'TRANSFORMATIONS TOWARDS SUSTAINABILITY'

Emerging approaches, critical reflections, and a research agenda

James Patterson, Karsten Schulz, Joost Vervoort, Carolina Adler, Margot Hurlbert, Sandra van der Hel, Andreas Schmidt, Aliyu Barau, Pedi Obani, Mahendra Sethi, Nina Hissen, Mark Tebboth, Karen Anderton, Susanne Börner, and Oscar Widerberg

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ABSTRACT

Over the last two decades researchers have come to understand much about the global challenges confronting human society (e.g. climate change; biodiversity loss; water, energy and food insecurity; poverty and widening social inequality). However, the extent to which research and policy efforts are succeeding in steering human societies towards more sustainable and just futures is unclear. Attention is increasingly turning towards better understanding how to navigate processes of social and institutional transformation to bring about more desirable trajectories of change in various sectors of human society. A major knowledge gap concerns understanding how transformations towards sustainability are conceptualised, understood and analysed. Limited existing scholarship on this topic is fragmented, sometimes overly deterministic, and weak in its capacity to critically analyse transformation processes which are inherently political and contested. This paper aims to advance understanding of transformations towards sustainability, recognising it as both a normative and an analytical concept.

We firstly review existing concepts of transformation in global environmental change literature, and the role of governance in relation to it. We then propose a framework for understanding and critically analysing transformations towards sustainability based on the existing 'Earth System Governance' framework (BIERMANN ET AL., 2009). We then outline a research agenda, and argue that transdisciplinary research approaches and a key role for early career researchers are vital for pursuing this agenda. Finally, we argue that critical reflexivity among global environmental change scholars, both individually and collectively, will be important for developing innovative research on transformations towards sustainability to meaningfully contribute to policy and action over time.

SERIES FOREWORD

This working paper was written as part of the Earth System Governance Global Research Alliance – www.earthsystemgovernance.org.

Earth system governance is defined in this Project as the system of formal and informal rules, rule-making mechanisms and actor-networks at all levels of human society (from local to global) that are set up to prevent, mitigate and adapt to environmental change and earth system transformation. The science plan of the Project focusses on five analytical problems: the problems of the overall *architecture* of earth system governance, of *agency* of and beyond the state, of the *adaptiveness* of governance mechanisms and processes, of their *accountability* and legitimacy, and of modes of *allocation and access* in earth system governance. In addition, the Project emphasizes four crosscutting research themes that are crucial for the study of each analytical problem: the role of power, of knowledge, of norms, and of scale. Finally, the Earth System Governance Project advances the integrated analysis of case study domains in which researchers combine analysis of the analytical problems and crosscutting themes. The main case study domains are at present the global water system, global food systems, the global climate system, and the global economic system.

The Earth System Governance Project is designed as the nodal point within the global change research programmes to guide, organize and evaluate research on these questions. The Project is implemented through a Global Alliance of Earth System Governance Research Centres, a network of lead faculty members and research fellows, a global conference series, and various research projects undertaken at multiple levels (see www.earthsystemgovernance.org).

Earth System Governance Working Papers are peer-reviewed online publications that broadly address questions raised by the Project's Science and Implementation Plan. The series is open to all colleagues who seek to contribute to this research agenda, and submissions are welcome at any time at workingpapers@earthsystemgovernance.org. While most members of our network publish their research in the English language, we accept also submissions in other major languages. The Earth System Governance Project does not assume the copyright for working papers, and we expect that most working papers will eventually find their way into scientific journals or become chapters in edited volumes compiled by the Project and its members.

Comments on this working paper, as well as on the other activities of the Earth System Governance Project, are highly welcome. We believe that understanding earth system governance is only feasible through joint effort of colleagues from various backgrounds and from all regions of the world. We look forward to your response.

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1. INTRODUCTION

Over the last two decades researchers have come to understand much about the global challenges confronting human society (e.g. climate change; biodiversity loss; water, energy and food insecurity; poverty and widening social inequality) (ROCKSTRÖM ET AL., 2009; WORLD RESOURCES INSTITUTE, 2011; ISSC/UNESCO, 2013). Increasingly efforts are being made to articulate what desirable futures may look like; for example, maintaining human society within a 'safe operating space' of planetary and social boundaries (ROCKSTRÖM ET AL., 2009; RAWORTH, 2012). However, the extent to which research and policy is succeeding in steering human societies towards more sustainable and just futures is unclear, and there is now increasing attention to better understanding processes of transformation in human society (e.g. BIERMANN ET AL., 2009, 2012; ISSC/UNESCO, 2013; FUTURE EARTH, 2014a; OLSSON AND GALAZ, 2014).

The notion of 'transformations towards sustainability' takes an increasingly central position in global environmental change research and policy discourse. For example, it is one of three core themes of Future Earth, the new 'umbrella' program for major international sustainability research programs (FUTURE EARTH, 2014a,b). The 'Future Earth Initial Design Report' states that the research theme of transformations towards sustainability *"goes beyond assessing and implementing current responses to global change and meeting gaps in development needs to consider the more fundamental and innovative long-term transformations that are needed to move towards a sustainable future"*. Future Earth identifies a particular need to understand *"how such transformations can be developed, designed and achieved"* (FUTURE EARTH, 2014a). The theme of transformations towards sustainability is identified as one of the critical priorities for global environmental change research over the next 3–5 years (FUTURE EARTH, 2014b). Additionally, international policy interest in this topic is growing, reflected in ongoing discussions on climate change and decarbonisation (e.g. WGBU, 2011) and the UN Sustainable Development Goals (e.g. HLPEP, 2013; HAJER ET AL., 2015). Transformations are being called for across several problem domains. For example, ideas of transformation have been applied to energy systems (ROTMANS ET AL., 2001; LOORBACH AND ROTMANS, 2010), water systems (PAHL-WOSTL ET AL., 2010; BROWN ET AL., 2013; FERGUSON ET AL., 2013), food systems (VERMEULEN ET AL., 2013), and cities and urban sustainability (MCCORMICK ET AL., 2013; SETHI AND MOHAPATRA, 2013; REVI ET AL., 2014).

Transformations refer to fundamental changes in structure, function and relations within socio-technical-ecological systems, that leads to new patterns of interactions (e.g., among actors, institutions, and dynamics between human and biophysical systems) and outcomes (following HACKMANN AND ST CLAIR, 2012). Transformations are likely to be inherently political and contested because different actors will be affected in different ways, and may stand to gain or lose as a result of change. For example, the urgent need for global transformation via decarbonisation of energy systems is promoted and resisted by different actors in a wide variety of ways (WGBU, 2011; HILDINGSSON, 2014). In the context of global sustainability, the notion of transformation is increasingly used to characterise aspirations to transform current (e.g., unsustainable, inequitable) conditions into more desirable (e.g., sustainable,

equitable) conditions in socio-technical-ecological systems. Hence the notion of transformations towards sustainability makes explicit the aspiration to bring about significant and enduring change. This can be viewed both in a normative way (e.g. as a good/desirable thing to do) as well as an analytical way (e.g. what actually 'happens', and how and why).

The notion of transformations towards sustainability has the potential to focus collective attention on transformative change in response to global sustainability challenges. However, there is an urgent need to clarify its meaning and reflect on how it is understood and analysed, giving particular recognition to its political aspects. We aim to address this gap by: (1) reviewing several prominent yet fragmented concepts of transformations in the global environmental change literature; (2) proposing a framework for analysing transformations towards sustainability based on the existing 'Earth System Governance' framework (BIERMANN ET AL., 2009); (3) outlining a research agenda for global environmental change scholars informed by both research and policy concerns; and (4) arguing that transdisciplinary research approaches and building the capacity of early career researchers are crucial for pursuing this agenda.

2. CONCEPTS OF 'TRANSFORMATION'

2.1 BACKGROUND TO THE NOTION OF TRANSFORMATIONS

While the notion of transformations is only recently being taken up as a specific focus within global sustainability discourse, it has a longer (although sporadic) background across several bodies of literature. Perhaps the earliest use of the notion of transformations was by the political economist Polyani, who examined political economic transformation in the emergence of the modern 'market state'. Polyani, (1944) described transformation as a fundamental altering of humankind's mentalities which creates new institutions reconstructing the state, the economy, and relations of distribution. In later decades, political science literature proposed the notion of punctuated equilibrium to explain radical policy change, which involves periods of stability and occasional abrupt change when the distribution of power among dominant actors changes significantly (BAUMGARTNER & JONES, 1993). However, BROWN ET AL., (2013) argue that looking at policy change alone is insufficient for understanding deeper and longer-term societal transformations. Contemporary political economy scholars have argued that institutional change is a deeply political process that goes beyond punctuated equilibrium, and is underpinned by ongoing strategic interaction among actor coalitions to shape and re-shape institutions (STREECK AND THELEN, 2005; THELEN, 2009; MAHONEY AND THELEN, 2010). More broadly, NORGAARD, (1995, 2006) argues that human development and societal change is a coevolutionary process that emerges from ongoing mutual interaction between human systems (e.g., values, knowledge, organisation, technology) and environment systems.

These various endeavours reflect an underlying interest in understanding change and transformation in human society, and collectively offer several significant insights for

transformations towards sustainability. First, transformations are complex, dynamic, political, and involve multiple dimensions of change (e.g., social, institutional, cultural, political, economic, technological, ecological). Second, trajectories of transformative change are likely to emerge from coevolutionary interactions between these many dimensions, and thus cannot be viewed in a narrow disciplinary-bounded or deterministic way. Taken together, this raises major questions about what 'governing' transformations towards sustainability might involve. For example, how can governance contribute to fostering transformations, particularly within the specific constraints of actual governance contexts (e.g., fragmented institutional arrangements, contested policy processes, and tightly constrained or poorly delineated roles and capabilities of policymakers and administrators), and given the complex, contested and coevolutionary nature of societal change? Finally, it cannot be assumed that institutional change will not be met with resistance, especially when norms are questioned – indeed, transformations may involve 'battles of institutional change' (CHHOTRAY AND STOKER, 2009), but the processes and implications of such disruptive change are little understood.

2.2 CONCEPTS OF TRANSFORMATIONS IN GLOBAL ENVIRONMENTAL CHANGE LITERATURE

The notion of transformations has been conceptualised in various ways. Perspectives include: resilience and transformation of social-ecological systems; social innovation for transformation; navigating planetary and social boundaries; transition management; and learning for transformation in resource governance. These perspectives often overlap, but each can be distinguished as contributing a unique perspective on transformations. They are discussed in turn below.

The theme of transformations is prominent in literature on resilience of social-ecological systems. In particular, 'transformability' is emphasised as a key property of interest in multi-scalar social-ecological systems (GUNDERSON AND HOLLING, 2002; BERKES ET AL., 2003; WALKER ET AL., 2004; FOLKE ET AL., 2010). Transformability is defined as: *"the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable"* (WALKER ET AL., 2004) and *"the capacity to cross thresholds into new development trajectories"* (FOLKE ET AL., 2010). It is strongly linked to resilience, as *"transformational change at smaller scales enables resilience at larger scales"* (FOLKE ET AL., 2010) and, conversely, undesirable transformations imply a loss of resilience. Transformations demonstrate *"fundamental change in a social-ecological system resulting in different controls over system properties, new ways of making a living and often changes in scales of crucial feedbacks"* and *"can be purposefully navigated or unintended"* (CHAPIN ET AL., 2009). Particular attention has been given to actively navigated transformation processes (e.g., OLSSON ET AL., 2004, 2006; GELCICH ET AL., 2010; PELLING AND MANUEL-NAVARRETE, 2011). These have been conceptualised as involving three key steps: being prepared or actively preparing a system for change; navigating a transition in management and governance regimes when a suitable window of opportunity opens; and then working to consolidate and build the resilience of the new regime (FOLKE ET AL., 2005; OLSSON ET AL., 2006; CHAPIN ET

AL., 2009). Several capacities are seen as critical for enabling transformation, including social memory, networks, and agency of key actors (individuals, organisations) (FOLKE ET AL., 2005, OLSSON ET AL., 2006). This perspective reflects a view of transformations as being actively navigated towards new management and governance regimes for building resilience and adaptive capacity within social-ecological systems.

Also within the resilience literature is work on social innovation for transformation in social-ecological systems (e.g., BIGGS ET AL., 2010; WESTLEY AND ANTADZE, 2010; WESTLEY ET AL., 2011, 2013). This perspective focuses on the role of agency and innovation within networks and institutions, and the potential for innovation to trigger transformation in social-ecological systems. It argues that understanding how 'strategic agency' operates within specific 'opportunity contexts' (e.g., institutional, economic, political) is vital for understanding how innovation can transform social-ecological systems (WESTLEY ET AL., 2013). Transformations towards sustainability at a broad scale are seen to emerge from interplay between top-down institutional conditions and bottom-up (catalytic and disruptive) innovation, leveraged through the agency of institutional entrepreneurs and networks connecting innovation and transformation processes across multiple levels of organisation (WESTLEY ET AL., 2011). This perspective reflects a view of transformations as emergent patterns of change towards sustainability, driven by social innovation and agency of key actors who harness innovation to trigger change in broader social-ecological systems.

Again within the resilience literature, from an explicitly global perspective, is an emerging view of transformations as being about navigating pathways of societal change and human development within planetary and social boundaries (ROCKSTRÖM ET AL., 2009; RAWORTH, 2012). Planetary boundaries are a concept proposed to identify key global biophysical thresholds that cannot be crossed without fundamentally compromising the resilience of planetary life support systems (ROCKSTRÖM ET AL., 2009). Subsequently it was argued that social conditions (e.g., equity, justice) are equally important and should form another set of boundaries to be met (RAWORTH, 2012). An approach to transformation has been proposed which involves navigating pathways between the 'foundation' of social boundaries and the 'ceiling' of planetary boundaries (LEACH ET AL., 2012, 2013). This perspective reflects a view of transformations as being navigated between planetary and social boundaries to shape pathways of human development.

Transition management is a body of literature that starts from a very different perspective. It is based on ideas of diffusion of innovation in society, and seeks to understand the mechanisms by which some innovations at a 'niche' level are taken up within broader socio-technical regimes (ROTMANS ET AL., 2001; GEELS, 2002; GEELS AND SCHOT, 2007). Transition management has been applied to problems such as urban water, energy and waste systems (FOXON ET AL., 2009; LOORBACH AND ROTMANS, 2010). It is originally based on concepts of diffusion of technical innovation and the idea that transitions are coevolutionary change processes (e.g., involving social, technological, institutional, economic and value systems) (ROTMANS ET AL., 2001;). The notion of a multi-level perspective is central (i.e., niche, socio-technical regime, and landscape levels), where strategic activities of various actors and dynamics at and between these levels can result in several possible transition pathways:

transformation, reconfiguration, technological substitution, and de-alignment and re-alignment (GEELS AND SCHOT, 2007). Each of these pathways results in what would be defined in this paper as transformative change. Transitions management conceptualises a typology of transition pathways. It proposes an approach for initiating transitions through fostering innovation at a niche level, and recognising windows of opportunity at broader regime and landscape levels. This perspective reflects a view of transformations as being about triggering transition pathways in socio-technical systems, through supporting niche innovation and its uptake into broader socio-technical regimes.

The final perspective is characterised by a focus on learning for transformation in resource governance. It refers to a loosely clustered literature that highlights the central role of (social and systemic) learning and reflexivity in triggering transformation in governance systems. One view is the concept of 'triple-loop learning' where learning and feedback can lead to policy adaptation (single-loop learning), problem re-framing (double-loop learning), and most deeply, transformation of wider social and institutional structures (triple-loop learning) (ARMITAGE ET AL., 2008; PAHL-WOSTL, 2009). Another view emphasises social learning as central to transformation in the knowledge and practice of actors, with the potential to be harnessed as a purposeful governance mechanism (SLIM, 2004; STEYEART AND JIGGINS, 2007; ISON ET AL., 2011). Other scholars have proposed 'reflexive governance' involving long-term policy design and ongoing feedback from the activities of actors and changes in wider contexts (VOß ET AL., 2009). Learning and reflexivity are also central to transformation in social-ecological systems (FOLKE ET AL., 2005; ARMITAGE AND PLUMMER, 2010) and transitions management (FOXON ET AL., 2009; LOORBACH, 2009). This perspective focuses on transformations in governance regimes through learning among actors within unfolding resource governance contexts.

These perspectives are compared in Table 1 based on several key characteristics (goals, mechanisms, and nature of resulting trajectories of change), and the theoretical backgrounds in which they are rooted. Commonalities include: a focus on social and institutional innovation as a key mechanism for triggering transformation; the critical importance of agency; the role of cross-level interplay where innovation at local scales is taken up in broader governance regimes; and a key role for learning and reflexivity (whether implied or explicit) within unfolding transformation contexts. Another less obvious theme is the importance of politics. This becomes clear when considering that societal transformations are always likely to result in actual or perceived winners and losers from change, and also because the normative goal of sustainability invokes political stances and demands (SCHULZ AND SIRIWARDANE, 2015). Actors who promote transformations towards sustainability do so from particular political perspectives, and carry with them a set of worldviews and values that influence what is considered appropriate or their own vision of what constitutes a desirable future (see for example HULME 2009).

Arguably on the whole there is an under-emphasis on the political dimensions of transformations. Much of the literature on transformations is couched in terms of social-ecological systems and/or transitions management. However, these literatures

have a tendency to under-appreciate dilemmas associated with power differences and contested values among actors (SMITH AND STIRLING, 2010; FABINYI ET AL. 2014). Cote and Nightingale (2012) state that the application of ecological principles within the social realm has reduced opportunities to ask important normative questions concerning the role of power and culture. For example, who makes decisions, what is considered a desirable future and (even if we assume consensus) how do we get there? Some scholars have indeed sought to integrate stronger appreciation of political aspects within social-ecological systems approaches (see: ARMITAGE, 2008; MILLER ET AL., 2010). Olsson and Galaz (2014) suggest that further areas for attention specifically in relation to transformations include: power relations and interests that reinforce existing system configurations, political power across scales, and agency of actors initiating transformations, and participation and deliberation within transformation processes. On the whole, issues of social difference and power require attention under a transformations agenda.

Another broad commonality is that while all the above perspectives draw on *ex-post* analysis of empirical situations to construct theory on transformations, they are on the whole relatively weak in analysing transformations *ex-ante*. This is significant because for transformations towards sustainability we are concerned with understanding how change in socio-technical-ecological systems towards desirable sustainable futures can occur. An exception is the transition management literature, which specifically focuses on the challenge of shaping transitions of socio-technical systems *ex-ante* over decadal timeframes (ROTMANS ET AL., 2001). In general, difficulties conceptualising transformations *ex-ante* is partly because theory building is still in its infancy, and also because of the broadly-agreed view that trajectories of change are complex, co-evolutionary and emergent. However, it is vital to explore how transformations can be better understood *ex-ante* to influence collective decision-making and action across scales.

2.3 GOVERNANCE AND TRANSFORMATIONS

It is important to think critically about the notion of transformations, and the value it can potentially add to the existing business of environmental policy and governance. For example, can the notion of transformations be applied to purposefully shape change towards sustainability, or is it largely confined to a descriptive and *ex-post* role because of the complex, unpredictable, and long-term nature of actual transformation processes in human society? This raises the issue of the role of governance in shaping transformations towards sustainability. Interestingly, the perspectives discussed previously reflect several sometimes-overlapping views on governance and transformation:

- governance *for* transformations i.e., governance that creates the conditions for transformation to emerge from complex dynamics in socio-technical-ecological systems,
- governance *of* transformations i.e., governance to actively trigger and steer a transformation process, and

— transformations *in* governance i.e., transformative change in governance regimes.

Governance refers to the structures, processes, rules and traditions that determine how people in societies make decisions and share power, exercise responsibility and ensure accountability (FOLKE ET AL., 2005; LEBEL ET AL., 2006; CUNDILL AND FABRICIUS, 2010). This includes multiple possible modes of policy and decision making (e.g., hierarchical, market, communicative), and multiple possible actors (e.g., government, industry, research, civil society). We draw on the definition of the Earth System Governance Project, that governance refers to "*the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development"* (BIERMANN ET AL., 2009). Governance can be seen in several ways, including: as a scientific concept employed to conceptualise and empirically trace transformations and institutionalised interventions in societies; as a normative program based on the ambition to realise and manage political change; and as a critical societal discourse linked to wider debates on global change (EGUAVOEN ET AL., 2013).

There has been growing interest in governance in relation to transformations in recent years. Resilience scholars have proposed that 'governance for navigating change' requires a dual focus on both 'adapting' (i.e. *"short and long-term responses and strategies to buffer perturbations and provide capacity to deal with change and uncertainty"*), and 'transforming' (i.e. *"strategies to create a fundamentally new system when current conditions make the existing system untenable"*) (ARMITAGE AND PLUMMER, 2010). More broadly, these scholars have focused on understanding how adaptive governance can facilitate adaptability and transformability in social-ecological systems (WALKER ET AL. 2004; FOLKE ET AL. 2005; OLSSON ET AL. 2006). Transitions management scholars have explored the governance of transitions in socio-technical systems (e.g., SMITH ET AL., 2005; FOXON ET AL., 2009; LOORBACH, 2010), assuming that whilst change cannot be controlled it can nevertheless be steered through a focus on 'goal-oriented modulation' of co-evolutionary socio-technical change processes (KEMP ET AL., 2007). Social learning scholars have explored how social learning can be utilised as *"an alternative governance mechanism"* (ISON ET AL., 2011). Reflexive governance scholars have highlighted the messy reality of bounded rationalities, partial and conflicting perspectives, and constrained roles of actors, and thus the politics of reflexivity in governance for change (HENDRIKS AND GRIN, 2007; VOß ET AL., 2009; VOß AND BORNEMANN, 2011).

Table 1: *Characteristics of the various perspectives on transformations towards sustainability*

Characteristics	**Concept of transformation**				
	Actively navigated transformations in social-ecological systems (Olsson et al., 2004, 2006; Folke et al., 2005)	Social innovation and transformation (Biggs et al., 2010; Westley et al., 2011, 2013)	Navigating 'planetary boundaries' and 'social foundations' (Rockström et al., 2009; Raworth, 2012, Leach et al., 2013)	Transitions management (Rotmans et al., 2001; Geels, 2002; Geels and Schot, 2007)	Learning and reflexivity in governance (Armitage, 2009; Pahl-Wostl, 2009; Ison et al., 2011; Voß and Bornemann, 2011)
Goals of transformations	New environmental management and governance regimes for managing resilience and adaptive capacity	Transformation of social-ecological systems through social innovation and institutional change	Human development within planetary boundaries (sustainability) and social foundations (justice, equity)	Transition in socio-technical systems (e.g., water, energy, waste) towards sustainability	Transformation in governance regimes through social learning and systemic change in practices and understandings
Mechanisms of transformations	Building capacity for transformation and responding to window of opportunity within adaptive change cycle	Fostering social innovation, which is harnessed through agency of key actors to trigger broader transformation	Shaping pathways of human development in context, while also monitoring global pathway trajectories	Niche innovation taken up into broader path-dependent regime during windows of opportunity	Social learning among key actors in governance system generates feedback and reflection that leads to systemic governance change
Trajectory of change	Emergent, steered	Emergent, triggered	Shaped, monitored	Triggered, steered	Emergent, triggered
Theoretical background	Social-ecological resilience	Social-ecological resilience, social innovation	Social-ecological resilience, human rights and justice	Diffusion of innovation, institutions theory	Adaptive governance, social learning

Duit et al., (2010) put a reality check on the notion of idealising the concept of transformation, harking back to Lindblom's (1959) concept of policy making as a process of 'muddling through', stating that: *"at the end of the day, governance solutions for many of those problems rooted in complex systems dynamics will, as always, consist in incrementally implemented, heterogenic, and piecemeal mixes of policy instruments, institutions, networks and organizations".* This poses pertinent questions for what governance entails under a normative view of transformations towards sustainability. Westley et al., (2011) propose a dual strategy of shaping 'top-down' institutional conditions and fostering 'bottom-up' innovation, which implies that while particular interventions may be incremental or piecemeal, over time these changes may trigger more substantive transformation at broader scales. However, Kates et al., (2012) take a critical position, arguing that it is important to recognise when incremental change is insufficient for meeting desired goals (e.g., climate change adaptation in their case), and thus when transformative change must be pursued[1]. Following both lines of reasoning, perhaps governance for transformations entails a dual focus on high-level transformation with incremental muddling at the same time. That is, incremental change with a transformative agenda, where a focus on transformations is valuable for situating incremental efforts (such as policy change) within a broader narrative of transformative change. This aligns with the argument of Levin et al. (2012) for a focus on 'progressive incremental' change, where policy-makers focus on relatively small yet cumulative incremental steps that contribute to creating new path-dependencies towards more desirable futures.

3. UNDERSTANDING AND ANALYSING 'TRANSFORMATIONS TOWARDS SUSTAINABILITY'

There is a need for a broad framework to understand and analyse important dimensions of governance in relation to transformations towards sustainability, which can accommodate several particular concepts of transformation. This is important for exploring the role of governance, and allowing cross-case analysis and comparison (even when differing conceptual perspectives of transformations are applied) to build higher-level theory over time. However, this also needs to allow for continued experimentation and conceptual development within any particular conceptual perspective of transformations (Section 2), as this area of research is in its infancy. The Earth System Governance (ESG) framework (BIERMANN ET AL., 2009) offers such an opportunity. This framework (Figure 1) identifies five core analytical problems faced in governance research (architecture, agency, adaptiveness, accountability, and allocation and access), and four themes that cut across these problems (power, knowledge, norms, and scale). These analytical dimensions are presented as a matrix to illustrate that they are all interconnected and salient to global environmental change governance (BIERMANN ET AL., 2009, 2010). This framework was developed by environmental governance researchers under the international Earth System Governance Project (now incorporated under Future Earth), and has also been

[1] See also Hulme (2009, p.284-321) for an interesting discussion exploring the multiple possible approaches to the governance of climate change.

extensively peer-reviewed by the wider environmental governance scholarly community (see: BIERMANN ET AL., 2009).

Architecture refers to "the overarching system of public or private institutions, principles, norms, regulations, decision-making procedures and organizations that are valid or active" in [a particular] issue area" (BIERMANN ET AL., 2010). Agency is constituted by the actions of actors (e.g., individuals, organizations, states), which interact with social and institutional structures (ARCHER, 2000) to shape change in socio-technical-ecological dynamics (BIERMANN ET AL., 2010). Adaptiveness describes "changes made by social groups in response to, or in anticipation of, challenges created through environmental change … [and] includes the governance of adaptation to social-ecological change, as well as the processes of change and adaptation within governance systems" (BIERMANN ET AL., 2010). Accountability and legitimacy are key concerns in regard to democratic governance and also in influencing institutional effectiveness (BIERMANN ET AL., 2010). Allocation and access entails issues relating to mechanisms for addressing questions of "who gets what, when, where and how" which "is a key question of politics" that fundamentally involves moral and ethical issues (BIERMANN ET AL., 2010).

At the centre of the ESG framework are particular problem domains (e.g., energy systems, water systems, food systems), which we propose are the focus of transformations towards sustainability. Here we extend the framework to include an explicit temporal dimension, which makes it possible to apply the framework to analyse transformation processes for one (or several) of the particular problem domains. The framework does not prescribe or make judgements about specific details of transformation processes (such as goals, mechanisms, trajectories of change), nor does it privilege any particular theoretical perspective. It is flexible enough to accommodate different conceptual perspectives that might be applied in different cases (Section 2), and for an analyst to define how transformation may be characterised in a particular context. It brings to attention the governance dimensions that need to be considered in any transformation case, regardless of the particular conceptual perspective applied, and can thereby allow cross-case comparison and theory-building over time.

As well as being applied in an analytical way, the ESG framework can also be applied in a normative way in order to investigate 'what needs to happen' and 'who decides' in governance of or for transformation. For example, the framework could be used to conduct research to inform policy enabling transformations towards sustainability by highlighting the inter-connected governance dimensions that need to be considered in order to shape transformation processes. Thus the framework offers a useful overarching lens through which to understand and analyse transformations. It also provides a boundary concept for researchers from diverse disciplines to speak a common language, appreciate the multiple analytical dimensions involved in understanding transformations towards sustainability (including those beyond any individual or group's particular research focus), and collectively identify research questions and opportunities for interdisciplinary and transdisciplinary inquiry (following BIERMANN ET AL., 2009; MATTOR ET AL., 2014).

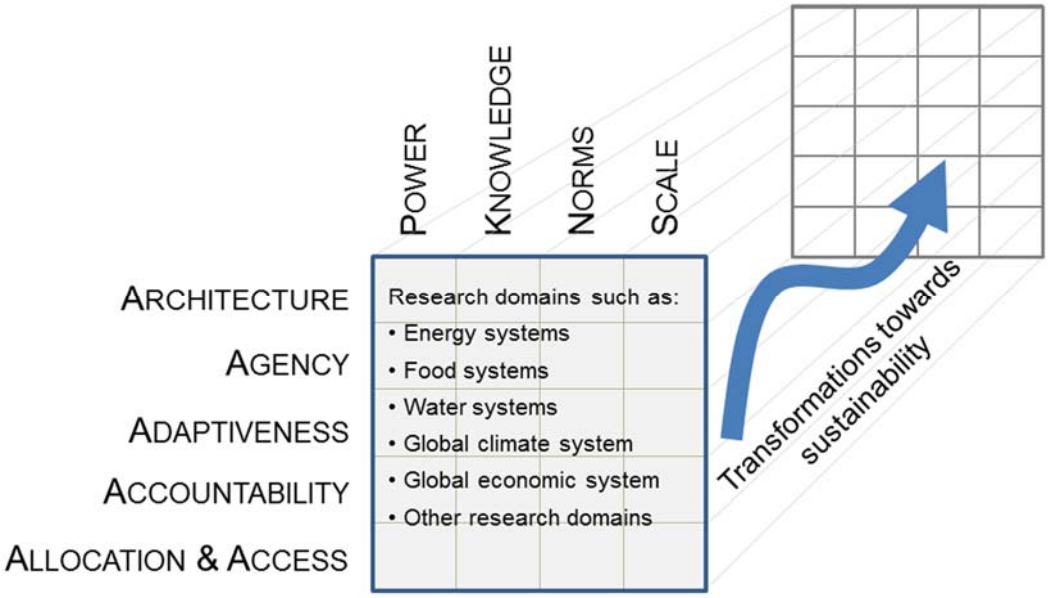

Figure 1: Framework for understanding and analysing transformations towards sustainability, based on the existing Earth System Governance framework (following Biermann et al., 2009).

4. RESEARCH AGENDA

In this section we develop a research agenda for understanding and analysing transformations towards sustainability, based on the ESG framework and a review of research questions proposed by several international initiatives. A broad research agenda for exploring transformations towards sustainability is proposed under Future Earth, including questions relating to decision-making, technology, knowledge and data, behaviour change and social practices, values and beliefs, economy, and adaptability to environmental change (FUTURE EARTH, 2014a,b). Some of these questions directly address governance, such as issues of initiating transformations, the role of global and regional political economies, overcoming path-dependency and inertia, institutional innovation and change, and evaluation of governance systems. A report by the International Social Science Council titled 'Transformative Cornerstones of Social Science Research for Global Change' (HACKMANN AND ST. CLAIR, 2012) identifies six main areas (or 'cornerstones') of global change research that relate closely to the theme of transformations towards sustainability. The six 'cornerstones' identify research needs on: (1) historical and contextual complexities of processes of change across different contexts; (2) consequences of global change, tipping points and evaluation of policy outcomes; (3) conditions and visions for change (e.g., understanding behaviour change, speed and scale of change, agreement on the directions for change); (4) interpretation and sense making (e.g., values, beliefs, worldviews, discourses and narratives of change); (5) responsibilities of societal actors under normative agendas of inter-generational equity and justice; and (6) governance and decision making (e.g., policy change, political will and influence, knowledge, institutions).

These existing research agendas provide a useful starting point for investigating transformations towards sustainability. However, what is lacking is an overarching analytical framework that can provide a meta-level of coherence in the way that different aspects of transformations towards sustainability are investigated and synthesised. The adapted ESG framework (Figure 1) provides an ideal analytical lens in this regard because it identifies dimensions of governance that are highly pertinent for all the research questions outlined by Future Earth, (2014a,b) and Hackman and St Clair, (2013). It provides the ability to focus on specific dimensions in particular cases, but also to contextualise and synthesise them within a higher-level governance lens. Transformations are fundamentally political in nature and will result in winners and losers (WGBU, 2011; STIRLING, 2014). For example, concerns relating to whose knowledge counts, what changes are necessary and desirable, and even what constitutes the end goal of transformation are all intensely political processes. The ESG framework is based on a political perspective of governance (BIERMANN ET AL. 2009, 2010) and provides a suitable framework to expressly engage with the more political aspects of the transformations towards sustainability agenda.

Notwithstanding progress to date, there is room for sharpening a research agenda on transformations towards sustainability. For example, a flagship report by the German Advisory Council for Global Change (WGBU, 2011) identifies several key political challenges for societal transformations across multiple sectors (e.g., energy, urban, and land use systems) in the context of climate change. These include: time pressure on incremental policy change and the inadequacy of short-termism in policy-making; dealing with powerful opposing interests and forces linked to existing path-dependencies; institutional fragmentation and poor coordination; and deficits in representation (e.g., voices not heard, including future generations). This report also emphasises the need for a 'new social contract' for sustainability and a 'proactive state' that *"actively sets priorities for the transformation, at the same time increasing the number of ways in which its citizens can participate"* (WGBU, 2011). This raises questions about power, norms, and accountability. For example, how new norms may arise and become embedded among societal actors, and whether there are tensions between a singular overarching transformation agenda as opposed to a more pluralist perspective of transformation 'pathways' in different cultural contexts (STIRLING, 2014). Questions also arise regarding sources of agency (e.g., whether from state or non-state actors) and its role in multi-scale transformations (FOLKE ET AL., 2005; OLSSON ET AL., 2006; WESTLEY ET AL., 2011).

It is often suggested to look at historical transformations to better understand future transformations towards sustainability (e.g., triggers, mechanisms, and multi-scale interactions) (e.g., WGBU, 2011; FUTURE EARTH, 2014a). However, this may have limitations when it comes to understanding transformations in an *ex-ante* sense[2]. Understanding transformations towards sustainability looking forward is likely to be very difficult because there may be *"no obvious turning or tipping points ... for clearly indicating the before and after of a transformation"* (WGBU, 2011). Similar points are also made in relation to uncertainties regarding thresholds governing transformations

[2] A similar argument is often made regarding the use of analogues to investigate the impacts of anthropogenic climate change (see Kniveton et al. 2009 and Patt et al. 2005).

within resilience and planetary boundaries literature (ROCKSTROM ET AL., 2009; WALKER AND SALT, 2006). Often it is not possible to know the distance to a threshold or even if that threshold has been crossed until it has happened (ARMITAGE ET AL., 2012). Such issues raise important questions about the short-term and long-term dynamics of transformations. For example, what do the early stages of transformations look like (e.g., timescale of years), and what types of dynamics are involved over the longer-term (e.g., timescale of decades)?

An important need is to better understand social and institutional mechanisms (STREECK AND THELEN, 2005; BARZELAY AND THOMSON, 2007; MAHONEY AND THELEN, 2010) involved in transformation. Mechanisms refers to dynamics among actors, institutions, and context (e.g., competition, commitment, performance feedback, bandwagoning, mainstreaming) which can be expected to arise under favourable conditions, thus offering the potential for purposeful design to generate desirable dynamics (BARZELAY AND THOMSON, 2007; BIESBROEK ET AL., 2014). This is significant because transformations are unlikely to be amenable to purely top-down steering but are instead likely to emerge from complex interactions among multiple actors, sectors and scales (Section 2). Thus understanding how to generate desirable dynamics, including those that challenge existing power relations to ensure more marginalised actors have a voice (FORSYTH, 2003), offers a potential strategy for nudging towards broader-scale and more equitable transformation.

Interest in the *ex-ante* analysis and exploration of transformation pathways is increasing (e.g., BERKHOUT ET AL., 2004; BERNSTEIN AND CASHORE, 2012; SACHS ET AL., 2014), including the use of foresight approaches. An example is the "Roads from Rio +20" study conducted by the Dutch Environmental Assessment Agency (PBL, 2012) that sought to quantify the feasibility of multiple transformative pathways toward achieving the Sustainable Development Goals. Building on this initiative, the "World in 2050" initiative, led by the Sustainable Development Solutions Network, the Earth Institute, the International Institute for Applied Systems Analysis and the Stockholm Resilience Centre is seeking to develop quantified pathways toward a common vision based on the SDGs with leading global researchers and support from global development organizations. A bottom-up approach is taken by the Future Earth "Bright Spots – Seeds of a Good Anthropocene" project which aims to identify a wide range of practices that could be combined to contribute to large-scale transformative change. Such foresight initiatives have to deal questions of legitimacy and representativeness, credibility and salience to societal actors across different scales in order to be useful (CASH ET AL., 2003). The diversity of actors, values, sense-making frames, scales and priorities involved suggests that inclusive, pluralistic and dynamic, iterative and dialogue-based approaches are most appropriate; yet such approaches to foresight run the risk of being too scattered and lacking the power of strong organizing ideas and metaphors (NEWELL, 2012). Researchers should focus on understanding the strengths and drawbacks of more centralized and more pluralistic approaches to foresight related to the governance of transformations as they are taken forward, in terms of their ability to understand as well as help facilitate transformative change.

Based on research questions proposed by several international initiatives reviewed in this section, and gaps that become apparent through the lens of the ESG framework, we outline a comprehensive research agenda in Table 2. In proposing this research agenda, we aim to synthesise and build on formative prior work on this topic to consolidate a strong focus on the governance aspects of transformations towards sustainability. We also aim to make clear how these research questions relate to the ESG framework to provide guidance for future research in not only tackling the questions individually, but also to support meta-level synthesis under this rubric.

Table 2: *Research questions for addressing the governance aspects of transformations towards sustainability, and their relationship to the Earth System Governance framework.*

Question	**Key elements of ESG framework**
Initiating transformations[2,3] How do transformations begin? Can they be initiated? What is the role of agency (including leadership and influence) in initiating transformations? How might transformations arise differently in different problem domains?	agency, architecture, norms, power
Processes of transformation[1,2,3,4] How do historical and contextual conditions influence possibilities and processes of future change? What are the short-term and long-term dynamics of transformations and how can we observe when (or when not) transformations are occurring? How can transformative change and its feasibility be modelled and explored in an *ex-ante* sense? What are sources of agency and leadership (including state and non-state actors) in enabling and supporting transformations? What drives transformations towards sustainability over long timeframes, and how might these drivers arise? Can incremental reforms contribute to longer-term transformation? If so, how does this occur, and what does it mean for the initiatives and activities taken by different actors? How does emergent self-organisation and top-down steering contribute to transformations in multi-scalar systems?	agency, architecture, adaptiveness, knowledge, scale,

Institutions and governance approaches[1,2,3] What types of institutions and governance approaches are required to enable and shape transformations towards sustainability across multiple scales? What types of innovation in institutions and governance approaches are needed in different problem domains, and how might this innovation arise and diffuse? What is the potential for purposeful design of social and institutional mechanisms to foster desirable dynamics (e.g., incentives for influencing behaviour, fostering desirable institutional interplay)? How might 'battles of institutional change' (Chhotray and Stoker, 2009) play out, particularly when change is disruptive and met with strong resistance?	architecture, adaptiveness, scale, power, norms
Policy and decision-making[4] How can the need for policy change contribute to and be framed within broader narratives of transformation? How can policy and decision-making that is anticipatory and long-term be encouraged over short-termism?	accountability, architecture, knowledge, scale, norms, power
Evaluating governance performance[2] How can trajectories of change across multiple dimensions (e.g., social, institutional, political, ecological, cultural) be observed in contextually relevant ways that also appreciate co-evolutionary and non-linear outcomes? What indicators could be used to measure governance *of* and *for* transformations? How can governance systems be evaluated and promoted in terms of their effectiveness in facilitating transformations? How can the capacity for reflexive governance be fostered?	accountability, architecture, allocation and access
Cultural-cognitive dynamics[1,2,3,4] How might new norms, ethics and values needed to underpin transformations towards sustainability arise? How could a 'new social contract' for sustainability (WGBU, 2011) be created? What types of new visions can support transformations towards sustainability, and how might these arise? What is the role of interpretation and sense-making (e.g., regarding worldviews, discourses, mental models, narratives of change) in the formulation of visions for transformations? How are different actors involved or excluded in this process? To what extent is agreement among different actors required on directions of change? What are the benefits, drawbacks, challenges and tensions between a single transformations agenda versus more pluralistic approaches? How are different perspectives heard and negotiated in the context of contested knowledge?	agency, norms, knowledge, power, scale

Roles and responsibilities[3,4] What are the roles and responsibilities of different actors in transformations towards sustainability? How can accountability mechanisms be developed to ensure that actors who 'should' be responsible, actually are, both in the short term and longer-term? How can institutional innovations contribute to addressing power inequalities and allowing actors who are poorly represented to participate? How can powerful opposing interests and forces linked to existing path-dependencies be addressed?	accountability, architecture, agency, allocation and access, power, scale
Broader political economies[1,2,4] *"How do global and regional political economies influence transformations to sustainability in different domains?"* (Future Earth, 2014b)	architecture, power, norms, scale, allocation and access

Sources: [1]Future Earth (2004a, p.38)

[2]Future Earth (2004b, p.23-25)

[3]Hackmann and St. Clair (2012, p.18-20)

[4]WGBU (2011, p.321-360)

5. SUPPORTING RESEARCH ON TRANSFORMATIONS

It is critical to consider how the research agenda outlined in Section 4 can be pursued, given that the questions posed are cross-cutting, ambitious and will require sustained efforts among a diverse set of actors including researchers over coming years and decades. Two particular themes are explored: the need for transdisciplinary research approaches; and the role of early career researchers. Strengthening capacity in both of these areas is vital for supporting research on transformations towards sustainability.

5.1 TRANSDISCIPLINARY RESEARCH APPROACHES

There is rapidly growing interest in transdisciplinary approaches for global environmental change research (BUIZER ET AL., 2011; WGBU, 2011; TRENCHER ET AL., 2013; HACKMANN AND ST CLAIR, 2013; ISSC/UNESCO, 2013; FUTURE EARTH, 2014a,b). Transdisciplinary research seeks to address complex problems of social relevance through transcending disciplinary boundaries, and collaboration between researchers, practitioners, policy-makers, business, and other societal actors (Jantsch, 1970; Brand, 2000; WICKSON ET AL., 2006; CRONIN, 2008; HIRSCH HADORN ET AL, 2008; MATTOR ET AL., 2014; MITCHELL ET AL., in press). It differs from interdisciplinary research (which focuses on integration across disciplines) through aiming to transcend disciplines, focusing on real-world complex problems through collaboration between academic and non-academic stakeholders in a pluralistic (CRONIN, 2008) and self-

reflexive manner (BECKER ET AL., 1999). Although transdisciplinarity can be defined in varying ways, three distinguishing features compared to other research approaches are: (1) a focus on addressing 'real-world' problems, (2) collaboration between academic and non-academic actors, and (3) contribution to mutual learning among multiple actors and to multiple academic, policy, and practice outcomes (HIRSCH HADORN ET AL., 2008; WICKSON ET AL., 2006; MATTOR ET AL., 2014; MITCHELL ET AL., in press). In transdisciplinary research, researchers and policymakers interact during the entire process of research co-design and knowledge co-production on problems of policy-relevance in a specific context. Through knowledge co-production, researchers and policymakers inter-relate understanding of systems (*systems knowledge*), consider diverse interests, values and goals (*target knowledge*) and explore and develop policy options or measures to enact solutions (*transformation knowledge*) (HIRSCH HADORN ET AL., 2008; ADLER ET AL., in review). Transdisciplinary research is necessary because understanding, analysing and contributing to transformations towards sustainability cuts across academic disciplines, policy domains, and societal sectors.

Transdisciplinary research on transformations towards sustainability is embedded in the political context of transformations, which the researcher is not separate from. Transdisciplinary research includes both research *on* transformations (understanding and analysing transformations) as well as research *for* transformations (research that aims to contribute to fostering transformations) (following WGBU, 2011; p.351-352). In particular, research *for* transformations, which will be a key focus over coming years and decades (HACKMANN AND ST CLAIR, 2013; FUTURE EARTH, 2014a,b), becomes explicitly normative in engaging with societal values, goals and change. This raises a key need for researchers to be critically aware of their own positionality in exploring, developing and promoting transformations. As Klein (2004) points out: *"transdisciplinarity raises the question of not only problem solution but problem choice"* (emphasis in original), which highlights the centrality of intersubjectivity, negotiation and power in the way that problems are identified and addressed.

Transdisciplinary research on transformations towards sustainability also raises issues linked to the politics of research institutions. Transdisciplinary research differs significantly from more traditional disciplinary research, and requires a different institutional support system. For example, a challenge relates to the way that transdisciplinary research *"involves more fluid and evolving methodologies than traditional academic research"* (PATTERSON ET AL., 2013) and has a strong focus on process design and re-design as research is conducted (PREGERNIG, 2006; WICKSON ET AL., 2006; CAREW AND WICKSON, 2010). Broader challenges related to incentives structures, funding opportunities, research evaluation, publishing opportunities, and institutional support can be significant barriers to conducting transdisciplinary research (WICKSON ET AL., 2006; CAREW AND WICKSON, 2010; PATTERSON ET AL., 2013; MATTOR ET AL., 2014). It is also important to recognise that transdisciplinary research may not always be appropriate or necessary, and there will always remain a strong role for disciplinary approaches (situated within broader transdisciplinary contexts) to enhance its contribution to research on transformations towards sustainability.

5.2 THE ROLE OF EARLY CAREER RESEARCHERS

Transdisciplinary research on and for transformations will require concerted efforts over decades. Today's early career researchers (ECRs) will come to play a central role in global research and policy activities over that timeframe, and hence it is important to support and develop capacity of ECRs in transdisciplinary research on transformations towards sustainability. However, ECRs stand in a paradoxical position; they will be central to and benefit from driving forward a transformations agenda but face many barriers within the wider research context that constrain their involvement (BRAND, 2000; WINOWIECKI ET AL., 2011; PATTERSON ET AL., 2013; MATTOR ET AL., 2014). These barriers relate to the challenges of transdisciplinary research (Section 5.1), which may also be magnified for ECRs, as well as others that are specific to their position as ECRs. Particular challenges faced may be professional (e.g., opportunities for suitable professional development and training, impacts on career progression), methodological (e.g., opportunities to gain experience with diverse research approaches, less power to shape the direction taken by research teams), project-related (e.g., shorter career track record may reduce funding opportunities, pressure to meet narrow performance metrics for career progression, short-term employment contracts which make it difficult to develop longer-term collaborations especially with actors outside academia), and personal (e.g., time and opportunities for reflexivity and breaking out of inherited worldviews) (PATTERSON ET AL., 2013).

Overcoming the many barriers to ECR involvement in transdisciplinary research will require concerted effort in several interdependent areas, including among ECRs themselves, more senior researchers, research institutions, and funding agencies (PATTERSON ET AL., 2013). Based on the experience and observations of the authors, strategies that ECRs can pursue include: taking on responsibility for promoting and experimenting with transdisciplinary research in their own projects and as part of broader teams; developing skills as leaders and change agents (e.g., building relationships with like-minded researchers and non-academic actors, participating in debates shaping research agendas, creating and participating in ECR networks and communities of practice); willingness to be reflexive (e.g., questioning traditional research cultures and approaches, and one's own role in replicating or changing these); and seeking support from mentors to support the development of innovative research projects. Senior researchers can contribute to creating opportunities for ECRs to be involved in transdisciplinary projects (e.g., collaborating with ECRs on research proposals, creating cross-cutting employment positions), acting as mentors, funding training and other professional development opportunities for ECRs, and helping to create and empower platforms for ECRs within global research networks. Research institutions cannot be easily changed, and hence it is important to find opportunities for ECRs within existing structures (e.g., supportive research groups, internal or external training opportunities, innovative sources of funding). Although, we also believe it is important that ECRs and senior researchers are involved in the politics of trying to change institutional structures that constrain transdisciplinary research (e.g., ranging from department-level decision-making, to broader structures and attitudes in

research communities). Research funders have significant power to support ECRs and transdisciplinary research although they may also be slow to change. Nevertheless, ECRs can try to seek out innovative sources of funding from non-mainstream bodies (e.g., philanthropic foundations, non-governmental organisations, international development organisations, business) and help each other to participate in such projects through their peer networks, as well as become involved in the politics of shaping research funding priorities over the longer-term.

A particular opportunity we see for building capacity among ECRs lies in building supportive platforms and networks. This could include platforms with a thematic focus (e.g., transformations in a particular problem domain), geographical focus (e.g., country, global region), or under international research programs (such as Future Earth and the Earth System Governance Project). Operating at different scales and with different sets of participants, different platforms and networks can offer different strengths, yet contribute in several common ways. For example, creating opportunities for peer interaction and dialogue, interaction with senior researchers, training, innovative projects and initiatives across traditional boundaries, collective reflection and learning, communication and advocacy of ECR perspectives, and engagement with wider research communities (WINOWIECKI ET AL., 2011; PATTERSON ET AL., 2013; MATTOR ET AL., 2014). This may also lead to building 'communities of practice' where participants are involved in sustained engagement and dialogue around particular issues of mutual interest (WENGER 2000), which would be particularly beneficial for developing thinking and capacity for transformations towards sustainability. Critically though, ECR platforms and networks need to be adequately supported financially and institutionally, and ideally linked to the institutional arrangements of broader research initiatives to provide legitimacy and ensure ongoing support.

6. DISCUSSION AND CONCLUSIONS

The notion of transformations towards sustainability focuses attention on the challenge of how fundamental change can occur in socio-technical-ecological systems, particularly given that change is likely to be highly political and contested. It has potential to focus the attention of researchers, policymakers, private actors and civil society on processes of change, and, as Hajer et al. (2015) state regarding the Sustainable Development Goals, contribute to *"a powerful political vision that can support the urgently needed global transition to a shared and lasting prosperity"*. It can also be seen as a response to challenges of path dependency and contingency (e.g., breaking out of current trajectories), encouraging us to create new (and perhaps bolder) narratives of change, and to think more systemically about how societal change occurs. However, in order to be taken up meaningfully in research and policy the notion of transformations towards sustainability needs to be better understood. This paper has reviewed concepts of transformations in the global environmental change literature, proposed a framework for understanding and analysing transformations towards sustainability, outlined a detailed research agenda, and argued that transdisciplinary research approaches and the role of ECRs are vital for impactful research on this topic.

While several concepts of transformations exist in the literature (Section 2), it is not necessary that these be unified into a single concept of transformations, as they are developed based on different assumptions and theoretical perspectives for different purposes. However, where all these concepts are weak is in systemically analysing the governance aspects of transformations, particularly in light of their inherently political nature. An extended version of the ESG framework (BIERMANN ET AL., 2009, 2010) can address this weakness by strengthening the capacity for analysing the governance aspects of transformations within specific conceptual perspectives.

A tension is evident between top-down steering and bottom-up self-organisation in the way that transformations are expected to arise. On the one hand, governance of and for transformations (such as via the UN Sustainable Development Goals) may be important for driving deep societal change. Furthermore, earth system governance in the Anthropocene is understood to require a rethinking of existing global institutions to better equip them for contemporary challenges and for driving deep societal change (BIERMANN, 2014). At the same time, it is also important that a focus on global-level approaches does not lead to a 'cockpit' view where it is assumed that *"top-down steering by governments and intergovernmental organizations alone can address global problems"* (HAJER ET AL., 2015). Power and politics (e.g., related to perceived winners and losers, competing interests, different perspectives and motivations) must be squarely engaged with in both deciding what is a desirable future, and how collective efforts are taken to move towards this goal. Both top-down governance and bottom-up self-organisation will play key roles, particularly as trajectories of transformations will emerge from complex and co-evolutionary interactions across multiple scales over time, which often may not be possible to predict. It therefore appears crucial to consider how both bottom-up self-organisation and purposive governance (top-down steering), and their interplay, contribute to transformations (following BERKHOUT ET AL., 2004; WESTLEY ET AL., 2011). WGBU, (2011) usefully observe that:

> *Transformations are usually open-ended processes, the results of a collective steering are never certain, and not clearly foreseeable, despite a defined goal. Transformations are not directly manageable; rather it is a case of allowing the transformation process to develop into a certain direction by creating the respective framework conditions. Exactly how a transformative world will look like at the end of this 'possibility path of many possibilities' cannot be predetermined. Today, the focus must above all be on providing the impetus for a change of course towards the right direction.*

By the same token, it is important to critically reflect on the relationship between incremental change and longer-term transformation, including whether incremental reforms with a general commitment to sustainability can lead to systemic transformations (PELLING, 2011). This could be explored through a triple-loop learning model (ARMITAGE, 2008; PAHL-WOSTL, 2009) in which incremental reforms such as policy change (first order learning) are embedded within broader re-framing of problems (second order learning) and transformation of social and institutional and contexts (third order learning). This provides a heuristic for conceptualising the relationship between incremental and transformative change. From this perspective, it may be possible to pursue 'incremental change with a transformative agenda' as

suggested in Section 2.3, through situating incremental efforts (such as policy change) within a broader narrative of 'transformations towards sustainability'. This highlights the need to consider trajectories of change across multiple dimensions (e.g., social, institutional, political, ecological, cultural) in contextually relevant ways that appreciate the potential for co-evolutionary and non-linear outcomes. Such a strategy would depend on the presence of significant reflexive capacity in governance (VOß ET AL., 2009; VOß AND BORNEMAN, 2011) to identify early signals of change (or lack of change) and to adapt collective efforts over time.

Taking forth a research and policy agenda on transformations towards sustainability will require a strong role for transdisciplinary approaches to support research co-design and knowledge co-production. It will also require a key role for ECRs who will be responsible for progressing research efforts over coming decades, and who also have an opportunity to innovate in addressing barriers currently faced in the shorter term. A particular opportunity for innovation is to create platforms and networks that build capacity of ECRs involved in transformations research. More broadly, we argue that critical reflexivity among global environmental change scholars, both individually and collectively, will be vital for developing innovative research on transformations towards sustainability to meaningfully contribute to policy and action over time. This is because shaping transformations towards sustainability is a highly cross-cutting endeavour (e.g., across academic disciplines, policy sectors, and the roles of many different actors in society), and thus researchers must always be critically reflexive of their role and its impact. Furthermore, transformations are likely to unfold over years and decades, which will demand sustained involvement, commitment and ongoing adaptiveness in research. Nevertheless, emerging interest in 'transformations towards sustainability' offers a promising new narrative for focusing research and policy attention on bringing about deep change that is understood to be necessary for environmental sustainability and human wellbeing globally.

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