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Politics of complexity: Conceptualizing agency, power and powering in the transitional dynamics of complex adaptive systems

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ABSTRACT

This paper seeks to bridge the gap between socio-material and complex adaptive systems approaches in conceptualizing the politics of transformation. Our contribution in particular is a further clarification of the relational nature of power, and the role of non-humans in transitional dynamics of complex adaptive systems. We explore and operationalize the role of non-humans and relationality in (1) agency and (2) power, and the implications thereof for processes of (3) powering, through which power relations shape resource distributions and associated macro-scale dynamics. We consider agency as an embedded and temporal capacity for reorientation. This also entails attributing agency to entangled networks of humans and non-humans. Such a capacitive conception of agency follows from our understanding that agents and structures consist of comparable ontological building blocks, both being (networks of) components in complex adaptive systems. Power we understand as a productive and relational phenomenon that emerges from interactions between components and that structures their agency. We argue that such a ‘force-field’ understanding of power enables the observation of different types of power relations. Finally, we consider six different mechanisms through which power relations can result in a (re)distribution of resources and with that, contribute to self-reproducing or transformative systemic dynamics. With this conceptualization, we hope to advance the debate on the different facets of the politics of transformation, and to help further urgently needed transitions towards a more sustainable future.

1. Introduction

Large-scale societal sustainability transformations in fields like energy, water, food, healthcare and mobility are needed to meet some of the most pressing global challenges. Useful to that end are scholars’ efforts at conceptualizing and understanding such transitions as non-linear processes of structural change (Geels & Schot, 2007; Rotmans & Loorbach, 2010). In an overview, Köhler et al. (2019: 19, drawing on Grin, Rotmans, & Schot, 2010) indicate that the field of transition studies focuses on “*problems of path-dependence and lock-in, and*

development patterns of self-organization, emergence and co-evolution.” To understand the stability of locked-in constellations, and to conceptualize the power at play in sustaining and changing these are among the major themes in the field’s current debates (Avelino & Rotmans, 2009; Avelino, Grin, Pel, & Jhagroe, 2016; De Haan & Rotmans, 2018; Geels, 2014; Grin, 2006; 2010; Hoffman & Loeber, 2016; Köhler et al., 2019; Markard, Raven, & Truffer, 2012; Smith, Stirling, & Berkhout, 2005). Yet, despite the many valuable conceptualizations of politics, power and agency in transitions, there is still a need to “*compare and integrate the diversity of studies on politics and power and to reflect what the findings so*

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far imply for transition theory” (Köhler et al., 2019: 8).

Interestingly, two main branches in the field conceptualize and relate agency and power quite differently.¹ A first is the socio-technical approach, which emerged from Science and Technology Studies (STS) and gave rise to the widely used multi-level perspective (MLP, see e.g. Geels, 2002; Geels & Schot, 2007; 2010).² Authors adopting this approach increasingly emphasize the power-laden role of materiality in system dynamics. Svensson and Nikoleris (2018) for example problematize the relation between (human) agency and (material) structure, arguing that undervaluing the causal influence of the material is problematic, since it can “make it difficult to understand why some systems undergo change slower than others” (ibid: 472). This view builds on classical STS insights regarding material forms of power, pointing out the power-laden role of (non-human) *actants*. More generally, it has been noted that understanding the ‘political’ as exclusively human/social is problematic and that developing an analytic language about the social and material worlds “as inseparable, [and] as constitutively entangled” is a key theoretical challenge (Orlikowski & Scott, 2008: 463). Another prominent understanding in scholarship on socio-material transformations refers to conceptualizing power as embedded in (social) relationships, in contrast to power being the property – or a capacity – of an agent (see e.g. Cooper, 1994; Foucault, 1978; and more recently Ahlborg & Nightingale, 2018).

In contrast, a second main branch within transition studies is the complexity-paradigm, which emerged from integrated assessment and Complex Adaptive Systems (CAS) science. Authors working in this field often sideline the role of materiality and non-humans in current conceptualizations of agency and power. Typically, studies focus on embedding human agency in structural contexts and on the power-laden role of specific categories of transformative actors, as e.g. “leaders of change” (Olsson, Folke, & Hahn, 2004), “front-runners” (Rotmans & Loorbach, 2009), or “topplers” (De Haan & Rotmans, 2018). Such an anthropocentric focus is surprising as the complexity approach to understanding transitions attributes a crucial role to non-humans in (modeling) systemic dynamics (see e.g. Sendzimir, Flachner, Pahl-Wostl, & Knieper, 2010; Van der Brugge, 2009) in a way that is similar – or: ‘symmetrical’ – to human actors. A prominent example of the turn towards an anthropocentric focus in complexity-thinking is De Haan and Rotmans’ recently developed framework that depicts transformative complex system dynamics as “the consequence of deliberate, or even strategic actions of specific types of value-driven actors” (2018: 276). In an effort to explicitly counterbalance the emphasis that is put on structures in the MLP framework, they focus on ‘intentional human actors’ and their aggregates, such as “alliances, the collectives and organizations of actors” (De Haan & Rotmans, 2018: 279). While De Haan and Rotmans’ wish to avoid an overly functionalist take is understandable, their adoption of an asymmetrical and anthropocentric perspective in analyzing transformative dynamics in CAS in our view is throwing out

¹ There are more branches and distinctions to make within the field that studies transformations or transitions in societal systems. See Hölscher et al. (2018) for an overview of the etymological discussion on ‘transformation’ versus ‘transition’ and Markard et al. (2012); Grin (2016); Köhler et al. (2019) for overviews of the field. Other branches include for instance social practice approaches (SPA) (e.g. Shove and Walker, 2010; Hoffman and Loeber, 2016; Cherunya et al., 2020) and technological innovation systems (TIS) approaches (e.g. Bergek et al., 2008).

² The multi-level perspective (MLP) developed in transition studies (Geels, 2002; 2011; Geels and Schot, 2007; Grin et al., 2010) distinguishes three analytical levels: niches (micro-level, where novelties and innovations are localized), regimes (a meso-level that comprises ‘incumbent actors’, structures, technologies as well as associated self-reinforcing rules and practices) and the landscape (macro-scale social and physical developments external to the studied system) in which regimes and niches are embedded. These levels span structuration space rather than spatial, geographical or governmental levels and thus represent degrees in stability (Geels and Schot, 2007, 2010; Geels, 2011).

the baby with the bathwater. We posit that in order to understand the dynamics and inertia in CAS, the ontological symmetry between humans and non-humans needs to be acknowledged. That requires an understanding of agency that does justice to the role of both humans and non-humans in power relations. Only in that way we can coherently grasp the causal influence of non-humans in transitional dynamics, that exert influence regardless of the (will) power of human actors in the system. In this paper, we seek to reconceptualize the relation between agency, power and transformation in CAS, inspired by the socio-technical approach to transition studies and its reevaluation of materiality’s causal influence in system dynamics (such as in Ahlborg, 2017; Chilvers & Longhurst, 2016; Geels, 2014; Svensson & Nikoleris, 2018).

A second point of departure in this paper concerns the role of power in both micro-politics as well as macro-scale systemic dynamics in a CAS context, as proposed by Room (2015). Room seeks to reconcile Parson’s conception of power as the generalized capacity of a system to ‘get things done’ with Weber’s and Wright Mills’ understanding of power as the capacity of an individual or group to secure their purposes, even against the resistance of others. Room’s synthesis concerns a focus on the ‘generative mechanisms’ (Elder-Vass, 2010; Harré, 1972) which “produce the patterns we observe” and involve “the potentialities or powers that are unlocked or closed down by contextual conditions” (Room, 2015: 24). Interesting about Room’s attempt is that he includes material system components in his understanding of the causal power of structures (drawing on Elder-Vass, 2010) which he combines with an interest in relating ‘macro-behavior’ with ‘micro-motives’ (drawing on Schelling, 1978) to explain ‘transformative synergies’ in complex systems. While Room makes an interesting start in his synthesis, along the way, through his focus on institutional structures, he seemingly loses Elder-Vass’ attention for materiality.

By bridging the gap between socio-material and CAS approaches in conceptualizing agency and power, we seek to contribute in particular to a further clarification of the relational nature of power, and the role of non-humans in the transitional dynamics of CAS. We do so by exploring and operationalizing the role of non-humans and relationality in (1) agency and (2) power, and its implications for processes of (3) powering, through which power relations shape resource distributions and associated macro-scale transformative dynamics. Below, we will first discuss the nature of CAS and their (transitional) dynamics. We then reflect on academic debates on the symmetrical and relational nature of agency (section 3) and power (section 4), which helps us operationalize structure, agency and power specifically for CAS. Subsequently, building on the work of Avelino and Rotmans (2009) and Giddens (1984), in section 5 we relate our operationalization to the effects that power relations produce in resource distributions and associated transformative systemic dynamics, and explore the implications for powering.

2. Transitions in complex adaptive systems

In recent decades, *Complex Adaptive Systems* (CAS) theory (Byrne, 1998; Holland, 1992; Holling, 2001; Mitchell, 2009) is used to study systems in both the physical and social sciences. Scholars of complexity indicate that there is yet no unified *Theory of Complexity*³ (see e.g. Chu, Strand, & Fjelland, 2003; Cilliers, 2001; Ladyman, Lambert, & Wiesner, 2013). There is, however, a general understanding in the field that CAS share certain deep commonalities (Holland, 1992) that can be

³ Whether there will ever be a unified *Theory of Complexity* is also a matter of debate, challenging assumptions on what one expects from a ‘theory’ or a ‘model’. See Cilliers (2001); Chu et al. (2003) for reflections on the scholarly pursuit of developing such unified theories. It also relates to the difference between descriptive and ontological complexity, where “the first has to do with the complexity of our descriptions, the second with the “actual” complexity of things in the world” (Cilliers, 2001: 139).

considered the generators of complexity (Chu et al., 2003). In order to substantiate our operationalization of agency, power and powering in complexity, we briefly reflect on such commonalities of CAS, regarding their structure and dynamics, and implications for (sustainability) transitions.

2.1. Systems and boundaries

Defining a system is drawing a line between what is 'in' and what is 'out'. It presumes that there is something (the *system*) with a particular functioning, or coherent behavior, that separates it from its environment and "constitutes which is bounded" (Cilliers, 2001: 141). For CAS, defining such boundaries is not straightforward (Cilliers, 2001) as they are radically open systems (Chu et al., 2003; Holland, 1992). The dynamic behavior of CAS reflects interactions within a system and interactions between a system and its environment.

If one manages to determine the bounds of a particular system, still the question remains: what does it consist of? The first answer is: subsystems. This rather unsatisfying answer is important in the context of transition studies (See section 2.3), as it points to the contextualized nature of CAS. Multiple systems and their components can overlap, interact and are often embedded in each other (Chu et al., 2003). For instance, following John Holland's (1992) example, an immune system can be considered a CAS which is embedded in another system (a human body), which itself is embedded in larger (and overlapping) socio-ecological systems. A second answer, scholars generally agree, it that complex adaptive (sub)systems exist of heterogeneous components and their non-linear interactions (Chu et al., 2003; Holling, 2001; Rotmans & Loorbach, 2009). Such components might be technological, ecological or social in nature, that is, they might be humans, animals, technological artefacts, laws, infrastructures, and so on. The macroscopic structural and dynamic properties of CAS are the result of micro-scale interactions. Therefore, let us zoom in on those interactions and the peculiar dynamical properties arising from them.

2.2. Dynamical properties of complex adaptive systems

There are three important, mutually related dynamical properties of CAS: emergence, self-organization and adaptation. A fundamental prerequisite for understanding their properties is that CAS are inherently dynamical, and that these dynamics are essentially non-linear (Holland, 1992; Holling, 2001; Ladyman et al., 2013). This means that linear superposition principles do not apply, and small changes in one interaction (or perturbations external to the system) do not linearly translate into similarly small changes in systemic behavior (Byrne, 1998). Due to non-linear interactions, systemic feedback-loops can emerge in the system, allowing small changes to either accelerate systemic change (positive feedback-loop) or dampen systemic change (negative feedback-loop). As a consequence, collective, macroscopic, or (sub) systemic properties may emerge that are not merely linear superpositions of the properties of the individual components. More precisely, according to Emmeche, Köppe, and Stjernfelt (1997: 83) the concept of *emergence* refers to "properties at a certain level of organization which cannot be predicted from the properties found at lower levels." Cairney (2012: 1) contends that complexity theory "suggests that we shift our analysis from individual parts of a system to the system as a whole". However, not considering the micro-scales that constitute macro-scale phenomena does not advance our understanding of underlying mechanisms either. We need to consider "the properties of wholes compared to those of their parts" (De Haan, 2006: 295). Emergence is, in other words, also related to novelty and to new properties that emerge at a particular systemic level, arising from interactions⁴ at underlying levels (see

Bunge, 2003; Emmeche et al., 1997).

The notions of non-linearity and emergence do not necessarily imply that CAS are chaotic (Cilliers, 2001; Folke, 2006). Structured hierarchies (Cilliers, 2001; Holling, 2001; Simon, 1977), patterns (De Haan, 2010) or spontaneous order (Ladyman et al., 2013) emerge through processes "by which systems acquire and maintain a certain emergent property: organization" (De Haan, 2010: 33). Systems exhibit a degree of *resilience* as local interactions may *adapt* to their environment through such self-organization, making the system compatible with, or resistant to, perturbations, and allowing it to retain its functional or structural configuration (Folke, 2006; Foxon, Reed, & Stringer, 2009; Walker, Holling, Carpenter, & Kinzig, 2004). Hence disturbances, instabilities, incumbent properties and (cross-scale) non-linear interactions drive both slow, fast and transformative (sub)systemic dynamics.⁵ Importantly, systems tend to co-evolve towards equilibrium states – *attractors* – in which certain configurations display a large degree of resilience (Oliver et al., 2018; Walker et al., 2004) or incumbency (see e.g. Stirling, 2019). They then tend to remain locked in those states (see e.g. Grin et al., 2010; Rotmans & Loorbach, 2009), even if those states are considered undesirable or unsustainable. Therefore, within transition studies, a particular goal is to understand and redirect systemic dynamics towards desirable attractors (or to create such novel attractors), representing desirable and sustainable system states (Rotmans & Loorbach, 2009).

2.3. Transitions towards sustainability

Transitions in complex socio-ecological and socio-technical systems⁶ entail "profound change in various or all aspects of a system's functioning" (De Haan, 2010: 59) and long-term processes of change that lead to "far-reaching changes in the system along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural" (Markard et al., 2012: 956). Transitions are multi-actor, multi-level processes that require co-evolutionary reconfigurations of structures, cultures and practices in societal (sub)systems (Rotmans & Loorbach, 2009), across geographical, temporal, sectoral and spatial scales (Coenen et al., 2012; Foxon et al., 2009). The notion of societal subsystems is important in the context of transition studies (see section 2.1), as transitions involve interactions (competition through variation and selection, or collaboration) between subsystems (or 'constellations', De Haan, 2010) that each have their own functioning within the system. These can be small and/or novel configurations ('innovations' or 'niches') or incumbent, dominant and highly structured configurations ('regimes'), each involving their own networks of structures, practices, cultures and actors (Grin et al., 2010; Rotmans & Loorbach, 2009). Their configuration exists through an interplay between ecological, technological and social components (Folke, 2006; Geels & Schot, 2007). For instance, an energy system may comprise constellations around coal, bioenergy, solar energy, wind energy, and so on, each with their own functioning and dynamics in the energy system. Analytically distinguishing between the 'landscape' as a system's context and the system itself may further help to explicate the 'how' and 'why' of societal

⁵ Holling and Gunderson (2002) for instance famously proposed 'Panarchy': a heuristic framework for understanding dynamics and stasis through phases in adaptive cycles of socio-ecological systems.

⁶ Alternatively: socio-technical-ecological systems (Ahlborg et al., 2019), incorporating technology into socio-ecological systems thinking.

⁴ Interactions also occur across systemic boundaries and across geographical, temporal and structural scales.

transitions (cp. Geels, 2002; Jørgensen, 2012).⁷

Transitions from one relative state of equilibrium to another involve a multitude of interactions in and between constellations. These non-linear, highly uncertain, and path-dependent processes have been conceptualized with typologies like ‘transition pathways’ (Geels & Schot, 2007), ‘transition patterns’ (De Haan & Rotmans, 2011) or ‘sustainability pathways’ (Leach, Scoones, & Stirling, 2010). Governance approaches aim at fostering pathways (or patterns) that destabilize regimes and create opportunities for niches (Transition Management, see Loorbach, 2007; Strategic Niche Management, (see Kemp et al., 1998), or enhance the resilience and adaptive capacity of sustainable system states (Adaptive Management, see Folke et al., 2002; Haasnoot et al., 2013). In order to understand and help influence (transitional) dynamics in CAS, scholars have obviously turned to studying the role of politics.

3. Agency in complexity

Transition scholars have time and again problematized and conceptualized the role of politics in transitions, producing a wide variety of definitions of power and agency, as well as of frameworks for analyzing their manifestations (among them Avelino & Rotmans, 2009; Grin, 2010; Smith et al., 2005; Späth & Rohrer, 2010; Geels, 2014; Geels, 2020; Hoffman & Loeber, 2016; Kern, 2011; Meadowcroft, 2011; Stirling, 2019). Yet, there still are blank spots in observing how agency and power relate to one another and play out in transitional dynamics (see also Avelino et al., 2016; Köhler et al., 2019). In order to substantiate our operationalization of power (Section 4) and powering in transitional dynamics (Section 5), we first elaborate our take on how the concepts of agency and structure can be understood in CAS.

A useful starting point is Anthony Giddens’ (1984) theorem of the duality of structure: “[T]he structural properties of a system are both the medium and the outcome of the practices they recursively organize” (ibid: 25). According to Giddens, agency refers “not to the intentions people have in doing things but to their capability of doing those things in the first place” (ibid: 9). Decoupled from intentionality, for Giddens agency is the human capacity “to act otherwise” (ibid: 14). Agency is therefore inherently related to the role of power in the reproduction of structures which, importantly, can both be constraining and enabling. Giddens’ work is both applauded and criticized, sparking debate on two issues: what exactly is it that agency does, and how does that relate to the possibility of non-humans to ‘have agency’?

3.1. What does agency do?

The first debate involves the *nature* of agency: what does it mean to have agency and how does it work? Like Giddens, many conceive agency as a capacity to act or to signify (e.g. Latour, 2018: 69–70). More ‘realistic’ scholars, like Margaret Archer (2000), see agency in the reflexive deliberation and normative orientation of human actors that lie at the heart of their actions. Such intentionalism is echoed in recent work on transitions by De Haan and Rotmans (2018: 278) who contend that “beliefs and desires are the basis for an agent’s intentional actions – the

⁷ Though CAS have a rather flat ontology in terms of their ‘building blocks’, emergence and self-organization allow for hierarchies to be (re)produced. This seems in contrast with social practice approaches and Actor Network Theory (ANT) that often reject ontological hierarchies (e.g. Law, 1992; Shove and Walker, 2010; Jørgensen, 2012). However, there might be room for reconciliation as complexity scholars move away from rigid levels of structuration (e.g. De Haan, 2010) and scholars of practice (e.g. Schatzki, 2011) indicate that macro-scale phenomena (e.g. regimes) have distinctly different characteristics than micro-scale phenomena (e.g. niches), even though ontologically they might exist of the same substance..

actions that manifest its agency”. It contrasts with Giddens’ decoupling of intention from agency and with Bourdieu’s⁸ understanding of structure influencing agency through the *habitus* in which the actor is situated. For Bourdieu, action can be “coherent without springing from an intention of coherence and a deliberate decision; adjusted to the future without being the product of a project or a plan” (1990: 51). Emirbayer and Mische (1998) provide a subtle solution for this apparent deadlock between agency either being deliberate and reflexive, or socially constructed. Agency, in their view, consists of different temporal and entangled dimensions that together co-constitute the capacity for action: human agency is “a temporally embedded process of social engagement, informed by the past (in its habitual aspect), but also oriented toward the future (as a capacity to imagine alternative possibilities) and toward the present (as a capacity to contextualize past habits and future projects within the contingencies of the moment)” (Emirbayer & Mische, 1998: 963). This three-fold nature of agency stresses both the importance of habitual construction of agency (first temporal dimension) as well as the importance of (a degree of) reflexivity and future action (second and third temporal dimensions). Such an understanding also gives body to conceptualizing agency as a capacity for *reorientation* (related to Giddens’ *capacity to act otherwise*, and, in the words of Stirling (2019: 3) to “orient[...J among many prehensible pathways for change”). Furthermore, considering agency as situated implies that agency is not necessarily the attribute of an actor as such, but rather the product of interactions between an actor and his/her environment. As Fuchs (2001: 39) argues, agency can then be seen as a dependent variable, “more likely in some situations, on some occasions, and in some networks than others.”

3.2. The role of non-humans

These considerations provide an interesting entrance to the second debate, on non-human agency. Critiquing the disentanglement of the ‘social’ and ‘natural’ worlds⁹, STS scholars have sought to explore the role of non-humans in the dynamics of socio-ecological and socio-material systems, leading to a wide variety of interpretations relating non-humans to agency. On the ‘symmetrical’ front, Jane Bennett (2010), for instance, proposes the concept of vital materialism, arguing that non-humans have a kind of agency – or vitality – as a “capacity of things – edibles, commodities, storms, metals – not only to impede or block the will and designs of humans but also to act as quasi-agents or forces with trajectories, propensities, or tendencies of their own” (2010: viii). This ‘thing-power’ she more broadly positions as being distributed in assemblages containing humans and non-humans. Bruno Latour too grants agency to non-humans (see e.g. Latour, 2018). Yet, he maintains that “[b]eing a subject does not mean acting in an autonomous fashion in relation to an objective context; rather, it means sharing agency with other subjects that have also lost their autonomy” (Latour, 2018: 62). As such, nuanced interpretations of symmetry between non-human and human agency stress that non-human agency is different “if only because they are never by themselves” (Sayes, 2014: 144).

The symmetrical stance – even in its nuanced form – is criticized for diluting the concept of agency so that it is applicable to a wide variety of ‘things’, leading to a devaluation of the analytic purpose of the concept. As a consequence, through that dilution, it is critiqued for allowing confusion between (or rather, failing to explicate the difference

⁸ According to Elder-Vass (2007) there are many differences between the works Archer and Bourdieu, yet their work can be reconcilable at the ontological level.

⁹ See for early work on Actor Network Theory (ANT) for instance Latour (1987), Law (1992), Callon and Latour (1992); Mol (1999); for geographies and spaces of socio-natural co-evolution see Coenen et al. (2012); Castán Broto (2016); and for postcolonial anthropological inquiries into the entanglement of social and natural worlds for instance Viveiros de Castro (1998); de la Cadena (2010).

between) power, action and agency. Such a confusion complicates studying power dynamics, as a consequence of the ontological flatness it brings along (see e.g. Cudworth & Hobden, 2015; Lemke, 2018). Other scholars stress that agency is an essentially human attribute (Archer, 2013) even though materiality and non-humans produce effects and have consequences (Hornborg, 2017), political strength (Akrich, 1992) or political dimensions (Winner, 1980).¹⁰ This is different from yet another debate on whether the prerequisite for agency should be 'human' or 'living' (like animals) or should also pertain to machines. For instance, Donna Haraway in the *Cyborg Manifesto* influentially posited that distinctions between these 'categories' should be eradicated (Haraway, 1991).

In this paper, we will not seek to resolve these debates, yet we aim to provide a conceptualization of power and agency in CAS that is at least coherent, while doing justice to these broader debates. In order to understand who or what can have agency, let us return to what we consider agency to do. We consider a multi-dimensional temporal conception of agency that is embedded in complex networks. We take agency to be a capacity for reorientation. Such capacity can be attributed to one component or a network of components in a system, and thus also serves as a collective capacity (see also Sewell, 1992). We therefore contend that a degree of agency can be attributed to non-humans, depending on how the non-human component expresses one or more of the temporal dimensions of its capacity for reorientation. This way, (non-human) living components and their collective networks (animals, ecosystems, companies, governments) and particular machines with a capacity for reorientation may have a degree of agency. For artefacts such as rocks, tables, windows and so on, this is more complicated. Such artefacts yet do play a role in the socio-material dynamics of particular networks. As it is difficult to disentangle non-linear dynamics in CAS, it might make more sense to consider the collective agency of such a network. In line with the so-called 'third stream' in research on science and technology dynamics that Orlikowski and Scott (2008) identified, we understand such collectivity in ontological terms, perceiving human components and non-human components to exist through "their temporally emergent constitutive entanglement" (cp. Pickering, 1995). With this conceptualization, a coal energy company for example could be said to have agency. This agency then refers to the collective capacity for reorientation of the non-humans and humans in the network combined, even though the non-humans (coal plants, transportation infrastructure, coal etc.) do not have agency by themselves and only take part in the collective agency of the network.¹¹

3.3. Structure(s) and agency

Before discussing consequences of this take on agency for power in CAS, let us briefly return to the concept of structure. It is widely argued that agency cannot be considered without structure, and vice versa (Giddens, 1984; Sewell, 1992). As Jessop (1996) indicates, their relation has been (erroneously) described in scientific work as either dichotomous, as a duality or as dualistic. Following Giddens' (1984) structuration theory in developing an understanding of the relation between structure, agency and power specifically for CAS, we rephrase his more general definition. We understand structures as those (networks of) components that engage with agents through structuration, thus forming the conditions for agency – i.e. as constituting components' capacity for

¹⁰ Others object that symmetrists favor methodological consistency at the expense of ethical or moral consistency (Shapiro, 1997)

¹¹ We might consider granting non-humans in such collectivity a 'projection' of shared collective agency.

reorientation (cp. Stirling, 2019; Sztompka, 2014). These structures may be rules, habits, routines, cultures but also materiality, ecology, technology etc. (see also Bourdieu, 1977; 1996; Giddens, 1984).¹²

Does our take then present structures as an odd collection of non-agents, while obviously the properties of something like socio-cultural norms differ from those of a technological artefact such as a traffic light? Are not the ways in which they structure agency different? Our answer is both yes and no. No, in the sense that from a CAS perspective the collective behavior of components (such as the manifestation of social norms or discourses) can be understood as an emergent phenomenon that exists by the virtue of a non-linear superposition of pluralities of components. Therefore, at the core such structures are not made up of different 'ontological building blocks' from, for example, ecological components or technological artefacts. Different structures are merely manifested across different scales. This helps in our view to further explicate that structures are "irredeemably concrete, temporalized and spatialized and have no meaning outside the context of specific agents" (Jessop, 1996: 126). Simultaneously, yes, there is obviously a qualitative difference in the mechanisms through which such collectivities structure agency (and in turn, how agency affects such collectivities) compared to agent-agent interactions or single agent-structure interactions. Acknowledging these differences is important for understanding how such interactions do or do not generate transitional macro-scale dynamics. But first, we turn our gaze to the concept of power.

4. Power in complexity

While some (anthropocentric) scholars seemingly equate the concepts of power and agency in CAS, or not explicitly discuss their relation (see e.g. Cudworth & Hobden, 2013; De Haan & Rotmans, 2018; Westley et al., 2013), we contend that there is an important ontological difference between them. While understanding agency as a capacity of components, we conceive power as an emergent and productive phenomenon that is embedded in relationships. Stirling (2019) provides a useful starting point in disentangling and relating these concepts by conceptualizing power as "asymmetrically structuring agency". Yet, he does not explicitly point out how such an understanding can be operationalized in CAS, nor where (by or through whom or what) it is located.¹³ In order to contribute to such an operationalization, we turn to the aforementioned debates on power in transitions: on its relational nature and on the role of non-humans.

4.1. Debating power: Relationality and non-humans

Let us first briefly explore the context of these debates on power in transitions, by looking at the longstanding tradition of scholarship on power. Answers to the question what power entails are manifold (Lukes, 2005: 30) as the concept is essentially contestable. Arts and Van Tatenhove (2004) argue that literature generally distinguishes three different manifestations of power: (1) dispositional power (2) relational power and (3) structural power. Dispositional power refers to the power resources of actors (such as knowledge, money, charisma, expertise) as well as to actors' positions in social arrangements that shape their capacity to act (Arts & Van Tatenhove, 2004; Clegg, 1989). The second manifestation - relational power - refers to the capacity to influence

¹² We acknowledge that such a definition is still rather shallow on the role of resources, which Giddens understood to be the other part of the duality of structure, but we will return to this in Section 5 when we discuss the effects of power relations for systemic dynamics.

¹³ That is understandable as his goal seems to be to provide general description that offers an 'umbrella understanding' of manifestations of power, and he argues that the "necessity in any given situation always to be more precise about the particular aspects and dimensions of power that come to the fore, is not necessarily impeded by a general heuristic framework like this" (Stirling, 2019: 4)

other actors as well as the capacity to shape structures¹⁴, and thus to achieve outcomes (Dahl, 1957). It may also be understood as the famous ‘second face’ of power: the capacity to influence the decision space of others in non-decision making (Bachrach and Baratz, 1962). Goehler (2000) further divides relational power into intransitive power (where power is exerted to achieve outcomes as a joint effort by multiple actors to benefit the community) in contrast to transitive power (where there is a zero-sum game and where power is deployed by actors at the cost of others). Drawing on Giddens and Bourdieu, Arts and Van Tatenhove (2004: 351) define their third manifestation of power, structural power, as “orders of signification, legitimization, and domination, which are materialized in discourses as well as in political, legal and economic institutions of societies”. Lukes’ notorious third dimension of power suggests that structural power is the power to influence the psychology (and thus the interests) of others through structures (Lukes, 2005), echoing Foucauldian ideas on power through domination and discourse (Foucault, 1978).

There are of course many different ways to categorize debates on forms of power. What Haugaard (2002) calls ‘consensual’ dimensions of power concern ‘power-with’, where power can build bridges and dialogue between different interests (Kanter, 1979; VeneKlasen et al., 2002). This contrasts with so-called ‘power-over’ conceptualizations that are concerned with conflict and domination (see e.g. Berger, 2005; Dahl, 1957). ‘Power from-within’ then focuses on a sense of capacity and self-worth and is related to empowerment (VeneKlasen et al., 2002). Avelino and Rotmans (2011) however argue that in spite of such nuances, most scholarship conceives manifestations of power either as ‘power-to’ (as a capacity) or ‘power-over’ (as a relationship).

This last point highlights the debate on the relationality of power. There is an uncomfortable dilemma (cf. Ahlborg & Nightingale, 2018): the same concept (*power*) cannot logically be both an attribute of entities (*capacity*) as well as a product of the relationships between those entities, in which it is embedded. We follow Ahlborg and Nightingale (2018) and with them, the likes of Cooper (1994), Allen (2008) and Foucault (1978) in siding with the (increasingly adopted) relational turn in the study of power. We understand power to be relational and “incorporated in numerous practices” (Barrett, 1991: 135), embedded in (social) relations or, in complexity jargon, in the interactions between components. In this tradition, power is seen as productive, meaning that it “shapes, creates and transforms social relationships, practices and institutional arrangements” (Cooper, 1994: 437). This productive view is echoed in recent work in transition studies, which views power not just as dominating or constraining, but also as a force enabling, or contributing to, processes of transformation (see e.g. Avelino & Rotmans, 2011; Ahlborg, 2017; Castán Broto, 2016; Geels, 2014; Hoffman & Loeber, 2016). We contend that such a relational understanding helps to distinguish power from agency and to clarify how structure, agency and power can be considered to co-constitute systemic dynamics in complexity.

The second debate concerns the role of non-humans in power dynamics. As we attribute agency to heterogeneous networks depending on how these networks act, it makes sense to acknowledge the role of non-humans in power relations. Even those who reject attributing agency to non-humans, consider “non-human objects [to] have causal powers that make a vital contribution to the causation of social events” (Elder-Vass, 2008: 471) or to have “impact on their surroundings (that is, have consequences for them)” (Hornborg, 2017: 98). It is in that sense that we consider non-humans (either by themselves or acting in heterogeneous networks) to appear in power relations where they structure the agency of other components, and exert causal influence on systemic dynamics. Considering such heterogeneous networks is important as multiplicities of interactions can lead to “broader and more elusive

mechanisms and processes whereby power relations are (re)produced, beyond the exercise of power by individuals” (Ahlborg & Nightingale, 2018: 385).

4.2. Relating power to agency in complexity

We consider power to be embedded in the relations between components and to structure their agency. Power, in other words, emerges from interactions. The constitutive or structural dimensions of power (Ahlborg, 2017; Allen, 2016; Foucault, 1978; 1980; Grin, 2010; Hoffman, 2013; Meadowcroft, 2011) point to the fact that power has an intensity as well as a directionality (Stirling, 2019). The capacitive concept of agency then refers to the potential of components to reorient dynamics as the product of internal properties of the components and their interactions. The difference between components as structures and components as agents lies in the simple fact that, even though they are both components able to engage in (power-laden) interactions, in contrast to agents, structures lack the ability to engage in processes of reorientation. This is in line with our take that agents and structures, ontologically considered, are not dialectically opposed discrete categories. Rather, agency is a situated and continuous property that can be attributed to some components but not to others.

An understanding of power that considers interactions of entire networks of components (and their emergent properties) with (the agency of) other components, is similar to the concept ‘(force) field’ in practice approaches (see Ahlborg & Nightingale, 2018; Bourdieu, 1996; Bourdieu & Wacquant, 1992; Hoffman, 2013; Nuijten, 2005). The different faces, manifestations or dimensions of power in this view are different types of ‘forces’ acting upon the (collective) agency of components. Structural or constitutive forms of power entail the emergent behavior of a collectivity of components acting upon an agent as a force-field. Other forms of power can be considered force-like too. For instance, power relations can reconfigure the agency of human actors (e.g. influencing their decision space), or they can act upon structures and as such, indirectly act upon the interactions of those structures with other agents.¹⁵

In Fig. 1, we visualize this conception of structure, agency and power in CAS and in several simpler subsystems. It shows how power relations emerge between human actors (Fig. 1a); how non-human components act as conditions for agency, thus co-constituting agency of components through structure-agency interactions (Fig. 1b); how collective embedded agency arises (for example in organizations, governments or ecosystems) as a consequence of the power relations between non-humans and humans, as well as how such collective emergent behavior of networks can be considered to result in an agentic component (Fig. 1c); and finally, how power relations of several constellations (each consisting of agentic components, human agents and non-agentic components) can be considered to constitute a CAS. In such a system the political dynamics is governed through multiplicities of non-linear interactions, embedded and situated agencies, historically dependent power relations, structuration of agency, and constellational self-organization (Fig. 1d).

Such a relational perspective, differentiating between agency and power while allowing for a degree of symmetry between humans and non-humans, might allow us to see all the known ‘colors’ of power but also to see new colors, namely of power dynamics that could not properly be understood before. Our operationalization captures the capacity of human (and some non-human) agents to act, the power-laden role of materiality as well as the structural dimensions of power that can shape agency. We believe that this operationalization of power, structure and

¹⁴ Note that this conceptualization of ‘relational power’ still conceives power as a capacity!

¹⁵ This builds on the notion that forces can both exist in the interactions between two or several components (agent-agent, agent-agent-agent or agent-component) as well as between multiplicities of components through force-fields (agent-network).

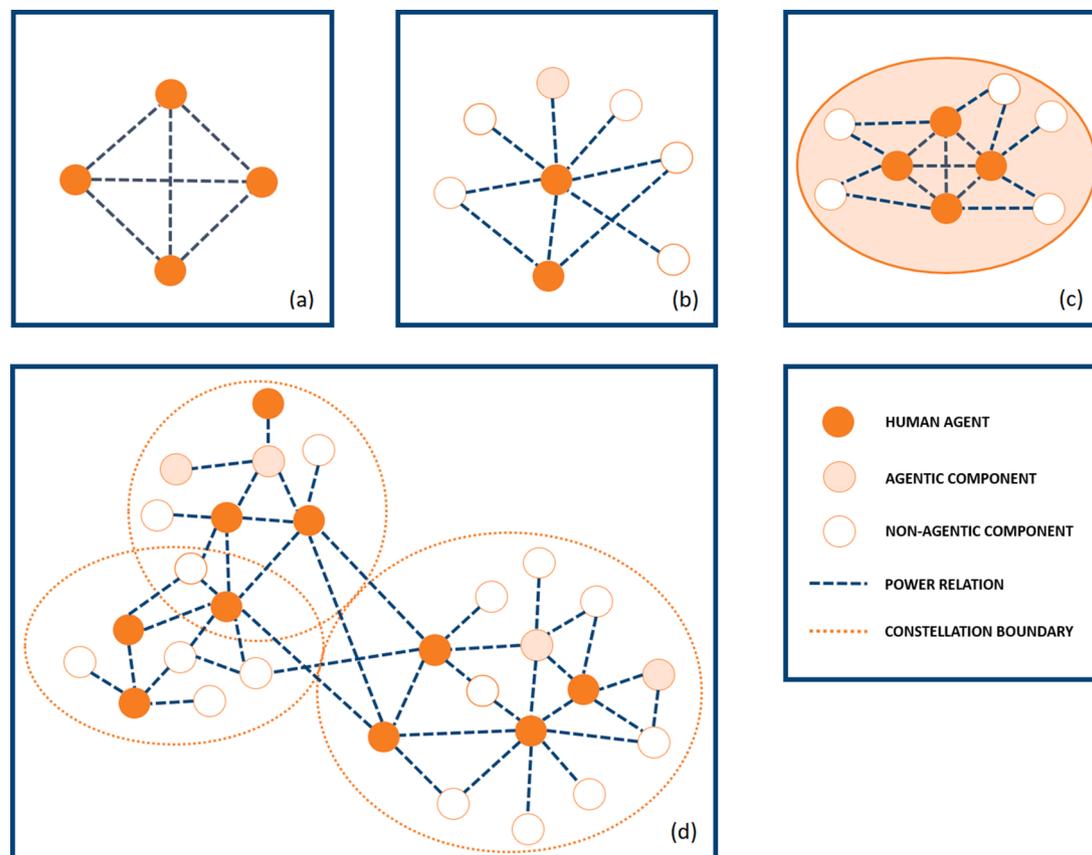


Figure 1. Schematic visualization of structure, agency and power in complexity. Specified for several (sub)systems: (a) power relations between human actors; (b) structure-agency interactions; (c) collective embedded agency in agentic components such as organizations and finally (d) power relations in several constellations (each consisting of agentic components, human agents and non-agentic components) that can be considered to constitute a complex adaptive system.

agency in CAS can be useful for exploring empirical cases as it allows for the explication of the role of non-humans in systemic dynamics. However, what it does not yet do, is help explore via which mechanisms agency and power (micro-politics) might lead to macro-scale systemic dynamics. For such an understanding, we turn to processes of *powering* through which power relations lead to dynamics of resources, that in turn might drive or hinder systemic transformation.

5. Powering: Operationalizing the effects of power on resource dynamics

As we have argued, scholars of socio-materiality are increasingly concerned with the situatedness of power: what kind of components are involved, and through which mechanisms do their interactions lead to macro-scale societal transformations? Identifying these mechanisms has been central in the work of anthropocentric scholars of power in CAS too. Seeking to link a temporal, embedded and capacitive understanding of agency and a symmetrical, relational understanding of power to transitional dynamics, we turn our gaze to the role of resource dynamics and processes of *powering*. A point of departure shared by many social scientists is that the politics of system dynamics is related to (dynamics of) resources (money, people, information, natural resources, artefacts, *et cetera*) for agents to draw upon in social action (Dahl, 1957; Giddens, 1984; Korpi, 1985; Parsons, 1967). Complex system transformation (and systemic resilience) is often associated with the control and distribution of resources by agents or entire constellations (Van Raak & De Haan, 2017), and the resulting reproduction of unsustainable configurations (Loorbach, 2007; Rotmans, Kemp, & Van Asselt, 2001), as well as persistent practices of social injustice (De La Cadena, 2010; Geyer & Rihani, 2010; Room, 2011). As Room (2015: 26) stipulates in his efforts

to link ‘micro-motivations’ to ‘macro-behavior’, for understanding these dynamics one cannot ignore the “*efforts of different groups to occupy and control particular resources and opportunities, and the dynamics of cumulative disadvantage that then develop*” throughout a system’s evolution. Therefore, linking micro-politics to macro-scale dynamics logically involves a focus on the effects of agency and power relations on the dynamics of resources.

Avelino and Rotmans (2009, 2011) effectively connect these notions, conceiving power as a capacity of human agents to mobilize resources, which can lead to transformative dynamics. However, in their aim to “*insist on power as a capacity of actors*” (Avelino & Rotmans, 2011: 801), they tend to undervalue the role of non-humans and the relational nature of power. Therefore, we propose to understand their characterizations of power as power relations that drive resource dynamics through processes of *powering*. These processes might be instigated deliberately or non-deliberately by human agents, but can, crucially, also result from power relations in which structures act upon agentic components. Such processes of *powering* can be embedded in socio-material or socio-ecological configurations (see e.g. Burns & Hall, 2012; Svensson & Nikoleris, 2018). Instead of focusing on ‘who has the capacity to, or the intention to’, we frame these political processes to be about *what causes what*, understanding *powering* processes as causal mechanisms (Burns & Hall, 2012). If *powering* is enabling agents or constellations to *mobilize* resources (cp. Avelino & Rotmans, 2009), it may become manifest either in the construction of new resources (innovative power) or in the deconstruction of existing ones (destructive power). An example of innovative *powering* could be that a sustainable start-up company, in competition with others, deploys strategic agency to contract novel innovators, which in turn would enhance its capacity to further scale-up (cp. Hoffman & Loeber, 2016). On another level, Avelino and

Rotmans relate power to the *distribution* of resources, and think of powering as agents or constellations constituting and reproducing distributions of resources, maintaining the status quo systemic equilibrium (constitutive power), or transforming the distribution of resources by deconstructing incumbent configurations and facilitating transitional change (transformative power). This of course reflects Giddens' insight that agents may both reproduce and transform structure (Grin, 2010: 224; 233–236). Importantly, constitutive powering processes lie at the very heart of systemic incumbency and contribute to systemic resistance to change. Conversely, in our view, this emphasizes again the need to understand how non-human components engage in the power relations underlying such constitutive powering processes. On the other side, transformative powering entails processes aimed at breaking down existing (self-reproducing) dynamics through the redistribution of resources. This is interesting because it emphasizes the role of regimes in fostering transitional dynamics (see also Grin, 2020; Hoffman & Loeber, 2016). It also relates to what Avelino (2017) in later work observes when attributing power to landscape trends, in the form of 'macro-scale reinforcing power' (structural power exercised by actors – cp. Grin, 2010) and 'macro-scale transformative power'.

We suggest that such processes of powering by themselves do not always lead to the creation or destruction of resources, nor do they inevitably effectively constitute or transform current resource distributions. Instead, they can also shape the distribution of pathways through which actors and constellations draw upon resources. These pathways are related to the aforementioned *force-field* interpretation of power, resulting from emergent collective behavior of larger networks of components. Such pathways describe dynamics that transition scholars attribute to the systemic 'landscape' or 'environment'. For instance, structural powering might entail the effect that an increased CO₂-concentration in the atmosphere (and associated consequences for ecologies and public opinion on climate change) leads to a decreasing number of pathways for coal-based constellations to influence resource-dynamics. One can imagine that for a windmill production facility the same trend has the opposite effect. In this case, thus, this structural powering works path-enabling.

In sum, building on the work of Avelino and Rotmans (2009) as well as on a Giddensian interpretation of structural manifestations of power, we consider three mechanisms by which power relations influence system dynamics, namely via powering processes of (1) resource mobilization, (2) resource distribution, and (3) distribution pathways. Those mechanisms are related in the sense that they are, potentially, each other's derivative. Furthermore, in empirical reality they are likely to co-exist, interact, hinder or reinforce one another. Obviously, the nature of these powering processes heavily depends on the 'starting point' of resource distributions. If in a particular situation agents or constellations have many resources at their disposal, contributing to their strong capacity for reorientation (agency), the resulting powering processes are different than if agents lack resources, and their capacity for reorientation is constrained by incumbent power relations. This history-dependent role of resources is important, as resource dynamics are both the medium (ex-ante) and outcome (ex-post) of the powering processes. Such a view mirrors a Giddensian interpretation of the role of resources in social dynamics.

Table 1

Overview of (empirically observable) effects of power, categorized in three orders of powering, and regarding their relation to resources. Based on the work of Avelino and Rotmans (2009) and Giddens (1984).

	Order of Powering		
	Mobilization	Distribution	Distribution Pathways
Relation to Resources			
Constructive	Innovative	Constitutive	Enabling
Deconstructive	Destructive	Transformative	Constraining

The implications of such a perspective on power are spelled out in Table 1, presenting 'three orders of powering' in a way that connects the work of Giddens (1984) to that of Avelino and Rotmans (2009). In this framework, the manifestations as identified by Avelino and Rotmans (2009) are interpreted not in their sense of power as a human capacity to act, but as processes of powering embodying the *effect of power relations* in heterogeneous networks. This is complimented by an order of powering on 'distribution pathways' based on a Giddensian interpretation of structural power.

6. Implications and concluding remarks

The aim of this article was to embed socio-material insights into the nature of societal dynamics in frameworks for analyzing transitions in CAS. To that end, we have constructed an operationalization of agency, power and powering as different facets of the 'politics of complexity'. We drew on various strands of work on the politics of societal transformation, seeking to contribute to an understanding of how to coherently connect agency, power and powering in the analysis of transitional dynamics. Our operationalization does so, we claim, in three ways.

First, we believe that our operationalization leaves open the possibility of established transition study frameworks such as the MLP as well as practice approaches to co-exist with CAS frameworks. By this, we do not mean that all theories can be reduced to a 'Grand Theory of Complexity', but we do see many opportunities for synergies between schools of thought. For example, within the MLP, scholars could consider how powering processes stabilize the dynamics of deeply connected (or institutionalized) networks of components (*regimes*). They could also study the emergence and dynamics of novel networks (*niches*), for instance by understanding how novel technologies or social innovations restructure power relations in existing networks. This relates to the literature on social practice approaches to conceptualizing transformative change (Genus and Coles, 2008; Hoffman and Loeber, 2016; Loeber, 2020; Schatzki, 2011; Shove and Walker, 2010). If one investigates how micro-scale dynamics are embedded in, as well as result from power relations between human components and their surrounding networks, in fact one is, arguably, studying *practices*. This implies that our operationalization allows for considering both hierarchies and structuration as well as human agency and micro-scale practices, depending on the perspective given primacy in the empirical analysis at stake.¹⁶

Second, we believe that our rather formal operationalization of the politics of complexity might contribute to modeling systemic dynamics. After all, structures and agents are both conceptualized as (networks of) components, meaning that their ontological building blocks are similar, while their properties vary greatly depending on their internal arrangement as well as their situated context. This enables us to differentiate between the concept of structures as the 'emergent properties of collectives of (human) components' and structures such as material artefacts. Both are 'structures', but the way they interact with agentic components can be different. Those interactions we also perceive as a matter of collectivity and therefore as emergent collective properties, instead of merely considering the social, ecological or material nature of the components involved. Conceptualizing power as a force that structures agency and that emerges from the interactions of components further formalizes these relations. This is important as there is an urgent need to combine qualitative and quantitative research approaches in the field of transition studies, so as to better understand and influence sustainable transformation (Köhler et al., 2019; Turnheim et al., 2015).

¹⁶ Recent work by Geels (2020) also aims to bridge the gap between micro-scale and macro-scale dynamics, by connecting a multi-dimensional perspective of (human) agency to the MLP. It does not however explicitly couple agency to power.

Thirdly, the operationalization presented here directs the gaze to resource dynamics, which are better observable in empirical work than more abstract conceptualizations of power and agency. This observability is an important practical reason to focus on resources in the final part of our operationalization. We consider our operationalization an explicit invitation to scholars to engage in empirical work to test our claims.

The work presented here also holds implications for future (research) policy. Not only are policy-making systems themselves complex, they also deal with problems that are increasingly acknowledged to be fundamentally complex ‘beyond wickedness’, in terms of radical uncertainty (Stirling, 2010) and system stability (Arkesteijn, van Mierlo, & Leeuwis, 2015, cp. Rittel & Webber, 1973). The complexity paradigm that emphasizes how societal systems involve non-linear self-organizing dynamics of heterogeneous networks has therefore recently gained ample attention in the field of policy studies (Cairney, 2012; Geyer and Cairney, 2015). We see at least three policy implications of a material-relational understanding of politics in complexity. First, the transformative capacity of organizations, countries, or constellations does not only depend on the agency of human actors, but rather on the collective agency of the networks in which material and ecological factors can seriously affect the capacity for reorientation. This has implications for facilitating processes of powering that favor transitional dynamics. Importantly, human actors aiming at societal transformation can creatively draw upon the potential capacity for reorientation among the networks’ ecological and material dimensions. As such, they could (non-linearly) enlarge the potential for systemic transformation. This is also relevant for efforts to facilitate nature-based solutions and local transformations drawing on the transformative potential of local spaces and ecologies (see Eggermont et al., 2015; Nesshöver et al., 2017). Second, efforts towards learning and reflexivity should be targeted not only to human agents, but to constellations as a whole (cp. Loeber & Laws, 2016). To be sure, learning is a key element of transition experiments (Grin, 2010; Huitzing et al., 2020; Loorbach, 2007; Voß and Bornemann, 2011) that however often fail to address the need of building transformative capacity in entire systemic constellations. This is needed to enhance the resilience of power relations that ‘hold together’ sustainable constellations, by deepening their institutionalization (thus solidifying those power fields) and enhancing their collective agency, while at the same time disrupting constitutive powering processes that reproduce unsustainable resource distributions. In this way, our work could also inform transdisciplinary processes of experimentation for sustainable transformation, helping to outline more precisely *how*, as researchers, we are part of the systems we aim to understand and transform (see e.g. Den Boer et al., 2020, Fazey et al., 2018). This points, thirdly, to the possibility to clarify how agency of researchers and their power relations are being shaped by structural and material dimensions of incumbent research and innovation systems (see e.g. Fazey et al., 2018; Kok et al., 2019). The need to explore these inter-systemic connections is also echoed in recent calls to study underlying mechanisms constituting multi-systemic incumbency in work on *Deep Transitions* (Schot & Kanger, 2018). Recently, attention is given to how such experimentation can be facilitated through policy mixes and transformative research and innovation policies (Rogge, Kern, & Howlett, 2017; Schot & Steinmueller, 2018).

To be sure, our contribution leaves many questions unanswered, not only on the level of ontological and epistemological stances in the social sciences but also in terms of how our operationalization can inform empirical research. Our hope is that others will consider this paper as an explicit invitation to empirically study and theoretically reflect upon the conceptualizations that we offer. In that way, we can further advance our understanding of the politics of complexity and the complexity of politics.

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Supplementary materials

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