TIPPING+ Working Documents Series

Towards transformative emergence.

Research challenges for enabling social-ecological tipping points toward regional sustainability transformations

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The TIPPING+ project

TIPPING+ provides an empirical in-depth social science understanding of fundamental changes in sociodemographic, geographical, psychological, cultural, political, and economic patterns which give rise to Social-Ecological Tipping Points (SETPs), both positive and negative in relation to socio-energy regional systems. Such empirical and theoretical insights will shed new light on the interdependencies between changes in regional socio-cultural structures and the technological, regulatory and investment-related requirements for embracing (or failing to embrace) low-carbon, clean-energy and competitive development pathways in selected coal and carbon intensive case study regions (CCIRs). The overall goal is to understand why and under which conditions a given social-ecological regional system heavily dependent on coal and carbon-intensive activities may flip into a low-carbon, clean energy development trajectory – or on the contrary may fall into an opposite trajectory with all its negative implications. Towards this goal, main focus of TIPPING+ is the participatory co-production of knowledge on the driving forces and deliberate tipping interventions leading to the emergence of positive tipping points toward clean energy transitions in European CCIRs

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Abstract

A crucial task to accelerate global decarbonisation is to understand how to enable fast, equitable, low-carbon transformations in those regions of the world most intensive in the production and use of fossil fuels. To support this endeavour, we underline the relevance of the boundary concept of social-ecological tipping points (SETPs) and highlight three key challenges for its robust conceptualisation and policy use in assessing regional sustainability transformations. Positive SETPs can be understood as the moments or critical thresholds in which, as a result of cumulative and beneficial effects of previous deliberate and targeted interventions, additional actions or events push a coupled social-ecological system towards an a more just and sustainable trajectory or configuration. Our review shows that research and policy usage of SETPs towards regional sustainability faces three key challenges: (a) integrating theoretical and empirical contributions from diverse social and ecological sciences, together with complexity theory (b) designing open transdisciplinary assessment processes able to represent multiple qualities of systemic change and enable regionally situated transformative capacities, and (c) moving away from one-directional metaphors, static ideas of individual agency or single equilibrium in energy transitions; and instead, focus on understanding the conditions and capacities for the emergence of systemic transformations and regenerative processes across multiple levels of changing agency, unfolding both in social and biophysical systems and in many moments in time. We refer to these complex and place-situated processes as learning to enable regional transformative emergence.

Table of Contents

1 Introduction

Accelerating global decarbonisation requires fast learning on how to enact rapid, equitable, transformative change towards sustainability in those regions of the world most intensive in the fossil fuel production and use. However, an operational integrated social theory on how to accelerate systemic change through strategic actions toward this end is missing. For this reason, we underline the relevance of the boundary concept of tipping points as a way to improve our understanding on how to approach the complexity of rapid sustainability transformations at the regional level. However, tipping points and their related terms, such as leverage points, turning points, or regime shifts adopt many diverse meanings and uses in the literature [Winkelmann et al. 2022; Biggs et al. 2018, Otto et al. 2020, Farmer et al. 2019, Van Ginkel et al. 2020; Shrivastava et al. 2020; Leventon et al. 2021; Fisher and Riechers 2019; Tàbara et al. 2018; Werners, 2013] which shows in practice the high polysemy and ambiguity of the term. Based on a synthesis from various social sciences contributions1, we introduce the notion of 'social-ecological tipping points' (SETPs) and underline three key challenges that face its robust conceptualisation, empirical operationalisation and policy use to assess and accelerate low-carbon regional sustainability transformations. On the one hand, acknowledging and integrating contributions from diverse social science; and on the other, designing open and transdisciplinary processes able to represent multiple qualities of systemic change. Furthermore, we argue that 'positive' tipping points, simply defined in this context as those aligned with sustainability goals, cannot be fully predicted when or whether they will happen, although the transformative capacities and conditions for their emergence may be enabled. So when they happen, transformations may emerge across multiple levels of agency - from individual, organisational and systems levels- and hence generate multiple learning processes and virtuous circles of regenerative feedbacks between social and biophysical systems.

2 Social-Ecological Tipping Points towards sustainability

Traditionally, the notion of tipping points was used in environmental sciences in a negative sense, e.g., to refer to catastrophic futures or show the effects of overshooting planetary boundaries [Folke et al 2021]. However, the concept is being reframed to address the potential of positive ones and in particular to identify social actions which at one point have attained or could attain deliberate visions such as those related to sustainability or

[1]as examined in the TIPPING+ project www.tipping-plus.eu

climate resilience [Sharpe and Lenton 2021, Lenton 2020 Tàbara et al., 2018]. Here we define SETPs as those hybrid thresholds derived from intertwined social and biophysical forces in which a relatively small action pushes a given social-ecological system towards an alternative development trajectory or basin of attraction. In the case of *positive* SETPs in terms of sustainability, such moments would occur when, and due to deliberate actions, tangible gains in terms of Sustainable Development Goals (SDGs), improvements in justice -e.g., distributive, recognition and procedural- and the building of the necessary transformative capacities and generate better adapted social-ecological interactions and institutions would emerge.

SETPs may then constitute an abrupt departure of an original system dynamics or create a completely different kind of system configuration. Because of their inseparable nature of coupled social and biophysical interactions, SETPs lead to multiple transformations, feedbacks and qualitative changes both in economic, policy and social practices as well as in life-support systems [Tàbara et al 2021]. Moreover, such transformative processes comprise of three main kinds of elements: (1) *an original context or system of reference*, the dynamics of which are driven both by social and biophysical components (2) a *tipping event or disruptive process* which may be brought about by a deliberate intervention or exogenous force, and (3) a set of *impacts*, ultimately changing *fundamentally* the original context conditions. Such consequences may be limited to one single system of reference or extend into a cascade of qualitative reactions in other systems. In this regard, conceptually, it is useful to distinguish between *sectorial tipping points*, occurring in specific sectors or domains - just as it could be the case of turning private mobility from fossil fuels to electric sources but without much broader institutional reforms. And those *systemic tipping points* which affect a whole array of interconnected systems, and do so across a whole sort of personal, organisational and political arrangements. The former is often referred to as transitions whereby system end-points, policy targets, and the new system equilibrium are assumed to exist, can be decided or are known beforehand (e.g., 'achieving a carbon-neutral Europe by 2050'). Whilst in contrast, in systemic tipping points these final outcomes, policy goals, or new system states cannot fully be known beforehand or specified -hence no equilibrium or final system configuration is assumed [see Stirling 2015]. However, note that in regional research and policy both approaches may be complementary. Eventually, enabling the emergence of a systemic tipping point may only be possible by creating the enabling conditions for multiple sectorial tipping points to appear and be combined across many kinds of systems, also referred as deep transitions [Schot and Kangera 2018]. For instance, in some regions the former dependence on carbon-intense activities in the energy sector at one point in time was abandoned or 'released' in a way that the system moved towards a new basin of attraction and reorganized itself around new governance, economic, energy, and socio-cultural foundations [Coenen et al 2018; Cowell,2020; Crowther et al 2021; Gailing et al, 2020].

In a nutshell, and although it is hard to know when or whether a tipping point will happen, it is also true that

when they happen, as in the case of aiming for climate neutrality, they rarely occur by chance. This means that in the case of social-ecological systems, the conditions for their emergence can be - at least partially - described and then possibly influenced by conscious and intentional actions2. In this vein, we define tipping interventions as those deliberate actions aimed at building the necessary transformative conditions and capacities for positive transformations to happen at multiple levels of agency in a dynamic way -that is, not only the system changes but the individuals within that system also do-, thus yielding desired structural effects in a given system of reference.

3 SETPs in regional sustainability transformations research. Three challenges ahead

3.1 Challenge I. Acknowledging and integrating diverse contributions from social sciences.

Tipping points can be observed in individual life trajectories as well as in community behaviours, but also in economic and distributional structures; in political, governance and institutional arrangements; in geographical and population dynamics [as those which could be derived from climatic risks, Owen and Wesselbaum 2020, McLeman 2017]; and in worldviews and beliefs systems, including conventions and public opinion trends [Galam and Cheon 2020]. Hence acknowledging the diverse interpretations of the notion and usages of tipping points by various social science disciplines is a first step for a robust conceptualisation and use in sustainability transformations research and action.

In psychology, models and theories of cognitive, socio-ecological and systemic kinds are key to understanding processes of qualitative change involved in socio-ecological tipping points at individual or community levels. Recent studies in human information processing investigate tipping points as 'the point at which people begin to perceive noise as signal' [O'Brien and Klein 2017], and show asymmetries between individual expectations and the actual moment at which this point is reached [O'Brien, 2020]. Going beyond the individual level of analysis, further insights on radical system transformation can be found in socio-ecological psychology,

[2] For a relevant philosophical discussion on the notion of transformative emergence, albeit not directly addressing sustainability issues, see [Van Dijk 2021]

dynamical system approach, and models of change based on critical junctures theory [Liu & Pratto, 2018; Reed and Vallacher, 2020; Uskul and Oishi, 2020]. Rooted in general system theory and in cultural and societal psychology, these models stress that interrelationships among elements, sub-systems and systems determine the forms of adaptation to internal and/or external factors. However, and despite the centrality of models of change, psychological studies barely refer to tipping points in energy transition [Otto et al., 2020]. Thus, research could fruitfully mobilize insights from other social science fields to better to understand psychological tipping points and support the emergence of sustainable development pathways. Individual, social and cultural psychological models of change should be integrated with studies on decarbonization, which use tipping point as an interpretative tool [Schmitz, 2017], for decision making [Cuppen et al 2015], as a threshold [Strauch, 2020; Weng et al 2018], or associated with speed and scale in non-linear transformations [Messner, 2015].

In economics, the emphasis lies on the identification, modelling and quantification of possible economic interventions such as investments in disruptive technologies [Berger et. al 2020, Lawrence 2020, Jaakkola and van der Ploeg 2019] and their effects in terms of structural changes in the composition of employment or GDP, competitiveness or in financial assets [Oei et al., 2020, Berger et. al., 2020, Bovari et al., 2020, Semeniuk et. al., 2020, Tàbara et al. 2018]. A main contrast exists between those analyses being made with single equilibrium models [Nordhaus 2019; Lemoine and Traeger 2016] seeking an optimal policy response and those models that account for the existence of multiple equilibria [Lamperti et al 2018]. The latter represent the move towards integrating system dynamics and agent-based approaches in future research on the economic determinants of tipping points [Hafner et. al. 2020]. For instance, an economic tipping point may be quantified or even partly anticipated when the costs of a technology decrease to a level which is able to replace an old one and create the conditions for the energy system to jump into a new enduring state or development dynamics [see also Patt and Lilliestam 2018]. However, many other social, cultural or political factors may contribute to adopting such new trajectory besides costs, as it is the case with electric mobility [Strauch 2020]. In this regard, several econometric methods are capable to detect structural change a macro and regional levels [Berger et al. 2020; Välilä, 2020].

In policy science and governance research, an obvious focus lies on fundamental changes in power dynamics and redistribution, the role of social mobilisation or particular events inducing radical modifications in institutional arrangements bringing about new constitutional regimes or breaking down former ones [Schmitz 2017, Linnér and Wibeck 2020]. This is the case, for instance, with those new regimes which emerged out of the fall of the Berlin wall, or more recently the change of the Chilean constitution following the uprising triggered by a relatively small increase in public transport fees [Heiss 2021; Arias-Loyola 2021]. This line of enquiry also

addresses how governance and innovation networks develop within and across time and space to the point that unfold new institutions or forms of durable collaboration or transformative agency [Galaz et al 2016, Westley et al 2017]. Tipping processes modify the degrees of freedom and the opportunity space for system transformation [Herrfahrdt-Pähle E, et al. 2020; Folke et al 2021]. That is, either reducing or expanding it, as when in the latter case when some institutional constraints are removed, or new access to resources, networks or knowledge systems are created and facilitate new forms of innovation and agents' interaction [Amundsen et al. 2018; Füg and Ibert 2020, Jaakkola and van der Ploeg 2019, Lutz et al 2017, Oei et al 2020, Wiseman 2018, Schaffrin and Fohr 2017]. In this guise the notion of transformative governance is of special relevance to map out and identify the different kinds of capacities which may lead to tipping points towards sustainability [Hölscher and Frantzeskaki 2020].

In inter and transdisciplinary approaches, the insights from social-ecological systems (SES) and resilience research [Folke et al. 2021; Hahn et al, 2017; Lauerburg et al 2020] social and natural systems are combined to understand how they mutually influence or change together. These approaches are usually conceptualized with notions such as the adaptive cycle [Walker et al. 2020] whereby successively repeated periods of stability/conservation, release, reorganization, and exploitation make up the 'panarchy' process. There may be tipping points in between each phase, but critical thresholds certainly occur in the release phase, whenever the system loses key societal or environmental components or processes that would otherwise allow reorganization to its original form. Moreover, in sustainability transformations research using the notion tipping points and their related concepts such as leverage points in many ways as it is the case using lens and metaphors derived from social quantum theory. Following these perspectives, it is argued that a new consciousness about alternative plausible worlds, qualitative kinds of relations and realities across personal, political and practical configurations and of the role of individual agency in turning them actionable and meaningful becomes fundamental [O'Brien 2016, 2018, 2021]. In addition, sustainability transformations require problematising current value systems and worldviews [Berzonsky & Moser 2017] so profound changes in worldviews can also be interpreted through the perspective of deep leverage points [Davelaar 2021]. In this respect, systemic tipping points in culture, education and policy processes are largely dependent on the role played by human information and knowledge systems [HIKS; Tàbara and Chabay 2013; van der Leeuw and Folke 2021] and normative values [Horcea-Milcu et al. 2019] and as argued by [Nyborg et al. 2016] tipping points can also be understood as the moments in which vicious circles in collective behaviour turn into positive ones, e.g, by a change of social norms and perceptions, which in turn can be induced by deliberate policies or the role of minority groups reaching a critical mass [Centola et al 20218]. Justice in particular is also considered a key driver for sustainability transformations and a crucial component to understand radical shifts in power dynamics regarding gender, ethnicity youth inclusion or the social recognition of disadvantaged groups [Allen et al 2018,

Blythe et al 2018, Ziervogel et al 2017] and it is also of especial significance in energy transitions research [Cronin et al 2021; Doyon 2019; Patterson et al 2018; Bouzarovski S, Simcock N. 2017].

3.2 Challenge II. Designing open transdisciplinary assessment processes able to represent multiple qualities of systemic change and enable regionally situated transformative capacities.

When considering deep structural change, different disciplines often portray and refer to very different kinds of systems and of how their dynamic components operate. Even within those disciplines using a 'systemic approach' to sustainability transformations [Scoones et al 2020, Fazey et al 2017] one can find important contrasts, as it is the case with transition theory [Köhler et al. 2019], resilience and social-ecological systems research [Folke et al 2021, Moore et al 2014], coupled natural-human systems (CNHS; Liu et al. 2021] or organisational science [Hestad et al. 2021; Westley et al 2011] whereby the use of terms as 'ecosystems' can have little to do with what natural scientists refer to. This means that they also tend to emphasize different temporal and spatial scales or conceive the role of social agency in them in different modes.

In addition, the position of the researcher with respect to the systems of reference is not independent of their analyses. Systems are always defined in relational ways and are inevitably influenced by previous socially-constructed categories. Moreover, systems operate under different logics, agents and complex dynamics [Hestad et al. 2020]. Using an open, pluralistic, transdisciplinary approach it is necessary to help to overcome such limitations. However, the difficulties for providing a transdisciplinary methodology for the research of tipping points in sustainability science derives, among other reasons, from the existence of different ontologies as well as for conflicts in epistemologies and normative criteria used to describe and assess the systems of interest in which different disciplines operate [Tàbara et al. 2021; Milkoreit et al. 2018].

A key task then is how to design open, plural and transdisciplinary assessment processes for the assessment of SETPs, given that complex systems can only be described partially by one single perspective. This in turn would entail: (a) identifying and assessing different qualities of deep structural change occurring in the different kinds of systems in which transformations are needed, even though they may not necessarily or immediately appear to be connected, and (b) to represent complex dynamics derived from alternative interventions according to multiple time, spatial and social scales or dimensions. In particular, and regarding time scales, the causality of events and the apparently trivial fact that 'timing matters' are crucial elements for investigation of tipping processes in regional transformations processes: 'what happens when' - the sequence of events - is important,

since actions from the distant past can initiate particular chains of reaction that have effects in the present - some largely unexpected. As Pierson [2000] suggested, 'small' events early on may have a big impact, while 'large' events at later stages may be less consequential. And in this sense, tipping points and be understood as the breaking of previous path-dependencies and lock-in situations that mark the entry to new locked-in states. However, using the chronologies, methods and time, spatial or social conceptual boundaries from one single discipline limits our ability to fully understand the complexity of addressing the full complexity of SETPs processes. To understand these complex processes, a systematic exploration of the underlying conditions and how they are conceived by different perspectives- e.g., in terms of transformability, resilience and specially, regarding systems' sensibility to possible tipping interventions -subject to multiple time lags including social hysteresis- is necessary.

3.3 Challenge III. Enabling transformative emergence in coal and carbon-intensive regions.

Sustainability transformations, whilst occurring at multiple levels of agency, they eventually materialise in places (Salomaa and Juhola 2020). In fact, it can be argued that sustainability science is always situated science. Research on the transformations of energy systems needs to pay especial attention to particular places, human geographies, spatial configurations and dynamics of networks within which deep transitions are embedded [Köhler et al 2019; Bridge and Gailing 2020; Coenen et al 2021; Mattes et al 2015; Naumann and Rudolph 2020]. Changing the configuration of energy production systems towards a distributed generation of renewables and multi-scale geographical shifts in energy demand underlines the importance of situating possible tipping points in socio-energy systems in specific places [Bridge, 2018]. However, when trying to apply the concept of SETPs to sustainability transformations in places, the actual meaning of regions and communities also needs to be reconceptualised and novel modes of analysis of trans-local and trans-regional action are required. In terms of tipping points, cross-scale interactions may be better assessed and mapped out by examining the extent to which positive synergies between different kinds of actors and networks around transformative solutions are being formed, rather than using other more rigid and less action-oriented operationalisation criteria. Thus, collective action in regional contexts is very much dependent on many intertwined and complex factors which cannot easily or simply be reduced to 'bottom-up/top-down dynamics' nor to the simple aggregation of fixed individual patterns of behaviour within larger systems configurations [Byrne and Callaghan, 2014]. Sustainability transformation processes do not occur only as a result of vertical and one-directional phenomena but in a much more complex, overlapping and dynamic processes of collaboration and competition between changing agents who operate under different perspectives, personal roles, organisational logics or capacity of influence.

A novel approach in this regard would require a further elaboration on the notion of regions so as to integrate new components necessary to understand and enable sustainability transformations. That is, to consider not only the *formal regions* based on the 'sameness' in geographic, administrative, cultural or economic attributes; or the *functional regions* defined in terms of their operational links, flows and interactions; or *the perceptual or cultural region* related to areas socially constructed by cultural beliefs, feelings or attachment, or other collective imaginaries. This new approach may entail extending the functional category of region based on identifying what would be needed to be transformed for achieving a positive tipping point in sustainability terms. This would be close to what EU refers to the Accelerator Regions[3], although a *transformative region*, would also encompass dynamic transformations at multiple of levels agency, as well as in the other formal and cultural defining categories.

However, considering such novel approach to regional change would also need moving away from simple and one-directional metaphors of causality in socio-cultural and technological change [see Hughes et al. 2022] towards understanding and enabling the conditions for *transformative emergence*. Using the notion of transformative emergence in tipping points would mean to abandon fixed and static ideas of individual agency (e.g., the rational actor paradigm) in their interactions with other organisational or large systems' levels. That is, moving from synchronic perspectives of systems configuration and changes occurring only at one point in time or one single level - e.g., at individual and organisational level with direct dependency among them - to understanding that multiple transformations of properties may emerge and influence in a recursive way multiple configurations at multiple periods of time -and where no single or direct dependency relationships between agents and systems may occur among them [Van Dijk 2021, Humphreys 2020, Schot and Kangera 2018 Guay and Sartenaer 2016]. Further research using such dynamic understanding of agency-systems interactions in which both agents and systems do and need to change at the same time, may have profound implications for sustainability science and policy. And in particular for those approaches, such as in modelling, aimed at identifying positive tipping points derived from coupling multiple systems of solutions at different scales or domains of action[4].

[3] As used both for regions and communities according to the EU Mission on Climate Change and Transformations [Hedegaard et al. 2020].

[4] http://www.highendsolutions.eu/page/transformative_solutions

In short, instead of one-directional and single end-point approaches, we advocate for a better understanding of those kinds of tipping interventions which may help to create the conditions for the emergence of larger and more lasting systemic effects in diverse but coupled social-ecological systems of reference; and do so at different levels of agency with special attention to be placed to individuals, communities and regions with higher potential for fast, positive systemic impact. Transforming systems require of empowered transformative agency operating in enabling environments which induce to such transformations in a recursive, 'multi-chronic' mode. This novel approach to accelerating transformative action in regions and communities would also call for the integration of both human and biophysical forces of change, insofar that improvements in biophysical conditions translate into improvements in human quality of life conditions and in turn generate multiple positive retroactive feedbacks in many kinds of systems (for the case of food systems see [Pereira et al. 2020]). But in any case, the possibility of such self-reinforcing positive learning loops leading to a systemic positive tipping point would be conditioned by the agents, networks and capacities required to implement transformative visions, and strategies in each particular regional contexts of action [Tàbara et al. 2018].

4 Conclusion

The need for understanding how to accelerate systemic and qualitative change towards sustainably derived from relative strategic and sensitive interventions is opening a large corpus of research on social-ecological tipping points. One additional reason for the attractiveness of this concept in sustainability science may lie in the belief - or hope- that few small actions or marginal additional forces could eventually lead to large, desirable and profound system' changes, as when seemingly trivial or imperceivable events trigger irreversible and accelerating chains of reactions [Nuttall 2012]. However, in the case of deliberate sustainability transformations, such belief has not yet been proven to be true. Or at least, such belief will only be confirmed when we better understand the previous and complex conditions that made such large systems' change possible in the first place. Whilst it may be the case that a disruptive event, intentional policy action, individual behaviour or technology may precipitate rapid change in a given system, whether it will eventually contribute to sustainability will depend very much on the extent to which many other conditions, contextual factors, previous forces of change come into play.

Tipping points, conceptualised as discontinuities in a development trajectory, as thresholds of qualitative structural change or as a move toward new basins of attraction, occur in many different kinds of systems, relationships and levels of agency; so, they can hardly be circumscribed to one single system of reference. Moreover, tipping points do not occur by chance. The building conditions by which SEPTs eventually unfold can be systematically described and analysed, albeit always partially and limited to the perspectives and tools that researchers use in their descriptions. But for this knowledge to become a solid basis for action, our review has

underlined three key challenges for research. First, acknowledging and connecting the contributions from diverse social sciences with complexity theory [Byrne & Callaghan 2014], also using a situated, place-based approach. Second, designing open transdisciplinary assessment processes able to assess multiple understandings of qualitative change in social-ecological systems, with special attention paid to supporting transformative capacities; and third, rethinking the nature and interactions between agents systems from a transformative emergence perspective in which multiple transformations and learning feedbacks can emerge - in a 'multi-synchronic' way over multiple periods of time- at different levels of agency hence generating the potential for accelerating social-ecological change.

A better understanding of the social, economic and environmental challenges that individuals and groups encounter before, during, and after a given regional systemic transformation might also help clarify to whom the tipping points may impact positively or negatively, e.g., in terms of justice and sustainability. Some of these challenges or injustices might originate from power asymmetries already in the system, such as social discrimination preventing participation in decision making spaces and gender inequities [Clancy et al.2020; Johnson et al. 2020]. Therefore, once both a target or directly affected group(s) and non-target ones have been identified, the sustainability potential of tipping interventions may be better tailored accordingly.

In this contribution we have argued that one of the most urgent tasks to move human societies towards sustainability has to do with learning how to accelerate sustainability change in those areas most intensive in the extraction and use of fossil fuels. Sustainability transformations research needs then to pay special attention to understanding the conditions by which coal and carbon intensive regions have managed to move to alternative, better-off structural situations and/or how radically clean-energy and socially just trajectories could be taken in other regions. However, and although the exact moment in which SETPs may occur cannot be known beforehand, we have argued that it is possible for sustainability science to contribute meaningfully to the assessment and policy learning processes to build the transformative capacities for their emergence.

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