexity in an iterative pattern. In such a trajectory, the involved organizations have to navigate several forms of complexity before reaching a new stable settlement. As we will outline in more detail below, our case study in San Francisco indeed provides an illustrative example of such a sequential transition trajectory.

3. Case study: the emergence of on-site non-potable water reuse in San Francisco

San Francisco's UWM sector was chosen as an adequate case study to illustrate our framework based on a theoretical sampling rationale (Siggelkow, 2007). The city's on-site non-potable reuse program and the UWM sector in particular promised to provide a particularly rich 'critical case' (Flyvbjerg, 2006) for illuminating the role of institutional complexity in a transition process.

San Francisco is a national and international frontrunner for introducing onsite water reuse at a citywide scale. Driven by recurring droughts and a desire to diversify the water portfolio, the local utility has been exploring water reuse since the 1990s (Lohan, 2016). The steep changes in elevation in San Francisco made conventional, centralized distribution costly and pushed the local utility to explore alternative approaches to water recycling in a dedicated 'onsite non-potable water systems' (ONWS) program (SFPUC, 2018b; Weiner 2012). Since 2015, a city ordinance (Article 12C) mandates all new building projects with a floor surface above 250′000 square feet to install and operate an on-site water reuse facility. The city has proactively engaged in policy work and advocacy to encourage implementation of ONWS systems on a broader scale. The recently accelerating adoption of on-site reuse systems in combination with recurring droughts and wildfires presents a 'critical moment' in the transition trajectory, which encourages diverse actors to voice their opinion about this new approach, which in turn enables researchers to more easily observe and identify areas of contestation where institutional logics overlap.

Given the UWM sector's strong and monolithic regime around centralized infrastructures solutions, the diffusion of onsite water reuse promised particularly rich insights into the emergence and settlement of institutional complexity in a transition process (Heiberg et al., 2020; Miörner and Binz, 2021). We here draw on prior work on transitions in UWM that has characterized this sector's field logics in more detail (Fuenfschilling and Truffer, 2014; 2016). The dominant 'hydraulic' logic has historically aligned around large-scale, centralized, end-of-pipe infrastructures and operations based on state actors and the engineering profession. Currently, the most transformative, alternative ('water-sensitive') field logic, revolves around a decentralized infrastructure paradigm and diverging cultural ideas that draw more strongly on a community logic (Gebauer et al., 2017). Actors aligning with this logic ascribe to values like environmental sustainability or the circular economy and ask for an active role for end users, building owners and the community (Hoffmann et al., 2020). A third, 'water market' field logic, revolves around the market and corporation, with economic efficiency serving as core values (Fuenfschilling and Truffer, 2014). Actors enacting this logic see UWM as a conventional commodity market, in which private firms provide services, supply-demand calculations play a key role and end users pay for the full costs of the provided infrastructure services (ibid.). Given the diverse array of priorities and core values between these three logics, transitioning away from the currently dominant 'hydraulic' logic will almost inevitably result in considerable institutional complexity. The case of San Francisco thus promised rich evidence on how the contradictions between these three logics play out and get settled in a transition trajectory (cf. Section 5).

Table 1
Definitions and examples for codes used in data analysis, with key concepts based on Raynard (2016) and Binz et al. (2016a).

Concept	*Codes/Indicators*	*Examples*
Jurisdictional Overlap. Situations where multiple logics claim authority over the same jurisdictional spaces.	**Roles**. Positions held by stakeholders in a field and instances in which they overlap / need to be adapted	*"But it sounds like this Institute is actually focusing on, okay, we want to give out the certification, but we realized that we also need to advocate and support the developers and how they're implementing these projects."*
	Responsibilities. Rights and duties associated with a stakeholder's role and instances in which they overlap / need to be adjusted	*"And even if an owner decides to engage in this [ONWS] endeavor, then you need to go and on behalf of the owner start to work through the regulatory channels… Where those channels aren't well-defined, it's just more risk to us and it is more risk to our owners as to whether or not we can get a project done and how economically you can get it done."*
Prioritization of Logics. Situations where the field does not have a well-recognized and agreed upon prioritization of logics.	**Influence.** Stakeholders and values that are described as being dominant in key decision-making processes.	*"We can make things happen really quick here in a way that other people can't. Because it's all about our relationships, you know…"*
	Priorities. Values that are held as most important to a stakeholder in a decision process.	*"From the perspective of [real estate] developers, there is an attitude of, 'what does it take to comply [with the ONWS mandate]? How can I do that for the least cost and how do I […] get it built?'"*
Logic Incompatibility. Situations where the prescriptive demands of multiple logics are not easily combined nor adhered to in practice.	**Prescriptive demands**. Specific requirements implied by a field logic and actions taken to reconcile competing demands.	*"If we had a national non-potable water rule, it would eliminate most of the hurdles - but we don't. And so we always were squeezed into the wastewater rules up until now under the Clean Water Act."*
	Demand specificity. Level of detail for the prescriptive demands of an institutional logic. A low demand specificity would be a general statement (e.g. 'protect human health'). A high demand specificity would have detailed requirements (e.g. 'water quality standards for ONWS systems').	*"But the new part of [Article 12C] was also getting the Department of Public Health involved, because they needed to actually also stamp off on it [ONWS projects]. So that was also a learning curve not only for the developers, but also for the city and county. It's like what's actually the easiest pathway to get there where this is an understanding also on their end as to what they're looking for in an engineering report as well."*
Transition Phases. Distinct phases in the adoption and legitimation of a novel socio-technical configuration.	**Preformation**. Structural preconditions in which alternative socio-technical configurations are developing. First gauging of local development potentials.	*"So this was sort of the next frontier, where could we go next to use water more efficiently and to actually develop new water supplies."*
	Local Innovation/Validation. Development of a new socio-technical configuration 'that works'. Experimentation and demonstration in protective spaces, identification of key development barriers.	*"But the new part [of Article 12C] was also getting the Department of Public Health involved, because they needed to actually also stamp off on it."*
	Diffusion. Diffusion of the new configuration and guiding field logic(s) into new market segments and places. Increasing contestation, active (de-) institutionalization, transformation of the incumbent regime settlement.	*"So you have the risk-based framework as proposed by San Francisco. There's conversations about it in Los Angeles. We're working on a project that would involve it in New Hampshire. But it's just starting to get going. And then the state of California though, is going to be developing risk-based framework for non-potable reuse…"*
Stakeholder Types	Accreditation organization	*LEED, Living Building Challenge*
	Building tenant	*Private companies who lease space in buildings*
	City government	*Various city departments,* e.g. *public health, building inspections, land use planning*
	Community group	*Activist groups, NGOs, the general public*
	Contractor	*Plumbing contractors, electricians*
	Design + engineering firm	*Architecture firms, engineers, design consultants*
	Developer + building owner	*Real estate and development companies who own the buildings*
	Operator firm	*Companies contracted to operate and maintain ONWS*
	Professional organization	*National Blue Ribbon Commission for On-site Non-potable Water Systems; US Water Alliance*
	State government	*Various state-level regulators,* e.g. *CA Water Board*
	Technology supplier + vendor	*Companies who sell ONWS systems to be installed in a project*
	Utility	*Local water and wastewater utility companies*

4. Data and methods

4.1. Data collection

To reconstruct this transition process in detail, twenty-five semi-structured interviews and a workshop were organized with key stakeholders in San Francisco and the surrounding Bay Area between January and February 2020. Detailed information on interviewees is provided in the supporting information (table A.1). Interview information was triangulated with scientific literature, media reports, and gray literature and initial findings were validated with interviewees and other related stakeholders during a follow-up (online) workshop in May 2021. Interviews lasted between 30 and 90 min., were audio recorded, and followed a semi-structured format, asking participants about their role with respect to onsite water reuse, projects that they were involved with, and situations where conflicting worldviews and/or demands emerged in the implementation of the ONWS program. Interviewees comprise a comprehensive sample of the key stakeholder types in San Francisco and the surrounding region, including decision-makers in private companies, government agencies, non-profit organizations, and academia, to name a few (table A.1). Audio recordings were transcribed verbatim and analyzed using qualitative content analysis, specifically thematic coding at three levels of analysis, as outlined below and shown in Table 1.

4.2. Data analysis

Data analysis took place in three steps. While previous research has ascribed field logics to various types of stakeholder categories ex ante, we took a more inductive approach here for analyzing what field logics were enacted by which actors, how this evolved over time, and framed our results against previous categorization (Fuenfschilling and Truffer, 2014). In some cases (like the local utility), we observed that the 'hydraulic' and 'water-sensitive' logics were enacted in parallel in most phases of development.

In a second step, we identified key events, projects or timeframes, where overlaps between field logics were reported by our interviewees. This was done by coding and analyzing interview transcripts using Dedoose, a software for qualitative content analysis (SCRC, 2016). Instances of jurisdictional overlap were identified through excerpts that mentioned instances where the roles and responsibilities held by different actors were reportedly overlapping, unclear or contested. The prioritization of logics was assessed through excerpts that indicated differences in the amount of influence held by various actor types, as well as excerpts that indicated which/whose priorities were dominant in key decision processes. Instances of (in-)compatibility between logics were in turn assessed through excerpts indicating that different actor's prescriptive demands overlapped with one another and the ways in which actors looked to meet or align these demands (Table 1). Within the interview transcripts, applicable excerpts were assigned with at least one code from the three categories, including characteristics of institutional complexity, stakeholder type, and transition phase (see Table 1 for these categories).

To give an illustrative example of the coding process, we reference the statement below expressed by a sustainability consultant regarding the initial city ordinance (Article 12C) for ONWS in San Francisco:

> "*… And when the City of San Francisco started looking at what were the possibilities of incorporating some sort of water stewardship strategy, then that's when we got involved with the process. So [we] got involved with the local city supervisor to help craft some legislation that the developers would also not completely sneer at, so what were some of the things that the development community was actually looking for. That was kind of the genesis of it, but then helping guide that process all the way through to the point now.*"

In this example, a sustainability consultant acts as a key intermediary for ONWS, helping coordinate between the utilities' interests and the real estate developers' interests in drafting legislation. As such, one would apply the following codes: *Role* - key intermediary; *Responsibilities* - drafting legislation; *Influence* - yes; *Priority* - legitimizing ONWS; *Stakeholder* - Sustainability consultant; *Phase* – Preformation.

The final step of analysis then comprised conceptually aggregating, mapping and cross comparing the institutional complexity observed in and across different transition phases. This longitudinal analysis helped tease out a narrative of what type of complexity had existed in which transition phase and to reconstruct in detail how actors collectively worked on the newly emerging and pre-existing socio-technical configurations to settle incompatible institutional demands. For example, using the excerpt above, we observed that sustainability consultants linked and already tried to reconcile some conflicting demands of the 'water-sensitive' and 'water market' logics in the *preformation* phase.

5. Results

In the remaining sections, we will present the transition trajectory for San Francisco's adoption of ONWS, providing contextual background on how stakeholders engaged with one another, major drivers of change in each phase, and describing the type of institutional complexity that was present throughout the transition phases covered in our phase model.

5.1. Identifying phases of development in the transition to on-site water reuse systems in San Francisco

Based on the information provided in the interviews, secondary literature and stakeholder feedback, we distinguish between three phases in the ONWS transition trajectory in San Francisco. Interviewees generally framed the adoption of ONWS through major policy changes, such as the city ordinance for ONWS (Article 12C), as shown below in Fig. 3. Institutional shifts took place over a 20-year period and have so far progressed through the *preformation, local innovation/validation,* and *diffusion* phases. *General validation* has not yet been reached, as some uncertainty still exist on what the final institutional settlement and socio-technical configuration will look like.

The *preformation* phase began in the 1990s, when the idea of (conventional, centralized) water reuse was first embraced by the San Francisco city council. A local ordinance (Article 22) was passed to support the uptake of centralized water reuse in certain parts of San Francisco, requiring new developments to integrate dual piping, which allowed buildings to use recycled water for non-potable uses like toilet flushing (San Francisco Board of Supervisors, 1991). This change in regulation provided some opportunity for later developments, as it established the general idea of water reuse in the city (Interview 17, 23). *Local innovation/validation* with onsite water reuse started in the mid- 2000s with the development of a first pilot project at the local water utility (the San Francisco Public Utility Commission, SFPUC) to determine the feasibility of on-site water reuse and to collect additional information about most effective technologies. The 'Living Machine' was installed at SFPUC headquarters in 2006 in partnership with local engineering firms and the system was made accessible to the public for raising awareness about the potential of onsite water recycling (SFPUC, 2006). This initial success inspired local real estate developers to implement ONWS systems in new building projects, which in turn triggered the adoption of a local ordinance (Article 12C) in 2013, requiring all new property developments of a certain size to submit water balance calculations, which included potential water savings from installing ONWS (Weiner, 2012). This was to prompt developers to discover the benefits of on-site water reuse in conjunction with a financial incentive program for installation of ONWS (Interview 2, 6, 17, 22). With this initially voluntary program, other supplementary state regulations (like the Californian plumbing code and some building standards) were amended to create space for ONWS implementation (Fig. 3). In 2015, in response to an extreme drought event in the state of California, an amended version of Article 12C became mandatory, thus forcing all new developments over 250,000 sq. ft. to install an ONWS system.

This regulative milestone pushed the transition trajectory into the *diffusion* phase. ONWS now spread quickly in various new buildings in the city center, as well as other cities in surrounding areas. In particular, developers and large tech companies (Google, Facebook, Microsoft) throughout Silicon Valley now adopted ONWS in some high-profile building projects (Interview 2, 3, 6, 17, 19). The most recent milestone was achieved in 2018, when Senate Bill 966 was passed to help standardize the regulative framework for ONWS adoption across the State of California. During this time, SFPUC employees also worked with utility and public health professionals in other states (e.g. in Colorado, Texas, New York, etc.) to organize the 'National Blue Ribbon Commission for Onsite Non-potable Water Systems,' which aimed at developing tools, resources, and best practices for other cities interested in adopting on-site water system (Lackey et al., 2020). In a next step, we will analyze in detail how institutional complexity built up and settled in the transition trajectory, and how navigating competing institutional demands made the quick diffusion of ONWS possible.

5.2. *Tracing the build-up and settlement of institutional complexity in San Francisco's transition journey*

A total of 377 interview excerpts contained information on the prioritization, compatibility, and/or jurisdictional overlaps of field logics in the transition trajectory in San Francisco. Using these findings and the timeline presented in Fig. 3, we will now explore in

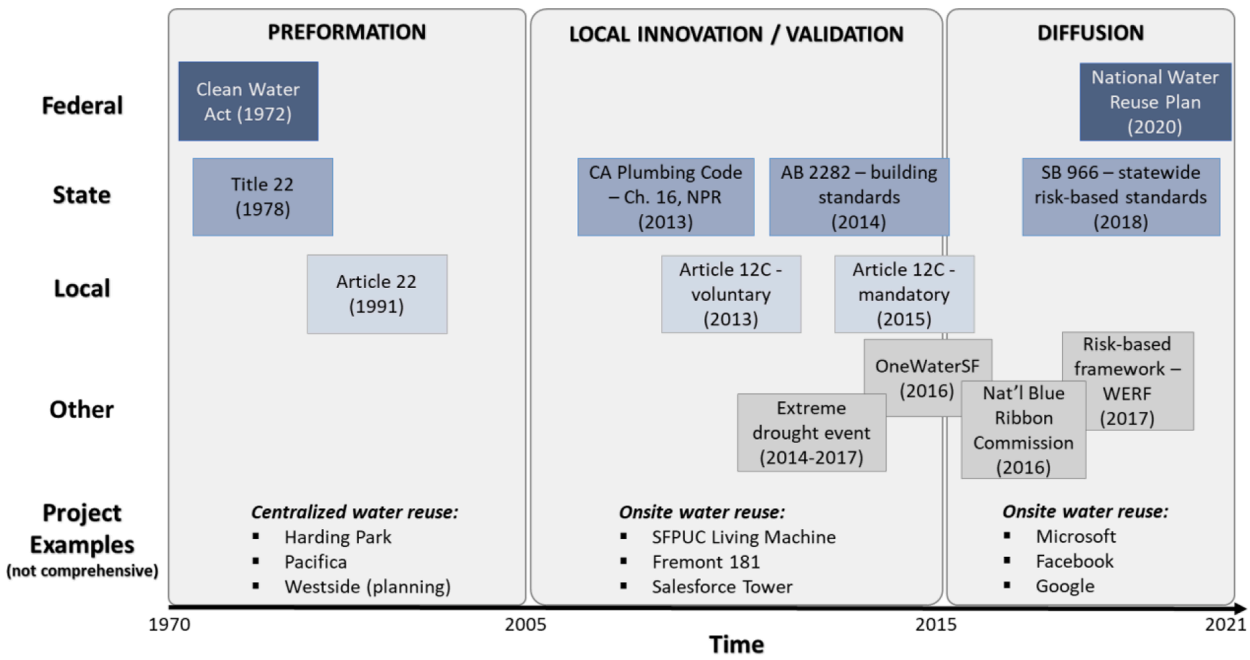

Fig. 3. Timeline of policy changes in San Francisco that help distinguish phases for the transition pathway.

depth how institutional complexity emerged and got settled throughout three transition phases.

5.2.1. Preformation (1970–2005)

San Francisco has historically obtained its potable water from a handful of sources, including the Hetch Hetchy Reservoir and five other reservoirs surrounding the Bay Area (SFPUC, 2019). SFPUC oversees this infrastructure, which has existed for several decades, and which is managed through dams and centralized pipe networks, largely in alignment with a 'hydraulic' logic as described by Fuenfschilling and Truffer, (2014). From the mid-1990s on, city officials and SFPUC recognized an increase in drought events, straining local water resources and triggering a need to diversify the city's water portfolio. Maintaining the security of water supply became a key objective, which was initially approached with a centralized water reuse program (San Francisco Board of Supervisors, 1991). The structural preconditions in the *preformation* phase thus represent a monolithic regime with the utility being responsible for solving water scarcity issues with large-scale centralized infrastructures and a service approach that was strongly rooted in the engineering profession. The subsequent discussion of alternative on-site water systems largely emerged from this backdrop. Water reuse at the building and district scale was first considered in the mid- 2000s, when SFPUC was approached by certain developers looking to install ONWS as part of their sustainability certification for large projects (Interview 17, 23).

Treating and reusing water directly inside buildings represented a radical departure from the existing regime both technologically and in terms of the guiding institutional logic. Technology-wise, ONWS show much more diversity, as each treatment system has to be adapted to a building's particular water supply and demand conditions. The regulation, management, and monitoring of ONWS systems, in turn, ask for a more polycentric governance arrangement, in which the utility shares responsibilities with private firms, regulators and building owners in managing a fleet of small treatment plants that are distributed in the city. Environmental sustainability, circular economy thinking and a 'community' logic were often put center stage by the proponents of ONWS projects, thus perfectly reflecting a 'water-sensitive' logic, including its characteristic frictions with the 'hydraulic' field logic (Fuenfschilling and Truffer, 2014).

First considerations of on-site reuse happened in a small group of key stakeholders (i.e., SFPUC, city government, regulators like the departments of public health, building inspections, etc.) with relatively aligned priorities, which however realized early on that they had to adapt and redefine their jurisdictional authorities for the adoption of ONWS. Emphasis was placed on the need for a 'champion' to lead the charge for ONWS systems with the driver being to offset potable water demand (Interview 3, 11, 17, 22, 23) and thereby increasing the resiliency of the city's water portfolio. As a utility representative put it:

> *"This was sort of the next frontier, where could we go next to use water more efficiently and to actually develop new water supplies. So it was just an idea […] seeing […] that new buildings wanted to install onsite water treatment systems to obtain LEED platinum [certification] from a green building and a sustainable building perspective." (Utility)*

The early ONWS pioneers had diverging priorities, yet complementary demands – e.g., obtaining sustainability certification versus diversifying the city's water portfolio. Both converged in an underlying priority of achieving sustainable outcomes for the city (Interview 1, 3, 13, 17, 22, 23). This common aim motivated real estate developers, regulators, and the utility to collaborate in exploring the viability of ONWS:

> *"So [we] got involved with the local city supervisor to help craft some legislation that the [real estate] developers would also not completely sneer at; what were some of the things that the development community was actually looking for? That was kind of the genesis of it, but then helping guide that process all the way through to now." (Sustainability Consultant)*

Intermediary actors, such as sustainability consultants, understood the need to address the overlapping institutional demands that could arise when diffusing ONWS systems early on. They initially took steps to better understand real estate developer's guiding ('water market') logic in order to present ONWS in a way that appealed to their prescriptive demands (Interview 13, 17). The local utility also engaged in efforts early on to anticipate where institutional frictions might pop up, particularly in relation to the pre-existing regime structures around centralized water infrastructures. The utility decided early on to frame ONWS as a hybrid addition to existing infrastructure, rather than looking to circumvent or replace centralized infrastructure networks:

> *"Well I mean in San Francisco, we've taken an approach of decentralized and centralized, so it's not one or the other, and so we don't see them as competition." (Utility)*

Overall, as expected by our framework, important groundwork for a later transition trajectory was laid in this phase, yet without creating significant institutional complexity (yet).

5.2.2. Local innovation/validation (2005–2015)

From the mid-2000s on, the conversation shifted from whether ONWS was a feasible and a good fit for San Francisco, to implementing first pilot and demonstration projects, moving the transition trajectory from *preformation* to the *local innovation/validation* phase. As expected by our framework, this shift brought institutional complexity more to the fore (Fig. 2). To accommodate specific projects looking to implement ONWS, a draft of a voluntary city ordinance (Article 12C) had to be created by the utility, regulators, and several involved city departments, which laid out a first regulatory framework for permitting such projects. Through this ordinance and when implementing first systems, multiple stakeholders suddenly had to coordinate their activities, each with their own set of priorities and demands, including 'hydraulic', 'water market' and 'water-sensitive' elements. Design firms and technology suppliers were keen on designing systems that met their customer's demands in being fully functional at the building scale and consistently meeting treatment standards, while keeping costs at a minimum ('water market' logic) (Interview 17, 22). The regulators in turn put strong emphasis on guaranteeing public health based on regulations already used in centralized water systems ('hydraulic' logic), while sustainability consultants and the utility tried to optimize the amount of water recycled inside buildings in a sustainability rationale ('water-sensitive' logic) (Interview 3, 22). Initially, it remained somewhat unclear which of these logics took precedence, how compatible their prescriptive demands were, and who held jurisdictional responsibilities for what part of the ONWS implementation process; Volatile complexity was thus created in the *local innovation/validation* phase, that subsequently had to be settled through collective institutional work and rearranging key structural elements of the socio-technical system.

In this phase, a spike in activity can be observed with local actors trying to sort out the jurisdictional overlaps, unclear prioritization, and incompatibilities between the three logics present in the ONWS space. Actors promoting a 'water market' logic were looking for ways to achieve return on investment while meeting sustainability and public health goals (Interview 2–4, 6, 12, 17, 21, 22). Regulators enacting the hydraulic logic adapted internal processes to regulate ONWS systems along with the building and permitting departments at the city level (Interview 14, 23). Roles and responsibilities were being redefined and reconfigured; for example, the utility was in constant negotiations with all involved actors in order to further tease out and streamline the permitting pathway, while developers provided documentation to justify what pricing model would be appropriate for their project in lieu of established guidelines (Interview 22, 25).

In the mid-2010s, during another extreme drought in the state, San Francisco started to work toward amending the city ordinance for ONWS from voluntary to a mandatory requirement, meaning that all new developments over 250,000 sq. ft. would be required to install ONWS. It became quickly apparent that one potential arena for sorting out complexity was further adapting and streamlining the regulatory framework for ONWS systems. The existing framework was originally designed for regulating water reuse at a centralized scale (State Water Resources Control Board, 1978). The prescriptive demands inherited from the 'hydraulic' logic in this framework put excessive financial burdens on developers looking to meet public health requirements, in particular because of the high costs of the requested water quality monitoring and compliance procedures (Rupiper and Loge, 2019). The local utility, technology firms, academic experts and consultants thus formed an expert panel with the aim to develop a new 'risk-based framework' for regulating ONWS systems (Interview 4, 11). This panel had to actively mitigate frictions between proponents of the 'hydraulic', 'water market' and 'water-sensitive' logic, by defining a framework that would guarantee public health, while keeping costs for quality monitoring and testing procedures to a minimum (Sharvelle et al., 2017). Interviews suggested that actors following a 'hydraulic' logic (regulators) were especially risk-averse and showed a slower pace of adoption for the new regulations than actors representing a 'water market' or 'water-sensitive' logic that strongly advocated for minimizing barriers to adoption (Interview 3, 11, 17, 18, 20–23, 25):

> *"Certainly, if you're going to bring [ONWS] into smaller projects or more rural projects and you want to be more cost effective, you've got to make it [regulations] more efficient […]. And I think the risk-based framework does that to a large degree. We don't want to stymie innovation by having regulations that are too prescriptive." (Operating Firm)*

Key intermediaries within the utility, regulatory agencies and design firms were instrumental in mitigating risk aversion in this process by working at the interface of the three competing logics and continuously translating concepts between the relevant stakeholder groups into verbiage and approaches more easily understood by all sides (Interview 3–7, 9, 12, 17, 18, 21–23).

Overall, at the beginning of the local innovation/validation phase, an initial disruption exists with the introduction of new technology systems (ONWS) and the agglomeration of a diverse set of actors holding a variety of institutional logics around the new configuration. Developing a novel regulative framework is a first step in mitigating the volatile complexity initially induced in the transition, by streamlining different actors' roles and responsibilities in the permitting process. At the end of this phase, volatile complexity still exists, but competing logics have been somewhat prioritized and jurisdictional overlap mitigated through the proactive adaptation of pre-existing regime structures, particularly the drafting of a new regulative framework.

5.2.3. Diffusion (2015-)

Based on the organizational and field-level adaptations in the prior phases, San Francisco's ONWS program moved into a *diffusion* phase after 2015, when article 12C became mandatory for new development over 250,000 sq. ft. Regulatory processes for these systems were by now explicitly laid out and the new roles of responsibilities of all involved actors got broadly disseminated through guidance documents published by SFPUC and local sustainability consultants (SFPUC, 2018a; WJW, 2018). In this phase, the State Water Board furthermore delegated permitting responsibility to San Francisco, giving the city strong agency in delineating clear roles between the local health and building departments in the permitting process, thus further minimizing jurisdictional overlaps (Interviews 13, 16, 21). Surrounding cities did not have this same arrangement, which complicated attempts to follow San Francisco's example in adopting ONWS systems:

> *"Not in San Francisco, but in other communities, yes, there are a lot of challenges. […] A lot of people are facing challenges, because some local County health [authorities] having jurisdiction are not sure, or aren't clear, what the plumbing codes allow them to do. […] But in San Francisco, because they have established their ordinance and have goals in regulations, there is a much clearer process." (Utility)*

Actors in San Francisco have accordingly increasingly tried to develop templates for other localities on how to structure their own ONWS programs. In particular, the National Blue Ribbon Commission developed a coalition of experts to develop guidance materials for other US cities looking to adopt similar programs. Some of the guidance documents cover general program management, regulatory frameworks, and the justification for ONWS adoption (NBRC, 2017; US Water Alliance, 2017). They also outline the prioritization of logics around ONWS systems. Similar to the development of risk-based regulation in the *local innovation/validation* phase, State legislation (California SB 966) was adapted and is still currently being operationalized, creating a path for consistent adoption across cities in the state of California.

Another key element in mitigating complexity in this phase was that the local utility, sustainability consultants and some private firms increasingly managed to blend prescriptive demands of the 'hydraulic' and 'water-sensitive' logic into a new narrative on how ONWS could help achieve sustainable water practices, while also protecting public health. Real estate developers, technology suppliers, the utility and sustainability consultants jointly framed outreach documents with an overarching storyline that reconciled environmental sustainability, public health (and to some degree even economic rationales) under one roof (see e.g. WJW WJW, 2018).

A second re-arrangement in the local actor structure proved central in further mitigating institutional complexity: Private firms active in San Francisco over time developed a 'design-build-operate' (DBO) business model, which made the same company responsible for planning and designing, implementing, and then also operating ONWS systems and guaranteeing their compliance with the local regulatory framework. This setup made these companies a key knowledge broker between all stakeholders involved in ONWS implementation and experts in bridging between and reconciling conflicting institutional demands (Interviews 11, 17). Those private firms played a key role in helping to establish a clarified regulatory framework, while also contributing to the above-mentioned narratives that blended key elements from competing logics. At the same time, through the DBO model, more stable income streams were created for these firms, creating an emerging market for environmentally and hygienically sound systems that are adapted to a given building's specific reuse challenges.

Overall, our results imply that San Francisco went from volatile to restrained complexity and eventually even to a partial settlement in the *diffusion* phase. The revision of regulatory frameworks, further clarification of roles and responsibilities, blending of competing logics, as well as the adoption of new business models strongly reduced jurisdictional overlaps and established a clearer prioritization of logics. Protection of public health in a 'hydraulic' logic has remained the key prescriptive demand in the transition process, and proponents of the two alternative logics have skillfully aligned their demands to this guiding rationality. By the end of 2020, ONWS is an established practice in San Francisco and the city is preparing to further expand the validity range of article 12C, despite some remaining challenges with regulating systems, reducing costs for monitoring/compliance management, improving return on investment, and creating updated curricula for the workforce engaged in operation and maintenance. Given San Francisco's expansive experience with reconciling stakeholder groups with competing demands, the ONWS path seems to be poised to further expansion. Outside of San Francisco, mitigation of jurisdictional overlap in turn remains a bigger challenge, but recent adoption of statewide legislation might further mitigate regulatory barriers for ONWS adoption.

6. Discussion

When connecting our results to the analytical framework developed in Fig. 2, the transition trajectory for San Francisco can now be characterized in more detail. The transition started from a monolithic regime, in which the 'hydraulic' logic was dominant. The implementation of ONWS initially introduced volatile complexity, which was first partially settled into restrained complexity and then further mitigated by clarifying jurisdictional roles, developing a new regulative framework and business models, and increasingly blending the 'hydraulic' and 'water-sensitive' logics (Fig. 4). This mitigation process went hand in hand with 'stretch and transform' reconfiguration of the socio-technical system in San Francisco's UWM sector. Key actors like the utility and regulators re-arranged their roles, new actors like DBO firms entered the field and took over a central role, and a hybrid 'water sensitive – water market' logic got increasingly institutionalized. While the diffusion of ONWS systems is still ongoing, the most plausible field-level settlement currently is that the regime is further being hybridized by taking up and accommodating ONWS-related elements of the 'water market' and 'water-sensitive' logics. As outlined in our empirical case study, this transition trajectory depended heavily on several key intermediary actors that were able to navigate complexity by constantly coordinating a diverse set of stakeholders and adapting the relevant storylines.

Connecting the case study in San Francisco back to the three ideal-type transition trajectories laid out at the end of Section 2, allows us to derive generic conceptual propositions that could be further explored in future work. First, our results imply that if competing field logics in a transition process have inherently incompatible features (as in trajectories one and two and as shown in the presented

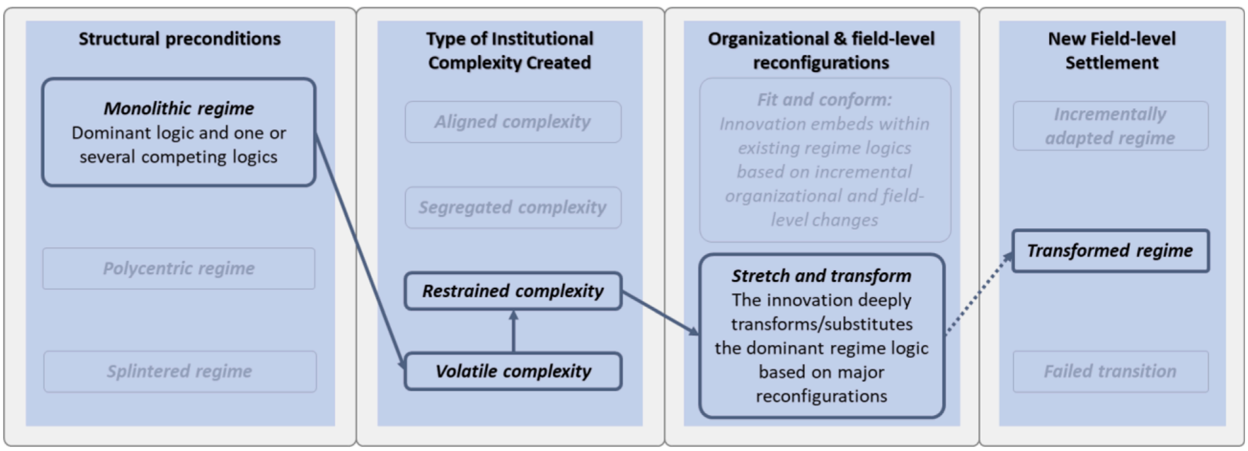

Fig. 4. The transition trajectory in San Francisco's UWM sector.

case study), a deep reconfiguration of the related socio-technical system structure is unavoidable. In these trajectories, incumbents are confronted with incompatible cultural demands, which can be settled not only with internal re-organization, but which also depend on a re-structuring of field-level arrangements. In San Francisco, institutional complexity could indeed not be mitigated through organizational responses alone. Rather, change inside organizations was complemented with reconfiguration of the incumbent socio-technical system configuration. The introduction and diffusion of ONWS pushed regime actors to reorient themselves and to pull new actor types (private firms, real estate developers, sustainability consultants) into the field. In parallel, regulative institutions had to be changed inside the city and even at a state level and key actor's jurisdictional roles had to be re-defined. If volatile complexity is created (as in trajectory three and our case study), the actors will furthermore have to first sort out either prioritization, compatibility, or jurisdictional overlap issues, before a more manageable situation is achieved that can then lead to field-level settlement and a new socio-technical configuration 'that works'.

The relevant mechanisms can be expected to be fundamentally different from the above situation in trajectory one. If the field logics of existing and alternative socio-technical configurations are compatible, the socio-technical system may transform in more subtle and incremental ways, thus requiring fundamentally different responses by the affected organizations. In this trajectory, incumbent actors may 'survive' a transition with decoupling strategies in which they affirm the new logic while still diverting from it or by hybridizing their internal structures in a rather incremental way. The old actor configuration would thus persist, yet with internally transformed organizational features after the transition. While we could not illustrate this trajectory in the present paper, we strongly encourage future empirical studies that explore relevant cases to explore this proposition in more depth.

Another key proposition emerging from our study is that actors pushing for alternative socio-technical configurations will need to either be located in - or quickly reach - a structurally superior network position to be able to navigate and withstand long periods of institutional complexity. Arguably, not all actor types can be in such a position. The literature generally hypothesizes that change agents will either be incumbents with strong social capital and a strategic long-term vision, intermediaries, or 'generalized others' who can act from a position of seeming independence (Battilana et al., 2009; a; Meyer and Jepperson, 2000; Fuenfschilling, 2019). In San Francisco's case study, key change agents were a blend of highly visible champions (the local utility) as well as intermediaries (sustainability consultants) and newcomers to the field (technology suppliers). The local utility played a particularly important role as it diverted from its traditional role in water service provision, to become a system intermediary that clarified roles and jurisdictions and established a clear prioritization of logics for other stakeholders implementing ONWS. Multiple overlaps with recent studies exploring the role of intermediaries in transition processes appear relevant here (Kivimaa et al., 2019, 2020).

Overall, we see a very high potential in further developing our conceptual approach at the interface of transition studies and organizational institutionalism. The institutional complexities perspective outlined above directs analytical attention to the manifold institutional inconsistencies and contestations that may jeopardize transitions trajectories in the long-term, but which are hard to fully assess with transition studies' conventional conceptual approaches like the multi-level perspective or technological innovation systems. In particular, this approach enables novel perspectives on how the organizations involved in a regime transformation process may best react to competing demands and navigate long periods of institutional contestation and insecurity. Last but not least, our approach is well adapted to understand the key transition challenges in sectors like energy or transport that have reached a new (*diffusion*) phase globally. Key challenges in these contexts do not revolve around protecting, nurturing and empowering radical innovation in niches anymore, but increasingly focus on navigating and reconciling incompatible prescriptive demands of declining regimes and newly emerging (transformative) proto-regimes.

7. Conclusions

This paper aimed at developing and illustrating an analytical framework for assessing the evolution of institutional complexity in socio-technical transition trajectories (Fig. 2). By linking transition studies with organizational institutionalism, we delineated a phase model of how different types of institutional complexity build up in a transition and get settled by ideal-type sequences of organizational and field-level responses. This approach contributes to transition studies in providing novel explanations on why actors may in some cases successfully navigate institutional complexity and push a transition process forward, while failing in others. Our phase model offers diverse inroads for further theorizing the generic success and failure conditions of ideal-type transition trajectories. Last but not least, the paper also hints at potential future contributions to organization studies, specifying in more detail, how complexity is mediated not only by organizational reconfigurations, but also by adapting field-level structures through collective system-building and institutional work activities.

Our empirical assessment of a structural transformation in the urban water sector of San Francisco uncovered a transition trajectory which evolved through multiple phases of (initially volatile and then restrained) institutional complexity (Fig. 4) and in which complexity was successfully mitigated. Mitigation strategies comprised both organizational changes within involved actors (like the utility or private firms), as well as reconfigurations in the wider socio-technical system (i.e., changing the actor configuration, developing new regulations, constructing blended logics). Key stakeholders like the local utility and regulators, but also more peripheral actors (e.g., design firms, sustainability consultants, technology suppliers) took on key coordinating roles in the system and showed remarkable skills in navigating competing institutional demands and stabilizing an initially turbulent transition trajectory. Other places going through similar transition trajectories will need to ensure that one or several actors are in a central network position and endowed with enough resources to sustain long phases of institutional contestation as complexity is mitigated. Supportive policies or subsidy schemes would accordingly have to be set up with a timeframe that is long enough to allow actors to maneuver extended periods of institutional complexity as roles and demands are prioritized and clarified.

It is understood that our study features areas needing more focused research. First, we could only illustrate one among four ideal-type transition trajectories in sufficient detail. Future studies should explore other contexts that allow for comparison across the other trajectories outlined in the conceptual part and discussion. Second, the institutional complexity framework by Raynard, which was used here quite extensively, does not reflect all types of complexity that are potentially conceivable in a field. Future work could further characterize combinations of characteristics seen in different types of field-level settlements. Furthermore, case studies based on qualitative expert interviews are subject to well-documented limitations; our analysis may not adequately capture every expression from interview participants or taken-for-granted cognitive structures. We accounted for this by avoiding the relegation of specific stakeholders to only one logic and by extensively triangulating interview data with secondary sources and validating findings with over 20 stakeholders in a follow-up workshop. Finally, this paper could only explore one particular conceptual interface between organizational institutionalism and transition studies. We acknowledge that a much broader research agenda exists at this theoretical interface, so we anticipate this study being used a building block for deeper exploration of conceptual overlaps between both fields.

Declaration of Competing Interest

No declaration of interest to report.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2021.09.003.

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