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Systems thinking as a paradigm shift for sustainability transformation

N. Voulvoulis *, T. Giakoumis, C. Hunt, V. Kioupi, N. Petrou, I. Souliotis, C. Vaghela, WIH. binti Wan Rosely

Centre for Environmental Policy, Imperial College London, United Kingdom

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ABSTRACT

The Sustainable Development Goals (SDGs), adopted as reference and universal guidepost for transitioning to Sustainable Development by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development, are intended to be used as a set of interconnected goals and global targets for 'Transforming our world', as the 2030 Agenda is titled. This is a far more challenging task than business as usual; it requires systems thinking for understanding the conditions that generate and propagate sustainability challenges, moving away from the reductionist and anthropocentric thinking that created them in the first place. Taking a systems approach to addressing these challenges has been gaining currency with academics and policymakers alike, and here we make the case for holistic, integrated, and interdisciplinary thinking that challenges assumptions and worldviews, crucially based on public participation and engagement, to create the enabling conditions for sustainability to emerge. System transformations require interconnected changes to technologies, social practices, business models, regulations and societal norms, an intentional process designed to fundamentally alter the components and structures that cause the system to behave in its current unsustainable ways, a *paradigm shift* enabling the transition to sustainability.

1. Introduction

Sustainability challenges are immensely complex (EEA, 2019), complicated and intricate problems, interlinked in processes of rapid, dynamic change, creating unprecedented challenges that are fundamentally systemic (Ramos & Hynes, 2019). The 17 Sustainable Development Goals (SDGs) introduced in 2015 as part of the UN 2030 Agenda provide a useful normative framework to understand sustainability, encompassing the vision of a *Sustainable Society* which is inclusive and takes into account social, environmental and economic capital and has the potential to attract public attention and influence public sentiment (Hák et al., 2018). The SDGs are integrated and indivisible, global in nature and universally applicable. They call for deep transformations in every country and yet there is a lack of shared understanding of how the goals can be operationalized (Sachs et al., 2019). In this context, our societies and economies need to transform from the current unsustainable state onto a sustainable and resilient path (Fig. 1), through an integrative approach that addresses all 17 SDGs, building on their synergies and benefits while alleviating their trade-offs (IIASA, 2018).

The continuous development and evolution of systems thinking in the field of policy and management (Funke, 2010) has seen environmental policies across the world evolving from narrow, sectoral, and little coordinated, or even overlapping and conflicting, towards more integrated decision-making (Fiksel et al., 2009; Bone et al, 2011; Giakoumis & Voulvoulis, 2018a), with the idea of taking a systems approach to addressing sustainability challenges gaining currency with academics and policymakers alike (Mansoor and Williams, 2018; Voulvoulis, 2012; Voulvoulis et al., 2017).

However, despite a prolific growth in environmental laws and agencies worldwide over the last four decades - a 38-fold increase since 1972 - adverse environmental changes are continuing (Yadvinder et al. 2020), with the opportunity to avoid catastrophic outcomes in societies around the world 'rapidly closing'. In the first ever global assessment of environmental rule of law (UNEP, 2019), failure to fully implement and enforce these laws was shown to be one of the greatest challenges to mitigating climate change, reducing pollution and preventing widespread species and habitat loss. A few months earlier, the UNs' Intergovernmental Panel on Climate Change (IPPC) had urged rapid action to transform the global economy at a speed and scale that has 'no documented historic precedent' (IPCC, 2018).

When governments do take action, the complexity of sustainability challenges makes it impossible to predict how all actors and

* Corresponding author.
E-mail address: n.voulvoulis@imperial.ac.uk (N. Voulvoulis).

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stakeholders will react, with even relatively simple regulatory interventions often having unintended consequences. Severnini (2019), for example, demonstrated how in the United States from 1998 to 2014, restrictions on the development of hydroelectric projects aimed at preserving ecosystems led to an increase in annual carbon dioxide emissions of about 1,400 tons for each megawatt of fossil fuel power-generating capacity replacing hydropower, which is a renewable, relatively low-emitting source of energy. The opposite effect was seen when the increasing influence of climate change objectives led UK government policy in 2001 to create incentives for people to switch to diesel cars, based on the CO_2 advantage of diesel vehicles compared to petrol, resulting in unintended and unlawful levels of air pollution (nitrogen oxides and particulate matter emissions) in urban areas (Ćavoški, 2017).

With several policies evaluating progress based on outcome indicators, another limitation is captured by what has become known as *Goodhart's law*, when interventions are selected based on their anticipated effects on targets and not on delivering the benefits they were introduced for. For example, weight-based recycling targets in the UK, have seen local authorities improving their performance by offering mixed recycling collections to maximise the amount of waste collected for recycling, but reducing the quality and value of materials recovered due to contamination, -with whole loads being rejected at reprocessing or sorting centres (Waste & Resources Action Programme, 2017), to the detriment of material made available to producers for use into new products; the main benefit of recycling waste (Isenhour, 2010; Department for Environment, 2019).

The current policy paradigm is also considered inadequate to address global crises such as climate change, biodiversity depletion, land degradation, deforestation and so forth (Biermann, 2021). Despite substantial focus on sustainability issues in both science and politics, humanity remains on largely unsustainable development trajectories (Global Sustainable Development Report, 2019). Partly, this is due to the failure of sustainability science to engage with the root causes of unsustainability (Abson et al., 2017), and its reliance on an unrealistic model for nature, where nature is perceived too simply, as a closely integrated, self-regulating, complex system that works best when left alone by humans (Laitos & Wolongevicz, 2014), a view not consistent with its complex adaptive systems nature.

Most policies have been anthropocentric (Biermann, 2021), -including those on environmental protection- in that their ultimate goal is to protect and benefit humans, considered more valuable than all other organisms -as opposed to Ecocentrism which finds intrinsic value in all of nature (Kopnina et al., 2018). Such a worldview of human exceptionalism and superiority to nature is the basis of the notion that humans are separate from nature, and ultimately not limited by planetary boundaries (Laitos & Wolongevicz, 2014), which underpins the optimism of those today who believe that human ingenuity and technology will 'come to our rescue' (Hickman & Banister, 2009). For Techno-optimists, systems thinking could be just another 'technology', invention, a new approach to adopt, to deal with these challenges. But how realistic is it to come up and implement these seemingly wondrous inventions, and how easy is adopting systems thinking to change the way we do things?

2. The challenge of putting systems thinking into practice

"Competence in systems thinking is implicitly assumed among the population of engineers, policy makers and managers and in fact, most technical people will self-identify as systems thinkers. But systems thinking competencies are not as prevalent as these assertions might lead one to assume" (Valerdi and Rouse, 2010). Research reveals that, currently, education does not adequately develop systems thinking competence in learners (Palmberg et al., 2017). According to Sterman and Sweeney (2007), even well-educated people with strong backgrounds in Science, Technology, Engineering and Mathematics (STEM) do not understand the basic elements of complex dynamic systems, including feedback, stocks and flows, time delays, and nonlinearities. Plous (1993) showed that simple, linear cause and effect relationships were used by people to explain phenomena and often when participants found an obvious cause they stopped the inquiry process. Time delays in systems are also misunderstood and this can lead to the justification of 'wait and see' attitudes that can exacerbate problems (Sterman, 2000; Buehler et al., 2002; Faro et al., 2010). Systems thinking performance, even among highly educated people, can be poor (Valerdi & Rouse, 2010). This has led some to refer to a 'learning crisis' (Ndaruhutse et al., 2019), with several factors converging to challenge education policymakers to think in new ways about education provision, with systems thinking competences higher up their agenda (Education Commission, 2016; World Bank; 2018; Lannon, 2018). While several authors suggest that incorporating systems thinking in education can benefit students to acquire a more holistic view of sustainability challenges (Hofman-Bergholm, 2018; Žalėnienė & Pereira, 2021), in programmes where systems thinking competences have been targeted, available evidence as to their effectiveness is varied (Verhoeff et al., 2018; Evagorou et al., 2009).

This means that policy makers, not necessarily trained to look at sustainability challenges holistically or from a systems perspective, may perceive them through their own disciplinary lens, consequently employing strategies that are isolated and narrowly focused. This

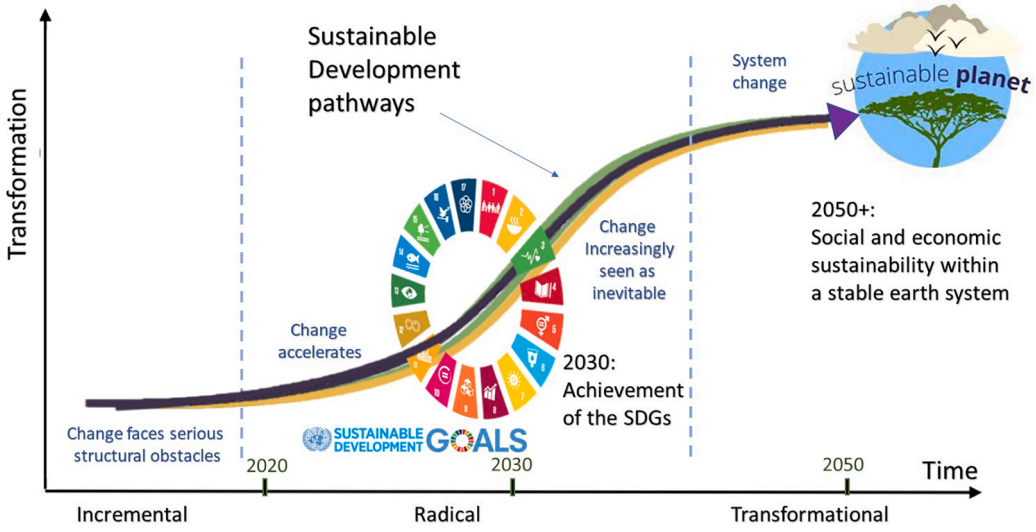

Fig. 1. The transformational process for the transition to a sustainable world through the achievement of the SDGs (adapted from IIASA, 2018).

hypothesis aligns with the current 'environmental policy' paradigm with its inherent focus on narrow problem-solving that seems to deemphasise questions of planetary justice and global democracy (Biermann, 2021), and to favour instead sectoral solutions, often developed in silos, that tend to maintain the status quo, missing opportunities for wide systemic changes (Ramos and Hynes, 2019). Even well-intentioned legislation aimed at prevention has been careless of potential alternative impacts (Hunt et al., 2021).

Systems thinking does not exist as an off-the-shelf tool that can be employed every time we face a complex sustainability challenge. Instead, understanding how things truly work requires critical and interdisciplinary thinking, the ability to consider multiple disciplinary perspectives, analyse the strengths and weaknesses of those perspectives, and integrate their insights to produce a new, more comprehensive understanding of sustainability. By challenging existing assumptions and potentially altering boundaries of or between fields, new ways of thinking about complex challenges can be introduced (Mathews et al., 2008; Montana-Hoyos & Lemaitre, 2011). "Systems thinking supports interdisciplinarity as a common denominator of generalizable knowledge useful to build a shared thinking space that cross-cuts the boundaries of various disciplines" (Barile & Saviano, 2021). It also relies on public engagement with science through intentional, meaningful interactions that provide opportunities for mutual learning between scientists and members of the public (Stave, 2002). "Mutual learning refers not just to the acquisition of knowledge, but also to increased familiarity with a breadth of perspectives, frames, and worldviews" (American Association for the Advancement of Science, n.d.]. Getting the public, policy makers, industry and scientists to come to a consensus in terms of the complex nature of sustainability challenges in order to bring about the necessary system changes is a process that requires effort and time, particularly as it is increasingly recognised that a 'change of mind' is required, 'a profound shift of awareness', with the changes needed of the transformational level of a paradigm shift (Laininen, 2019).

3. Systems thinking for sustainability transformations as a paradigm shift

The term 'paradigm shift' was coined by Kuhn (1962), referring to the shift in science from Newtonian to Einsteinian physics. Kuhn's work has since been extensively used to capture system transitions, with Hall (1993), for example, using the concept to explore the transition from a Keynesian economic paradigm to a monetarist one. Paradigm shift, according to both Kuhn and Hall, happens when the anomalies and shortcomings of the current paradigm are repeatedly pointed out; proponents of the new paradigm speak loudly and with assurance about it and are placed into positions of visibility and power; and energy is focused on converting those people who are likely to be open-minded to the change (Ramos and Hynes, 2019).

In practice, the many interlinkages within and between the complex, multi-functional systems behind sustainability challenges mean that there are often strong economic, social and psychological incentives that lock society into its current unsustainable ways (Partidário et al., 2010). There is therefore an opportunity to influence the evolution of various macro-systems in a way that it will change actors' behaviour favourably (Nemecskeri et al., 2008). For example, to effectively mitigate the adverse impacts of current transportation systems, strategies can be devised to manage demand for passengers and freight through various interrelated ways (Noussan et al., 2020).

Several authors have explained how mundane patterns of everyday activities routinely lock people into unsustainable practices, that are difficult to change, even when proven harmful from a planetary and sustainability point of view (Henwood, 2019). There is widespread acceptance that the challenges of transforming inconspicuous habitual ways of everyday activities need to reflect the ways in which people make their daily lives meaningful, and take into consideration lived experiences and everyday practices and the ways in which they are socially organised and culturally patterned (Henwood et al., 2016). There are also limits to how much a person can deviate from dominant consumerist norms no matter how reflective and concerned they are (Isenhour, 2010). Much individual behaviour is pre-configured by existing institutions and socio-material arrangements, which are structural and must be dealt with collectively (Klintman and Boström, 2015). According to Boström (2020), the mechanisms at the level of social life that serve to reproduce mass and excess consumption must be understood before attempts to change them to build bottom-up the transformative learning capacity needed to achieve and legitimize top-down reformation or transformation of institutions.

There is clearly a need for the development of policies that promote large-scale social, political and institutional change, generating options for deliberate transformations that address societal ills such as consumerism, and deliver social, technical and policy innovations that can overcome lock-ins and create incentives towards visions of prosperity beyond material sustenance (Boström et al., 2019). The potential of such policies to facilitate new management paradigms that aim to radically transform production and consumption processes has been recognised (Bengtsson et al., 2018). Helping people to move away from consumerism and refocus on 'experiences, identities, relationships and values that matter to people' can be a policy objective for change, one that facilitates a paradigm shift, ultimately resulting in sustainability. At the same time policies need to incorporate a mechanism of 'supportive governance' on top of specific policy interventions to ease the development of social resilience as well (Parkhill et al., 2015).

4. Reframing sustainability challenges for reaching the SDGs

Sustainability challenges can be conceptualised as the gap between the current situation (unsustainable state A), and the desired state (sustainable state D) (Fig. 2), to be better understood from a whole systems perspective (Voulvoulis & Burgman, 2019). Transformation is the process of transition from the current unsustainable state (A) to the desired state (D) as collectively envisioned future state of the system becoming sustainable (Kioupi & Voulvoulis, 2019). There can be several means to close the gap or pathways to reach the desired state, but social difficulties arise where such means are not obvious, are not immediately available, or when there is disagreement over the preferred solutions. There is a need to 'take plural pathways seriously,' as no matter how specific the context, there is never only one relevant, viable path (Scoones et al., 2020). Smith & Humphries (2004) emphasise the need for improved inclusivity and multi-actor participation to provide a greater understanding of the plurality of perspectives when defining the gap and evaluating alternative paths, and Funtowicz and Ravetz (1994) propose extending the peer community to include scientists together with industry, government, citizen groups and environmental organizations.

Understanding the complexity of sustainability challenges therefore requires a shift in problem structuring, transforming the way problems are defined into a more collaborative process that first defines the vision (desired state) (Giakoumis & Voulvoulis 2018b), and then selects the most appropriate pathway for 'getting there', using collective knowledge and skills traversing all disciplines and scales of assessment. "Vision without action is useless. But action without vision does not know where to go or why to go there. Vision is absolutely necessary to guide and motivate action. More than that, vision, when widely shared and firmly kept in sight, brings into being new systems", according to Donella Meadows (1941–2001), a pioneer in systems thinking and practice (Meadows et al., 1972). A clear, widely shared vision attracts partners and resources, and aligns action (Zurcher et al., 2018).

Sustainability transition is the pathway, the "radical transformation towards a sustainable society" (Grin et al., 2010). This is the transformation required for the vision to realise, the subject of a whole field of research that has emerged in the past few decades in the context of a growing scientific and public interest in large-scale societal

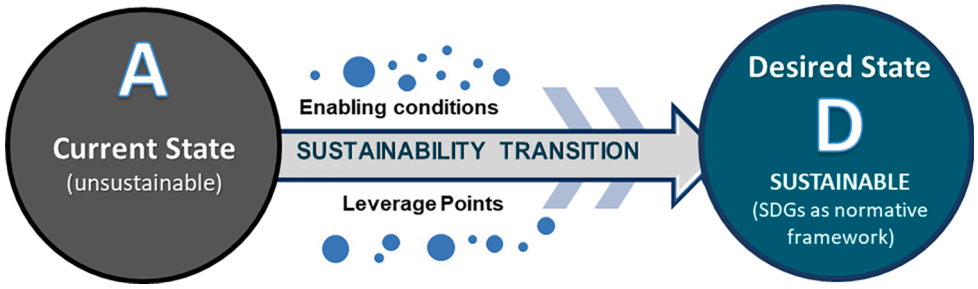

Fig. 2. Sustainability transformation as the transition from the current unsustainable state to society's desired state, using the SDGs as end points (Voulvoulis & Burgman, 2019; Kioupi & Voulvoulis, 2019).

transformations toward sustainability (Loorbach et al., 2017). There are several analytical frameworks for analysing socio-technical transitions to sustainability such as 'Multi-Level Perspectives' (Geels et al., 2008; Kern, 2012; Papachristos et al., 2013; Wu et al., 2021), transition management (Berkhout et al., 2004, Köhler et al., 2019), niche experiments (Sengers et al., 2019; Reda et al., 2021), technological innovation systems (Markard et al., 2015) and several tools for the development of pathways, such as backasting (Bibri, 2018; Giessecke et al., 2012; Mendoza et al., 2017), a participatory process for defining a desired future (vision) and then looking back to assess what would be required to make that vision realise (Holmberg and Larsson, 2018).

System transitions can take several decades, as they involve interconnected changes to technologies, social practices, business models, regulations and societal norms and inevitably involve struggles over the direction and pace of change (Meadowcroft, 2011; Rosenbloom et al., 2018). Understanding the many factors that cause the system to function the way it does and having a clear vision and commitment to the direction and pace of change required, is a prerequisite for sustainability transformation (Sanwal, 2015). The process can be accelerated through leverage points (places where change needs to occur) and an enabling environment supportive of change (Meadows, 1999). This includes actions and strategies to trigger such transformative processes, from coordinated action by governments to innovation in the private sector, experimentation, and pressure from civil society (Romero-Lankao et al., 2018). Openness and transparency and diversity and equity for example, have the potential to transform Government and businesses, strengthen people's trust in institutions and encourage greater public participation in decision-making, and are considered enabling factors for sustainability transformations (CDP, 2020). Social equity, justice and equality also play a key role in providing a just operating space for humanity, and can facilitate transformations in that direction (Kioupi & Voulvoulis, 2019).

Governments, politics, and policy are central to sustainability transformations (Patterson et al., 2017). With positive feedback loops kicking in as consumers become increasingly familiar with the new paradigm, green infrastructure built, complementary innovations coming to market, and more favourable policy and regulatory frameworks put in place, change eventually starts impacting the overall configuration of the system (Fig. 1). Effective leverage occurs where the mechanisms for change are feasible and, when enacted, will shift the system in a desirable direction - one in which a target outcome is achieved while minimizing other non-target effects (Kennedy et al., 2018). Systems thinking helps people see the bigger picture and envision a sustainable human society, enabling interventions beyond 'end of pipe' solutions and towards addressing the deeper structures and mental models at the root of unsustainability, creating the enabling conditions for sustainability to emerge.

5. Discussion

Environmental sustainability problems have been at the centre of policy debates and public concern since the 1970s, and while there have been some successes, most have not been addressed (Wiedmann et al., 2020). While systems thinking as a concept has seen its popularity increase over the years, interventions have not been truly systemic, in some cases due to an overemphasis on systems engineering and computational efforts focusing more on infrastructure than people (UNESCO, 2005). Indeed, most interventions to date, classified according to their potential for system wide change and sustainability transformation, have been shown to be partially driven by research methods and problem framings, with 'deep leverage points' related to changing the system's rules, values and paradigms rarely addressed (Riechers et al., 2020). A potential reason for this is that most interventions do not target root causes but tend to deal with symptoms, or target 'low hanging fruit' when new more complex, path-dependent capabilities need to be developed instead (Forés, 2019).

Systems thinking means understanding the web of interrelations that create complex problems, a different way of thinking about our relationship with the world (Allen et al., 2019), and about how change happens. It is about understanding what causes the problems we face, the conditions that support unsustainable behaviour, the root causes of unsustainability. This goes beyond cause and effect relationships, or simply applying *root cause analysis* as a tool. By implying—even inadvertently—that a single root cause (or a small number of causes) can be found, the term 'root cause analysis' promotes a flawed reductionist view, with the risk of simple linear narratives displacing more complex, and potentially fruitful, accounts of multiple and interacting elements (Peerally et al., 2017).

Sustainability, for example, is "often treated as something to be attained simply by quantitative assessments, technological improvements, plus whatever behavioural adjustments are needed to 'bring us back to sustainability'", stopping our current 'misbehaviour' (Clark, 1994). "Modern H. sapiens is unsustainable by nature—unsustainability is an inevitable emergent property of the systemic interaction between contemporary techno-industrial society and the ecosphere", according to Rees (2010), explaining that what is blocking sustainability is 'human nature, cognition, and denial'. This narrative places too great an emphasis on our misbehaviour and results in interventions directed at changing it, while ignoring the reasons behind it. In fact, we seldom ask why we do what we do, what causes the maladaptive social behaviours that lead to environmental destruction. If we want indeed to establish what sorts of behavioural adjustments will 'work', we need to first understand what drives our current behaviour. On the one side, unless the biopsychic needs of humans (the 'needs' our genes prescribe for us) are met, humans will misbehave in ways detrimental to their own ultimate survival (Williams et al., 2021). On the other, such behaviours are embedded in complex socioeconomic systems outside the influence or control of individuals (Ewert, 2020). Individual and collective behaviours exist in complex systems, and system structures are often the biggest barriers to behavioural change (Amel et al., 2017). While science helps unravel these complexities, we are just starting to realise that we need to get better at turning behavioural science insights into real change for sustainability (Reddy et al., 2017). This is not about targeted campaigns, the use of nudging techniques or other behavioural

interventions (Linder et al., 2018; Ewert, 2020), that often make people feel guilty (Genevsky et al., 2013) and can have the opposite or unintended effects on how they behave (Lertzman and Baragona, 2016). It is about increasing our understanding of human behaviours, why people do what they do, the role of circumstances and the mental models behind their actions. Using systems thinking to understand and enlarge citizens' mental models can improve public policy and market-based incentives to promote global sustainability (Garrity, 2018).

By contrast, the focus of authorities and governments on tackling unsustainability has been mainly on public pro-environmental behaviour change (Department for Environment, Food and Rural Affairs, 2008; Department for Environment, Food and Rural Affairs, 2011a; Department for Environment, 2011b; Dobson, 2010), despite the growing realization that it is our economic system with its mandatory pursuit of endless industrial growth that is harming the planet, producing poverty at a rapid rate, and threatening the basis of our existence, with the challenge of unsustainable consumption, and by extension climate change, falling increasingly on the individual as a consumer, a principal actor and a lever of change (Sheth et al., 2011). Systems thinking could reveal how distracting such focus is (Shove, 2010), as well as expose the economic system's role in our unsustainability. An investigation of major 'industrial epidemics' that constitute a very large share of the current public health burden, offers a valuable insight on the topic: "Tobacco, alcohol misuse and obesity have remained such intractable problems only because our economic system allows free ranging corporations to use evocative promotion, ubiquitous distribution, perpetual new product development, and seductive pricing strategies to encourage unhealthy consumption, the main cause of the inevitable escalation of lifestyle illnesses such as cancer, heart disease, and diabetes" (Hastings, 2012). These are maladies that governments try to prevent by targeting consumers instead, whereas consumption, although often considered an individual choice, is deeply ingrained in behaviours, cultures, and institutions, and is driven and supported by corporate and government practices (O'Rourke & Lollo, 2015). Consumers have responsibility for the consequences of their consumption and lifestyles, but it is governments that drive mass shifts in culture and consumption and production patterns. Both businesses and policy makers are choice architects, and dominant societal values, practices, and social norms are shaped by policies through regulations, infrastructure, pricing mechanisms, and education (Kinzig et al., 2013). With much of the literature on sustainability transformations implicitly also assuming that they can and need to be initiated, directed, managed and governed, this might look contradictory to bottom up systemic transformations that have a greater chance of taking place and being embraced (Patterson et al., 2017). Indeed, 'command and control' approaches to systemic solutions fail to recognise transformation as a truly systemic process that defies the top-down and bottom-up dichotomies that contribute to controversies and resistance, particularly by those who are 'being transformed' (Stirling, 2015). But this is where systems thinking and public participation can play a major role, as an empowering process for people to handle challenges and influence decisions that will impact their lives. This leads to joint decision making about what should be achieved and how, a vision of a sustainable world that they have co-created, 'increasing problem ownership and thus the chances of both proposition acceptance and implementation success' (Kirkman & Voulvoulis, 2017).

Systems thinking is about understanding the underlying drivers, the interactions and conditions that influence our decisions, helping us articulate problems in new and different ways and expand our boundaries of time and space to avoid or reduce potential unintended consequences. It is the intentional process of understanding how to alter the components and structures that cause a system to behave in a certain way, and identifying places where relatively small actions can lead to potentially transformative systemic changes. Systems thinking can empower people to realise the power they have, learn for themselves how to be self-determined, engaged and informed citizens with a clear vision of a sustainability future they desire. It helps to gain a deep, holistic understanding of sustainability challenges, to develop multi-pronged strategies that reinforce one another, are sustained over time, and reflect a comprehensive understanding of the major forces driving and constraining change. Change takes place in a complex political system made up of an intricate web of institutions, interest groups, individual leaders, and citizens — all connected in countless ways. There are no simple answers or silver bullets, so we need to embrace the complexity of sustainability challenges. In a democratic, dynamic, and diverse society, solving problems depends heavily on informed, critically thinking, and active citizens. Each one of us remains individually responsible: to stay informed, engaged, and to keep politicians and institutions in check. Governments have unique capacities, resources and authority to identify and agree society-wide goals and targets, to create institutions and networks, and to facilitate structural socio-economic change, both via policy interventions and by creating space for the emergence of alternative sustainable economies. We should hold them accountable for how well they perform on this.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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