

Sustainability transformation calls for complexity-informed systemic policy design

Harri Jalonen & Petri Uusikylä

To cite this article: Harri Jalonen & Petri Uusikylä (23 Sep 2025): Sustainability transformation calls for complexity-informed systemic policy design, Public Management Review, DOI: [10.1080/14719037.2025.2564747](https://doi.org/10.1080/14719037.2025.2564747)

To link to this article: <https://doi.org/10.1080/14719037.2025.2564747>



© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 23 Sep 2025.



Submit your article to this journal [↗](#)



Article views: 175



View related articles [↗](#)



View Crossmark data [↗](#)

Sustainability transformation calls for complexity-informed systemic policy design

Harri Jalonen  and Petri Uusikylä

School of Management, University of Vaasa, Vaasa, Finland

ABSTRACT

This paper develops a conceptual framework for integrating complexity theory into systemic policy design for sustainability transformations (ST). We conceptualize ST as a dynamic design challenge requiring enabling conditions—relational, cognitive, and institutional—rather than predetermined solutions. The framework operates across three levels: at the macro-level, sustainability trajectories are framed as attractor landscapes; at the meso-level, adaptive spaces enable experimentation beyond dominant institutional constraints; and at the micro-level, self-organizing collective agency drives transformative action. Central generative mechanisms, particularly sensemaking and sensegiving, facilitate the imagination of emergent opportunities, navigation of uncertainty, and mobilization of collective responses.

ARTICLE HISTORY Received 12 March 2025; Accepted 15 September 2025

KEYWORDS Complexity theory; policy design; sustainability transformation; systems thinking

Introduction

Climate change adaptation will not be achieved through approaches that ignore the transboundary nature of its impacts (Haddad et al. 2022; Harding, Nauwelaers, and Haegeman 2024; Karimo et al. 2023). Extreme weather events lead to displacement and migration, disrupt economies, threaten food security and public health, and pose challenges to democratic governance (IPCC 2023). When development trajectories become unsustainable (Mosneaga 2022), mere adaptability is insufficient (Hanberry 2022); instead, *transformability* will be required. The current study views that as the capacity to imagine and initiate new pathways for sustainable living (Bhatia et al. 2025; Day 2025; Mulgan 2022; Sokolova 2023).

Scholars have proposed systemic approaches to address the issue of *sustainability transformation* (ST), emphasizing the need to reconcile

CONTACT Harri Jalonen  harri.jalonen@uwasa.fi

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

environmental limits with social and economic demands and to understand the societal dynamics driving transformation (Ison and Straw 2020; Pickering et al. 2022; Ungar 2021). Although the complexity of an ST has been documented (Skinner 2017; Wells 2012), and many researchers have addressed the notion from a systems perspective (Scoones et al. 2020; Voulvoulis et al. 2022), there is a notable lack of research on the use of *complexity theory* (CT) as a conceptual lens to design enabling conditions for the ST. For example, a search conducted in May 2025 in leading journals using the terms ('design') AND ('sustainab*') AND ('complexity theor*' OR 'complexity science*') yielded only seven results. That number is surprising considering the rise of CT in the analysis of politico-administrative systems (Castellani and Gerrits 2024; Jalonen 2025; M. Rhodes et al. 2011). This brief overview of previous studies highlights the research gap addressed in this paper. We ask *how can complexity theory inform the design of enabling conditions that advance sustainability transformation across different governance levels?* We build on Scoones et al. (2020), Ang (2023), and Day (2025) to reframe systemic policy design as creating *enabling conditions* – understood broadly as relational, cognitive, and institutional factors – that allow adaptive solutions to emerge. We argue that although much of the ST will occur in the future, the sustainability process must be reimagined as a complex design challenge in the present. This perspective aligns with Day (2025), Innerarity (2025), and others who suggest that CT can provide a bridge between diverse areas of policy expertise and the decisions that policymakers are required to make. While our approach is conceptual, we draw on examples from the world of the ST to enrich our interpretation, although not to present empirical evidence.

Traditionally, policy design refers to the programmatic formulation of instruments to achieve defined objectives (Capano and Howlett 2021; Howlett and Lejano 2013). This process involves analysing societal issues, identifying appropriate interventions, and crafting policy instruments that are coherent and feasible within a given political and administrative context (Mukherjee, Coban, and Bali 2021). Traditional approaches to policy design often focus on the technical aspects of policy formulation. However, it is important to recognize that a broader perspective can be useful for policy design: *systemic policy design* emphasizes understanding and leveraging the interdependencies between relational, cognitive, and institutional factors to create adaptive policies (Blomkamp 2021; Rava 2021). This shift in perspective highlights the interactions between elements within a system through which emergent properties and unintended consequences arise – dynamics that can significantly alter the system's overall behaviour in ways that are difficult to foresee (Byrne and Callaghan 2022). While emergence is often invoked as a high-level descriptor, it alone cannot explain the policy challenges of the ST. We therefore offer an interpretation of the *generative*

mechanisms (see Elder-Vass 2010; see also Elder-Vass and Morgan 2022) informed by CT. Generative mechanisms are not individual actors or resources, but dynamic relationships through which change may happen. Those mechanisms give rise to emergent properties, and thereby provide a structured foundation for systemic policy design. Although CT does not offer prescriptive solutions, it can support systemic policy design by sensitizing policymakers to the dynamic patterns, critical interdependencies, and conditions under which sustainable practices may emerge and stabilize.

Complexity theory helps understand how the actions and interactions of individual actors generate collective outcomes and how they subsequently influence and are affected by individual actions (Morçöl 2023). Interventions spanning multiple levels are often crucial in complex systems, as small changes at one level can have significant systemic impacts. Therefore, we argue that systemic policy design to advance the ST must be pursued across *macro* (institutional), *meso* (organizational), and *micro* (individual) levels. At the macro level, sustainability policies reflect societal values, regulations, and strategic directions (Mukherjee, Coban, and Bali 2021). At the meso level, organizations interpret and adapt to those policies, shaping implementation practices (Hill and Hupe 2022). Policymakers and policy-takers operate at the micro level; the former design the frameworks and incentives that shape actions, and the latter interpret and implement the policy interventions in their everyday decisions, influencing overall policy outcomes (Howlett, Ramesh, and Capano 2020). The dynamics between the levels are neither top-down nor bottom-up but a complex interplay of bidirectional influences, resulting in a continuous feedback loop that shapes and reshapes ST efforts at all levels (Radtke 2025).

We contribute to the existing body of knowledge by providing a conceptual framework that integrates CT into policy design to advance the ST. Drawing on Gilson and Goldberg's (2015) definition of a conceptual paper and its function, we consider new relationships among relevant constructs and expand the scope of our thinking in that area. Accordingly, we move beyond merely working on complexity to working *with* complexity (see Byrne 2001). We employ a CT lens to envision interventions that acknowledge and engage with the dynamic nature of the ST. The method aligns with research that reframes systemic policy design not as a process of selecting optimal tools and instruments but as one that involves the consideration of multiple factors to address the specific challenges of a given policy issue, such as the ST (Capano and Howlett 2021; Rogge and Reichardt 2016).

The managerial value of our framework rests with its potential to guide policymakers and practitioners designing enabling conditions that allow sustainable practices to arise and stabilize within continuously evolving contexts. In this regard, we emphasize practitioners' ability to imagine

alternative future policy landscapes and the role of generative mechanisms – particularly sensemaking and sense-giving – in recognizing emerging possibilities and initiating collective action in response. They also help practitioners identify and seize unexpected opportunities as they arise.

Preliminary exploration of sustainability transformation using complexity theory

Sustainability and transformation are multifaceted constructs approached from diverse perspectives (e.g. West et al. 2024). *Sustainability* encompasses environmental, social, economic, and cultural dimensions (Portney 2015; Soini and Birkeland 2014). Those dimensions are deeply intertwined, with actions in one area influencing others through synergies and trade-offs (Giovannoni and Giacomo 2013). *Transformation* is a profound change process that redefines structures, systems, or mindsets. It represents a systemic shift or tipping point (Lenton et al. 2022) where a system crosses a threshold and triggers adaptive responses, reconfiguring mechanisms to sustain new trajectories or altered system outcomes (Avelino 2017; Chaffin et al. 2016).

While the conceptual vocabulary of CT has enriched sustainability scholarship, the transfer of its core notions, such as self-organization and ecosystems, into socio-political contexts is not without risks. Some scholars argue that pure self-organization, by which they mean organization without external guidance, can occur in nature and human communities. However, Fuchs (2003, 147) offers a contrasting view, contending that ‘re-creativity is based on the creative activities of human beings’. That view suggests that human agency is indispensable, making pure self-organization in social systems improbable. Similarly, it is unlikely that the intricate interdependencies found in natural ecosystems, such as those of pollinating bees, can be fully replicated in organizational networks. While the concept of an ecosystem has been successfully used for understanding complex organizational environments (e.g. Osborne et al. 2022; Trischler et al. 2023), the removal of a single actor from an organizational network would not lead to the kind of collapse that the extinction of pollinating bees would in food production. Unlike natural ecosystems, where interdependence is often critical to species survival, organizational ecosystems are characterized by relatively flexible connections.

Despite the inherent challenges, CT has garnered significant attention in the field of public administration and management for its usefulness in comprehending politico-administrative systems (e.g. Battaglio and Hall 2019; Castelnovo and Sorrentino 2024; Eppel and Rhodes 2018; Gilbride 2025; Jalonen 2025; M. L. Rhodes and Dowling 2018; Rajala and Jalonen 2025; Tenbenschel 2018). Although there are different schools of thought

(Richardson 2008), scholars have agreed upon certain core characteristics of CT. Table 1 presents seven pillars derived from CT, along with examples related to the ST. We use the term *system* in a broad sense to refer to functional entities consisting of interconnected and interdependent elements.

The table above shows that ST is a complex, developing phenomenon that is defined by deeply interconnected systems whose properties cannot be reduced to their individual components. This understanding implies that systemic policy design is not about prescribing outcomes but about fostering enabling conditions under which the ST can unfold across macro, meso, and micro levels. We understand enabling conditions as relational, cognitive, and institutional factors that shape and are shaped by the interactions between actors and structures, and that can be supported or reinforced through systemic policy design. The ST process is shaped by policymakers and leaders with significant influence, as well as the self-organizing behaviours of individuals and communities working towards or opposing change. More specifically, ST occurs in contexts involving institutional complexity and multilevel governance architectures (Biermann and Kim 2020), in which cooperation is characterized by multiple (Friedland and Alford 1991) and incompatible institutional logics (Greenwood et al. 2011). Recognizing and addressing these institutional logics is crucial, as they shape both the opportunities and the constraints for STs (Vikstedt and Vakkuri 2025). Owing to the unpredictable and complex nature of ST, complete control over the process is unattainable, but inaction is not an option.

Complexity theory has its roots in the natural sciences, but it does not represent as radical a departure as some proponents suggest (see Jalonen 2025). Many core concepts had been explored in public administration and policy before CT was formally articulated. While the cross-disciplinary transfer of theoretical frameworks is common, the practice carries epistemological and methodological risks (Whetten, Teppo Felin, and King 2009). Despite structural similarities, differences between biological and social systems are substantial. Although both system types may reach states described in CT as ‘far from equilibrium’, the underlying drivers differ: disequilibrium in thermodynamic systems arises from opposing physical forces (e.g. hot and cold), whereas in policy contexts, it stems from conflicting interests. Consequently, recommendations from CT have often been too abstract to offer robust guidance for public leaders (Cairney 2012). To address the above limitations and develop a complexity-informed interpretation to support systemic policy design, we build upon literature on emergent causality, agency, and structure. Following Sawyer (2005), Elder-Vass (2010), and Byrne and Callaghan (2022), we argue that social structures, such as norms and institutions, depend on individuals for their existence, yet they possess emergent causal powers that cannot be reduced to individual-level

Table 1. Complexity theory and sustainability transformation.

| Complexity element | ST example |
|---|---|
| <p>Emergent complex whole: Repeated interactions among individuals, events, and phenomena create a complex system whole (Eppel 2017). The system consists of numerous interconnected components that interact dynamically, making it greater than the sum of its parts (Teisman and Klijn 2008). Due to this interdependency, the system's behaviour cannot be fully understood by analysing individual components in isolation, as emergent properties arise from the interplay between the parts. Far from being merely a problem, interdependence must be seen as a prerequisite for systemic adaptation (Alexiou 2011).</p> | <p>Efforts to reduce carbon emissions through renewable energy adoption can trigger economic shifts and social changes. For instance, according to the International Energy Agency's (2021) net-zero scenario, clean energy technologies will generate significant opportunities by 2050 and foster the creation of new businesses and jobs while driving innovations that enhance industrial development. However, this outcome depends on a range of interdependent factors, including the pace of technological advancements, the effectiveness of policy frameworks, the willingness of industries to adapt, and broad social and economic conditions. From a systemic policy design perspective, emergence challenges the assumption that transformation can be engineered through top-down interventions. Instead, CT suggests that policy should focus on fostering the enabling conditions, such as cross-sectoral dialogue, that allow emergent patterns of ST to unfold organically.</p> |
| <p>Nested systems: Complex systems are parts of larger ones. They share components and exhibit self-similarity, and characteristics at one level are present throughout the system (Tenbenschel 2018). This multilayered interdependence necessitates a systemic approach to interventions targeting policy transformation. To ensure effectiveness, actions taken at one level must harmonize with and reinforce changes at other levels within the hierarchy of nested systems.</p> | <p>The principal impact of the ecological crisis lies not in fostering environmental stewardship but in dissolving the perceived divide between nature and policy (Innerarity 2025). Nested systems encompass physical, societal, and economic dimensions (Mori and Christodoulou 2012). The survival of human society depends on well-functioning life-support systems, while economic prosperity relies on stable and functioning social systems (Ferng 2014). For instance, efforts to scale renewable energy technologies depend not only on their technical efficiency but also on societal acceptance, regulatory frameworks, and financial incentives (Sen and Ganguly 2017). Nested systems imply that interventions at one level of governance resonate across others. Therefore, systemic policy design informed by CT emphasizes alignment and mutual reinforcement across local, national, and global levels, enabling adaptive renewal and transformation through polycentric governance structures.</p> |
| <p>Feedback loops: Interactions between systems create feedback loops involving continuous participant interactions, which lead to patterns of influence (van Buuren and Gerrits 2008). Positive feedback amplifies certain patterns of behaviour, and negative feedback suppresses others, contributing to a system's ability to evolve and adapt to changing conditions. Over time, such dynamics reinforce or dampen systemic behaviours, potentially triggering tipping points and regime shifts (Preiser 2019). The structure and interplay of feedback loops are therefore central to understanding how and why systems transform.</p> | <p>The decreasing costs of renewable energy technologies, such as solar, wind, lithium batteries, and hydrogen electrolysers, follow Wright's law, which states that unit costs drop consistently with each doubling of production, thus creating conditions for the rapid reduction of emissions (Way et al. 2022). These dynamics indicate the feasibility of achieving the climate targets set by the Paris Climate Accord in 2016, with minimal expense, under favourable system interactions. In systemic policy design, feedback loops are not merely descriptive features of systems but levers for change. Complexity-informed design seeks to amplify positive feedback while dampening path-dependent reinforcements that lock systems into unsustainable trajectories.</p> |
| <p>Adaptation and coevolution: Adaptation involves changes in a system in response to external environmental changes, potentially causing further external changes (M. L. Rhodes and Dowling 2018). The system's adaptive responses not only ensure its survival in changing environments but also continuously redefine its structure and functions, leading to coevolution with its surroundings.</p> | <p>A transition strategy aimed at establishing a circular economy exemplifies coevolution through its emphasis on system-level adaptation and multistakeholder collaboration. Achieving a circular economy requires reshaping societal structures, consumer behaviours, and business models; in turn, these evolving systems help refine strategic objectives and methods (Sitra 2016). The interplay between these elements enables the emergence of circular economy ecosystems in which interconnected actors co-create innovative solutions and drive systemic change (Aarikka-Stenros, Paavo, and Llewellyn 2021). CT reframes policy design as the facilitation of mutual learning and co-development between institutions, actors, and environments, allowing transformation to emerge through dynamic interaction.</p> |

(Continued)

Table 1. (Continued).

| Complexity element | ST example |
|---|---|
| <p>Nonlinearity: Development can exhibit nonlinear behaviour, with dramatic shifts triggered by minor stimuli (Scott et al. 2018). A trigger can be understood as an external or internal event, stimulus, or condition that initiates a process of change (Houtgraaf 2022).</p> | <p>Socio-political shocks can create opportunities for the transformation of social-ecological systems into new developmental pathways (Herrfahrdt-Pähle et al. 2020). For instance, the rapid expansion of electric vehicle markets following a single policy intervention, such as a subsidy or a ban on internal combustion engines, demonstrates how minor actions can drive systemic changes in energy and transportation networks (e.g. Meckling and Nahm 2019). Nonlinearity implies that ST may occur through disproportionate effects from small interventions. Systemic policy design should therefore focus on identifying social, institutional, or technological leverage points where enabling conditions can catalyse nonlinear shifts towards sustainability.</p> |
| <p>Self-organization: Self-organization takes different forms when social systems exchange information and adapt to others' actions, contrasting with plans imposed by a central authority (Cilliers 1998). Self-organization enables systems to spontaneously create order and coherence and reconfigure themselves in response to internal and external stimuli (Nederhand, Bekkers, and Voorberg 2016).</p> | <p>Self-organization can occur, for instance, when communities address sustainability challenges by developing localized solutions, leveraging local knowledge and resources, and enhancing their capacity for ST (Bhatia et al. 2025; Hoppe 2021). Self-organization points to the novel order from within. A complexity-informed policy approach avoids prescriptive blueprints and instead fosters diversity, experimentation, and bottom-up initiatives, thus supporting the conditions under which locally adapted, created, and collectively shaped sustainability innovations can thrive.</p> |
| <p>Path dependency: A system's history and initial conditions, along with its feedback loops, create path dependencies that influence its potential for change (Butler and Allen 2008). Path dependency underscores the importance of historical trajectories, as past decisions and interactions shape current structures and constrain the range of future possibilities.</p> | <p>Path dependency highlights the inertia of existing systems and the constraints imposed by past decisions. It is imperative to acknowledge how historical policies, infrastructure, and cultural norms influence contemporary practices and opportunities for transformation. Scholars have emphasized that recognizing the significance of technology does not necessitate allowing it to manage ST autonomously. The historical trajectory of energy demonstrates that novel technologies seldom supplant existing ones entirely; rather, they frequently complement established systems and provide innovative methodologies for utilizing traditional, often fossil-based, resources (Fressoz 2024). Complexity-informed systemic policy design focuses on disrupting unsustainable trajectories by creating institutional flexibility, narrative shifts, and space for alternative pathways to emerge and gain legitimacy.</p> |

properties. These structures are sustained through recurring practices, while simultaneously shaping the conditions under which individuals act.

The above view has emergence corresponding to a stratified ontology in which higher-level properties stem from lower-level elements but are not reducible to them. However, irreducibility and causality as properties of emergence are not unproblematic. For example, Greve (2012), draws on the causal exclusion argument to question whether emergent properties can genuinely exert autonomous causal influence if their effects are always realized at the individual level. Greve suggests that unless it can be demonstrated that social properties produce effects that cannot be explained through their individual-level realizers, the claim of structural autonomy cannot be substantiated. We address this conceptual tension by employing the strategic-relational approach developed by Jessop (2005). Jessop does not conceive of structures as external forces but rather as strategically selective

contexts that constrain but do not determine action. For Jessop, agency is relationally and temporally embedded: actors interpret, respond to, and can also transform the structural conditions they encounter. This recursive relationship enables a nuanced understanding of social change within complex systems, such as an ST. Despite the epistemological caution over importing CT from natural to social systems, we argue that it remains heuristically valuable, provided it is used not as a prescriptive theory but as a conceptual tool for identifying the enabling conditions that make an ST possible.

Designing for multilevel complexity

The sustainability transformation represents a complex, multifaceted challenge that manifests differently across various societal levels. To capture the dynamics of that ST, we have developed a complexity-informed policy design framework tailored to the macro, meso, and micro levels. Although CT is grounded in the premise that systems are more (or less) than the sum of their parts, Castellani and Gerrits (2024) note that its application has too often been confined to a single analytical level, underscoring the need for a genuinely multilevel perspective. We drew on J. Coleman's (1990) bathtub model to structure the macro-micro relationships in social reality, as well as Jepperson and Meyer's (2011) detailed macro-meso-micro framework. This approach helps to simultaneously direct attention to individuals' everyday experiences (*zooming in*) and the institutional foundations of the ST (*zooming out*), thereby offering a comprehensive lens on the dynamics of change (Keller, Sahakian, and Francis Hirt 2022). A systematic approach to understanding these relationships is crucial for enhancing policy design capacity (Mukherjee, Coban, and Bali 2021). We also adhered to Holling's (2001, 391) principle of being 'as simple as possible but no simpler than is required for understanding and communication'. This multilevel structure aligns with Archer's (1995) view that macro and micro are not defined by scale, but by relational positioning within emergent social strata. Social structures and agency unfold in interdependent and temporally layered ways, making it necessary to analyse how emergent properties manifest differently across levels of reality. We analyse the macro level of the ST through the lens of *an attractor landscape*, which we argue helps conceptualize systemic dynamics and stability. At the macro level, enabling conditions primarily involve *institutional factors*. At the meso level, we focus on *adaptive space* and emphasize the importance of balancing conflicting logics, with enabling conditions centred on *relational factors*. Finally, at the micro level, we focus on *self-organizing collective agency* by examining how individual actors, shaped by structural conditions, interact and coalesce into collective forms

that drive transformative change, with enabling conditions are understood largely as *cognitive factors*.

Macro level: understanding stability and change based on attractor landscapes

Examining the mechanisms that maintain stability or drive change is an essential prerequisite for research seeking to illuminate the progress towards an ST. These mechanisms can be understood through the concept of *attractors*, which are principles or states that generate predictability and order and ensure that a system operates within defined boundaries (Kiel 1993). A key aspect of attractors is their ability to guide a system towards equilibrium when it temporarily falls into a state of disorder (Haynes 2008), making significant deviations from its trajectory unlikely (Heino et al. 2023). Ingrained societal attitudes, longstanding policies, and the enduring influence of economic structures are some examples of attractors. A cynical standpoint might view current attractors, such as reliance on the fossil fuel industry, as barriers to the ST. While reliance on carbon-based energy and the unsustainable exploitation of natural resources for industrial purposes serve as powerful stabilizing forces within the existing system, they could also be contributing to long-term systemic instability, ultimately challenging their role as attractors (Day 2025). For example, P. T. Coleman et al. (2007) illustrated how an attractor can shape development so that a complex system transitions from having a broad range of potential outcomes to being a highly polarized state, significantly increasing the likelihood of conflict. Human-driven destructive forces may indeed soon become dominant attractors in the global system (Sears 2021).

From a more optimistic perspective, attractors are not immutable but can be reshaped to foster desirable outcomes. That insight implies we should expand our perspective from individual attractors to the broader concept of *attractor landscapes* (also referred to as attractor basins; see Heino et al. 2023; Janssen, Anderies, and Walker 2004). Doing so could illuminate how attractors evolve and influence system behaviour. Walker et al. (2004) argued that transformative change requires the creation of new rules and policies capable of disrupting the current attractor landscape. Attractor landscapes can be visualized as valleys within a state space (Heino et al. 2023). The strength or pull of an attractor is analogous to the depth of a valley and determines how strongly a system will remain within the current state. Determinants such as regulations that govern renewable energy projects, market incentives to divest from fossil fuels, warnings from the scientific community about climate warming and biodiversity loss, corporate sustainability initiatives, and activist-led movements aimed at influencing consumer behaviour can shape a system's potential trajectory. These determinants may be

intentionally designed (Janssen, Anderies, and Walker 2004) or may emerge organically through social processes (Hatt 2013). The shift from an unsustainable trajectory to a sustainable one depends on changes in these determinants and the subsequent reshaping of the attractor landscape (see Figure 1). Changes can trigger two types of transitions: bifurcation-induced tipping (B-tipping) and noise-induced tipping (N-tipping) (Ashwin et al. 2012; Heino et al. 2023). B-tipping occurs when intentional systemic shifts, such as changes in economic paradigms or regulatory frameworks, destabilize dominant attractors and open a pathway towards a new, sustainable state. For example, eliminating fossil fuel subsidies or investing in green infrastructure may alter economic and institutional priorities and strengthen the pull of sustainable attractors (Day 2025). In contrast, N-tipping is driven by unplanned or disruptive events, such as extreme weather, geopolitical crises, or technological breakthroughs, that perturb the system in unpredictable ways. While such events may initially reinforce existing attractors, they can also expose latent tensions and create openings for reconfiguration.

While analytically distinct, B- and N-type tipping mechanisms typically reinforce each other. Policy interventions (B-tipping) can reshape the attractor landscape, increasing sensitivity to external shocks and enabling N-tipping. Conversely, unexpected events can destabilize established structures, creating political space for directional change (B-tipping). For instance, public investments in green infrastructure (B-tipping) not only shift economic and regulatory priorities but also enhance institutional capacities and societal readiness to address climate-related challenges. Similarly, the intensifying consequences of climate change (N-tipping) can shift public opinion and stakeholder power dynamics, legitimizing more radical policy responses (B-tipping).

Understanding this interplay helps avoid overly simplistic models of policy design and supports a complexity-aware approach to the ST (see e.g. Sewerin, Cashore, and Howlett 2022). Systemic policy design can thus be characterized as ontologically contingent, in line with the work of Luhmann (1995) and Innerarity (2025). Contingency becomes evident in situations where the foundations for action are neither fully clear nor convincing, where there are no definitive reasons for a course of action, nor certainty that any such action will achieve the desired outcome. At the same time, inaction is itself a choice that carries risks. Recognizing this contingent condition underscores the need to balance strategic intent with adaptive responsiveness when shaping the ST. More specifically, systemic policy design should be understood as the creation of enabling conditions that allow the ST to emerge. Shaped by relational, cognitive, and institutional factors, these conditions both emerge from dynamic interactions and guide actors and structures, thereby reinforcing an attractor landscape conducive to sustainability.

Meso level: fostering adaptive spaces to balance competing logics

The concept of an attractor landscape consists of parameters, like valleys in a state space, that establish the boundaries within which organizations operate. These boundaries shape options while allowing organizational choices within certain constraints. As organizations navigate these landscapes, they shape and reinforce institutional logics in the form of the practices, structures, and values that guide behaviour and decision-making (Friedland and Alford 1991). Institutional logics determine which behaviours and outcomes are desirable or undesirable in specific contexts (Thornton, Ocasio, and Lounsbury 2012). While these logics tend to be enduring due to their embeddedness in social structures, they are not static, and strategic choices and deliberate interventions can reshape them over time. Recognizing the multifaceted nature of expectations, beliefs, and demands equips policymakers to anticipate conflicts and design interventions that promote coherence among competing institutional logics (Greenwood et al. 2011). A meso-level analytical approach is necessary to manage institutional complexity effectively and to understand how these dynamics shape organizational adaptability.

Numerous studies indicate that the ST is happening in complex institutional environments that involve competing institutional logics (Braams et al. 2024; Keiff and David Talbot 2025). Therefore, organizational adaptability requires maintaining a balance between competing demands, such as

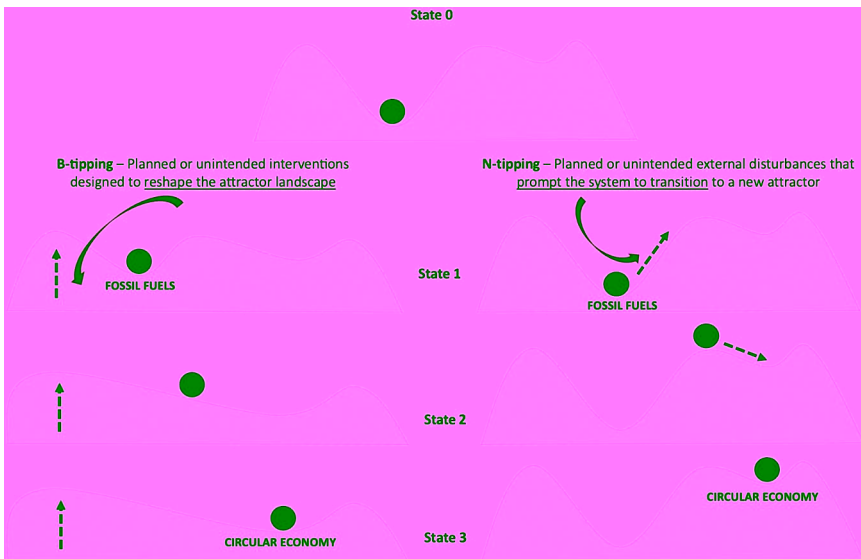


Figure 1. Two mechanisms by which a system transitions to a new state (adapted from Day 2025; Heino et al. 2023).

exploration (developing new knowledge and capabilities for future success) and exploitation (refining existing resources and processes to ensure current efficiency) (March 1991). That balance is critical because overemphasizing future development can undermine operational effectiveness, while excessive focus on current operations can hinder an organization's capacity for renewal and change (Brix 2019).

While the need to balance competing institutional logics is evident, this goal will remain unrealized unless accompanied by efforts to find practical means for its achievement. Challenges stem from opposing poles rooted in divergent values and interests; therefore, any solution must include mechanisms to bridge such divides. That course of action calls for the exploration of *adaptive space*; a domain where conflicting logics can coexist and evolve through interaction. Such a space does not simply facilitate mediation between opposites but enables processes that transcend binary divisions and create opportunities for fragmented interests to align. The relational, fluid construct of adaptive space is defined as a 'network and organizational context that allows people, ideas, information, and resources to flow across the organization and spur successful emergent innovation' (Arena et al. 2017, 40). Uhl-Bien and Arena (2017, 2018) and Uhl-Bien (2021) stated that adaptive space is a conflicting and connecting climate that generates an environment or a context involving interactions that bridge entrepreneurial and operational activities, allowing events in the surrounding environment to translate into everyday organizational realities. The dynamics of entrepreneurial activity are intrinsic and emerge from the bottom up. Within such a space, proactivity emphasizes flexible structures, leverages diverse arenas, and embraces agency that operates independently of hierarchies, potentially leading to unconventional and creative solutions.

Entrepreneurial activities are needed to foster transformative dialogues between policymakers, scientists, businesses, and communities and thus enable the questioning of entrenched norms and envisioning of new pathways for sustainability. These activities can support the emergence of alternative narratives and mindsets, such as circular economy practices or regenerative agriculture, which are critical for driving the cultural and institutional shifts underpinning the ST. The emerging dynamic creates what Lichtenstein (2014) calls opportunity tension – a drive to push forward the ST. It is characterized by increasing levels of conflict as agents search for new ideas, processes, and designs (Uhl-Bien 2021). The role of operational activities is to reorganize structures and policies and connect them to new ideas. Operational responses enable the emergence of new organizational policies and provide the structural foundation necessary to integrate new ideas and practices that drive the ST.

Attractor landscapes define the structural boundaries and tendencies that shape change, while adaptive space determines how organizations engage

with these boundaries and influence the system's trajectory. In an adaptive space, organizations can sustain their core functions and simultaneously explore transformative pathways. This dual capability enables organizations to anticipate challenges, respond effectively to disruptions, and critically reassess assumptions and practices. They can also actively engage with and reshape the attractor landscape and steer systemic change to benefit sustainability.

Facilitating the development of adaptive spaces necessitates a leadership committed to reconciling competing logics. While acknowledging the inconvenient truth that various leadership styles exhibit more similarities than differences (Eva et al. 2025), complexity leadership (Uhl-Bien, Marion, and McKelvey 2007; see also Callens 2024) stands out through its emphasis on adaptive dynamics within institutional complexity. From the perspective of complexity leadership, competing logics are not detrimental but essential for the emergence of something novel and potentially beneficial. To this end, complexity leadership emphasizes the intentional creation of adaptive space, focusing particularly on the processes of conflicting and connecting (Arena et al. 2017). Adaptive space can be understood as a boundary zone, a dynamic interface where divergent perspectives meet, interact, and potentially recombine into new forms of understanding or practice (see Burt 2005). For example, in the ST, competing logics (e.g. the pursuit of economic viability and the adherence to strict environmental regulations) often appear irreconcilable. The role of leadership is to create adaptive spaces where these logics can be brought into dialogue (Paananen et al. 2022). This enables – though does not guarantee – the emergence of solutions that would not be possible if a single logic dominated the process. However, it is important to note that leadership does not always emerge from formally recognized leaders, and a leader cannot fully control the ways in which people interact locally to drive transformation (Mowles 2022). This underscores the need for leadership approaches that enable rather than direct, and that focus on cultivating the conditions for emergent change rather than enforcing predetermined outcomes.

Within boundary zones, conflict and connection coexist, placing a distinct demand on leaders: they must cultivate productive tensions to spark innovation, while simultaneously offering the relational and structural support needed to turn emerging ideas into tangible outcomes. This requires combining interactional trust – built through transparent communication, inclusive dialogue, and the legitimization of diverse perspectives – with institutional trust, grounded in fair, meaningful, and co-created structures that guide actors' autonomy without stifling it (Bentzen 2023). Together, these dimensions of trust create an environment for experimentation and learning, enabling actors to take the risks required for transformation. Without trust, the willingness to take the risks required for meaningful

transformation diminishes (Uhl-Bien and Arena 2018). Trust does not arise from control or predictability, but through transparency, inclusion, and the creation of psychologically safe conditions for experimentation and dialogue (Edmondson 1999). Public leaders foster trust by making reciprocal obligations explicit, communicating candidly about challenges and uncertainties, and treating both fulfilment and breach as opportunities for collective learning (Burgess et al. 2025). Such an approach equips leaders to neither retreat from complexity nor reduce it to oversimplified models, but to engage with it directly, by enabling self-organization and balancing top-down direction with bottom-up emergence (Joose and Teisman 2021; Uhl-Bien, Marion, and McKelvey 2007).

Micro level: enabling self-organizing collective agency

The concepts of the attractor landscape and adaptive space feed into a useful but under-socialized interpretation of the ST, as they focus on structural and systemic dynamics while potentially downplaying the role of agency and social interactions in shaping these dynamics. These systemic forces, including path dependencies, often undermine the ability to make broad individual decisions, even when clear evidence and an understanding of the necessary actions are present (Maibach et al. 2023). Although actions are undoubtedly shaped by the broader landscape, where attractors such as reliance on private cars, plastic-based packaging, and traditional heating systems create significant barriers to individual efforts such as combating climate change, agency and initiative remain crucial. Notably, Teerikangas (2021, 1–2) stated that ‘the question of sustainability agency can arguably be considered one, if not *the*, burning question of our times’. Sustainability agency is shaped by past routines and resource arrangements, oriented to the future by imagining alternatives, and enacted in the present by adjusting practices and negotiating goals within existing structures (Salovaara and Hagolani-Albov 2024).

Agency manifests through individuals’ capacity for self-organization, yet the systemic change emphasized in the ST depends on collective behavioural shifts that effectively challenge and transform deeply entrenched attractors (Day 2025, 21). Therefore, when analysing micro-level ST, it is essential to acknowledge the pivotal role of the collective nature of agency and to foster *self-organizing collective agency*, defined as the autonomous capacity of a specific group to engage in collective action (Pelenc, Bazile, and Ceruti 2015). Self-organization takes place when social systems exchange information, take action, and continuously adapt to others’ actions, in contrast to situations where a central authority imposes an overarching plan (Cilliers 1998; Nederhand, Bekkers, and Voorberg 2016; Teisman and Klijn 2008). Self-organization occurs when individuals and groups independently initiate

and direct actions based on their cognitive processes and choices, rather than merely responding to external environmental pressures (Comfort 1994). It can also arise when an entity or a government engages with such initiatives by withdrawing control, imposing restrictions, or attempting to steer self-organizing processes (Nederhand et al. 2019). For instance, a municipal government might facilitate self-organization by providing funding and networking opportunities for local renewable energy cooperatives, or, conversely, it might block such initiatives by imposing restrictive regulations and bureaucratic hurdles. It is also essential to recognize that self-organization does not occur in a vacuum but is deeply embedded in relational power dynamics and existing social inequalities (Walby 2007). While adaptive spaces at the meso-level promise interaction across boundaries, their generative potential may be unevenly distributed, because that is influenced by actors' positionality, access to resources, and the weight of their voice within the system. Those factors determine whose ideas are heard and whose are marginalized (D. J. Davis 2007) thus shaping the attractor landscape by reinforcing dominant trajectories and suppressing alternative pathways.

The connection between self-organization and information illuminates the significance of trust as a fundamental enabler. Trust is a relational concept necessary for collaborative activity (Baier 1986; Bentzen, Siverbo, and Winsvold 2025). Luhmann (1979, 23) states that, 'trust goes beyond the information it derives from the past and takes the risk of defining the future'. The same work highlighted the foundational role of trust and suggested that it must first be tested for a system to fully process information (Luhmann 1995, 112). Trust is commonly defined based on two key aspects: first, the trustor's willingness to embrace vulnerability, which reflects the reliance on the trustee; and second the trustor's optimistic expectations of the trustee's future actions (Fulmer and Gelfand 2012; Liu and Duarte 2025). For citizens, trust reflects their public confidence in the government's intention to serve the public interest (Mizrahi, Vigoda-Gadot, and Cohen 2021). Conversely, from the government's viewpoint, administrators' trust in citizens enhances the implementation of participatory initiatives (Vento 2024). Trust is particularly tested in situations involving significant uncertainty, where traditional structures and routines may falter (Bouckaert 2012). In such contexts, trust is a crucial in enabling adaptive responses and facilitating coordinated action, even when the available information is incomplete. In the context of the ST, openness and transparency strengthen public trust in institutions, in turn fostering societal participation in decision-making and empowering the public administration to engage with communities and mobilize collective action (Borrás et al. 2024; Voulvoulis et al. 2022). Further, Kuenkel (2019) and B. Davis, Alan Reid, and Rogers (2024) highlighted how trust acts as

a catalyst for collaborative dynamics, thereby enabling diverse actors to self-organize around shared goals and fostering collective agency.

This relational perspective can be further deepened by viewing collective agency as an emergent causal power. Building on Elder-Vass (2010), we understand collective agency as arising from, but not reducible to, social structures that themselves exert downward causal influence. These structures are sustained and reproduced through interaction, making it possible for individuals and groups to reshape them reflexively over time. That aligns with a relational ontology in which enabling conditions both shape and are reshaped by the actions of situated actors. Such a view emphasizes that agency is not merely constrained or enabled by external forces but also continuously co-constituted through social interaction. In other words, the relationship between the individual and the collective is mutually constitutive: individuals shape societal patterns and, in turn, are shaped by them (Mowles 2022). That assertion does not deny individuality but explains how individuality itself emerges in and through interaction.

This conceptual lens also provides a foundation for understanding community-based self-organization. Interactions between individuals generate emergent structures, which in turn influence and reshape those very interactions (i.e. downward causation) (Andersen et al. 2000; Sawyer 2005). Community-based self-organization may manifest, for example, as citizen-led initiatives aimed at solving local problems without direct governmental control (Edelenbos, van Meerkerk, and Schenk 2018). Such grassroots efforts emerge from the community's own needs and resources, supporting local ownership and reinforcing civic engagement. However, this does not occur in a vacuum but within the constraints of the attractor landscape.

Discussion

The issue of the sustainability transformation should not be framed as a traditional policy problem that requires solutions that follow diligent policy analysis (see Weimer and Aidan 2017). It is a challenge that defies straightforward definition and is certainly not amenable to solutions that garner unconditional support from all stakeholders. Accordingly, systemic policy design should be resistant to oversimplification. Drawing on Heylighen (1999), we posit that research should advocate *complexification*. Complexification is a strategy that involves creating the conditions and opportunities needed to disrupt harmful outcomes and escape the limiting cycles that flow from oversimplification (Joose and Teisman 2021). Such complexification responds to the ontological nature of the ST as an emergent phenomenon, one that arises through generative mechanisms situated within multilevel, recursive structures. Integrating CT into the design of policies can help navigate the multifaceted challenges that arise at the macro, meso, and

micro levels. For example, while self-organizing collective agency emerges from within a system, it actively shapes and influences the associated attractor landscape, reinforcing positive feedback mechanisms that either stabilize or disrupt existing institutional configurations.

This perspective indicates that the ST will not only be an outcome of systemic structures but also deeply intertwined with the agency of individuals and groups who navigate, resist, and reshape institutional logics. Considering that many decision-makers operate in institutional frameworks that incentivize short-term efficiency over long-term resilience (Z. Smith and Jacques 2022), sustainability policies should be designed to counteract systemic constraints. Policies should actively shape an institutional environment where sustainable choices become more attractive than unsustainable ones. This approach not only addresses systemic dynamics but also emphasizes the critical role of human agency in driving the ST. Integrating self-organizing collective agency into the analysis of sustainability approaches could unveil how grassroots initiatives, local innovations, and collaborative networks contribute to the establishment of attractors that support sustainable practices. Here, one attractor may represent unsustainable practices (e.g. inadequate implementation of environmental regulation), while another may represent sustainable practices (e.g. promotion of renewable energy use). Because actors implicated in maintaining unsustainable practices are sometimes also positioned as agents of change, it is essential that governance arrangements and incentive structures are designed to reshape the attractor landscape, thereby reducing the viability of unsustainable behaviours while enhancing the stability of sustainable alternatives. The identification and analysis of attractors could help policymakers design policies incorporating incentives and sanctions that create a sticky landscape for sustainable behaviours, making policy-takers (Howlett, Ramesh, and Capano 2020) less likely to revert to unsustainable practices. That environment becomes particularly important in the face of political and economic pressures favouring the status quo. Owing to the path dependency of unsustainable systems, the ST will remain an elusive goal unless policies actively dismantle structural barriers and mitigate the influence of entrenched interests.

Figure 1 depicts two critical junctures that facilitate system transitions or profound systemic transformations. B-tipping involves policy interventions that mandate change, whereas N-tipping emphasizes a system's intrinsic ability to adapt, with unforeseen shocks creating opportunities for sustainability. However, this heuristic representation does not clearly show the implications of these tipping points for systemic policy design. Importantly, the two tipping dynamics are not mutually exclusive. For instance, a government's decision to invest heavily in clean energy infrastructure (B-tipping) may, over time, enable or amplify spontaneous changes in market behaviour or consumer culture (N-tipping). That argumentation

reflects the idea that the ST does not follow a fixed trajectory but is continuously shaped and reshaped by the actions of individuals and collectives, often in ways that are not entirely foreseen or intended. Effective systemic policy design, therefore, should not aim to control tipping points, but rather to design enabling conditions that increase the likelihood of an ST, regardless of their origin.

Figure 2 presents a complexity-informed systemic policy design framework with the potential to advance the ST. *Imagining alternative future policy landscapes*, as proposed by Mulgan (2022), Sokolova (2023), and others, would help policymakers move beyond reactive governance by expanding their imaginative and institutional repertoires to enable the ST. This perspective resonates with the view that delivering the ST would require more than incremental adjustments, it would need the capacity to envision discontinuous shifts in societal trajectories. Such imaginative work is a generative resource for shaping enabling conditions under uncertainty and complexity. However, applying imagination is challenging, as inherent tensions (red arrow) exist between inertia factors (negative feedback) and pull factors (positive feedback). Inertia factors, which include historical dependencies, institutional resistance, and deeply embedded socioeconomic structures, can reinforce path dependencies that limit the scope of imaginative policymaking. Conversely, pull factors, such as regulatory pressures, market shifts, and societal demands for sustainability, drive change by creating windows for the imagination of solutions.

Nevertheless, the opening of such windows does not guarantee that imagined occurrences will be realized. As many studies have shown (e.g. Rogers 2003), *seeing* things differently does not automatically lead to *doing* things differently. Even when new ideas gain traction, their translation into practice is often hindered by uncertainty, conflicting interests, and entrenched routines. To explain why imagination often fails to materialize into occurrence, we draw on Elder-Vass's (2010, 4–5) conception of emergent entities that possess causal powers irreducible to individual actors. Imagination is not a static solution imposed from above but one dynamically shaped, reproduced, and transformed through collective agency. This dual nature, simultaneously guiding action and subject to change, highlights the importance of generative mechanisms that operate between system-level constraints and actor-level initiatives. From this perspective, the ST cannot be understood as solely agent-driven or structurally determined. It emerges from the ongoing interplay between enabling structures and situated action. To capture this interplay, our framework introduces *self-organizing collective agency within adaptive spaces*, which are transitional zones where novel ideas and practices can be explored and refined without being immediately constrained by dominant institutional logics. The capacity for such agency hinges on two generative mechanisms: cognitive and relational. *Cognitive*

mechanisms enable actors to envision and perceive novel possibilities in complex environments, while *relational mechanisms* foster the alignment and mobilization of diverse stakeholders. A central cognitive process is *sensemaking*, which involves interpreting ambiguous or uncertain conditions (Weick 1995) and envisioning alternative futures (Termeer and van den Brink 2012). In parallel, *sense-giving* operates as a relational mechanism (Cuevas Shaw 2021) through which actors seek to influence how others interpret and respond to sustainability challenges.

In our framework, sensemaking functions as an intermediary process (blue arrows) between seeing and doing differently. It involves envisioning and understanding the implications of the challenges of advancing sustainability, while fostering processes through which diverse perspectives can interact and potentially converge around actionable understandings. Sensemaking requires the integration of scientific knowledge with experiential and contextual understanding, which then enables adaptive responses to evolving issues. Sensemaking is shaped by differing perspectives, making competing interpretations of sustainability challenges more prevalent than consensus. Accordingly, there is a need for spaces of political action (Weimer and Aidan 2017) that empower bridging agents or brokers (Arena and Uhl-Bien 2017) to turn imaginative policymaking into pragmatic policy solutions.

While sensemaking enables actors to recognize and interpret sustainability challenges, perception alone is insufficient to catalyse transformation. Sokolova (2023) notes that we should not assume that only professionals or experts have the capacity to imagine alternative futures. Successful transformation relies on engaging a broad range of people in transparent and participatory processes. Therefore, our framework highlights a second generative mechanism: sense-giving, which involves the dissemination of narratives, frames, and policy discourses to mobilize action (Cuevas Shaw 2021; see also Polanyi 1967). More specifically,

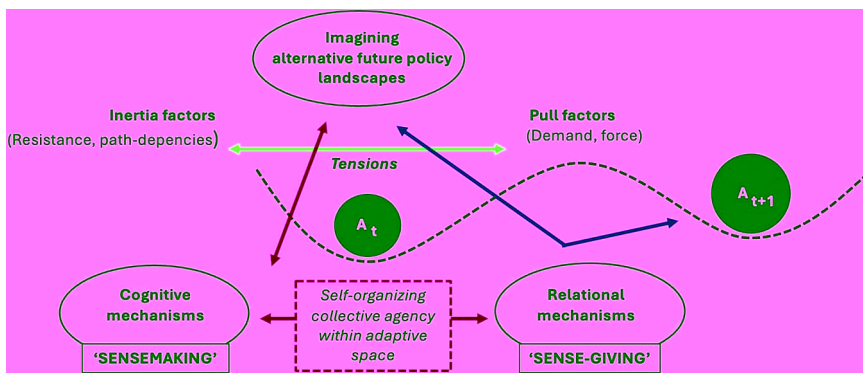


Figure 2. Systemic policy design for advancing the ST.

sense-giving is a communicative and performative process permitting actors to shape their perceptions, align their interests, and legitimize specific courses of action. Sense-giving functions as a counterpart to sensemaking in the framework, operating in a reciprocal and iterative manner. It enables the translation of complex sustainability issues into actionable policies, with stakeholders perceiving change as both necessary and viable. Effective sense-giving requires compelling narratives that harness attractor dynamics and foster commitment and collective agency to advance towards sustainability goals. Sense-giving plays an important role in overcoming inertia and institutional lock-in effects. Resistance to change is often rooted in uncertainty, vested interests, and cognitive dissonance. By framing the ST as in terms of opportunity, sense-giving can mitigate opposition and build momentum for transformative action.

As generative mechanisms, both sensemaking and sense-giving can be understood as enabling structured yet unpredictable transformations: they mediate between system-level constraints and actor-level initiatives, creating new properties, shared narratives, institutional repertoires, and action logics that did not previously exist. Imaginative policymaking acquires transformative potential only when it alters the conditions that enable sensemaking and sense-giving to recursively reshape collective understanding and action. In this sense, the framework visualizes an emergent process rather than a linear one, where causality is distributed and layered across domains and levels. These properties emerge from interactions but possess causal power in their own right, shaping subsequent decisions and action options.

Figure 2 illustrates the evolutionary, nonlinear trajectory of the ST, with phase transitions from At (current state) to $At + I$ (future state). This transformation is contingent on the dynamic interactions between imagining alternative future policy landscapes and generative mechanisms, which collectively facilitate the emergence of a stable yet evolving attractor landscape that aligns with sustainability imperatives. From the perspective of STs, the optimal attractor landscape at time At may not be appropriate at time $At + I$, necessitating continuous policy evaluations (green arrows). The transition from At to $At + I$ is not merely the cumulative result of deliberate interventions, but a novel outcome of interacting generative mechanisms. These mechanisms reorganize meaning, authority, and structure across levels. The new attractor landscape at $At + I$ is ontologically distinct, not just temporally new, but qualitatively different, possessing properties irreducible to the prior state. Accordingly, Figure 2 serves as a depiction of layered causality, where outcomes are shaped by recursive interdependencies rather than linear input-output logics. The iterative interplay between imaginative policymaking, sensemaking, and sense-giving ensures that systemic policy design for the ST remains adaptive and responsive to emergent challenges.

Conclusion

Previous research has highlighted that narrowly framing ST can constrain policy choices and hinder innovation (Blue 2015; Zeitfogel, Daw, and Collste 2024). To overcome these limitations, we propose a framework that captures a shift from system-supporting to system-challenging frames (Zeitfogel, Daw, and Collste 2024), which broadens the space for transformative action. Addressing ST thus requires not only deliberate policy formulation (Howlett, Ramesh, and Perl 2020) but also the capacity to navigate policy formation (Hill and Hupe 2022) processes across different levels of governance.

Applying CT to promote an ST generates three key managerial implications for decision-makers and public leaders. While an ST cannot be governed through rational planning alone, advancing it requires more than simply letting go. First, *adaptive governance* (see e.g. Juhola 2023; Nolte and Lindenmeier 2023) is needed to navigate the complexity of transformation. The term refers to the capacity of institutions and leadership structures to respond flexibly to emerging issues and shifting contexts. Rather than prescribing fixed policy solutions, adaptive governance focuses on establishing mechanisms or systems that can sense changes in the environment and adjust accordingly. Such governance builds on polycentric coordination (Morrison et al. 2023) and responsiveness to local knowledge and emergent phenomena (Soininen et al. 2025).

Here, generative mechanisms play a critical role: sensemaking enables continuous monitoring, interpretation, and learning from evolving conditions, while sense-giving supports the construction of narratives that mobilize support for course corrections. These mechanisms can be supported through institutional arrangements and experimental infrastructures. For example, adaptive governance can be supported at the local level through innovation labs, collaborative platforms, and micro-environments that foster co-creation, mutual learning, and iterative adjustment in response to changing conditions (Criado, Alcaide-Muñoz, and Liarte 2023). Such infrastructures function as platforms for joint sensemaking, generating context-specific knowledge through iterative experimentation, while also contributing to sense-giving by legitimizing experimental practices and constructing shared narratives that build political support and social licence for scaling successful innovations. When local experimentation is translated into broader strategic learning, these arrangements operate as intermediaries between grassroots initiatives and systemic policy shifts, thus activating generative mechanisms that bridge micro-level agency with macro-level transformation.

Second, breaking down silos and fostering collaboration across sectors, government, business, academia, and civil society is essential. Policymakers must engage with diverse stakeholders to build shared understanding, co-

create solutions, and mobilize collective action that advances the ST. That course of action will require building trust, ensuring clear communication channels, and aligning interests through mutually beneficial partnerships. Those practices are especially important when structural inequalities shape whose knowledge is recognized, who frames the problem, and who participates in devising solutions. In such contexts, leaders must simultaneously convene stakeholders and cement epistemic plurality by creating space for situated, context-sensitive deliberation. Ensuring these conditions often requires active *boundary spanning*, not merely assembling stakeholders, but facilitating interaction across institutional and cultural divides (Aldrich and Herker 1977; Nederhand, Van Der Steen, and Van Twist 2019). Successful boundary spanning entails negotiating meaning, translating between world-views, and creating environments that support adaptation. Sensemaking supports boundary spanning by helping actors interpret divergent framings and values, while sense-giving enables the alignment of actors through shared language, frames, and policy imaginaries. Without these generative mechanisms, boundary spanning risks becoming a merely procedural exercise, lacking the deeper cognitive and relational work necessary for an ST. Generative mechanisms thus provide the connective tissue for collective agency to emerge across institutional silos.

Third, the ST can be advanced through approaches that help illuminate dynamic interrelationships across different system levels. *Participatory Systems Mapping* (PSM) offers a complexity-consistent method for this task. It enables stakeholders to collaboratively map, visualize, and analyse complex systems to understand how different actors and components are interrelated, and how changes in one part affect the whole (Barbrook-Johnson and Penn 2021). Importantly, PSM supports both sensemaking, constructing shared understanding of evolving systems, and sense-giving, the dialogical development of shared interpretations and future-oriented narratives. By unveiling how stakeholders frame problems, responsibilities, and solutions, PSM helps identify gaps in participation and influence and facilitates engagement with diverging perspectives across the transformation process. The technique does not require consensus but supports the iterative adaptation essential for transformations that involve both institutional restructuring and shifts in how actors perceive their roles and relationships within a broader systemic whole.

We have engaged with three distinct levels and posited that this approach is essential to comprehend the complex policy design challenges associated with the ST. We assert that systemic policy design should prioritize the conditions that facilitate the ST. In our analysis, the term *systemic* pertains to these three levels. While we maintain our core argument, we must also acknowledge that a discerning reader might reasonably question whether our use of a three-level framework in the analysis risks oversimplifying the

inherent complexity of ST. Although we have argued that engaging with all these levels is essential for addressing ST, we recognize that this structural device could impose artificial boundaries on processes that are, in reality, fluid and recursive. Our intention was not to compartmentalize phenomena into discrete levels, yet the macro-meso-micro distinction might obscure more intertwined dynamics and emergent properties that transcend such levels. Indeed, the classification of a phenomenon as emergent may be contingent upon the observer's perspective and the analytical methodologies employed. In the terms of Rescher (2003, 220), our interest in the ST is influenced by the mechanisms through which we conduct our enquiries. From this standpoint, emergence is not solely an attribute of systems but also a manifestation of the epistemic frameworks through which complexity is understood.

While our analysis does touch upon interactions across levels, we recognize that these cross-level dynamics may require elaboration. To further unpack this complexity, it is necessary to look beyond structural levels and consider how actors within and across these domains construct meaning, interpret change, and influence outcomes. One promising avenue for future research lies in *paradox theory*, which focuses on dealing with tensions and contradictions. The goal is not to resolve tensions incontrovertibly but to harness them dynamically (W. Smith and Lewis 2011), and embrace complexity (Braathen 2016; Mowles 2022). A paradox theory perspective could clarify conflicting demands and the institutional logics of actors, and manage the resulting opposition (W. Smith and Tracey 2016; Vangen 2016). For example, applying paradox theory to adaptive space encourages finding solutions through *both-and* rather than *either-or* thinking. Such a perspective could support policymakers and practitioners in designing interventions that remain robust under contradictory pressures, for example, balancing short-term political demands with long-term sustainability commitments (Z. Smith and Jacques 2022). In this way, paradox theory complements CT by offering a mindset more attuned to governing through, rather than away from, systemic tensions. Similarly, a *relational perspective* could provide a valuable complementary lens to the macro-meso-micro framework by shifting attention from predefined levels to the continuously evolving relationships that constitute systems. Relational approaches emphasize that meanings, roles, and responsibilities are constructed through interaction and situated practices (Bartels and Turnbull 2019; West et al. 2024). That finding opens a window onto the epistemic and affective practices through which ST unfolds. A relational approach complements the complexity lens by helping to understand how actors come to see themselves as part of the transformation and capable of shaping its

direction. Ultimately, the question is how transformation is lived, enacted, and embedded in practice.

Generative artificial intelligence

The language editing of this manuscript has been assisted by ChatGPT AI, supporting the authors in expressing content in a non-native language. The authors remain accountable for the originality, validity, and integrity of the content of their submission.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The project has received funding from the Strategic Research Council at the Academy of Finland under [Grant 359018].

Notes on contributors

Dr. Harri Jalonen is a Professor of Social and Health Management at the University of Vaasa, Finland. His research interests include complex governance systems, knowledge and ignorance management, value co-creation, and public service ecosystems. He has authored approximately 100 scientific articles and over 100 publications designed for a broader audience.

Dr. Petri Uusikylä is a Research Director at the University of Vaasa, Finland. His research interests include performance management, complex governance systems, social network analysis and systems thinking. He has authored more than 150 scientific articles, evaluation reports and publications designed for a broader audience.

ORCID

Harri Jalonen  <http://orcid.org/0000-0002-6941-7969>

References

Aarikka-Stenros, Johanna, Ritala Paavo, and D. W. Thomas. Llewellyn. 2021. "Circular Economy Ecosystems: A Typology, Definitions, and Implications." In *Research Handbook of Sustainability Agency*, edited by Satu Teerikangas, Tiina Onkila, Katariina Koistinen, and Marileena Mäkelä, 260–276. Cheltenham: Edward Elgar Publishing.

- Aldrich, Howard, and Diane Herker. 1977. "Boundary Spanning Roles and Organization Structure." *Academy of Management Review* 2 (2): 217–230. <https://doi.org/10.5465/amr.1977.4409044>.
- Alexiou, Katerina. 2011. "Understanding Design as a Multiagent Coordination Process: Distribution, Complexity, and Emergence." *Environment & Planning B: Planning & Design* 38 (2): 248–266. <https://doi.org/10.1068/b35099>.
- Andersen, Peter, B. Claus Emmeche, O. Finnemann Niels, and V. Christiansen Peter (eds.) 2000. *Downward Causation*. Aarhus: University of Aarhus Press.
- Ang, Yuen Yuen. 2023. "Adaptive Political Economy – Toward a New Paradigm." *World Politics* 75 (5): 1–18. <https://doi.org/10.2139/ssrn.4813107>.
- Archer, Margaret S. 1995. *Realist Social Theory: The Morphogenetic Approach*. Cambridge: Cambridge University Press.
- Arena, Michael, Rob Cross, Jonathan Sims, and Mary Uhl-Bien. 2017. "How to Catalyze Innovation in Your Organization." *MIT Sloan Management Review* 58 (4): 38–47. <https://doi.org/10.7551/mitpress/11858.003.0004>.
- Ashwin, Peter, Sebastian Wiczorek, Renato Vitolo, and Peter Cox. 2012. "Tipping Points in Open Systems: Bifurcation, Noise-Induced and Rate-Dependent Examples in the Climate System." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 370 (1962): 1166–1184. <https://doi.org/10.1098/rsta.2011.0306>.
- Avelino, Flor 2017. "Power in Sustainability Transitions: Analysing Power and (Dis) Empowerment in Transformative Change Towards Sustainability." *Environmental Policy Governance* 27 (6): 505–520. <https://doi.org/10.1002/eet.1777>.
- Baier, Anette. 1986. "Trust and Antitrust." *Ethics* 96 (2): 231–260. <https://doi.org/10.1086/292745>.
- Barbrook-Johnson, Pete, and Alexandra Penn. 2021. "Participatory Systems Mapping for Complex Energy Policy Evaluation." *Evaluation* 27 (1): 57–79. <https://doi.org/10.1177/1356389020976153>.
- Bartels, Koe, and Nick Turnbull. 2019. "Relational Public Administration: A Synthesis and Heuristic Classification of Relational Approaches." *Public Management Review* 22 (9): 1324–1346. <https://doi.org/10.1080/14719037.2019.1632921>.
- Battaglio, R. Paul, and J. L. Hall. 2019. "Ordo Ab Chao? Complexity and Its Implications." *Public Administration Review* 79 (6): 807–809. <https://doi.org/10.1111/puar.13128>.
- Bentzen, Tina Øllgaard. 2023. "The Tripod of Trust: A Multilevel Approach to Trust-Based Leadership in Public Organizations." *Public Management Review* 25 (12): 2255–2277. <https://doi.org/10.1080/14719037.2022.2132279>.
- Bentzen, Tina Øllgaard, Sven Siverbo, and Marte Winsvold. 2025. "Keeping the Magic Alive: The Multiple Functions of Magic Concepts." *Public Administration Review* 85 (2): 280–295. <https://doi.org/10.1111/puar.13814>.
- Bhatia, Riina, Matti Pihlajamaa, Kirsi Hyytinen, and Anni Jäntti. 2025. "Capabilities for Transformative Sustainability Management in Cities." *Public Management Review* 27 (4): 1179–1203. <https://doi.org/10.1080/14719037.2024.2394955>.
- Biermann, F., and R. E. Kim, Eds. 2020. *Architectures of Earth System Governance: Institutional Complexity and Structural Transformation*. Cambridge: Cambridge University Press.
- Blokkamp, Emma. 2021. "Systemic Design Practice for Participatory Policymaking." *Policy Design and Practice* 5 (1): 12–31. <https://doi.org/10.1080/25741292.2021.1887576>.

- Blue, Gwendolyn. 2015. "Public Deliberation With Climate Change: Opening Up or Closing Down Policy Options?" *Review of European, Comparative & International Environmental Law* 24 (2): 152–159. <https://doi.org/10.1111/reel.12122>.
- Borrás, Susana, Stine Haakonsson, Christian Hendriksen, Francesco Gerli, René Taudal Poulsen, Trine Pallesen, Lucas Somavilla Croxatto, Susanna Kugelberg, and Henrik Larsen. 2024. "The Transformative Capacity of Public Sector Organisations in Sustainability Transitions." *Environmental Innovation and Societal Transitions* 53:100904. <https://doi.org/10.1016/j.eist.2024.100904>.
- Bouckaert, Geert. 2012. "Trust and Public Administration." *Administration* 60 (1): 91–115.
- Braams, Rik, J. H. Wesseling, A. J. Meijer, and M. P. Hekkert. 2024. "Institutional Conditions for Governments Working on Sustainability Transitions." *Science & Public Policy* 51 (5): 836–849. <https://doi.org/10.1093/scipol/scae028>.
- Braathen, Petter. 2016. "Paradox in Organizations Seen as Social Complex Systems." *Emergence: Complexity & Organization* 18 (2): 1–25. <https://doi.org/10.17357/e5b6cf66b725a23565b6c822a7d2670b>.
- Brix, Jacob. 2019. "'Ambidexterity and Organizational Learning: Revisiting and Reconnecting the Literatures.'" *Learning Organization* 26 (4): 337–351. <https://doi.org/10.1108/TLO-02-2019-0034>.
- Burgess, Nicola, Graeme Currie, Tina Kiefer, John Richmond, and Julian Hartley. 2025. "Building and Maintaining Trust "Even When Things Aren't Going Well": Meta-Regulation Through an Explicit Psychological Contract." *Public Administration Review*, Early View. <https://doi.org/10.1111/puar.13956>.
- Burt, Ronald S. 2005. *Brokerage and Closure: An Introduction to Social Capital*. Oxford: Oxford University Press.
- Butler, Michael J. R., and P. M. Allen. 2008. "Understanding Policy Implementation Processes as Self-Organizing Systems." *Public Management Review* 10 (3): 421–440. <https://doi.org/10.1080/14719030802002923>.
- Byrne, David. 2001. "What is Complexity Science? Thinking as a Realist About Measurement and Cities and Arguing for Natural History." *Emergence: Complexity & Organisation* 3 (1): 61–76. https://doi.org/10.1207/S15327000EM0301_05.
- Byrne, David, and Gill Callaghan. 2022. *Complexity Theory and the Social Sciences. The State of the Art*. London: Routledge.
- Cairney, Paul. 2012. "'Complexity Theory in Political Science and Public Policy.'" *Political Studies Review* 10 (3): 346–358. <https://doi.org/10.1111/j.1478-9302.2012.00270.x>.
- Callens, Chesney. 2024. "Achieving Collaborative Innovation by Controlling or Leveraging Network Complexities through Complexity Leadership." *Public Administration* 102 (3): 936–952. <https://doi.org/10.1111/padm.12958>.
- Capano, Giliberto, and Michael Howlett. 2021. "Causal Logics and Mechanisms in Policy Design: How and Why Adopting a Mechanistic Perspective Can Improve Policy Design." *Public Policy and Administration* 36 (2): 141–162. <https://doi.org/10.1177/0952076719827068>.
- Castellani, Brian, and Lasse Gerrits. 2024. *The Atlas of Social Complexity*. Cheltenham: Edward Elgar Publishing.
- Castelnovo, Walter, and Maddalena Sorrentino. 2024. "Public Sector Reform Trajectories: A Complexity-Embracing Perspective." *Public Money and Management* 44 (2): 165–173. <https://doi.org/10.1080/09540962.2022.2117894>.

- Chaffin, Brian C., Ahjond S. Garmestani, Lance H. Gunderson, Melinda Harm Benson, David G. Angeler, Craig Arnold, Barbara Cosens Cosens, R. K. Robin Kundis Craig, J. B. Ruhl, and C. R. Allen. 2016. "Transformative Environmental Governance." *Annual Review of Environment and Resources* 41 (1): 399–423. <https://doi.org/10.1146/annurev-environ-110615-085817>.
- Cilliers, Paul. 1998. *Complexity and Postmodernism Understanding Complex Systems*. London: Routledge.
- Coleman, James. 1990. *The Foundations of Social Theory*. Cambridge, MA: Harvard University Press.
- Coleman, Peter T., Robin R. Vallacher, Andrzej Nowak, and Lan Bui-Wrzosinska. 2007. "Intractable Conflict as an Attractor: A Dynamical Systems Approach to Conflict Escalation and Intractability." *The American Behavioral Scientist* 50 (11): 1454–1475. <https://doi.org/10.1177/0002764207302463>.
- Comfort, Louise K. 1994. "Self-Organization in Complex Systems." *Journal of Public Administration Research & Theory* 4 (3): 393–410. <https://doi.org/10.1093/oxfordjournals.jpart.a037220>.
- Criado, J. Ignacio, Laura Alcaide-Muñoz, and Irene Liarte. 2023. "Two Decades of Public Sector Innovation: Building an Analytical Framework from a Systematic Literature Review of Types, Strategies, Conditions, and Results." *Public Management Review* 27 (3): 623–652. <https://doi.org/10.1080/14719037.2023.2254310>.
- Cuevas Shaw, Lisa. 2021. "From Sensemaking to Sensegiving: A Discourse Analysis of the Scholarly Communications Community's Public Response to the Global Pandemic." *Learned Publishing* 34 (1): 6–16. <https://doi.org/10.1002/leap.1350>.
- Davis, Belinda, J. Alan Reid, and Briony Rogers. 2024. "The 'Butterfly Effect': Identifying Pathways for Sustainability Transformation Through Social Processes of Disaster Resilience." *Global Sustainability* 7:e49. <https://doi.org/10.1017/sus.2024.44>.
- Davis, Dannielle Joy. 2007. "Complexity and Chaos Theories as Metaphoric Lenses: An Alternative in Exploring the Voices of Marginalized Populations." *Essays in Education* 22 (1): 8.
- Day, Adam. 2025. *The Forever Crisis. Adaptive Global Governance for an Era of Accelerating Complexity*. London: Routledge.
- Edelenbos, Jurian, Ingmar F. van Meerkerk, and Todd Schenk. 2018. "The Evolution of Community Self-Organization in Interaction with Government Institutions: Cross-Case Insights from Three Countries." *American Review of Public Administration* 48 (1): 52–66. <https://doi.org/10.1177/0275074016651142>.
- Edmondson, Amy C. 1999. "Psychological Safety and Learning Behavior in Work Teams." *Administrative Science Quarterly* 44 (4): 350–383. <https://doi.org/10.2307/266999>.
- Elder-Vass, Dave. 2010. *The Causal Power of Social Structures: Emergence, Structure and Agency*. New York, NY: Cambridge University Press.
- Elder-Vass, Dave, and Jamie Morgan. 2022. "'Materially Social' Critical Realism: An Interview With Dave Elder-Vass." *Journal of Critical Realism* 21 (2): 211–246. <https://doi.org/10.1080/14767430.2022.2028233>.
- Eppel, Elizabeth A. 2017. "Complexity Thinking in Public Administration's Theories-in-Use." *Public Management Review* 19 (6): 845–861. <https://doi.org/10.1080/14719037.2016.1235721>.

- Eppel, Elizabeth A., and Mary L. Rhodes. 2018. "Complexity Theory and Public Management: A 'Becoming' Field." *Public Management Review* 20 (7): 949–959. <https://doi.org/10.1080/14719037.2017.1364414>.
- Eva, Nathan, Joshua L. Howard, Robert C. Liden, Alexandre J. S. Morin, and Gary Schwarz. 2025. "An Inconvenient Truth: A Comprehensive Examination of the Added Value (Or Lack Thereof) of Leadership Measures." *Journal of Management Studies*. <https://doi.org/10.1111/joms.13156>.
- Feng, Jiun-Jiun. 2014. "Nested Open Systems: An Important Concept for Applying Ecological Footprint Analysis to Sustainable Development Assessment." *Ecological Economics* 106:105–111. <https://doi.org/10.1016/j.ecolecon.2014.07.015>.
- Fressoz, Jean-Pabstiste. 2024. *More and More and More – An All-Consuming History of Energy*. London: Allen Lane.
- Friedland, Roger, and Robert R. Alford. 1991. "Bringing Society Back In: Symbols, Practices, and Institutional Contradictions." In *The New Institutionalism in Organizational Analysis*, edited by Walter Powell and J. DiMaggio Paul, 232–266. Chicago, IL: University of Chicago Press.
- Fuchs, Christian. 2003. "Structuration Theory and Self-Organization." *Systemic Practice and Action Research* 16 (2): 133–167. <https://doi.org/10.1023/A:1022889627100>.
- Fulmer, C. Ashley, and M. J. Gelfand. 2012. "At What Level (and in Whom) We Trust: Trust Across Multiple Organizational Levels." *Journal of Management* 38 (4): 1167–1230. <https://doi.org/10.1177/0149206312439327>.
- Gilbride, Neil M. 2025. "The Challenges of Teaching Complexity Sciences to Novice Learners in Public Administration." *Teaching Public Administration* 43 (2): 143–156. <https://doi.org/10.1177/01447394251360758>.
- Gilson, Lucy, and C. B. Goldberg. 2015. "Editors' Comment: So, What Is a Conceptual Paper?" *Group & Organization Management* 40 (2): 127–130. <https://doi.org/10.1177/1059601115576425>.
- Giovannoni, Elena, and Fabietti, Giacomo. 2013. "What Is Sustainability? A Review of the Concept and Its Applications." In *Integrated Reporting*, edited by Cristiano Busco, Mark Frigo, Angelo Riccaboni, and Paolo Quattrone, 21–40. Cham: Springer. https://doi.org/10.1007/978-3-319-02168-3_2.
- Greenwood, Royston, Mia Raynard, Farah Kodeih, E. R. Micelotta, and Michael Lounsbury. 2011. "Institutional Complexity and Organizational Responses." *Academy of Management Annals* 5 (1): 317–371. <https://doi.org/10.1080/19416520.2011.590299>.
- Greve, Jens. 2012. "Emergence in Sociology: A Critique of Nonreductive Individualism." *Philosophy of the Social Sciences* 42 (2): 188–223. <https://doi.org/10.1177/0048393110381770>.
- Haddad, Carolina, V. Valentina Nakić, Anna Bergek, and Hans Hellsmark. 2022. "Transformative Innovation Policy: A Systematic Review." *Environmental Innovation and Societal Transitions* 43:14–40. <https://doi.org/10.1016/j.eist.2022.03.002>.
- Hanberry, Brice B. 2022. "Global Population Densities, Climate Change, and the Maximum Monthly Temperature Threshold as a Potential Tipping Point for High Urban Densities." *Ecological Indicators* 135:108512. <https://doi.org/10.1016/j.ecoind.2021.108512>.
- Harding, Richard, Claire Nauwelaers, and Karel Haegeman. 2024. *Transformative Innovation for Climate Change Adaptation – Mapping-Based Framework for*

- Territories*. Luxembourg: Publications Office of the European Union. <https://doi.org/10.2760/319559>.
- Hatt, Ken. 2013. "Social Attractors: A Proposal to Enhance 'Resilience Thinking' About the Social." *Society & Natural Resources* 26 (1): 30–43. <https://doi.org/10.1080/08941920.2012.695859>.
- Haynes, Philip. 2008. "Complexity Theory and Evaluation in Public Management: A Qualitative Systems Approach." *Public Management Review* 10 (3): 401–419. <https://doi.org/10.1080/14719030802002766>.
- Heino, Matti T. J., Daniel Proverbio, Gwen Marchand, Kenneth Resnicow, and Nelli Hankonen. 2023. "Attractor Landscapes: A Unifying Conceptual Model for Understanding Behaviour Change Across Scales of Observation." *Health Psychology Review* 17 (4): 655–672. <https://doi.org/10.1080/17437199.2022.2146598>.
- Herrfahrdt-Pähle, Elke, Maja Schlüter, Per Olsson, Carl Folke, Stefan Gelcich, and Claudia Pahl-Wostl. 2020. "Sustainability Transformations: Socio-Political Shocks as Opportunities for Governance Transitions." *Global Environmental Change* 63:102097. <https://doi.org/10.1016/j.gloenvcha.2020.102097>.
- Heylighen, Francis. 1999. "The Growth of Structural and Functional Complexity During Evolution." In *The Evolution of Complexity*, edited by Francis Heylighen, Johan Bollen, and Alexander Riegler, 17–44. Dordrecht: Kluwer Academic.
- Hill, Michael, and Peter Hupe. 2022. *Implementing Public Policy*. London: Sage.
- Holling, Crawford S. 2001. "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4 (5): 390–405. <https://doi.org/10.1007/s10021-001-0101-5>.
- Hoppe, Thomas. 2021. "Local Governments Using Their Agency in Sustainable Transitions." In *Research Handbook of Sustainability Agency*, edited by In Teerikangas, Tiina Onkila Satu, Katariina Koistinen, and Marileena Mäkelä, 350–365. Cheltenham: Edward Elgar Publishing.
- Houtgraaf, Glenn. 2022. "Public Sector Creativity: Triggers, Practices and Ideas for Public Sector Innovations. A Longitudinal Digital Diary Study." *Public Management Review* 25 (8): 1610–1631. <https://doi.org/10.1080/14719037.2022.2037015>.
- Howlett, Michael, and Raul P. Lejano. 2013. "Tales from the Crypt: The Rise and Fall (And Rebirth?) of Policy Design." *Administration and Society* 45 (3): 357–381. <https://doi.org/10.1177/0095399712459725>.
- Howlett, Michael, M. Ramesh, and Giliperto Capano. 2020. "Policy-Makers, Policy-Takers and Policy Tools: Dealing with Behavioural Issues in Policy Design." *Journal of Comparative Policy Analysis: Research and Practice* 22 (6): 487–497. <https://doi.org/10.1080/13876988.2020.1774367>.
- Howlett, Michael, M. Ramesh, and Anthony Perl. 2020. *Studying Public Policy. Principles and Processes*. Oxford: Oxford University Press.
- Innerarity, Daniel. 2025. *A Theory of Complex Democracy: Governing in the Twenty-First Century*. London: Bloomsbury Publishing.
- International Energy Agency. 2021. *Net Zero by 2050 – A Roadmap for the Global Energy Sector*. https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroBy2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.
- IPCC. 2023. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change IPCC*. Geneva: IPCC. <https://doi.org/10.59327/IPCC/AR6-9789291691647>.

- Ison, Ray, and Ed Straw. 2020. *The Hidden Power of Systems Thinking. Governance in a Climate Emergency*. London: Routledge.
- Jalonen, Harri. 2025. "A Complexity Theory Perspective on Politico-Administrative Systems: Insights from a Systematic Literature Review." *International Public Management Journal* 28 (1): 1–21. <https://doi.org/10.1080/10967494.2024.2333382>.
- Janssen, Marco, J. M. Anderies, and B. H. Walker. 2004. "Robust Strategies for Managing Rangelands with Multiple Stable Attractors." *Journal of Environmental Economics & Management* 47 (1): 140–162. [https://doi.org/10.1016/S0095-0696\(03\)00069-X](https://doi.org/10.1016/S0095-0696(03)00069-X).
- Jepperson, Ronald, and J. W. Meyer. 2011. "Multiple Levels of Analysis and the Limitations of Methodological Individualisms." *Sociological Theory* 29 (1): 54–73. <https://doi.org/10.1111/j.1467-9558.2010.01387.x>.
- Jessop, Bob. 2005. "Critical Realism and the Strategic-Relational Approach." *New Formations: A Journal of Culture, Theory, and Politics* 56:40–53.
- Joose, Hans, and Geer Teisman. 2021. "Employing Complexity: Complexification Management for Locked Issues." *Public Management Review* 23 (6): 843–864. <https://doi.org/10.1080/14719037.2019.1708435>.
- Juhola, Sirkka. 2023. *Handbook on Adaptive Governance Elgar Handbooks in Energy, the Environment and Climate Change*. Cheltenham: Edward Elgar Publishing. <https://doi.org/10.4337/9781800888241>.
- Karimo, Aasa, P. M. Wagner, Ana Delicado, James Goodman, Antti Gronow, Myanna Lahsen, Tze-Luen Lin, et al. 2023. "Shared Positions on Divisive Beliefs Explain Interorganizational Collaboration: Evidence from Climate Change Policy Subsystems in 11 Countries." *Journal of Public Administration Research & Theory* 33 (3): 421–433. <https://doi.org/10.1093/jopart/muac031>.
- Keiff, Sébastien, and D. David Talbot. 2025. "Between Science, Authority, and Responsibility: Exploring Institutional Logics to Rethink Climate Governance." *Environmental Policy & Governance* 35 (1): 64–78. <https://doi.org/10.1002/eet.2126>.
- Keller, Margit, Marlyne Sahakian, and L. F. Francis Hirt. 2022. "Connecting the Multi-Level-Perspective and Social Practice Approach for Sustainable Transitions." *Environmental Innovation and Societal Transitions* 44:14–28. <https://doi.org/10.1016/j.eist.2022.05.004>.
- Kiel, L. D. 1993. "Nonlinear Dynamical Analysis: Assessing Systems Concepts in a Government Agency." *Public Administration Review* 53 (2): 143–153. <https://doi.org/10.2307/976707>.
- Kuenkel, Petra. 2019. *Stewarding Sustainability Transformations. An Emerging Theory and Practice of SDG Implementation*. Cham: Springer. https://doi.org/10.1007/978-3-030-03691-1_4.
- Lenton, Timothy M, Scarlett Benson, Talia Smith, Theodora Ewer, Victor Lanel, Elizabeth Petykowski, Thomas W. R. Powell, Jesse F. Abrams, Fenna Blomsma, and Simon Sharpe. 2022. "Operationalising Positive Tipping Points Towards Global Sustainability." *Global Sustainability* 5:e1. <https://doi.org/10.1017/sus.2021.30>.
- Lichtenstein, Benyamin B. 2014. *Generative Emergence: A New Discipline of Organizational, Entrepreneurial, and Social Innovation*. Oxford: Oxford University Press.
- Liu, Yifan, and Henrique Duarte. 2025. "Repairing Public Trust Through Communication in Health Crises: A Systematic Review of the Literature." *Public*

- Management Review* 27 (5): 1292–1312. <https://doi.org/10.1080/14719037.2023.2284224>.
- Luhmann, Niklas. 1979. *Trust and Power*. Chichester: John Wiley & Sons.
- Luhmann, Niklas. 1995. *Social Systems*. Stanford, CA: Stanford University Press.
- Maibach, Edward W., Sri Saahitya Uppalapati, Margaret Orr, and Jagadish Thaker. 2023. “Harnessing the Power of Communication and Behavior Science to Enhance Society’s Response to Climate Change.” *Annual Review of Earth and Planetary Sciences* 51 (1): 53–77. <https://doi.org/10.1146/annurev-earth-031621-114417>.
- March, James G. 1991. “Exploration and Exploitation in Organizational Learning.” *Organization Science* 2 (1): 71–87. <https://doi.org/10.1287/orsc.2.1.71>.
- Meckling, Jonas, and Jonas Nahm. 2019. “The Politics of Technology Bans: Industrial Policy Competition and Green Goals for the Auto Industry.” *Energy Policy* 126:470–479. <https://doi.org/10.1016/j.enpol.2018.11.031>.
- Mizrahi, Shlomo, Eran Vigoda-Gadot, and Nissim Cohen. 2021. “Drivers of Trust in Emergency Organizations Networks: The Role of Readiness, Threat Perceptions and Participation in Decision Making.” *Public Management Review* 23 (2): 233–253. <https://doi.org/10.1080/14719037.2019.1674367>.
- Morçöl, Göktuğ. 2023. *Complex Governance Networks Foundational Concepts and Practical Implications*. New York, NY: Routledge.
- Mori, Koichiro, and Aris Christodoulou. 2012. “Review of Sustainability Indices and Indicators: Towards a New City Sustainability.” *Environmental Impact Assessment Review* 32 (1): 94–106. <https://doi.org/10.1016/j.eiar.2011.06.001>.
- Morrison, Tiffany H., Örjan Bodin, Graeme S. Cumming, Mark Lubell, Ralf Seppelt, Tim Seppelt, and Christopher M. Weible. 2023. “Building Blocks of Polycentric Governance.” *Policy Studies Journal* 51 (3): 475–499. <https://doi.org/10.1111/psj.12492>.
- Mosneaga, Ana. 2022. “Unsustainable Development, Disasters and Displacement: Revisiting the Governance Challenge.” *International Journal of Disaster Risk Reduction* 79:103172. <https://doi.org/10.1016/j.ijdrr.2022.103172>.
- Mowles, Chris. 2022. *Complexity. A Key Idea for Business and Society*. London: Routledge.
- Mukherjee, Ishana, M. K. Coban, and A. S. Bali. 2021. “Policy Capacities and Effective Policy Design: A Review.” *Policy Sciences* 54 (2): 243–268. <https://doi.org/10.1007/s11077-021-09420-8>.
- Mulgan, Geoff. 2022. *Another World Is Possible: How to Reignite Social and Political Imagination*. London: Hurst & Company.
- Nederhand, José, Victor Bekkers, and William Voorberg. 2016. “Self-Organization and the Role of Government: How and Why Does Self-Organization Evolve in the Shadow of Hierarchy?” *Public Management Review* 18 (7): 1063–1084. <https://doi.org/10.1080/14719037.2015.1066417>.
- Nederhand, José, Erik-Hans Klijn, Martijn van der Steen, and Mark van Twist. 2019. “The Governance of Self-Organization: Which Governance Strategy Do Policy Officials and Citizens Prefer?” *Policy Sciences* 52 (2): 233–253. <https://doi.org/10.1007/s11077-018-9342-4>.
- Nederhand, José, Martijn Van Der Steen, and Mark Van Twist. 2019. “Boundary-Spanning Strategies for Aligning Institutional Logics: A Typology.” *Local Government Studies* 45 (2): 219–240. <https://doi.org/10.1080/03003930.2018.1546172>.
- Nolte, Isabella M., and Jörg Lindenmeier. 2023. “Creeping Crises and Public Administration: A Time for Adaptive Governance Strategies and Cross-Sectoral

- Collaboration?" *Public Management Review* 26 (11): 3104–3125. <https://doi.org/10.1080/14719037.2023.2200459>.
- Osborne, Stephen, M. Madeline Powell, Tui Cui, and Kirsty Strokosch. 2022. "Value Creation in the Public Service Ecosystem: An Integrative Framework." *Public Administration Review* 82 (4): 634–645. <https://doi.org/10.1111/puar.13474>.
- Paananen, Soili, A. Puustinen, H. Raisio, and Harri Jalonen. 2022. "Embracing Dynamic Tensions: Peacekeeping as a Balancing Act of Complexity." *Public Administration Review* 82 (6): 1168–1178. <https://doi.org/10.1111/puar.13535>.
- Pelenc, Jérôme, Didier Bazile, and Cristian Ceruti. 2015. "Collective Capability and Collective Agency for Sustainability: A Case Study." *Ecological Economics* 118:226–239. <https://doi.org/10.1016/j.ecolecon.2015.07.001>.
- Pickering, Jonathan, Thomas Hickmann, Karin Bäckstrand, Agna Kalfagianni, Michael Bloomfield, Ayşem Mert, Hedda Ransan-Cooper, and A. Y. Lo. 2022. "Democratising Sustainability Transformations: Assessing the Transformative Potential of Democratic Practices in Environmental Governance." *Earth System Governance* 11:100131. <https://doi.org/10.1016/j.esg.2021.100131>.
- Polanyi, Michael. 1967. "Sense-Giving and Sense-Reading." *Philosophy* 42 (162): 301–325. <https://doi.org/10.1017/S0031819100001509>.
- Portney, Kent E. 2015. *Sustainability*. Cambridge, MA: MIT Press.
- Preiser, Rika. 2019. "Identifying General Trends and Patterns in Complex Systems Research: An Overview of Theoretical and Practical Implications." *Systems Research & Behavioral Science* 36 (5): 706–714. <https://doi.org/10.1002/sres.2619>.
- Radtke, Jörg. 2025. "Understanding the Complexity of Governing Energy Transitions: Introducing an Integrated Approach of Policy and Transition Perspectives." *Environmental Policy & Governance* 35 (4): 595–614. <https://doi.org/10.1002/eet.2158>.
- Rajala, Tomi, and Harri Jalonen. 2025. "Beyond Simplification in Public Sector Accountability: Contradictions Between Principal-Agent and Complexity Theories." *Public Administration Review*. Early view. <https://doi.org/10.1111/puar.13941>.
- Rava, Nenad. 2021. "Systems Design Approach to Public Policy." In *Handbook of Systems Sciences*, edited by Gary Metcalf, S. Kyoichii Kijima, and Hiroshi Deguchi, 719–733. Singapore: Springer. https://doi.org/10.1007/978-981-15-0720-5_52.
- Rescher, Nicholas. 2003. *Epistemology: An Introduction to the Theory of Knowledge*. Albany, NY: State University of New York Press.
- Rhodes, Mary, L. Joanne Murphy, Jenny Muir, and John Murray. 2011. *Public Management and Complexity Theory. Richer Decision-Making in Public Service*. London: Routledge.
- Rhodes, Mary L., and Conor Dowling. 2018. "What Insights Do Fitness Landscape Models Provide for Theory and Practice in Public Administration?" *Public Management Review* 20 (7): 997–1012. <https://doi.org/10.1080/14719037.2017.1364412>.
- Richardson, Kurt A. 2008. "Managing Complex Organizations: Complexity Thinking and the Science and Art of Management." *Emergence: Complexity & Organization* 20 (2): 13–26.
- Rogers, Everett. 2003. *Diffusion of Innovations*. New York, NY: Free Press.
- Rogge, Karoline S., and Kristin Reichardt. 2016. "Policy Mixes for Sustainability Transitions: An Extended Concept and Framework for Analysis." *Research Policy* 45 (8): 1620–1635. <https://doi.org/10.1016/j.respol.2016.04.004>.

- Salovaara, Janne J., and S. E. Hagolani-Albov. 2024. "Sustainability Agency in Unsustainable Structures: Rhetoric of a Capable Transformative Individual." *Discover Sustainability* 5 (1): 138. <https://doi.org/10.1007/s43621-024-00341-z>.
- Sawyer, R. Keith. 2005. *Social Emergence. Societies as Complex Systems*. Cambridge: Cambridge University Press.
- Scoones, I., A. Stirling, D. Abrol, J. Atela, L. Charli-Joseph, H. Eakin, A. Ely, et al. 2020. "Transformations to Sustainability: Combining Structural, Systemic and Enabling Approaches." *Current Opinion in Environmental Sustainability* 42:65–75. <https://doi.org/10.1016/j.cosust.2019.12.004>.
- Scott, Amanda, Geoff Woolcott, Robyn Keast, and Daniel Chamberlain. 2018. "Sustainability of Collaborative Networks in Higher Education Research Projects: Why Complexity? Why Now?" *Public Management Review* 20 (7): 1068–1687. <https://doi.org/10.1080/14719037.2017.1364410>.
- Sears, Nathan A. 2021. "International Politics in the Age of Existential Threats." *Journal of Global Security Studies* 6 (3): 1–23. <https://doi.org/10.1093/jogss/ogaa027>.
- Sen, Souvik, and Sourav Ganguly. 2017. "Opportunities, Barriers and Issues with Renewable Energy Development: A Discussion." *Renewable and Sustainable Energy Reviews* 69:1170–1181. <https://doi.org/10.1016/j.rser.2016.09.137>.
- Sewerin, Sebastian, Benjamin Cashore, and Michael Howlett. 2022. "New Pathways to Paradigm Change in Public Policy: Combining Insights from Policy Design, Mix and Feedback." *Policy and Politics* 50 (3): 442–459. <https://doi.org/10.1332/030557321X16528864819376>.
- Sitra. 2016. "Leading the Cycle – Finnish Road Map to a Circular Economy 2016–2025." *Sitra Studies* 21, Helsinki. <https://circulareconomy.europa.eu/platform/sites/default/files/selvityksia121.pdf>.
- Skinner, Rob M. 2017. "Water Policy in a Time of Climate Change: Coping with Complexity." *Public Administration Review* 77 (1): 13–16. <https://doi.org/10.1111/puar.12669>.
- Smith, Wendy, and M. W. Lewis. 2011. "Toward a Theory of Paradox: A Dynamic Equilibrium Model of Organizing." *Academy of Management Review* 36 (2): 381–403. <https://doi.org/10.5465/amr.2009.0223>.
- Smith, Wendy, and Paul Tracey. 2016. "Institutional Complexity and Paradox Theory: Complementarities of Competing Demands." *Strategic Organization* 14 (4): 455–466. <https://doi.org/10.1177/1476127016638565>.
- Smith, Zachary, and Peter Jacques. 2022. *The Environmental Policy Paradox*. New York, NY: Routledge.
- Soini, Katriina, and Inger Birkeland. 2014. "Exploring the Scientific Discourse on Cultural Sustainability." *Geoforum* 51:213–223. <https://doi.org/10.1016/j.geoforum.2013.12.001>.
- Soininen, Niko, J. B. Ruhl, Barbara Cosens, and Lance Gunderson. 2025. "Governing Complexity: A Comparative Assessment of Four Governance Models with Applications to Climate Change Mitigation and Adaptation." *Environmental Innovation and Societal Transitions* 57:101020. <https://doi.org/10.1016/j.eist.2025.101020>.
- Sokolova, Tatiana. 2023. "Co-Producing 'The Future(s) We Want': How Does Political Imagination Translate Into Democratised Knowledge-Action Models for Sustainability Transformations?" *Environmental Science and Policy* 144:162–173. <https://doi.org/10.1016/j.envsci.2023.03.018>.

- Teerikangas, Satu. 2021. "Tiina Onkila." In *Research Handbook of Sustainability Agency*, edited by Katariina Koistinen and Marileena Mäkelä. Cheltenham: Edward Elgar Publishing.
- Teisman, Geert, and E.-H. Klijn. 2008. "Complexity Theory and Public Management: An Introduction." *Public Management Review* 10 (3): 287–297. <https://doi.org/10.1080/14719030802002451>.
- Tenbense, Tim. 2018. "Bridging Complexity Theory and Hierarchies, Markets, Networks, Communities: A 'Population Genetics' Framework for Understanding Institutional Change from Within." *Public Management Review* 20 (7): 1032–1051. <https://doi.org/10.1080/14719037.2017.1364409>.
- Termeer, Catrien, and M. A. van den Brink. 2012. "Organizational Conditions for Dealing with the Unknown Unknown: Illustrated by How a Dutch Water Management Authority Is Preparing for Climate Change." *Public Management Review* 15 (1): 43–62. <https://doi.org/10.1080/14719037.2012.664014>.
- Thornton, Patricia, William Ocasio, and Michael Lounsbury. 2012. *The Institutional Logics Perspective*. Oxford: Oxford University Press.
- Trischler, Jacob, Maria Röhnebak, Bo Edvardsson, and Bård Tronvoll. 2023. "Advancing Public Service Logic: Moving Towards an Ecosystemic Framework for Value Creation in the Public Service Context." *Public Management Review*: 1–29. <https://doi.org/10.1080/14719037.2023.2229836>.
- Uhl-Bien, Mary. 2021. "Leadership and Followership: Changed Leadership in a Changed World." *Journal of Change Management* 21 (2): 144–162. <https://doi.org/10.1080/14697017.2021.1917490>.
- Uhl-Bien, Mary, and Michael Arena. 2017. "Complexity Leadership: Enabling People and Organizations for Adaptability." *Organizational Dynamics* 46 (1): 9–20. <https://doi.org/10.1016/j.orgdyn.2016.12.001>.
- Uhl-Bien, Mary, and Michael Arena. 2017. "Complexity Leadership: Enabling People and Organizations for Adaptability." *Organizational Dynamics* 46 (1): 9–20. <https://doi.org/10.1016/j.orgdyn.2016.12.001>.
- Uhl-Bien, Mary, and Michael Arena. 2018. "Leadership for Organizational Adaptability: A Theoretical Synthesis and Integrative Framework." *The Leadership Quarterly* 29 (1): 89–104. <https://doi.org/10.1016/j.leaqua.2017.12.009>.
- Uhl-Bien, Mary, Ross Marion, and Bill McKelvey. 2007. "Complexity Leadership Theory: Shifting Leadership from the Industrial Age to the Knowledge Era." *The Leadership Quarterly* 18 (4): 298–318. <https://doi.org/10.1016/j.leaqua.2007.04.002>.
- Ungar, Michael. 2021. "Modeling Multisystemic Resilience: Connecting Biological, Psychological, Social, and Ecological Adaptation in Contexts of Adversity." In *Multisystemic Resilience*, edited by Michael Ungar, 6–31. New York, NY: Oxford University Press. <https://doi.org/10.1093/oso/9780190095888.003.0002>.
- van Buuren, Arjen, and Lasse M. Gerrits. 2008. "Decisions as Dynamic Equilibriums in Erratic Policy Processes: Positive and Negative Feedback as Drivers of Non-linear Policy Dynamics." *Public Management Review* 10 (3): 381–399. <https://doi.org/10.1080/14719030802003038>.
- Vangen, Siv. 2016. "Developing Practice-Oriented Theory on Collaboration: A Paradox Lens." *Public Administration Review* 77 (2): 263–272. <https://doi.org/10.1111/puar.12683>.
- Vento, Isak. 2024. "Trust, Collaboration, and Participation in Governance: A Nordic Perspective on Public Administrators' Perceptions of Citizen Involvement." *Public Administration Review*. *Public Administration Review* 84 (5): 870–887. <https://doi.org/10.1111/puar.13833>.

- Vikstedt, Elina, and Jarmo Vakkuri. 2025. "Multiple Logics in Performance Management of Collaborations for Sustainability: An Integrative Review." *Public Administration Review* 85 (5): 1316–1331. <https://doi.org/10.1111/puar.13959>.
- Voulvoulis, Nikolaos, Theodoros Giakoumis, Claire Hunt, Vasiliki Kioupi, N. Petrou Petrou, Ioannis Souliotis, C. Vaghela, and Binti Wan Rosely. Binti Wan Rosely. 2022. "Systems Thinking as a Paradigm Shift for Sustainability Transformation." *Global Environmental Change* 75:102544. <https://doi.org/10.1016/j.gloenvcha.2022.102544>.
- Walby, Sylvia. 2007. "Complexity Theory, Systems Theory, and Multiple Intersecting Social Inequalities." *Philosophy of the Social Sciences* 37 (4): 449–470. <https://doi.org/10.1177/0048393107307663>.
- Walker, Brian, Crawford S. Holling, Stephen R. Carpenter, and Ann Kinzig. 2004. "Resilience, Adaptability and Transformability in Socio-Ecological Systems." *Ecology and Society* 9 (2): 5. <https://doi.org/10.5751/ES-00650-090205>.
- Way, Rupert, C. Ives Matthew, Penny Mealy, and J. Doyne Farmer. 2022. "Empirically Grounded Technology Forecasts and the Energy Transition." *Joule* 6 (9): 2057–2082. <https://doi.org/10.1016/j.joule.2022.08.009>.
- Weick, Karl E. 1995. *Sensemaking in Organizations*. Thousand Oaks, CA: Sage.
- Weimer, David, and R. Vinning. Aidan. 2017. *Policy Analysis – Concepts and Practice*. New York, NY: Routledge.
- Wells, Jennifer. 2012. *Complexity and Sustainability*. London: Routledge.
- West, Simon, L. Haider, T. Hertz, Mancilla Garcia, and M.-L. Moore. 2024. "Relational Approaches to Sustainability Transformations: Walking Together in a World of Many Worlds." *Ecosystems & People* 20 (1): 2370539. <https://doi.org/10.1080/26395916.2024.2370539>.
- Whetten, David, T. Teppo Felin, and B. G. King. 2009. "The Practice of Theory Borrowing in Organizational Studies: Current Issues and Future Directions." *Journal of Management* 35 (3): 537–563. <https://doi.org/10.1177/0149206308330556>.
- Zeitfogel, Corinna, Tim Daw, and David Collste. 2024. "What Do You Mean 'Climate Change'? An Analysis of Climate Change Framings in Three Climate Assemblies." *Environmental Science and Policy* 162:103936. <https://doi.org/10.1016/j.envsci.2024.103936>.