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On the discovery and enactment of positive socio-ecological tipping points: insights from energy systems interventions in Bangladesh and Indonesia

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Abstract

Notions, such as leverage points, sensitive interventions, social tipping points, transformational tipping points, and positive tipping points, are increasingly attracting attention within sustainability science. However, they are also creating confusion and unresolved questions about how to apply these concepts when dealing with urgent global challenges such as rapid decarbonisation. We propose a relational methodology aimed at helping how to identify and support the emergence of positive ‘Social-Ecological Tipping Points’ (SETPs) that could bring about sustainability transformations. Our approach emphasises the need to pay attention to processes of social construction and to time dynamics. In particular, in a given social-ecological system, three key moments need to be considered: (1) The *building of transformative conditions and capacities* for systemic change, (2) A *tipping event or intervention* shifting the system towards a different trajectory or systems’ configuration, and (3) the *structural effects* derived from such transformation. Furthermore, we argue that the discovery and enactment of positive SETPs require considering multiple ontological, epistemological, and normative questions that affect how researchers and change agents define, approach, and assess their systems of reference. Our insights are derived from examining the implementation of household renewable energy systems at regional level in two rural areas of Indonesia and Bangladesh.

Keywords Social-ecological tipping points (SETPs) · Renewable energy systems · Transdisciplinary methodologies · Systems transformations · Indonesia renewable energy · Bangladesh renewable energy

Introduction

In recent times, the concept of leverage points, as originally formulated by Donella Meadows (1999), has regained a lot of attention within sustainability transformations research and practice (O’Brien 2018; Leventon et al. 2021; FOLU 2021). Related to that, other concepts such as positive tipping points (Tàbara et al. 2018; Lenton 2020), sensitive interventions (Farmer et al. 2019), social tipping points (Otto et al. 2020), or transformational tipping points (van Ginkel et al. 2020; O’Riordan 2013) are being used, especially when dealing with global challenges, such as the need for rapid global decarbonisation. However, this literature is not exempt from notable confusions (Leventon et al. 2021), conflicting interpretations of the same study areas, or even of different realities that refer to the same concept. This is particularly the case regarding the term ‘tipping points’ being used differently by natural or social scientists (Milkoreit

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et al. 2018). We argue that this lack of clarity stems from a number of causes. First, discourses on tipping points often take understandings of systems for granted as if they were known in advance or shared among different audiences. However, our views of systems are always socially, politically, and historically constructed, besides being embedded in, and influenced by, biophysical dynamics. Second, empirical evidence supporting the various theoretical underpinnings is lacking, as well as a clear outline clarifying what structural change means in practice. And third, an explicit consideration of the temporal dimension in systems' transformations and their interactions with other systems is missing.

Against this backdrop, we introduce the concept of 'socio-ecological tipping points' (SETPs) and propose an open methodology aimed at helping researchers and practitioners identify the emergence of positive SETPs to support sustainability transformations. We argue that transdisciplinary practice may benefit, on one hand, from making explicit the time and structural dynamics that affect the emergence of positive SETPs; and on the other, by considering three kinds of critical ontological, epistemological, and normative questions that affect how researchers and change agents define, approach, and assess their systems. We base our perspectives on insights gained from our TIPPING⁺¹ project. In particular, on what we have learned by reviewing the implementation of household renewable energy systems in two rural areas of Indonesia and Bangladesh. This research considers access to affordable and sustainable forms of energy as a key component for achieving Sustainable Development Goals (SDG7).

Socio-ecological tipping points (SETPs) in sustainability transformations

The social construction of SETPs

According to Milkoreit et al. (2018), a tipping point can be understood as a critical threshold crossed when a small quantitative change results in fundamental, non-linear qualitative changes in the configuration and dynamics of a given system. This process is triggered by internal feedback mechanisms, which may lead either to a new stabilised state, or to further destabilisations. In this comment, we elaborate on these ideas and introduce the notion to 'socio-ecological tipping points' as an integrative and transdisciplinary concept indicating those critical moments where the combination of events, individual actions, or policy interventions lead *at*

a given moment to structural qualitative effects *in coupled social-ecological systems (SES)*.

Focusing on the role of human agency, in both individual and policy actions, we further elaborate on the notion of *positive SETPs* as those moments at which, due to *previous cumulative and targeted interventions or individual activities*, an additional action or event is able to shift a given social-ecological system towards a more just and sustainable development trajectory or configuration. This conceptual distinction between a 'sectoral tipping point' and a 'full-systems' tipping point allows us to differentiate between those limited changes or technological *transitions* that may occur within certain sectors, such as replacing fossil-fuel powered mobility with electrical mobility, but with limited impacts on other institutional systems; and those *transformations* that also entail profound cultural, psychological, ethical, and institutional changes in multiple social-ecological systems. Numerous interactions—feedbacks, synergies, and trade-offs—between sectoral and systemic tipping points and between social and biophysical components are manifold and in fact may be needed.

Social systems are always historically and culturally constructed. Different languages of motive in each system (Wright Mills 1940) as well as other social mechanisms that affect agent's interactions and worldviews (e.g., the monetary economy, media, or education system) define a given object or subject's boundaries and shape how it relates with other objects or subjects, and, in our case, how it relates to biophysical systems. Research on SETPs first needs to acknowledge the existence of many classes of social-ecological systems and relationships. They operate under different timescales and spatial scales, are driven by different logics, and all are bound to be subject to different types of qualitative change. Hence, a deep structural change in an energy system may be understood and assessed very differently from one in a political, financial, or educational system, and which lens, concepts or language an observer uses can make a difference to the way the same parcel of reality or 'system' is interpreted.

Social time and systems transformations

The notion of time in social systems is a cultural construction (Adam 1990, 1999). In this regard, whether a given development is assessed to occur rapidly or slowly is also dependent on culturally ingrained social conventions—and even cosmologies—which affect how researchers see its evolution and they relate to their objects and subjects of reference. The underlying assumption of the existence of a single instance of time across different kinds of social-ecological systems, often prevalent in transitions and transformation research, needs to be carefully examined. Different social-ecological systems follow different chronologies and cycles,

¹ <https://www.tipping-plus.eu/>.

often associated with their specific logics and purposes of their composing agents but also biophysical rhythms. This is why, the speed and moment at which a particular phenomenon unfolds needs to be assessed in relation to how we see it occurring according to our own perception of time in the system within which we observe it. Thus, how time is characterised or measured is not independent from our own position within the system we assess and how we relate to it.

To examine these complex nuances, and when trying to identify potential or actual positive SETPs in a given socio-ecological system of reference, we argue that three key moments need to be considered: (1) the *building of transformative conditions and capacities* for systemic and appropriate, deliberate change, (2) a *tipping event*, precipitating the system towards a desirable trajectory or basin of attraction, and (3) the *qualitative, irreversible, and structural effects* derived from such transformation. This would include the welcoming of new ways of governing that involve sharing the benefits of the new situation and, to some extent, a redistribution of power. All this would entail considering the key role played by leaders, social entrepreneurs, and instigators of change, as well as by innovative and disruptive technologies and new forms of funding that could encourage alternative development pathways, enabling more sustainable and equitable long-term socio-technological arrangements to be built. Therefore, the study and potential policy use of intentional SETPs would require making early decisions, and focus on the interlinked dynamics of.

The nature of the original system of reference where the SETPs are to be explored,

The multiple endogenous and exogenous social-ecological forces—including alternative visions or narratives—that impose mounting pressures on its original structure, The ways in which *tipping interventions or actions*, contextually defined, at a *point in time* provoke the system to tip and unleash transformative changes, and

The types of *new system or configurations of systems* that may unfold from this tipping point; how they will be approached and assessed, as positive or negative, for whom, and under what kinds of sustainability criteria.

A methodological proposal

As mentioned earlier, one of the shortcomings that often faces the study of tipping points and other related concepts is the lack of empirical grounding of certain generalisations about how systems evolve or relate to other systems. Deep transformations are often only associated or discussed in connection with fundamental changes in power, governance, or equity (Blythe 2018). Often, other socio-ecological systems' dimensions or plural conceptualisations of complex

systems tend to be disregarded. This position may lead to the conclusion that it may be impossible to enact positive tipping points in the face of abrupt change, e.g., given the current (mal)functioning of market and political institutions in that they do not operate in accordance with virtuous principles (O'Riordan 2013).

To avoid these risks and to learn how to explore and enact SETPs to bring about sustainability transformations, an alternative approach is to limit the empirical study of tipping points to specific regional systems. This task is being carried out by the TIPPING⁺ project, examining the conditions for positive tipping towards low-carbon, sustainable development in more than 20 coal- and carbon-intensive regions in the world. Here, we synthesise the first methodological insights gained from the project in the development and implementation of renewable household energy systems in two rural areas of Bangladesh and Indonesia². In the case of Bangladesh, we examined the deployment of an off-grid Solar Home System (SHS). This is a government-sponsored programme that eventually resulted in 4.5 million SHS installations, for around 14% of the rural population in off-grid areas, using micro-credit and market strategies (World Bank, 2018; World Bank Group and Lighting Global 2018). In the case of Indonesia, we studied the work of grassroots organisations in the alternative development, with eventual government support, of decentralised biogas technologies (Tàbara et al. 2019; Devisscher et al. 2017; Rumah Energi 2020). These two national governance contexts are very different. In Bangladesh, government and international financial agencies played a key leadership role, whilst in Indonesia, local NGOs drove those innovations. The *fundamental* positive effects of such interventions, e.g., the transformations in poor people's lives from not having access to basic energy services and associated improvements in health and environmental conditions, were manifold. These included: access to lighting, reduction of indoor pollution, increased time for education, reduced pressures on deforestation, additional income opportunities for small-scale businesses, and the empowerment of women. All of these beneficial outcomes have major sustainability pay-offs at individual and community levels.

These examples show, among other things, that the building of transformative conditions for positive SETPs, or the actual tipping intervention that could flip a system, may occur at any given scale, e.g., at individual and household levels with limited connections to government and larger organisations, or other larger scales; and that they may

² Based on a synthesis of the ongoing empirical and Doctoral research carried out in by author Rafia Zaman for the case of Bangladesh (Zaman and Brudermann 2018) and the action-research carried by Takeshi Takama and Cynthia Ismail (See Tàbara et al. 2018 and <https://su-re.co/>) for the case of Indonesia.

happen in certain systems (energy) but not others, such as market or political ones, being only ‘sectorial tipping points’. Moreover, some interventions may only contribute to building the nascent conditions for positive tipping but not be the actual tipping event or intervention. In such conditions, it may not be possible to isolate one single causal driver that enacts or supports the emergence of positive tipping points³. As mentioned, the identification of a tipping event, socio-technological innovation, or policy intervention as contributing to or enacting a positive SETP, depends on the relational position of the observer to the system of reference; in other words, such judgements are socially constructed within a particular biophysical context. Hence positive tipping points should not be considered by any means to be ‘end-points’. They should be regarded as moments in time in which self-reinforcing learning feedback (e.g., virtuous cycles leading to net positive sustainability) lead to deep transformations in development processes and, in our case studies, as a product of interlinked social and ecological system dynamics.

Based on these insights, we now provide a methodological proposal aimed at helping how to identify and assess SETPs in sustainability science. We argue that the ‘discovery’ of tipping point processes in complex SES is conditioned by a series of ontological, epistemological and normative questions which originally influence how researchers or agents of change approach their system of reference. Answers to such questions affect and are affected by the attitudes, beliefs, ideologies, and expectations held by researchers in approaching their objects and subjects of interest, and the interactions involved. Given that there is no one single best manner in which to respond to such questions, multiple approaches need to be openly considered. In Fig. 1, and below, we summarise this methodology as a series of tasks that we deem important for such reflexive research on SETPs:

- (1) Decide and make explicit what ontological, epistemological, and normative positions are to be adopted in relation to the object-subjects of reference. Consider that different approaches may yield different insights, with equally relevant interpretations, into the same system’s dynamics. From this standpoint, the following questions arise:
 - *Ontologies*: clarify what is, and what lies inside or outside, our system of reference, its various components, what they have in common and their interactions with other systems. Make explicit *the time, spatial and social-*

³ Therefore, the use of metaphors such as ‘top-down’ or ‘bottom-up’ interventions obscures the fact that complex system interactions are not necessarily organised in vertical ways.

ecological scales under consideration. Reflect whether a dualistic or holistic position is being taken in relation to (non-)human worlds or other systems. Thus, whilst it is possible to consider that ‘we are all part of one total single system’ (Boulding 1985); or ‘everything is inside the system’; or ‘we are the system’, we should acknowledge that different positions will inevitably affect, and will be directly affected by, personal attitudes, and worldviews held when approaching such systems.

- *Epistemologies*: decide what kind of relationships and which interpretative tools and methods we wish to engage with in order to understand or intervene in our system of reference. In this regard, we could take both an *emic* (‘from inside’) and/or *etic* (‘from outside’) perspective; or we could decide to use models and quantitative indicators (e.g., when searching for tipping points in macroeconomic dynamics); or we might adopt a qualitative approach to the analysis of inter-subjective and community meanings, values, and worldviews; or we could make use of participatory or action-research-oriented processes.
 - *Normative issues*: make explicit at an early stage which normative criteria will be used and how they will be used to assess our system of reference and align the production of knowledge processes to sustainability goals or targets (Horcea-Milcu et al. 2019; Grasso and Tàbara 2019). This entails making explicit which *visions, values, and criteria* will be taken into account to qualify changes in development trajectories as positive (or negative) and for whom, from both sustainability and justice points of view; or whether particular visions achieved what they were expected to achieve.
- (2) Characterise structural changes over time: structural, abrupt, or qualitative change is defined differently in different social-ecological systems and at different scales. This requires the consideration of a variety of tools and methods to characterise them at many levels and entities (individual, community, organisational, societal or biophysical) or within different kinds of systems. It is necessary to track previous and underlying trends, or the possible effects of interventions that generate cumulative effects, to anticipate both negative and positive SETPs (e.g., negative ones from growing inequalities, progressive land desertification, rural depopulation, or mounting poverty). Such analyses should help in assessing to what extent observed changes have been fundamental, irreversible or endure for long enough to qualify as positive or negative tipping points, e.g., by achieving expected normative visions, or policy targets such as Sustainable Development Goals (SDGs).
 - (3) Identify options and interventions that might contribute to building transformative capacities and conditions

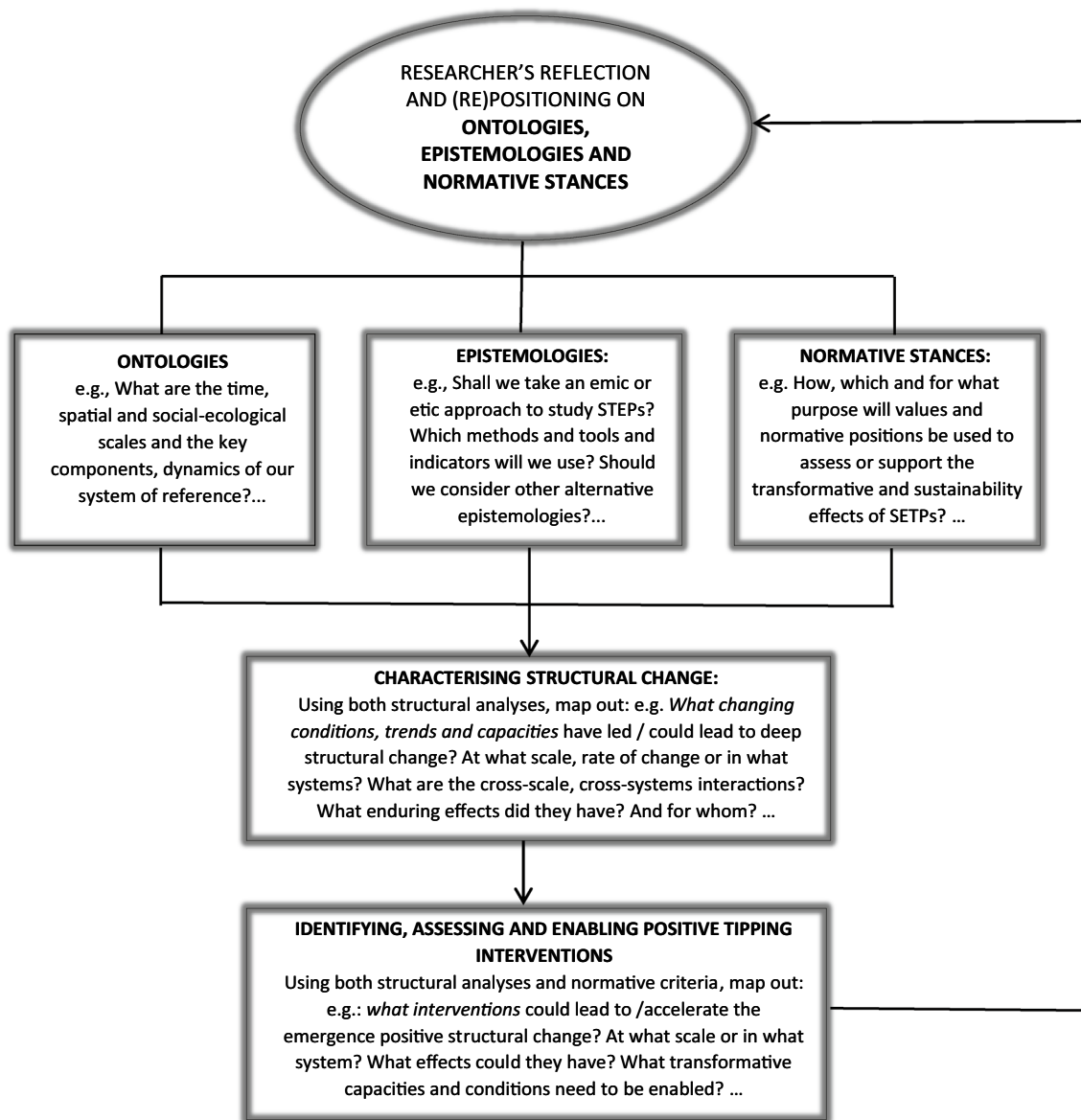


Fig. 1 Identifying, assessing, and enabling positive SETPs. This procedural synthesis is to be understood a continuous multi-faceted process of self-reflection, questioning, and reframing, rather than a sequential approach. The discovery, evaluation, and possible enact-

ment of SETPs is always dependent on new understandings of systems' boundaries and dynamics, as well as of personal interactions and alternative pathways and options for transformative change

for the emergence of positive SETPs: select the most effective and equitable ones which could have greater potential for enduring structural change. In particular, whenever the purpose is to accelerate systemic change, as in the case of global decarbonisation, select those where a relatively small and feasible action could lead to faster and deeper transformative effects. An important additional task would be to search for ways of combining different and relatively small-scale solutions which, e.g., by combining them, could create additional and even multiplicative structural effects, both at larger

scales or in other systems; and in particular, to find ways for new institutional arrangements to redistribute agent's rights and responsibilities in sustainable and equitable ways.

- (4) Go back to reflective learning: lessons learned from carrying out the previous tasks need to be reassessed in terms of changes in the personal relationships that researchers formed and the experiences that they gained during the process. Thus, there is also the opportunity for researchers to transform the manner in which they interact with other researchers, agents of change and

stakeholders, as their ultimate views of their systems of reference depend on using such iterative, reflective learning processes. Reflecting on such transformations in perspectives could help examine to what extent our original individual assumptions and positions—regarding ontologies, epistemologies and the role of normative criteria—may also have been transformed during the research (and/or action) process, so as to inform and help future research into SETPs.

In the two case studies, we are following these prescriptions as a continued learning process. We found that the scale of entry of solar heating technologies in Bangladesh was accelerated by the coordination of both funding and agencies cooperation. This led to greater community take up by encouraging and stimulating leadership and first promoters in the various communities involved. As the advantages to health, community livelihoods and to overall energy availability became clear, the emergence of SEPT was all the more evident (see also Komatsu et al. 2011 and Samad et al. 2013). In Indonesia, similar trajectories of both take up and identifiable community benefits were supported and promoted by the active NGOs. In the latter case, the community links enabled the NGOs to be so effectively led as to reach a wider understanding of the overall benefits of the alternative biogas technology to health, reduced environmental impact, energy access, and well-being.

Final remarks

A general shortcoming of the literature on sustainability transformations is that whilst this often refers to rapid and systemic change, authors rarely make explicit the complex nature of different kinds of systems, who are the agencies of change, the time, and spatial scales that are being considered, the role of biophysical components, or even how to assess the qualitative changes that they deem to be fundamental. Even those authors trying to elucidate possible ‘transformational leverage points’ encounter great difficulties in operationalising them (see Abson et al. 2017; Leventon et al. 2021). The agents, types of interaction, and feedback—including multiple system intersections and overlaps between them—or the indicators and different social logics and biophysical phenomena that drive their different systems’ trajectories and dynamics, often remain obscure. Here, we focused our attention of the analysis of SETPs, understood as moments or critical thresholds in developmental change emerging from deliberate actions, conditions, and capacities which lead to more equitable and sustainable systems’ configurations. In this way, our emphasis on both method and context provides a breakthrough which we believe could help to address these limitations. In view of

this, we have proposed a reflective and relational methodology on SETPs which could elucidate *how* to carry out empirical research and action on sustainability transformations. We do not claim that the insights gained from assessing these studies provide a definite answer on how SETPs may operate on all systems and at all scales. Instead, we suggest that lessons on the potential of positive tipping points can be drawn from their examination, resulting from an improved understanding of the early stages in the emergence of SETPs. Much then depends on how this critical initial phase leads to the spilling over in achieving the SDGs or overall deeper sustainability transformations (Tàbara 2020).

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