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Viewpoint

An agenda for sustainability transitions research: State of the art and future directions☆

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ABSTRACT

Research on sustainability transitions has expanded rapidly in the last ten years, diversified in terms of topics and geographical applications, and deepened with respect to theories and methods. This article provides an extensive review and an updated research agenda for the field, classified into nine main themes: understanding transitions; power, agency and politics; governing transitions; civil society, culture and social movements; businesses and industries; transitions in practice and everyday life; geography of transitions; ethical aspects; and

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methodologies. The review shows that the scope of sustainability transitions research has broadened and connections to established disciplines have grown stronger. At the same time, we see that the grand challenges related to sustainability remain unsolved, calling for continued efforts and an acceleration of ongoing transitions. Transition studies can play a key role in this regard by creating new perspectives, approaches and understanding and helping to move society in the direction of sustainability.

1. Introduction

This article presents an updated research agenda of the Sustainability Transitions Research Network (STRN). This network was inaugurated in 2009 and published its first mission statement and research agenda in July 2010 (STRN, 2010). Since then, research on sustainability transitions has developed rapidly. STRN-membership has grown from about 200 in 2010 to more than 1700 in 2018, and now reaches beyond Europe to include scholars from Australia, Asia, Africa and the Americas. This growth is reflected by the numbers of published books and articles (Fig. 1)[1]. More than 500 new articles appeared in 2018 alone. The field has not only expanded but also diversified in terms of topics and publication outlets.

While early publications often focused on electricity and transport, articles now also regularly investigate other societal domains like food, water, heat and buildings, cities and waste management. There has also been a geographical expansion beyond the early focus on Northern European countries. Studies increasingly investigate transitions in other jurisdictions as well, which bring to light new conceptual issues and questions related to political economy, transnational networks, poverty and justice.

Thanks to all these developments, the research on sustainability transitions has become a collective, productive and highly cumulative endeavor. To take stock of the field's expansion and diversification over the last 8 years, a working group of the STRN Steering Group (Köhler, Geels, Kern, Markard, Onsongo, and Wieczorek) has coordinated a process aimed at updating the research agenda. This working group first reviewed suggestions and ideas from the 6th International Sustainability Transitions (IST Conference in Brighton (2015)). STRN-members were invited to put forward suggestions for the research agenda along with brief arguments for their inclusion. This collective process mobilized deep and diverse expertise, and made it possible to address various themes of sustainability transitions research in sufficient depth and breadth. The initial web agenda was reviewed by two further experts and the sections updated to obtain the present version.

The underlying motivation for research on sustainability transitions continues to be the recognition that many environmental problems, such as climate change, loss of biodiversity and resource depletion (e.g. clean water, oil, forests, and fish stocks), comprise grand societal challenges. The challenges are brought about by unsustainable consumption and production patterns in socio-technical systems such as electricity, heat, buildings, mobility and agro-food. These problems cannot be addressed by incremental improvements and technological fixes, but require radical shifts to new kinds of socio-technical systems, shifts which are called 'sustainability transitions' (Elzen et al., 2004; Grin et al., 2010). Therefore, a central aim of transitions research is to conceptualize and explain how radical changes can occur in the way societal functions are fulfilled. The unit of analysis is thus primarily situated at the 'meso'-level of socio-technical systems (Geels, 2004). The focus of the research on sustainability transitions therefore differs from long-standing sustainability debates at the 'macro'-level (e.g. changing the nature of capitalism or nature-society interactions) or the 'micro'-level (e.g. changing individual choices, attitudes and motivations). Sustainability transitions have several characteristics that make them a distinct (and demanding) topic in sustainability debates and the broader social sciences:

- *Multi-dimensionality and co-evolution*: Socio-technical systems consist of multiple elements: technologies, markets, user practices, cultural meanings, infrastructures, policies, industry structures, and supply and distribution chains. Transitions are therefore co-evolutionary processes, involving changes in a range of elements and dimensions. Transitions are not linear processes, but entail multiple, interdependent developments.
- *Multi-actor process*: Transitions are enacted by a range of actors and social groups from academia, politics, industry, civil society and households. These actors and groups have their own resources, capabilities, beliefs, strategies, and interests. Transitions involve many kinds of agency (e.g. sense-making, strategic calculation, learning, making investments, conflict, power struggles, creating alliances), which makes them very complicated processes that cannot be comprehensively addressed by single theories or disciplines.
- *Stability and change*: A core issue in transition research is the relation between stability and change. On the one hand, there are many 'green' innovations and practices (e.g. car sharing, community energy, meat-free Mondays, urban farming, district heating, passive houses, heat pumps, solar-PV, wind turbines, and electric vehicles). On the other hand, there are deeply entrenched systems around petrol cars, coal and gas-fired power plants, intensive agricultural systems and retail chains with locked-in production and consumption patterns, creating stable, path-dependent trajectories (Unruh, 2000; Walker, 2000). Because of its interest in system change, transitions research aims to understand the multi-dimensional interactions between impulses for radical change and the forces of stability and path dependence. Transition research mobilizes insights from different disciplines and theories to understand this dialectic relationship between stability and change.

[1] For details on the method see Markard et al. (2012).

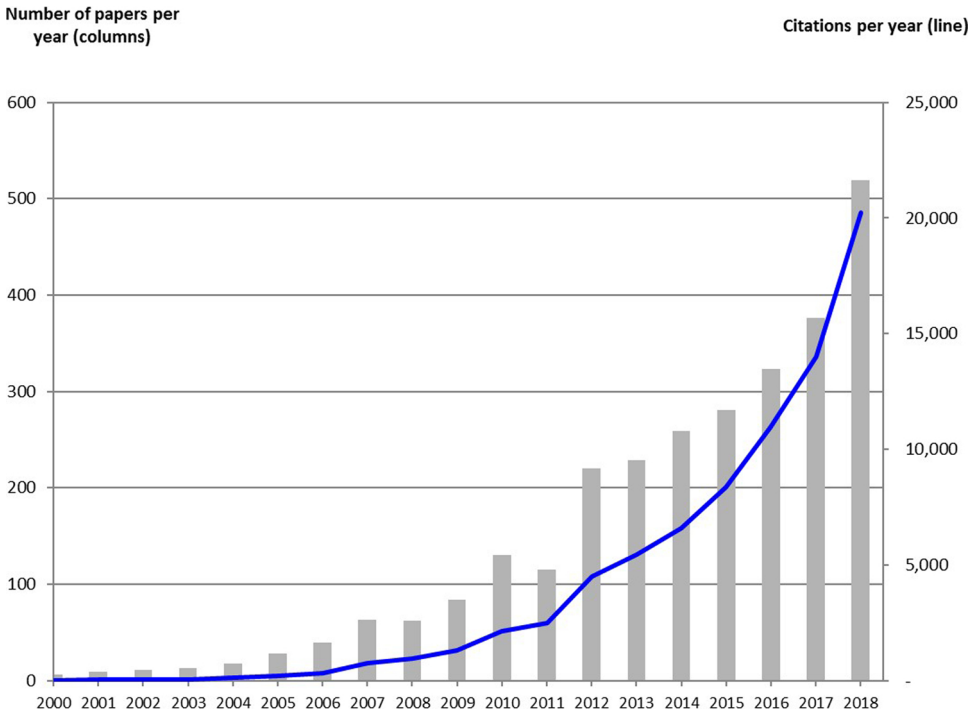

Fig. 1. Number of papers on sustainability transitions in peer reviewed journals and citations.
(Source: Scopus, January 12, 2019)

- *Long-term process*: Transitions are long-term processes that may take decades to unfold. One reason is that radical 'green' innovations and practices often take a long time to develop from their early emergence in small application niches to widespread diffusion. Another reason is that it takes time to destabilize and 'unlock' existing systems and overcome resistance from incumbent actors. To make research tractable, transitions can be divided into different phases, e.g. predevelopment, take-off, acceleration, and stabilization (Rotmans et al., 2001). A potential drawback of phase models (particularly S-shaped diffusion curves) is that their portrayal of transitions can be seen as relatively linear and teleological.
- *Open-endedness and uncertainty*: In all domains, there are *multiple* promising innovations and initiatives and it is impossible to predict which of these will prevail. Since there are multiple transition pathways (Geels and Schot, 2007; Rosenbloom, 2017), the future is open-ended. Uncertainty also stems from the non-linear character of innovation processes (which may experience failures, hype-disappointment cycles or accelerated price/performance improvements), political processes (which may experience setbacks, reversals or accelerations) and socio-cultural processes (which may experience changes in public agendas and sense of urgency).
- *Values, contestation, and disagreement*: The notion of sustainability is, of course, highly contested, so different actors and social groups also tend to disagree about the most desirable innovations and transition pathways for sustainability transitions. Since sustainability transitions may threaten the economic positions and business models of some of the largest and most powerful industries (e.g. oil, automotive, electric utilities, agro-food), such incumbents are likely to protect their vested interests and contest the need for and speed of transitions.
- *Normative directionality*: Since sustainability is a public good, private actors (e.g. firms, consumers) have limited incentives to address it owing to free-rider problems and prisoner's dilemmas. This means that public policy must play a central role in shaping the *directionality* of transitions through environmental regulations, standards, taxes, subsidies, and innovation policies. This necessitates normative statements about what transitions seek to achieve.

The characteristics listed above indicate the transdisciplinary nature of the research on sustainability transitions. It is broader and more inter-disciplinary than many other sustainability approaches, such as industrial ecology, eco-innovation or environmental economics, which tend to focus on single dimensions or particular social groups, have a relatively short-term orientation, fail to acknowledge the systemic dimension, or are overly managerial and technocratic. Sustainability transitions research asks 'big picture' questions, which is probably one reason it has sparked such enthusiasm and creativity.

This updated research agenda takes stock of the past decade and looks forward to the next. The discussion has been divided into the following nine themes, which address different aspects of transitions or transitions research (in no particular order of importance):

i. Understanding transitions (Frank Geels and Lea Fünfschilling)
ii. Power and politics in transitions (Flor Avelino and Florian Kern)
iii. Governing transitions (Bjorn Nykvist and Paula Kivimaa)
iv. Civil society, culture and social movements in transitions (David Hess and Harald Rohracher)
v. Organizations and industries in sustainability transitions (Jochen Markard and Peter Wells)
vi. Transitions in practice and everyday life (Andrew McMeekin, Sampsa Hyysalo, Mari Martiskainen, Johan Schot, Dan Welch)
vii. Geography of transitions: spaces, scales, places (Rob Raven and Anna Wieczorek)
viii. Ethical aspects of transitions: distribution, justice, poverty (Benjamin Sovacool, Kirsten Jenkins, Elsie Onsongo)
ix. Reflections on methodologies for transitions research (Frank Boons, Floortje Alkemade, Georg Holtz, Bonno Pel)

The first theme addresses conceptual frameworks that aim to capture the complexity and multi-dimensionality of sustainability transitions. Themes 2, 3, 4, 5 and 6 focus on particular social groups and dimensions, mobilizing insights from various social sciences to provide deeper insights. While transitions research has always been strong in the temporal dimension, theme 7 addresses the spatial dimension of transitions. Themes 8 and 9 are new compared to the 2010 research agenda. The former addresses ethical issues and the latter moves from modelling to discussing methodological questions in general.

This agenda is intended to provide a general overview and reasoned proposals for future research directions, rather than in-depth analyses of the themes. Each section addresses a theme and starts with a short introduction, followed by two main parts: a brief review of the current state of the art, and a list of interesting directions and open questions for future research.

2. Understanding transitions

This section focuses on the founding theoretical frameworks in the field of sustainability transition studies (van den Bergh et al., 2011; Markard et al., 2012). These are the *Multi-Level Perspective (MLP),* the *Technological Innovation System* approach *(TIS), Strategic Niche Management (SNM)* and *Transition Management (TM)*. They all take a systemic perspective to capture co-evolutionary complexity and key phenomena such as path-dependency, emergence and non-linear dynamics.

Most of the analytical frameworks in this section come from the field of innovation studies, which provides the origin of transitions research (Smith et al., 2010). The focus on innovation has the advantage of drawing analytical attention to novelty and existing structures that tend to privilege particular kinds of actors.

2.1. Current state of the art: existing analytical frameworks

A prominent approach in transition studies is the *Multi-Level Perspective (MLP)* (Rip and Kemp, 1998; Geels, 2002; Smith et al., 2010), which combines ideas from evolutionary economics, the sociology of innovation and institutional theory. It argues that transitions come about through dynamic processes within and between three analytical levels: 1) niches, which are protected spaces and the locus for radical innovations; 2) socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and 3) exogenous socio-technical landscape developments. Radical innovations are assumed to emerge in niches, where new entrants (pioneers, entrepreneurs) nurture the development of alternatives (Rip and Kemp, 1998). These niche-innovations may break through more widely if landscape developments put pressure on the regime that leads to cracks, tensions and windows of opportunity. Subsequent interactions between niches and regimes occur on multiple dimensions (e.g. markets, regulations, cultural meanings, technologies) and are enacted by interpretive actors that fight, negotiate, search, learn, and build coalitions as they navigate transitions. The systemic dimension of transitions and the tension between stability and change are central to the MLP, represented by the interplay of different degrees of structuration at different levels of analysis (niche/regime/landscape).

Another important framework is the *Technological Innovation System* approach *(TIS)* (Hekkert et al., 2007; Bergek et al., 2008a; Negro et al., 2008; Markard et al., 2015) which mobilizes ideas from innovation systems theory (Malerba, 2002) and industrial economics (Carlsson and Stankiewicz, 1991; Weber and Truffer, 2017). A technological innovation system comprises technologies, actors and institutions. The development of a new technology is understood to result from the positive fulfilment of seven functions: 1) knowledge development and diffusion, 2) entrepreneurial experimentation, 3) influence on the direction of search, 4) market formation, 5) legitimation, 6) resource mobilization and 7) development of positive externalities (Bergek et al., 2008a). In terms of the stability/change tension, the TIS approach focuses more on the emergence of novel innovations than on the stability of existing systems.

Strategic Niche Management (SNM) (Rip and Kemp, 1998; Geels and Raven, 2006; Schot and Geels, 2008) is another framework that is widely used for analyzing the emergence of radically new innovations. Combining ideas from the sociology of innovation and evolutionary economics, SNM-scholars suggest that radical innovations emerge in 'protected spaces' (e.g. subsidized demonstration projects, experiments or dedicated users like the Army), which shield them from mainstream market selection. Niche-innovations are often (but not always) developed by new entrants or relative outsiders, who are willing to invest time and money in nurturing and developing a fledgling innovation. Niche-innovations develop through interactions between learning processes (on various dimensions), social networks, and visions and expectations (Kemp et al., 1998). Sequences of experiments and demonstration projects enable recursive cycles of these processes, which can generate innovation trajectories (Geels and Raven, 2006). The specific shape and character of innovation trajectories is influenced by the quality, specificity and robustness of expectations, the depth and breadth of social networks, and the relative emphasis on first- or second-order learning (Schot and Geels, 2008).

Transition Management (TM) (Rotmans et al., 2001; Loorbach, 2010) is a policy-oriented framework, which combines ideas from complexity science and governance studies. It has developed a prescriptive framework, which suggests that policy makers can shape transitions through four sequential steps (Loorbach, 2010): 1) *Strategic* activities in a 'transition arena' aim at vision development and the identification of potential transition pathways. 2) *Tactical* activities develop more specific plans for concrete routes and build agendas and support coalitions for these routes, preferably with investment commitments. 3) *Operational* activities include on-the-ground activities like innovation experiments, demonstration projects and implementation activities, aimed at learning-by-doing. 4) *Reflexive* activities (evaluation of projects, monitoring of progress) should lead to adjustments in visions and the articulation of best-practices. Transition management is further discussed in Section 4.

Sustainability transitions research has exploded in the last 10 years, giving rise to the differentiation of the founding analytical frameworks, the mobilization of new concepts from different fields and theories, and the investigation of new (sub) topics.

MLP elaborations include the following areas First, going beyond substitution dynamics, increasingly differentiated views of the *interactions between niche-innovations and existing regimes*. These include: the selective translation of niche elements into regimes (Smith, 2007), political struggles between niche and regime actors (Hess, 2016a), the role of intermediary actors and boundary spanners in aligning niche and regime developments (Diaz et al., 2013; Kivimaa, 2014; Smink et al., 2015a), niche-empowerment activities aimed at adjusting existing regimes (Smith and Raven, 2012). or collaborations between incumbent firms and new entrants (Geels et al., 2016). Second, while early transition scholars often studied niche-innovations, more attention is now also dedicated to *incumbent regime actors*, including active resistance to transitions (Geels, 2014) and institutional processes that shape regime rules (Smink et al., 2015b; Fuenfschilling and Truffer, 2014). Moving beyond initial dichotomies (new entrants develop radical innovations, incumbents do incremental innovation), scholars have shown that incumbent actors can also reorient towards radical niche-innovations (Berggren et al., 2015; Penna and Geels, 2015), or that incumbents from different sectors move in to engage with niche-innovations (Hess, 2013).

Third, more differentiated views of *transition pathways* have been developed, leading to various typologies, which vary in terms of the dimensions they emphasize. Berkhout et al., (2004) distinguish: purposive transition, endogenous renewal, reorientation of trajectories and emergent transformation. (Geels and Schot, 2007) differentiate: substitution, transformation, reconfiguration, and de-alignment and re-alignment. (Haan and Rotmans, 2011) discuss a range of dynamic patterns that combine in different ways to produce multiple pathways. Fourth, scholars have 'zoomed in' to study the roles of particular actors or dimensions in transitions and the MLP, e.g. users (Schot et al., 2016), civil society actors (Smith, 2012), cultural discourses (Roberts, 2017), and firms (Farla et al., 2012). Although important and useful, such 'zooming in' runs the risk of losing sight of co-evolution and multi-actor dynamics.

Important elaborations in the TIS framework include the following areas (see Markard et al., 2015 for an overview). First, interactions of TIS with broader technological, sectoral, geographical and political context systems (Bergek et al., 2015) aim to capture more complex technology dynamics including competing and complementary technologies (Markard et al., 2009; Magnusson and Berggren, 2018) or the dependency of TIS dynamics on institutional contexts (Dewald and Truffer, 2012; Wirth et al., 2013). Second, the strategic actions of different kinds of actors in system building have been elaborated to understand the creation and use of system resources (Musiolik et al., 2012; Planko et al., 2016; Kukk et al., 2015). Third, legitimacy dynamics and legitimation strategies for technological innovation systems have been elaborated (Bergek et al., 2008a; Binz et al., 2016; Markard et al., 2016b).

Fourth, the TIS framework has been spatially differentiated through the spatial analysis of innovation networks (Dewald and Truffer, 2012; Binz et al., 2014), local sources of market formation, and the interaction of TIS across countries (Bento and Fontes, 2015; Wieczorek et al., 2015b) or global innovation systems (Binz and Truffer, 2017). Fifth, a TIS lifecycle model has been proposed to accommodate the later stages of maturation and decline and the dynamics of sustainability transitions (Bergek and Jacobsson, 2003; Bento and Wilson, 2016). Sixth, more differentiated patterns of change have been addressed, e.g. how interactions between TIS functions may lead to recurring 'motors of change' (Suurs and Hekkert, 2012). Varied interaction patterns are also explored by applying new methods such as computer models (Walrave and Raven, 2016). Seventh, conceptual interactions between TIS and MLP are discussed in Markard and Truffer (2008). Eighth, the development of systemic problems and policy instruments has aimed at improving how innovation systems function (Wieczorek and Hekkert, 2012).

SNM research has also been elaborated along the following lines. First, a different typology of core niche processes including shielding, nurturing, and empowerment has been proposed (Smith and Raven, 2012; Raven et al., 2016). Building on this, two empowerment patterns describe possible relations between niche-innovations and existing regimes: fit-and-conform and stretch-and-transform (Smith and Raven, 2012). Second, learning processes and experimentation with regard to radical innovations have been elaborated (van Mierlo et al., 2010; Sengers et al., 2016). Third, the role of expectations in niche development has been elaborated (Brown and Michael, 2003) and how this may trigger hype-disappointment cycles (Bakker and Budde, 2012; van Lente et al., 2013; Konrad, 2016). Fourth, research on grassroots innovation has addressed possible roles of activists and local communities (Seyfang and Smith, 2007; Seyfang and Haxeltine, 2012; Hargreaves et al., 2013). Fifth, research on niche experimentation as seeds of change moved away from studying state-driven, western, single projects in local contexts towards examining decentralized and civil forms of networked experiments across multiple spatial dimensions (Sengers et al., 2016; Broto, Vanesa and Bulkeley, 2013; Wieczorek et al., 2015a).

This overview shows that transition research has become a collective and progressive research program with cumulative findings and increasingly nuanced and differentiated understandings.

2.2. Research directions

One important new topic is the destabilization, decline, and phase-out of existing systems and regimes (Karltorp and Sandćn, 2012; Turnheim and Geels, 2012; Kungl and Geels, 2018; Roberts, 2017), which represent the 'flip-side of transitions'. Existing systems may decline *because of* pressure from niche-innovations, but systems may also be phased-out deliberately (Rogge and Johnstone, 2017; Stegmaier et al., 2014) to create space for the accelerated diffusion of niche-innovations.

Second, more research is needed on breakthrough, diffusion, and tipping points, because this is beginning to happen in the real world in some domains (e.g. renewable electricity technologies, electric vehicles) and problems like climate change require accelerated transitions.

Third, there is a need to move beyond single innovations towards (complementary and competing) interactions between *multiple* emerging and existing technologies (Sandén and Hillman, 2011) or niches (Raven, 2007; Verbong et al., 2008; Papachristos et al., 2013), and the repercussions these dynamics have for the 'functioning' of the larger system (Markard and Hoffmann, 2016).

Fourth, some scholars are 'zooming out' to develop a more encompassing understanding of transitions. This includes interactions between multiple systems such as electricity-transport, agriculture-transport, and heat-electricity (Raven and Verbong, 2007; Konrad et al., 2008; Papachristos et al., 2013). New research on 'deep transitions' has also begun to ask bigger questions, investigating how multiple regime shifts can shape landscape developments and thus societies as a whole (Schot, 2016).

Fifth, the speed of transitions and how can they be accelerated is an important topic (Sovacool, 2016; Bento and Wilson, 2016). Do transitions always take multiple decades? Or can they be quicker? If so, under what circumstances can acceleration occur?

Sixth, new research has begun to investigate the strengths of lock-in mechanisms, and how they vary over time or between sectors (Klitkou et al., 2015). Such studies could enable more precise assessments of the degree of path dependency as well as tensions/cracks in regimes.

Seventh, research could fruitfully mobilize insights from other social science fields to better understand particular processes or dimensions of transitions. These include, for instance, deeper theoretical anchoring via institutional theory (Fuenfschilling and Truffer, 2014, 2016), theories of power (Avelino and Rotmans, 2009) and policy change (Markard et al., 2016a), organizational theories (Farla et al., 2012), and economic geography (Hodson and Marvin, 2010; Coenen and Truffer, 2012; Bulkeley et al., 2014; Truffer et al., 2015).

Finally, it is also striking that transitions research has so far had little interaction with research in (environmental) economics. Even though there are major differences in approaches, there might be common ground to explore such as the complementarity and interaction of policies proposed within transition research (e.g., diversity of local experiments, community initiatives, network formation) with pricing of negative externalities (van den Bergh, 2013).This discussion could contribute to the debate on limits to growth (van den Bergh, 2017).

3. Politics and power in transitions

Transitions are inherently political processes, in the sense that different individuals and groups will disagree about desirable directions of transitions, about appropriate ways to steer such processes and in the sense that transitions potentially lead to winners and losers. As incumbent industries might be threatened, they often exercise power to protect their vested interests and resist transformative innovation. At the same time, new entrants or actors in favor of alternative socio-technical configurations will lobby for public support. In and around the field of transition research, these issues of *politics* and *power* in transitions are receiving increasing attention. This is a response to several critiques that these aspects were neglected in the early work on transitions and their governance (Shove and Walker, 2007; Meadowcroft, 2009; Smith and Stirling, 2010; Scoones et al., 2015; Kern, 2015).

These discussions can be contextualized within a broader debate about the politics of sustainable development (e.g. Meadowcroft, 2007; Scrase and Smith, 2009; Swyngedouw, 2010). These critiques have led to a series of theoretical and empirical studies of power and politics in transitions (Hendriks and Grin, 2007; Kern and Howlett, 2009; Voß et al., 2009; Avelino and Rotmans, 2009; Hoffman, 2013; Hess, 2013; Geels, 2014; Avelino et al., 2016; Partzsch, 2016; Ahlborg, 2017; Lockwood et al., 2016; Smith and Stirling, 2018) so that this has now become a widely acknowledged theme within sustainability transitions research. Issues of power and agency are closely related to the theme of governance and the implementation of transitions discussed in Section 4 and the ethics of transitions discussed in Section 9.

3.1. Current state of the art

Understanding the politics of transitions implies attention to "who gets what, when, and how" (Lasswell, 1936). This means careful attention to the question of who wins or loses when innovations emerge and get implemented (Smith and Stirling, 2018), and which vision(s) of sustainability predominate in deciding the direction of sustainability transitions (Stirling, 2011). Scholars in the transition field have started to move beyond simply analyzing the content of public policies to think more systematically about the politics of policy processes and how they shape policy outputs (e.g. (Kern, 2011; Hess, 2014; Normann, 2017, 2015). This emerging strand of work draws on well-known policy process theories from the field of policy sciences (see Kern and Rogge, 2018 for an overview). These include Sabatier's advocacy coalition framework (e.g. see (Geels and Penna, 2015; Markard et al., 2016a), Hajer's discourse coalitions (e.g. see Kern, 2011; Rosenbloom et al., 2016), Marsh and Rhodes's policy networks (e.g. see Normann, 2017), Kingdom's multiple streams (e.g. see Elzen et al., 2011; Normann, 2015), Baumgartner's punctuated equilibrium theory (e.g. Geels and Penna, 2015) and Pierson's policy feedback theory (e.g. see Edmondson et al., 2018).

These approaches mainly differ in terms of how they conceptualize what holds the actor coalitions together (e.g. shared beliefs, shared discourses or common interests). A recent review of five of the above policy process theories argues that they are useful for studying the politics of sustainability transitions and suggests that the decision of which of these approaches to use (or any others) depends on the research focus and question and requires a critical appreciation of their respective strengths and weaknesses: "For example, some of these approaches are more focused on explaining agenda setting processes (e.g. multiple streams approach, punctuated equilibrium theory), while others are used to understand all stages of policymaking. Some of the theories focus more exclusively on policy makers and stakeholders routinely involved in policymaking (e.g. advocacy coalition framework, multiple streams approach), while others also include the influence of mass publics potentially affected by policy (e.g. policy feedback theory)" (Kern and Rogge, 2018: 112). However, these frameworks are also criticized for not paying enough attention to policy outcomes (rather than policy outputs) and that they are too often applied to the study of single policy instruments rather than wider policy mixes (see section 4). In addition, an important insight from transition studies is that technology and changes in technology may affect and even facilitate policy change (Hoppmann et al., 2014; Markard et al., 2016b; Schmidt and Sewerin, 2017). This creates a need to better conceptualize the co-evolution of policy change and socio-technical change (Edmondson et al., 2018).

Voß et al. (2009) put together a special issue focusing on designing long-term policy for transitions. They highlight what they see as three critical issues: the politics of societal learning, contextual embedding of policy design and dynamics of the design process itself and propose a view on policy design as a contested process of social innovation. In a special issue on the politics of innovation spaces for low-carbon energy, Raven et al. (2016) bring together a collection of articles, which explore the politics of transitions by drawing on evolutionary, relational and institutional perspectives. They also identify a number of lessons for actors involved in the daily struggle of creating, maintaining and expanding protective spaces for sustainable innovations. In their special issue on the politics of sustainability transitions, (Avelino et al., 2016) call for a broad understanding of politics, which does not only concern studying (government-led) policy processes, but also unpacking the 'micro-politics' of transition processes (Hess, 2014).

The topic of politics is inextricably linked with the notion of power. It is now well established in the literature that transitions involve various aspects of power. However, there are diverse interpretations of how power should be understood in relation to the transition concept. In the socio-technical perspective on transitions (Geels and Schot, 2010), power is primarily understood in terms of the regulative, cognitive and normative rules underlying socio-technical regimes, and the 'power struggles' between incumbent regimes and upcoming niches. (Geels and Schot, 2007:415) position power as a specific perspective on agency that revolves around actors and social groups with "conflicting goals and interests", and which views change as the outcome of "conflicts, power struggles, contestations, lobbying, coalition building, and bargaining". In a more recent account, Geels (2014) has expanded the power of regimes in terms of neo-Gramscian political economy notions of hegemonic power regime 'resistance'.

In the governance perspective on transitions, (Grin, 2010) discusses transition agency in terms of agents' capacity of 'acting otherwise' (in reference to Giddens) and triggering institutional transformation by 'smartly playing into power dynamics at various layers'. Moreover, Grin links the MLP to an existing multi-levelled power framework by Arts and van Tatenhove (2004). Grin argues that the three levels of power distinguished correspond to the three levels in transition dynamics: 1) relational power at the level of niches, 2) dispositional power at the level of regimes, and 3) structural power at the level of landscapes (Grin, 2010: 282–283).

Avelino (2017) has built on a diversity of social and political power theories to re-conceptualize niches and regimes as different functional spaces in which different forms of power are exercised: regimes are viewed as spaces of *reinforcive power* (where institutions are reproduced), niches as spaces of *innovative power* (where new resources are developed), and 'niche-regimes' as spaces of *transformative power* (where institutions are renewed). Based on this typology of different kinds of power, it is argued that niches can challenge regimes on power grounds because even if regimes hold 'more' power than niches in absolute terms, they do not necessarily exercise power 'over' niches, because niches can exercise a *different* kind of power (i.e. innovative power) that provides them with a certain level of independence from regimes (by creating new resources and thereby becoming less dependent on existing structures of domination that predetermine how resources are distributed) (Avelino and Rotmans, 2009; Avelino and Wittmayer, 2016).

Besides these examples of how power theories have been related to transition theory, there have been several other contributions, for instance on how power relates to creativity in wind energy projects in Denmark (Hoffman, 2013), on how power is relational, contingent and situated in the case of energy transitions in Tanzania (Ahlborg, 2017) and on the countervailing power of competing industrial fields in distributed solar energy in the United States (Hess, 2013). Overall, this short summary of some of the contributions to this theme shows how vibrant this discussion has become within the transitions community and also shows the variety of theories and perspectives scholars have drawn on. In the next section we make an argument for why this diversity is important in addressing diverse research questions about the politics and power in transitions.

3.2. Research directions

As transitions take off and accelerate, issues of politics and power remain extremely important. For example, Markard (2018) argues that in the case of transitions towards renewable electricity, economic and political struggles of key actors such as utility companies and industry associations are intensifying. While questions about the contestation of desirable directions may fade in such cases, the polarization between winners and losers may become more pronounced. It also becomes increasingly interesting to ask how we can explain the varied progress with transitions in different sectors and countries. There are also interesting but unexplored questions about how global power shifts (such as from the West to the East) will influence the international politics of transition processes (Schmitz, 2013).

If we aim to understand politics as spanning different dimensions and levels of society, it follows that we need diverse perspectives on politics and power, drawing on diverse fields of research (Avelino et al., 2016). For instance, third sector studies and other

institutional perspectives help to specify the role of different actors and institutional logics and how these in turn play diverse roles in multi-actor transition dynamics (Stirling, 2014; Smink et al., 2015b; Fuenfschilling and Truffer, 2016; Avelino and Wittmayer, 2016). Lockwood et al. (2016) propose drawing on historical institutionalism to improve our understanding of the effects of different institutional arrangements on the diversity in transition outcomes.

Practice theory and other relational approaches feature notions such as 'fields' (Hoffman and Loeber, 2016), 'ecologies of participation' (Chilvers and Longhurst, 2016) and 'Trojan Horses' (Pel, 2016) as perspectives through which to grasp the (micro-political) dynamics of niche-regime interactions. Social movement theory can help to conceptualize the role of bottom-up pressure for transitions (see Section 5; Sine and Lee, 2009; North, 2011).

Swilling et al. (2016) has argued a need to reconsider 'socio-technical' regimes as 'socio-political' regimes in the context of development studies. Critical geography offers a broad range of notions to analyze how the politics of geographic boundaries intertwine with the development of specific technologies (e.g. Castán Broto, 2016).

Critical-theoretical accounts of post-political ideology (Kenis et al., 2016) offer conceptual tools to unpack post-political dimensions Swyngedouw (2013) in transition governance, drawing on insights from critical political theorists such as Mouffe (2005).

Further studies may also draw on comparative political economy frameworks (such as varieties of capitalism) to try to explain the large variation of transition pathways and outcomes across countries (Ćetković and Buzogány, 2016; Kern and Markard, 2016).

In conclusion, there is no lack of interesting perspectives to address politics and power in transitions. However, the main challenge for future research might actually be to compare and integrate the diversity of studies on politics and power and to reflect what the findings so far imply for transition theory. Many of the existing studies on politics and power as introduced above have been developed in parallel, using very dissimilar concepts, perspectives and empirics, which makes it difficult if not impossible to compare results in order to obtain more generic insights.

Given the interdisciplinary and multi-level ambitions of transition studies, a potential next step is to conduct a more comparative discussion on politics and power in transition processes across disciplines, frameworks, levels (macro/meso/micro) and case studies. Such comparative discussion could occur, for instance, by reviewing one and the same empirical case-study or empirical research question from different power perspectives. Here it is important not only to study power as an instrument for transitions - i.e. how power is exercised by different actors and structures to achieve or obstruct sustainability transitions - but also to scrutinize what are the (un)intended political implications of transition processes regarding structural power inequalities in class, race, gender, and geographical location (see section 9).

4. Governing transitions

Various approaches have been developed that aim to produce analyses supporting governance for transitions, including work on Transition Management (Rotmans et al., 2001; Loorbach, 2010), Strategic Niche Management (Kemp et al., 1998) and Reflexive Governance (Voß and Bornemann, 2011). These contributions partly draw on the wider field of governance studies as well as other fields like complexity theory or systems theory. Apart from the close ties to power and agency discussed in section 3, governance is also part of several other themes: geography and scales (section 8), as well as ethics and justice (section 9).

4.1. Current state of the art

Research on governing transitions draws from multiple strands of work, but rest on broader work on governance and institutional change which is briefly covered first in this section. After this, some specific work on means of governance in Transition Management and Strategic Niche Management, analysis of public policy from a transitions perspective and experimental approaches to governance are reviewed.

Much of the work on governing transitions starts by recognizing that transitions cannot be solely governed from a top-down perspective and that a plurality of actors, not just governments are involved. They have to deal with uncertainty and appropriate interventions may change over the course of a transition depending on the phase (see e.g. Grin et al., 2010). Classic work on governance (Kooiman, 2003, p.4) defines governing as "the totality of interactions, in which public as well as private actors participate, aimed at solving societal problems or creating societal opportunities; attending to the institutions as contexts for the governing interactions, and establishing a normative foundation for all those activities". This definition is suitable for discussing the governance of sustainability transitions, as it acknowledges its multi-actor nature and normative ambitions. In line with this, transition scholars engaging with governance have looked at the role of institutions in shaping transition policies (Kern, 2011), how institutional logics shape transition processes (Fuenfschilling and Truffer, 2014) and have applied practice-oriented perspectives drawing on actor-network theory that investigate the role of transition arenas (Jørgensen, 2012).

The frameworks of the transitions literature, in particular Transition Management and Strategic Niche Management, propose means of governing through particular processes oriented to transitions. For example, the core idea of the transition arenas featured in Transition Management is to change governance to facilitate transitions by bringing together actors from science, policy, civil society and businesses and develop cooperative rather than competitive relationships between them. It should be said upfront that the barriers to such cooperation can be deeply rooted due to the entrenched nature of existing socio-technical regimes (Geels, 2004). This includes not only vested interests and resistance to change from, e.g. incumbent regime actors, but also wider societal structural challenges such as inequality or corruption creating deep political conflicts. Various applications have been made to develop transition arenas for solving predominantly local but also broader regional and national issues (e.g. (Voß et al., 2009; Loorbach and Rotmans, 2010; Frantzeskaki et al., 2012). Transition arenas have recently been applied in the context of illiberal democracies

(Noboa and Upham, 2018) and coupled with design studies (Hyysalo et al., 2018a,b). The work on strategic niche management has evolved from study of the processes of learning, visioning and networking to examining the ways in which niches become empowered. Some attention has been paid to how niche actors may be able to change existing regulations favoring the current regime towards rules favoring their preferred niches (Smith and Raven, 2012; Raven et al., 2016). Moreover, the framework has been used more explicitly to analyze the role of different governance actors, such as intermediaries (e.g. innovation and energy agencies), in transitions (Kivimaa, 2014; Barrie et al., 2017).

While specific policy analysis played little role in early transitions research, in recent years, research on policy from the perspective of transitions has proliferated. This includes studies on policy instrument mixes ((Kivimaa and Kern, 2016; Schmidt and Sewerin, 2018), policy coherence ((Huttunen et al., 2014; Uyarra et al., 2016), and the interplay between policy processes and instruments ((Rogge and Reichardt, 2016; Johnstone et al., 2017), among others. An emerging strand of work on wider policy mixes (Flanagan et al., 2011) argues that these are required for sustainability transitions ((Reichardt et al., 2016; Kivimaa and Kern, 2016; Rogge and Reichardt, 2016) and that the ways in which mixes of policy goals, instruments and processes interact is of crucial importance for the degree to which policy facilitates (or hinders) transitions. This new research pays increasing attention to the role of existing policies as part of transitions, and aims to analyze them as well as suggest new ways of evaluating policies to determine how policies support or hinder transitions.

Finally, experiments (e.g. Bulkeley et al., 2014; Luederitz et al., 2017; Sengers et al., 2016), are an approach to the governance of transitions in practice (Hoogma, 2002). Recently, attention has been directed explicitly to experimentation as a governance approach, that not only applies to niche development but also changing the regime from within (Matschoss and Repo, 2018), connecting to increasing political and academic interest in governance experimentation (e.g. (Hoffmann, 2011; Sabel and Zeitlin, 2012). Governance and policy experimentation for transitions can advance social learning (Bos and Brown, 2012), challenge dominant values and bring in new actors (Kivimaa et al., 2017), and support the accelerated diffusion of new solutions (Matschoss and Repo, 2018).

4.2. Research directions

The research on the governance of transitions has grown in recent years and there are multiple directions for future work. These include forward looking analysis and governing later phases of transitions, further developing the study of policies in the context of transitions and the role of experiments and transition intermediaries in connecting actors.

Some of the thinking behind approaches such as Transition Management and Strategic Niche Management has been used by policy makers in a variety of settings at different governance levels (e.g. the national level in the Netherlands, or the provincial level in Belgium) with mixed results (e.g. see Kern and Smith, 2008; Hendriks and Grin, 2007; Kemp et al., 2007). Recently, there has been increased interest from international organizations like the OECD and the European Environment Agency. Calling for application of transitions thinking at a large-scale societal level and long term sustainability challenges, this interest from policy makers challenges transition scholars to focus more on forward-looking analysis. It means moving on from historical lessons or analyses of transitions in the making, to be more explicit in how we develop policy-relevant scenarios and toolboxes based on interdisciplinary knowledge generated by transition scholars, e.g., across institutional levels (Nilsson and Nykvist, 2016). Such forward-looking analysis requires the combination of transitions research with more in-depth analyses of institutions and governance (Turnheim et al., 2015; Foxon et al., 2013; Nilsson et al., 2012). Furthermore, much of the existing thinking on how to govern transitions focuses on the early stages of the process (e.g. transition arenas, experiments). A real challenge for current transition scholars now concerns developing more insights into how to govern later phases of transition (for example, how to achieve acceleration, e.g. see (Gorissen et al., 2018; Sovacool, 2016).

The transitions community has emphasized the role of new kinds of instruments for governance processes, such as transition arenas and arenas for development (which stimulate learning processes, network building, visioning). While these remain important and should be studied in different contexts, we should also investigate the role of more traditional policy instruments such as economic instruments (taxes, subsidies, capital grants, loans, exemptions) and regulations in transitions. While the end goal of, for example, strategic niche management is to create conditions of learning and interaction across actors and processes, the ideas are originally firmly rooted in the perspective that niches need to be nurtured and protected by public policy (Kemp et al., 1998). Some examples of such protection include markets induced by regulation or deployment subsidies for more sustainable solutions, and protected spaces for experimentation through RÉD funding. Public policy is still very relevant, and may be especially relevant for diffusion, acceleration and upscaling, while also affecting the speed and direction of innovations that are critical to sustainability transitions. While the transitions approaches can point towards ideal policy instrument mixes (cf. (Kivimaa and Kern, 2016; Rogge and Reichardt, 2016), the politics underlying decision processes have a significant influence on whether new policy designs, supporting transitions better, are successfully adopted and implemented. See section 3 on future research directions regarding politics.

Recent contributions have highlighted the lack of sufficient research on the roles of intermediaries in governing transitions i.e. facilitating and accelerating transitions, destabilizing incumbent regimes and operating in later phases of transitions (Ingram, 2015; Bush et al., 2017; Kivimaa et al., 2018). Such actors range from energy and innovation agencies (Kivimaa, 2014; Barrie et al., 2017) to individuals, such as planners and energy managers taking on intermediary roles. New research on intermediaries needs to address intermediation for governing different transition stages, and explore how and when intermediaries function best as part of policy-making.

Finally, the further development of the analysis of transition experiments is needed including the application of the ideas of micro-politics, power and agency in experimentation, the geography of experimentation and the role of business in experiments. There is also a need to go beyond case study approaches towards frameworks to analyze the ways in which experimental governance

approaches support transitions (Bernstein and Hoffmann, 2018; Matschoss and Repo, 2018) and how experiments lead to broader sociotechnical and governance change (Sengers et al., 2016).

5. Civil society, culture and social movements in transitions

The sustainability transitions literature has increasingly recognized the importance of civil society and social movements in the transformation of energy, transport, or food systems and more generally our systems of production and consumption. Civil society and social movements affect industrial transitions by building support for transition policies and by providing protective spaces for innovation, but they also can have more pervasive and less obvious effects on broader cultural values and beliefs.

Definitions of the terms “civil society,” “social movement,” and “culture” vary widely. As the third sector alongside the public and private sectors, civil society includes a wide range of associational organizations that are often granted special non-profit status in a country’s legal code and can be involved in transition governance (section 4). Whereas not all civil society organizations (CSO) have the goal of social change, social movements are networks of individuals and organizations that have the goal of changing established institutions in the state, private sector and/or civil society. Social movements are often comprised of CSOs, but they can also include organizations from the private and public sector. Culture is the collective network of semiotic systems of cognitive and normative categories for a demarcated population, or what (Geertz, 1973) referred to as the "models of" action (beliefs, cognitive categories) and "models for" action (norms, values). It can be shared or contested, conscious or unconscious and strategic or habitual. Sustainability transitions involve many types of cultural change, including in the legal and normative frameworks that guide the production and use of technology, in the everyday practices of organizations and consumers, in social relations and social structures and in the material culture involving the design choices among products and infrastructures. Social movements, especially when they are engaged with industrial change, can bring attention to the need for cultural change.

5.1. Current state of the art

Research to date on the role of civil society and social movements in sustainability transitions can be classified into three pathways for how they affect transitions: the politics and governance of transitions (Kern and Rogge, 2018 see also sections 3 and 4), grassroots innovation (Seyfang and Smith, 2007) and cultural change (Geels and Verhees, 2011).

With respect to the politics of transitions, there is substantial general social science work on industrial opposition movements (e.g. grassroots mobilizations against genetically modified food or fossil fuels), but their effects on sustainability transitions is only beginning to attract attention in the transition studies literature (e.g. (Elzen et al., 2011; Penna and Geels, 2012; Törnberg, 2018). Social movements may become a source of resistance to innovations, for example, by generating opposition to the introduction of wind farms or by connecting with the industrial interests of incumbent actors and stabilizing existing regime structures (Hess, 2013; Avelino and Wittmayer, 2016). But CSOs and social movements also play a role in broad advocacy coalitions that support transition policies (Markard et al., 2016b; Haukkala, 2018) and they can affect public support for policies that lead to the decline of some technologies and the uptake of others. Social movements are often motivated by an alternative vision for society as a whole (Smith, 2012) and thus they help to articulate new directions of societal change (Leach et al., 2012; Allan and Hadden, 2017). In doing so, they draw attention to justice, fairness, and inclusive innovation that can affect the design of transition policies and the selection of innovations (Smith et al., 2016; Sovacool and Dworkin, 2014; see section 9 on ethics).

The second area of research draws attention to the direct effects of CSOs on industrial innovation by providing protective spaces for grassroots innovation and by creating consumer demand (Hossain, 2016; Seyfang and Smith, 2007; Ornetzeder and Rohracher, 2013; Smith et al., 2016). These protective spaces are often anchored in CSOs such as community organizations, but researchers, local governments, and entrepreneurs can also play a significant role. A substantial strand of the literature on reform-based movements anchored in CSOs examines innovation in “energy communities” (Dóci et al., 2015; Seyfang et al., 2014; Seyfang and Haxeltine, 2012; Heiskanen et al., 2015) such as the UK transition town movement (Stevenson, 2011). An important dynamic for grassroots innovation is the relationship with regime organizations that may attempt to circumscribe the grassroots innovations in a “fit and conform” pattern that modifies design innovations while incorporating them into the regime (Hess, 2016a; Pel, 2016; Smith and Raven, 2012). Grassroots innovation projects anchored in CSOs may also gain support from regime actors from countervailing industries but, again, this support may involve significant design transformations that accompany the benefits of diffusion and scale shifts (Hess, 2016b).

The third area of research studies how civil society and social movements bring about broader cultural changes. By challenging taken-for-granted systems of meaning, CSOs and social movements can affect public opinion and policy preferences as well as consumer preferences and everyday practices (e.g. Sine and Lee, 2009 on wind energy in the U.S.; Balsiger, 2010; Holzer, 2006 on political consumption). Social movements create new semiotic maps of the possible and desirable and they can drive shifts in political and consumer awareness and values. Analyses that draw on institutional theory have also shown how CSOs and social movements motivate the contestation of dominant institutional logics and the formulation of alternative logics (e.g. Fuenfschilling and Truffer, 2016). Likewise, research has connected frame analysis with design innovation and with changes among broader political ideologies that orient policy change (Elzen et al., 2011; Hess, 2016b). A third approach involves examining the relationship between social movements and changes in everyday practices (Spaargaren et al., 2012).

5.2. Research directions

There are many opportunities for future research for each of the three areas of research discussed above. This section will review some opportunities stemming from the three areas of research outlined above, then discuss some additional possible future directions.

With respect to the politics of transitions, an important but understudied area is how CSOs and social movements influence the development of public support for regime destabilization, the phasing out of unsustainable technologies, and sustainability policy development (Turnheim and Geels, 2012; Kuokkanen et al., 2018). What role do civil society actors play in overcoming regime resistance to sustainability transition policies? Under what conditions are social movements and CSOs significant players in the governance and politics of transitions, and under what conditions are their aspirations and goals marginalized? (See sections 3 and 4 on politics and governance.)

With respect to the role of CSOs and social movements in supporting grassroots innovation, more research is needed on how local innovations undergo scale shifts and escape niche stasis and how CSOs and social movements can enable or constrain this process (Ornetzeder and Rohracher, 2013; Boyer, 2018). More research is also needed on how the "stretch and transform" aspirations of niche actors become connected with broader goals of societal transformation and "deep transitions" (Schot, 2016; Schot et al., 2016) versus being channeled toward a "fit and conform" pattern consistent with industrial regimes. How do the grassroots innovations become institutionalized, and how do they become connected with broader societal change aspirations such as improvements in social justice and democracy? (see section 9)

With respect to the topic of broader cultural changes, emerging work on institutional logics, discourses and frames in transitions can be more closely integrated with the study of social movements in coalitions that develop and contest cultural logics. For example, what role do CSOs and social movements play in the changing configurations of everyday practices of both consumers and producers? (see section 7). Under what conditions do they bring about major redefinitions in the way people think about sustainability, transitions, and industrial change?

In addition to research that builds on and contributes to these three fundamental areas, there are opportunities for more systematic comparative analyses (see section 10). For example, the category of civil society is very general and there is a need to delineate types of civil society (e.g. political, community, occupational, charitable, religious, educational, environmental, and consumer) and to explore their sometimes convergent and sometimes conflicting roles in the politics of transitions. Moreover, civil society groups may take on new organizational forms, such as online user communities and Internet fora (see e.g. Hyysalo et al., 2018a, b). Likewise, social movements have diverse goals with respect to industry and technological systems, among them ending or sunsetting some types of technology (e.g. fossil fuels), enhancing the emergence of new technologies (e.g. low carbon) achieving access to basic goods for low-income households and creating good jobs and also bringing about more democratic forms of ownership and governance of technological systems. These diverse goals create complicated dynamics that affect policy mixes that guide transitions, the configuration of coalitions in the politics of transitions, the mixes of technological and institutional innovation and the broader cultural changes involving practices and values. Thus, there are significant opportunities for opening up the "black box" of categories such as CSOs and social movements and examining the tensions and distinctions within the categories.

6. Businesses and industries in sustainability transitions

Firms and other industry actors play critical roles in sustainability transitions. As innovators, they develop new products, services and business models, contribute to market creation for novel technologies, or work toward the formation of new industries (Farla et al., 2012; Musiolik et al., 2012; Berggren et al., 2015; Planko et al., 2016). Firms and industry associations also engage in broader institutional work as they shape societal discourses and problem framing, lobby for specific policies and regulations, develop industry standards, legitimate new technologies, or shape collective expectations (Geels and Verhees, 2011; Konrad et al., 2012; Binz et al., 2016; Rosenbloom et al., 2016). As a consequence, new industries emerge and existing industries transform, or even decline (Bergek and Jacobsson, 2003; Turnheim and Geels, 2013; Rosenbloom, 2018).

While transition scholars have only just started to look into the role of businesses and industries, research in organizational studies has a long history of studying innovation, disruptive change and industry emergence. Organizational scholars have also studied social responsibility and sustainability issues (Bansal and Song, 2017; Hahn et al., 2016), and – more recently – taken an interest in grand sustainability challenges such as climate change (Wittneben et al., 2012; Lefsrud and Meyer, 2012; Etzion et al., 2017).

When transition scholars study businesses and industries, they are typically interested in how firms and other organizations contribute to (or slow down) transitions and how changes in the organizational and business dimension affect transformation more broadly, i.e. institutional, political, societal change. Scholars in transition studies often take a holistic and systemic perspective, which is less common in management research (Bansal and Song, 2017).

Nonetheless, there is significant potential to intensify research at the intersection of these two fields. One way of doing this is to work with concepts and frameworks used in management studies, applying and adapting them to transitions related research questions. Examples include organizational strategy and resources (Farla et al., 2012; Musiolik et al., 2018), institutional entrepreneurship (Garud and Karnøe, 2003; Planko et al., 2016; Thompson et al., 2015) or institutional theory (Greenwood et al., 2008; Fuenfschilling and Truffer, 2014; Smink et al., 2015a; Markard and Hoffmann, 2016). Building bridges between different strands of research can open new perspectives but also comes with some challenges such as ontological compatibility (Geels, 2010; Garud et al., 2010).

Research on businesses and industries has connections with other parts of the transitions research field, including politics (section 3) or social movements (section 5).

6.1. Current state of the art

Research in this sub-field of sustainability transitions has so far addressed three main topics: the role of business actors in creating novel technologies and industries, their role in facilitating institutional change and the relations and struggles between newcomers and incumbent actors.

The latter is a classic theme in transitions research. Many studies find newcomers driving radical innovation while incumbent actors obstruct major technological and institutional changes (Rothaermel, 2001; Smink et al., 2015b; Wesseling et al., 2014; Lauber and Jacobsson, 2016). Incumbents are therefore often viewed as regime (defending) actors, while newcomers are associated with radical innovation in niches. However, this perspective is increasingly questioned. Scholars show that incumbents develop and push clean(er) technologies in transportation (Berggren et al., 2015; Dijk et al., 2016), conventional power generation (Bergek et al., 2013) or horticulture (Kishna et al., 2016). Also, incumbents from adjacent sectors such as IT or telecommunications may drive innovation (Dolata, 2009; Erlinghagen and Markard, 2012; Berggren et al., 2015).

A closely related topic is about firms contributing to the development of new technologies and the formation of niches or innovation systems, or the re-orientation of industries (Karltorp and Sandén, 2012; Bakker, 2014; Planko et al., 2016). Key insights from these studies are that 1) technology development needs to be complemented by market formation, value-chain creation and regulatory and institutional changes, 2) firms often form alliances to achieve such complex tasks and 3) resistance from existing structures and interests is often substantial. It is important to note that while many studies have looked into the emergence of new industries (Bergek and Jacobsson, 2003; Garud and Karnøe, 2003; Budde et al., 2012; Bohnsack et al., 2016), industry re-orientation and decline has so far received much less attention (Dolata, 2009; Karltorp and Sandén, 2012; Turnheim and Geels, 2012).

A third key topic is about firms targeting institutional change in the context of sustainability transitions. Studies have shown how businesses and other actors shape their institutional environments with discourse activities and framing, through political coalition building and lobbying, or by strategically influencing collective expectations (Garud et al., 2010; Konrad et al., 2012; Hess, 2014; Sühlsen and Hisschemöller, 2014; Rosenbloom et al., 2016). A closely related issue is the creation (or undermining) of legitimacy in relation to firms, business models and technologies, which has been observed as an essential element in the struggle for public policy support of new technologies (Bergek et al., 2008b; Bohnsack et al., 2016; Markard and Hoffmann, 2016; Markard et al., 2016b).

6.2. Research directions

As research on the role of businesses and industries in sustainability transitions is quite recent, there are plenty of opportunities for further work on the above and on new topics. One rationale for future research is that, in some places and sectors, transitions progress to the next phase of development (Markard, 2018). This has several implications: destabilization and decline become more prominent, struggles among actors intensify and transitions become more pervasive, i.e. they affect various industries and involve different parts of a sector (Geels, 2018).

Industry destabilization and decline offer many research opportunities (Turnheim and Geels, 2013; Kivimaa and Kern, 2016). Are there certain patterns of industry decline, how to accelerate decline, how to cope with decline (both from a business and societal perspective) or how do emerging and declining industries interact?

A related issue is the pace of change and increasingly fierce struggles of actors, e.g. to defer change, or to slow down the pace of change (Wells and Nieuwenhuis, 2012; Smink et al., 2015b). Slow pace of change represents an area of increasing concern (Sovacool, 2016). Research questions include seeking a better understanding of the expression of path dependency in organizational structures and the factors that accelerate or decrease the pace of change. This topic is closely connected to the politics of transitions (section 3).

A third topic is pervasiveness of change across industries. We have already witnessed the pervasive transformational impact of ICT on multiple industries including transport, energy, manufacturing, banking or music via apps, or the Internet of things (Dolata, 2013; Erlinghagen and Markard, 2012). In mobility, we currently see an ongoing convergence with ICT and with electricity (Dijk et al., 2016; Manders et al., 2018). What are the consequences of industry convergence for sustainability, how can existing transition frameworks deal with the complexity of transitions that involve multiple sectors and industries, and how do firms handle these challenges?

Conceptually, future studies might also want to further explore the potential of institutional theory (and 'institutional work') and how it can be connected with established concepts in transition studies (Sarasini, 2013; Wirth et al., 2013; Fuenfschilling and Truffer, 2014).

A fifth topic for further research is about the role of finance capital (private equity, hedge funds, pension funds, sovereign wealth funds etc.) in restricting or promoting change in a certain direction. A recent UNEP report points to the significance of changes in the financial system for sustainable development (UNEP, 2015). A variety of approaches indicate that issues such as economic crises and long-term growth (Swilling, 2013) and financial regulation (Loorbach and Lijnis Huffenreuter, 2013) need to be addressed in future studies.

Moreover, business is confronted with a rapid expansion of new ways of organizing, including open innovation, peer-to-peer platforms for sharing resources, digital manufacturing systems, or new intermediaries in production and consumption systems (Dahlander and Gann, 2010; Kivimaa, 2014; Hyysalo et al., 2018a, b). These could all have profound and enduring significance for socio-technical transitions. Relevant research questions include, among others, the potential of organizational innovations, including grassroots social movements on the one hand and the influence of powerful new actors such as Amazon or Uber, on the other.

Finally, there is scope to test whether business model innovation can assist in sustainability transitions or defer radical change (Huijben et al., 2016; Wainstein and Bumpus, 2016; van Waes et al., 2018). Among other topics, business models for sustainability

may be enhanced through boundary-spanning activities beyond the traditional scope of the firm (Brehmer et al., 2018). Potential avenues for future research on sustainable business models include flexible business models in rapidly changing environments, business models in the sharing economy, business models based on sufficiency, or servitisation and sustainability (Bocken and Short, 2016; Täuscher and Laudien, 2018).

7. Transitions in practice and everyday life

A founding assumption in the literature on sustainability transitions is the importance of understanding transformation across the entire production-consumption chain. Nevertheless, interest in consumption and everyday life has remained relatively marginal in IST conferences and publications. There has been renewed interest in science and technology studies' focus on 'users' (Schot et al., 2016; Hyysalo et al., 2018a, b) and calls for better integration between practice theory approaches to consumption and the MLP (McMeekin and Southerton, 2012; Geels et al., 2015; Hargreaves et al., 2013).

Practice theory approaches have been influential in the study of sustainable consumption (Welch and Warde, 2015), but largely beyond the STRN community and have tended to isolate everyday practices from the wider socio-technical systems that service them. This indicates a need to review the theoretical frameworks presented in section 2, and connects to the role of civil society organizations, discussed in section 5. We first discuss recent practice-oriented research on consumption and everyday life and the role of users in transition processes, and then address future directions.

7.1. Current state of the art

Building on Giddens, Bourdieu, Schatzki and others, early practice theory studies on *sustainable consumption* emerged as offshoots from ecological modernization theory (Spaargaren, 2003), the sociology of consumption (Warde, 2005) and science and technology studies (Shove, 2003). Practice-theoretical approaches in this area bear a family resemblance, but do not constitute a single theory. Practice theories offer deep insights into processes of socio-technical change and complex causal interactions that result in resource-intensive patterns of everyday consumption (Welch and Warde, 2015).

They share a commitment to foreground *practices* (such as everyday eating or mobility) as the central units of social scientific analysis, with the aim to go beyond the dualisms of agency/structure and holism/individualism"often specifically critiquing the dominant 'pro-environmental behavior change' approaches in policy stemming from psychology and behavioral economics (Shove, 2010). By drawing attention to the endogenous dynamics of practices " through stability and change in cultural conventions, habits, practitioner know-how and technologies " these studies of everyday life help to explain persistent resource-intensive patterns of everyday consumption and point to the potential sites for intervention to facilitate transitions (Spurling et al., 2013). In another approach, (Spaargaren, 2013) and Welch and Yates (2018) emphasize the crucial role of organized citizen-consumers in environmental governance processes and purposive political struggles. This application of practice theoretical thinking has some, as yet underexplored, connection to the recent revival of interest in the role of users in sustainability transitions. The role of users in innovation and systems change is an established research area in innovation studies, consumption studies and science and technology studies.

Across these disciplines, the understanding of users has shifted in the last two decades from passive consumers to active players in socio-technological change (Oudshoorn and Pinch, 2003; Hyysalo et al., 2017; Schot et al., 2016; Hippel, 2016). With regards to transitions, users play important roles in the formative stages of technology development, having contributed to the development of socio-technical innovations such as wind turbines, solar collectors, and low energy housing. They also generate entrepreneurial ideas, trials and gradual improvements in understanding how technical systems and their interplay with everyday life plays out (Ornetzeder and Rohracher, 2006; Seyfang, 2010; Vries et al., 2016). User influence on transition technologies is not limited to the early start-up phase. In addition to merely adopting transition technologies, users typically need to adapt their practices to suit innovations in their particular contexts (Judson et al., 2015; Juntunen, 2014). Many users go further, and adjust, innovate and advocate transition technologies to suit their circumstances, also during the acceleration phase (Hyysalo et al., 2013; Ornetzeder and Rohracher, 2006).

These findings change the view of accelerating transitions at the household level from smooth diffusion to one where various necessary reconfigurations take place in specific country, area and household contexts, and where users in different roles mobilize to support transition. (Schot, 2016) and (Schot et al., 2016) propose a typology of user roles in different transition phases. They suggest that user producers and user legitimators contribute to the available technological variety and discourse in the start-up phase. In the acceleration phase, user consumers emerge to make choices that favor niche innovations and expand their markets. During both phases user intermediaries are crucial for building socio-technical systems and the alignment of producers, users and regulators. Users can also affect the acceleration and stabilization phases as active citizens who mobilize against the existing regime, hollowing out its legitimacy and commercial strength.

7.2. Research directions

Firstly, future research could extend understanding of the key social mechanisms and dynamics underpinning transitions in consumption and everyday life by expanding its theoretical repertoire beyond recent applications of practice theories (Evans et al., 2016). For example, there is currently a lack of attention to social difference " such as ethnicity, class and gender " in sustainability transitions research (e.g. McMeekin and Southerton, 2012; Oudshoorn and Pinch, 2003; Wajcman, 2010). Relatedly, there are questions of how collective political projects change everyday life (e.g. feminism) and processes through which collective actors

emerge from everyday life practices. Such collectives often arise in relation to specific practices, whether collectives representing users or practitioners (e.g. groups representing motorists or vegetarians) or collectives of those affected by specific practices, such as citizens protesting traffic pollution (Welch and Yates, 2018).

These research directions intersect, secondly, with those regarding users in transitions. User roles across entire transition processes require further research regarding, as noted, social difference, but also in relation to the variation in technologies, country contexts and cultures (Schot, 2016; Kanger and Schot, 2016), as well as with respect to changes in how users self-organize. For instance, new digitally mediated user collectives take major intermediating roles among users in accelerating markets and technologies (Hyysalo et al., 2018a, b; Meelen et al., 2019). These (and other) emerging user collectives and practices, associated with new forms of organizing and producing social innovations, need to be understood better (Schot et al., 2016; Jalas et al., 2017), intersecting with research outlined on civil society organization in section 5. Also changes in broader trends such as individualization (Middlemiss, 2014), and their bearing upon users, need further investigation.

Thirdly, there is a need for broader frameworks that bridge production and consumption at system, technology and product levels (see e.g. McMeekin et al., 2018; Geels, 2018 for applications of a 'whole system' approach). Moreover, new concepts such as the circular/sharing economy require an understanding of consumption dynamics, prosumer contributions and user roles within wider systems, and a focus on changes in the way that goods and services are provided and consumed (within households, communities, markets and via state redistribution). While much practice theory work to date has focused on specific, single practices, more recent developments are moving towards deploying a practice lens to study wider configurations, complexes or systems of practice (Watson, 2012).

Fourthly, there is potential for methodological advances for longer-term historical analyses of changes in everyday life that align with transition timescales and mixed research designs that combine long-term analysis with detailed ethnographies of everyday consumption and user actions. Quantitative approaches are also required (e.g. concerning social stratification through survey data or temporal rhythms using time diaries), as is comparative research across domains of practice and in different social, cultural and geographical contexts to understand contrasting trajectories and dynamics of change in everyday life (see also sections 8 and 10).

8. Geography of transitions: Spaces, scales and places

The geography of transitions literature is primarily concerned with understanding how and why transitions are similar or different across locations. For instance, in energy transitions it is important to recognize that cities, regions or countries demonstrate different patterns in the emergence of renewable energy systems (e.g. in terms of pace or scope as well as in type of policies or technologies that are preferred or implemented). The geography of transitions is concerned with explaining such similarities and differences and developing insights in how place-based factors such as institutional settings, local cultures, social networks and particular infrastructures or resource endowments enable or constrain the emergence and evolution of transitions to sustainability. Moreover, the geography of transitions literature is also concerned with understanding how transitions 'travel' between places and across different scales, e.g. from local experimentation and technology development in a particular region to the establishment of global production and innovation networks that enable the flow of innovations, knowledge, technologies and so on beyond the places where they were initially conceived.

8.1. Current state of the art

Drawing on economic, institutional and evolutionary geography, research on the geography of transitions has expanded rapidly (Coenen and Truffer, 2012; Raven et al., 2012; Lawhon and Murphy, 2011; Lawhon, 2012; Binz et al., 2014; Truffer et al., 2015). This has led to a better understanding of how geography matters in sustainability transitions. On the basis of an extensive literature review of the state of the art, Hansen and Coenen (2015) identified various place-specific factors.

1) Urban and regional visions and related policies are relevant as they mobilize a range of different actors and provide collective direction to facilitate the local development and diffusion of niche innovations and the formation of regional innovation systems. Scholarship has emphasized that such visions can be an outcome of contestations and struggles across different scales rather than being the outcome of a consensus among local stakeholders alone (see e.g. Hodson and Marvin, 2010; Bulkeley and Castán Broto, 2011; Truffer and Coenen, 2012; Rohracher and Späth, 2014).
2) Next to more formal visions and policies, localized informal institutions such as territorially bound values, norms and practices are also important to understand the geography of transitions. Informal institutions such as high levels of trust within local networks or the broad acceptance of environmental values within a particular region, can facilitate the development and diffusion of environmental innovations or enable regulatory push for the development and adoption of environmental regulation. Informal institutions can differ between, but also within local and urban territories, which may result in conflicts and contestations regarding formal sustainability visions and policy processes (e.g. Maassen, 2012; Bridge et al., 2013; Wirth et al., 2013; Shove et al., 2012).
3) Local natural resource endowments or scarcity can shape investment decisions in environmentally sustainable technologies and practices (e.g. (Bridge et al., 2013; Carvalho et al., 2012; Murphy and Smith, 2013; Essletzbichler, 2012).
4) Local technological and industrial specialization can condition the development of innovations needed for sustainability transitions through the existence of particularly relevant skills and capabilities in the labor market and organizational and institutional capacities of established industrial networks (Carvalho et al., 2012; Monstadt, 2007; Ornetzeder and Rohracher, 2013).

5) The existence of particular consumer demand (e.g. because of particularly strong environmental values in a certain region) and the early formation of local markets for sustainable products and services facilitates early end-user engagement in emerging niches and provides early testing grounds for wider development and diffusion (Binz et al., 2012; Dewald and Truffer, 2012).

Hansen and Coenen also found that, next to identifying the key local and regional factors that are critical to the emergence of sustainability transitions, existing literature has also started to highlight how particular inter-organizational relations and actor networks are influenced by geographical factors. In particular, empirical and conceptual contributions have highlighted to various degrees the role of relations within and between value chains, between users and producers, among policy makers, and between donors and recipients, and the ways in which such relations are shaped by and co-evolve with geographical factors across different scales. A range of studies has foregrounded local and regional scales, highlighting the influence of proximity in actor networks in stimulating niche formation or the emergence of technological innovation systems (e.g. (Coenen et al., 2012). Other studies focused in particular on international scales (and its interplay with local scales, in particular when discussing relations between developing and developed countries, donor interventions and their impact on sustainability transitions (Angel and Rock, 2009; Berkhout et al., 2009; Hansen and Nygaard, 2013; Raven et al., 2012). Specifically, research on transitions in developing countries has explored the transnational nature of sustainability experiments (Berkhout et al., 2010; Wieczorek et al., 2015a) as well as the global nature of innovation systems (Binz and Truffer, 2017; Wieczorek et al., 2015b) and socio-technical regimes (Fuenfschilling and Binz, 2018).

8.2. Research directions

Geography of transitions has become a thriving part of the wider sustainability transitions community, which continues to explore more specific questions along the lines discussed above. Given the increasing interconnectedness of globalization, sustainable development and urbanization, transitions in developing countries and urban transitions are particularly interesting avenues for future research, which enable the exploration of a variety of new and challenging research directions.

First, future research could unpack the spatial variety in regime configurations, in particular in terms of their stability, change and heterogeneity (Fuenfschilling and Binz, 2018), and especially in (but not limited to) the context of developing countries (Furlong, 2014; Wieczorek, 2018). Regimes in the developing world reveal a high degree of non-uniformity and are tied not to one but to many technologies that can fulfil the same need (Berkhout et al., 2010; Furlong, 2014; Sengers and Raven, 2013).

In that context, new, spatially-nuanced regime conceptualizations are needed encompassing differing grades of uniformity, stretching from highly monolithic to highly hybrid configurations. Given this diversity, related questions are: whether sustainability transitions in developing contexts always imply the destabilization of regimes and technological substitution and how the fractured character of regimes influence the opportunities for their transformation (van Welie et al., 2018).

Second, future research could explore the normative orientations of transitions (Raven et al., 2017, see also section 9). For instance, understandings of sustainability and what should be priorities in sustainable development agendas can differ substantially between poor rural contexts and urban regions, both within and between the global south and the global north. Social inequality, poverty and lack of access to modern services such as sanitation or education in low-income economies might be considered more important than global environmental rationales such as climate change. Concepts of sustainability and resilience may be more challenging to operationalize in practice in poor communities (Romero-Lankao and Gnatz, 2013). All this implies the need to reconcile the divergent place-specific views of sustainability for the purpose of stimulating transitions and a better understanding of governance of transitions in contested and place-specific normative end points.

Third, future research needs to unpack the dominant catch-up and convergence theories, which suggest that innovations and thereby also transitions are created in the West and travel to the rest of the world by means of technology transfer (Jolly et al., 2012). The current qualitative changes occurring in developing countries seem to be driven by emergent, place-based and sustainability-oriented experimentation, which might lead to alternative, more sustainable, development pathways. Together with an increase in innovation for and by the poor and with lower environmental footprint, this process points to a broader, more socially-embedded model of innovation (Jolly et al., 2012; Berkhout et al., 2011). The question is whether these bottom-up local activities provide reliable sources of such pathways. Research could help clarify what projects could provide the seeds of radical change, which mechanisms can stimulate the upscaling of such initiatives, whether this is a place-determined process and what the role is of transnational, local-global connections therein.

Fourth, with rapid urbanization the quest of sustainable development will largely be an urban challenge, which is also recognized by cities' actors themselves. In particular, geography of transitions scholars have started to conceptually and empirically explore urban experimentation, which is a quickly expanding discourse and practice in urban sustainable development (Broto, Vanesa and Bulkeley, 2013; Evans et al., 2016; Raven et al., 2017; Marvin et al., 2018). Future research could focus on questions concerned with the conditions, processes and pathways through which urban living labs and experiments emerge, on how cities become experimental, how experiments 'scale up' and shape wider institutional change beyond their initial geographies (Turnheim et al., 2018).

Fifth, the digitization, and automation of various flows such as resources, cars, people and energy through big data analytics are increasingly influencing development and investment agendas world-wide, including their geographies. In urban contexts, this is manifested in the rapid uptake of a discourse around 'smart cities' to urban challenges (Luque-Ayala and Marvin, 2015), but questions around the interplay between digitization, automation and sustainable development are relevant more widely. A key line of research is to identify the political, institutional and material implications of the emerging smart urban agenda for sustainable urban development, to better understand how the 'smart' agenda contributes productively to challenge-led transitions (Coenen et al., 2015) and how digitization is potentially changing the geography of sustainability transitions more widely.

Sixth, research could engage more explicitly with urban infrastructures and the challenges of transforming them. As a starting point, the multiplicity of regimes that occupy the urban arena and infrastructural space need to be recognized within sectors and at the intersections of different regimes, and how boundaries between them (e.g. transport and electricity, communication and transport) are maintained or rendered unstable (Monstadt, 2009). There is a need to consider the work involved in maintaining and sustaining existing urban socio-technical networks and the infrastructures produced. Literatures from urban political ecology, actor-network theory and governmentality studies illuminate the ways in which the active maintenance of flows, metabolisms, networks and circulations is central to the (re)production of urban life (Bulkeley et al., 2014). Yet our understanding of how such stability is produced and of the junctures and openings within the urban fabric that enable transitions to occur is relatively limited.

9. Ethical aspects of transitions: Distribution, justice, poverty

Sustainability transitions have an *irreducibly normative* impact embedded in the notions of equity and justice, where questions of value choice are at their core. Yet research in this area is often splintered and highly contextual despite 1) a general normative case that ethical questions *ought* to be tackled, 2) the knowledge that transitions have the potential to create or reinforce injustices, or 3) the knowledge that failures to secure social acceptance can halt the progress of transitions.

In this section, we reflect on developments in this area to date, and draw the STRN community's attention to the need for engaging explicitly with ethical considerations that arise from sustainability transitions. We go on to highlight six areas for further research. Due to the challenges of space, our section is necessarily limited in its breadth, considering just a narrow lens of concern – issues of 'justice', 'distribution' and 'poverty' that are comparatively well versed in the literature. We do acknowledge, however, that a wider variety of ethical concerns arise including the nature of human wellbeing and social welfare, the theory and practice of democracy, and relations between humans and the natural world are inevitably bound up in sustainability transitions. These are considered as avenues for further research.

Our reflection connects to the themes of power and politics (section 3) as well as governance and policy (section 4). Ethical aspects are also critical in the role of civil society and social movements (section 5). There is also an important question around how ideas of justice are incorporated into the analysis frameworks (section 2) and distributions across geographical and political scales (section 8).

9.1. Current state of the art

To date, attention to the ethical aspects of transitions have been relatively limited. Even though the literature suggests that contemporary issues such as poverty or race, gender, age or ethnic disparities " usually caused by processes firmly embedded in societal structures " could be resolved by innovative practices and structural adaptation (Grin et al., 2010; Swilling and Annecke, 2012), there has been a dearth of attempts to actually explore their antecedents and mitigation (Eames and Hunt, 2013). Additionally, a concerted effort to analyze the distributional consequences of transitions ex-ante, during and ex-post is lacking, revealing a moral vacuum in transitions research (Newell and Mulvaney, 2013; Sovacool et al., 2016). Equally important are issues of participation and recognition that relate to decision making in innovation processes and policy processes addressed in empirical studies of power, politics and governance of transitions, as well as mechanisms for addressing these issues (see sections 3,4 and 10).

The concept of justice has been tackled more explicitly in the energy transitions stream of literature. There, the concept of energy justice has recently been positioned as a mechanism that can 1) expose exclusionary and/or inclusionary technological and social niches before they develop, leading to potentially new *and* socially just innovation; 2) provide a way for these actors to normatively judge them, potentially destabilizing existing regimes using moral criteria; and 3) if framed as a matter of priority at the landscape level could exert pressure on the regime below, leading to the widespread reappraisal of our energy choices and integration of moral criteria (Jenkins et al., 2018).

Scholars explore where injustices emerge, which sections of society are ignored, and what processes exist for their remediation (Jenkins et al., 2016)), on topics such as ethical energy consumption (e.g. (Hall, 2013), fuel poverty (e.g. Walker and Day, 2012; Sovacool, 2015) and energy justice applied in policy-making.

Further examples of explicit attempts to deal with the integration of moral criteria include the work on 'just transitions' (e.g. Swilling and Annecke, 2012; Newell and Mulvaney, 2013), which advocates and explores sustainability transitions that simultaneously address inequalities, are low-carbon and could be implemented through interventions by "developmental states that prioritize minimization, restoration, reconstruction and redistributive justice.

Other studies explore how innovations for inclusive development induce or play a role in sustainability transitions, e.g. openness and inclusion in innovation processes for sustainability (e.g. Smith and Seyfang, 2013), or inclusive innovation and rapid transitions in low-income contexts (Onsongo and Schot, 2017). Insights can also be drawn from the research on transitions in developing and low-income countries that address the developmental aspects of transitions to different degrees. For example, transitions literature has developed in relation to the role of capability development in diffusing poverty-reducing technologies (Romijn and Caniëls, 2011; Tigabu et al., 2015), or the challenges of leapfrogging approaches to fast track development (e.g. Murphy, 2001; Binz et al., 2012) (see also section 8).

With regards to other sectors, Sheller (2015) considers the social distribution of trends towards decreasing automobility, making a connection between racial space and transport inequality. Justice in transport and accessibility needs to be addressed in sustainability transitions (Mullen and Marsden, 2016). Bork et al. (2015) identify procedural justice as a significant factor in legitimizing electric boating in Amsterdam, for instance. In the context of a transition to sustainable agriculture, Darnhofer (2014) argues that organic

farming needs to articulate issues of social justice as well as economic sustainability. Jerneck and Olsson (2011) consider global health and sustainability transitions, including the need to consider social justice. However, these contributions do not yet form a coherent body of research on how social justice can be included in sustainability transitions, one exception being (Mullen and Marsden, 2016)

9.2. Research directions

Broadly speaking, we highlight a failure to acknowledge a range of normative orientation of transition studies that, in addition to environmental concerns, explore transition dynamics geared towards sustainable development. That is, orientations that are embedded in notions of justice and give attention to alleviating poverty and promoting more egalitarian participation in development processes (amongst other goals). We have also identified that these failures exist ex-ante, during and ex-post. Thus, we identify six particular avenues for research.

First, and conceptually, distributive and participatory struggles within sustainability transitions can be explored using insights from three streams of literature. The neo-institutional approach to operationalise system change (Fuenfschilling and Truffer, 2014) can capture formal and informal institutional configurations that engender poverty, inequality and exclusion, and the institutional shifts thereof associated with technological development. Furthermore, there are various new models of 'innovation for inclusive development' such as inclusive innovation (Heeks et al., 2014), frugal innovation (Rosca et al., 2017) and grassroots innovation (Seyfang and Smith, 2007). These explore how top-down or bottom-up technological developments geared towards specific segments of society scale up to induce transformations in socio-technical systems and scale up innovations (Jolly et al., 2012) to new technological pathways (Romijn and Caniëls, 2011). Finally, more work can be done to mobilize a developing area of the transitions management literature (Loorbach, 2010; Grin et al., 2010), which has explored how actors can influence the movement toward sustainable development by developing and nurturing alternative technological interventions designed to mitigate poverty, inequality and social exclusion, for instance through local experimentation (Berkhout et al., 2011). Combined, all approaches provide insight into the participatory struggles facing sustainability transitions.

Second, future research could explore transition dynamics that induce, reinforce, exacerbate or mitigate poverty, inequality and exclusion within and across past, current and future timeframes. In what ways do these phenomena influence or mediate societal change processes and the trajectory of technological development? Further, how can the ethical consequences of sustainability transitions be anticipated and mitigated at an early point during innovation journeys? Learning is important to recognize the negative impacts of new technologies and respond appropriately. What kinds of lessons can be drawn? How do we know if they are the right ones (Raman and Mohr, 2014)? How do marginal and powerful actors respond to these ethical dilemmas?

Third, we identify a need for greater reflexivity within the transitions community in order to highlight and deal with social justice issues that are otherwise below-the-radar outcomes of transition processes. This requires further consideration of new methods to assess not only transition snapshots, but also transitions with longitudinal processes with social justice outcomes (a challenge that inevitably links to section 10). For instance, what may seem like a social justice gain today (e.g. strong support for wind farms or large-scale solar energy) can become a social injustice loss tomorrow when implemented poorly or unfairly, e.g. wind farms in Mexico that forcibly displace indigenous people from their lands (Oceransky, 2010) or solar energy parks in India leading to exclusion and land grabbing (Yenneti et al., 2016).

Fourth, further research can also explore how 'inclusive forms of transition' can be conceptualized or operationalized. Questions concerning 'who wins, who loses, how and why' (Newell and Mulvaney, 2013; Moss et al., 2014) could be considered here. Studies often only highlight ethical implications or dilemmas, for instance, the marginalization of the poor and their livelihoods in developing countries as large companies grab common land for commercial production (Byrne, 2013), or food-versus-bio-fuel conflicts (Raman and Mohr, 2014) and the unequal distribution of biofuel benefits in LDCs (Romijn and Caniëls, 2011). In addition, a more explicit consideration of power and politics in transitions (section 3) could be applied to sector analyses of social justice in, e.g. energy, accessibility, health or food systems. Other pertinent questions relate to the roles and agency of non-traditional actors in transitions, including the role of users (Schot, 2016) and even non-users (Kahma and Matschoss, 2017). Due consideration should be given to marginalized groups such as non-users, non-dominant and non-state-based actors in shaping transition processes (Seyfang and Smith, 2007).

Fifth, and as one particularly promising avenue, normativity can be brought into sustainability transitions through the 'pathways approach' (Leach et al., 2012) that attempts to link environmental sustainability with poverty reduction and social justice. This could take into account dynamics, complexity, uncertainty, differing narratives and the value-based aims of sustainability, for instance, bridging the pathways approach and SNM. In addition, conceptual bridges between sustainability transitions literature and developmental state literature, complexity theory, consumer ownership models and ecological economics are being pursued with relevance to developing economies (Swilling and Annecke, 2012; Jenkins, 2018). More case studies of developing economies in the global South, where developmental and sustainability goals are combined, could crystalize these approaches. These directions are also linked to the scale and geographical issues discussed in section 8.

Sixth, and lastly, a broadening of conceptual lenses and heuristics holds promise, especially justice approaches that extend beyond Western theorists (e.g. Immanuel Kant or John Rawls) and human-centered impacts (e.g., disruption to employment, public health impacts of fossil fuels). As Sovacool and Hess (2017) note, eight alternate frameworks shown in Appendix may offer as much novelty as more conventional approaches focusing on say Western human rights or utilitarianism.

10. Reflections on methodologies for transitions research

As the transitions research field matures, transitions scholars have started to interrogate the epistemologies and methodologies currently in use. This is demonstrated by the various identifications of methodological challenges and proposals for corresponding advances. As a research field that is empirically broad, theoretically highly interdisciplinary and driven by different normative commitments and research aims (cf. Loorbach et al., 2017), transitions research should arguably rely on an accordingly broad range of methodological approaches[2]. Taking this methodological pluralism as a basic stance, recent discussions do bring out clearly however that not everything goes. This methodology agenda provides a concise overview of prevailing methodological approaches (10.1), highlighting several methodological advancements that have been proposed for future research (10.2). Rather than aiming for an exhaustive overview, this account structures the methodological state of the art along five key methodological dilemmas [2] .

10.1. Current state of the art

10.1.1. Case studies: in-depth particularity vs. Generic insight

Transitions research displays a sustained reliance on case-based research methods, resulting in a vast archive of in-depth single case studies. Its roots in innovation theory, institutional theory and STS have induced a strong commitment to the construction of detailed narratives of innovation journeys unfolding in particular national contexts and policy domains. This methodological preference fits transitions research for its assumptions of complex causation, emergent realities, and non-linear development trajectories (Geels and Schot, 2010). On the other hand, transitions research typically breaks with the 'reificophobic' STS inclination towards deconstruction and meticulous description, reaching for more generic insights, middle-range theory and explanation (Geels, 2007, 2010). Typical comparative efforts towards such systematic insights have been the typologies of transition pathways (Geels and Schot, 2007; Boschma et al., 2017), or the functions of innovation systems (Hekkert and Negro, 2009; Bergek and Jacobsson, 2003). These attempts at theory-building from cases have had an abundant following in the form of further comparative case studies (Geels et al., 2016), meta-analyses (Wiseman et al., 2013; Raven et al., 2016), and surveys (Schmidt et al., 2012). The 'geographical turn' in transitions research (section 8) has further encouraged these comparative approaches, whilst simultaneously underlining the continued importance of context-sensitivity and empirical detail. Overall, the single-case research design remains prominent in transitions research, also as new regions, new actors, new technologies and new societal domains are explored. In turn, the increasing wealth of case materials creates demands and opportunities for methodological approaches that reach for generic insights across cases.

10.1.2. Process analysis: historical transitions vs. system innovation in-the-making

The strong reliance on case-based methodologies is related to the process rather than outcome or indicator-oriented modes of theorizing. Understood as processes of change with complex chains of causation, multiple actors and dynamic framework conditions, transitions research arguably calls for process-oriented modes of investigation (Geels and Schot, 2010). Two quite distinct approaches stand out, marking a methodological dilemma between retrospective and contemporary analytical foci. Foundational for the field have been the macroscopic historical case studies. Reconstructing transition processes unfolding over several decades or more, these approaches drive towards deeper understanding and explanation of transition dynamics. On the other hand, the work on transitions governance (Voß et al., 2009) has underlined the importance of methodological engagement with system innovation in-the-making, following situated actors in their negotiation of contested and uncertain attempts at system innovation (Smith, 2007; Hoffman and Loeber, 2016).

In addition to the distinction between historical and contemporary analyses, the evolutionary/synoptic and relational/situated perspectives on innovation journeys (Garud and Gehman, 2012) indicate quite fundamentally different modes of analysis – a difference that is interlinked with other methodological dilemmas on engagement vs. distance or levels of analysis. On the other hand they mark extreme positions on a wide spectrum of available process-methodological approaches, as such inviting thoughtful combinations of elements and fine-tuned process analyses more generally.

10.1.3. Levels of analysis: micro vs. macro

Aimed to understand broad system changes, transitions research typically involves analysis on the level of regions, nation states or the supra-national scale. Comprehensive frameworks like the MLP provide some structure for such 'macro' analyses. Unsurprisingly, this macro orientation has evoked critiques underlining the need for detailed micro-level investigations of underlying actors, technologies, infrastructures and institutional contexts (Bergek et al., 2015; Farla et al., 2012; Smith et al., 2010). Seeking to bridge the micro versus macro dilemma, transitions researchers e.g., (Fünfschilling, 2014; Hermans et al., 2013) have drawn on various research strands to address more confined micro-level phenomena such as technological learning, network effects and increasing returns to adoption, institutionalization, and socio-psychological dynamics. Likewise, there have been reflections on alternative units of analysis through which to 'zoom in' onto micro-processes as played out in arenas of development (Jørgensen, 2012), practices (Hargreaves et al., 2013), initiatives for innovation system building (Musiolik et al., 2018; Planko et al., 2016), or 'socio-energetic

[2] The term 'methodological approach' is a shorthand for a congruent epistemological position with associated choices for research design and tools for data collection and analysis. This extends well beyond methodology in the narrow sense of a set of research tools. This definition also takes into account that knowledge production need not be restricted to academics and that analysis can serve diverse knowledge interests.

nodes' (Debizet et al., 2016). Meanwhile, many challenges remain regarding the connection between the micro- and macro-levels of analysis, which is typically made implicitly during the development of case narratives. Divergent operationalizations of central concepts – such as 'regime' and 'niche' – are thus leading to varying analytical foci on the micro level. Notwithstanding attempts towards clear analytical guidelines, import of disciplinary insights and conceptual advances (Binz and Truffer, 2017), the micro-macro linkage thus remains a challenge.

10.1.4. Complexity: reduction vs. articulation

Transitions research is premised on assumptions of systemic complexity, involving problems of path-dependence and lock-in, and development patterns of self-organization, emergence and co-evolution (Grin et al., 2010). This leads to the basic methodological challenge, related to the first dilemma and described by Byrne (2005): Should investigations be directed towards structuring of complexity and the disclosure of 'hidden order', or stick to the detailed articulation of irreducible complexity? How to develop solid transition insights whilst 'taking complexity seriously'?, Vasileiadou and Safarzyńska (2010) inquired similarly. While the descriptive single-case research design remains a prominent way of articulating complexity, various kinds of formal models have been used to reduce complexity and identify essential factors and processes through various degrees of abstraction. Holtz et al. (2015) argue that formal models provide explicit, clear and coherent system representations, help to make inferences about elements and processes underlying emergent phenomena and facilitate systematic experiments. To cover the non-linear dynamics of transitions, agent-based models and system dynamics models seem well suited (Köhler et al., 2009, 2018a; Walrave and Raven, 2016). Modelling approaches, however, need to exercise caution against over-simplification in representing the complex unfolding processes of events (McDowall and Geels, 2017).

Formal modelling requires the use of indicators that provide a structured view on the complexity of transitions while respecting their multi-dimensional nature. Such indicators would also be required to monitor the progress of transitions and to assess rates of change, for example as crucial information for transition governance (Scheffer et al., 2012). However, a widely used set of indicators that goes beyond technological change rates has not yet been extensively discussed among transition scholars (Turnheim et al., 2015). The development of a harmonized set of indicators would foster comparability, yet it runs into the manifold differences across sectors and countries. The appropriateness of indicators (quantitative, semi-quantitative or qualitative) depends on the system of provision analyzed, the transition phase, temporal and spatial scales, and on case specifics. Moreover, the development of transitions indicators involves confronting the reductionist flaws of traditional innovation indicators (Smith, 2005) (neglect of pivotal social and institutional factors, overlooked innovation by non-firm actors, narrow focus on product and process innovation, difficulty in capturing innovation processes in emerging economies). The quest for appropriate indicators thus marks a frontier for complexity-structuring transitions research.

10.1.5. Transdisciplinarity: engaged vs. distanced research

As transitions research is gaining ground not only as a field of research but also as an influential policy concept (Voß, 2014), questions concerning the societal role of transitions scientists are accordingly becoming important (Wittmayer and Schäpke, 2014). Transitions research has in this regard been positioned as a transdisciplinary "mode-2′ science (Rotmans, 2005) and subsequent work in transition management has further developed intervention repertoires and action research methods through which to co-create transitions knowledge (van den Bosch, 2010). More broadly there is an increasing commitment to research that not only describes societal transformation processes, but initiates and catalyzes them (Schneidewind et al., 2016; Luederitz et al., 2017; Kampelmann et al., 2018). Building on the 'experimental turn' in the social sciences, various methodological approaches of real-world experimentation and participatory action research are being developed that make the commitments to knowledge co-production operational. On the other hand, transitions research also faces the engagement vs. distance dilemma that runs through social science methodology more generally. There remain strong commitments to objectifying, distanced modes of investigation (e.g. historical case studies, formal modeling, as discussed above). Regarding the societal role of transitions researchers, this amounts to seeking societal relevance through sound science and impartial assessment, especially given the growing demands for policy-relevant evidence.

10.2. Research directions

Structured in the form of key methodological dilemmas, the state of the art overview underlines that generic solutions for advance cannot be recommended. The following discussion of future research directions is therefore far from exhaustive. It mainly sketches some of the multiple methodological approaches that seem fruitful balances regarding the five dilemmas, i.e. leading to research projects that extend existing knowledge and that allow the discovery of new perspectives on societal transitions.

10.2.1. Case studies: in-depth particularity vs. generic insight

The key methodological challenge remains to combine in-depth attentiveness to particularity with the development of generic insight. The overall direction for future transitions research involves a continued dedication to in-depth single-case research designs, also as new topics and transitions contexts are being explored. Still, there is an unmistakable drive towards systematic comparison and theory-building from cases. Next to the many multiple-case study designs and meta-analyses of case studies, the applications of Qualitative Comparative Analysis (QCA) (Hess and Mai, 2014; Osunmuyiwa and Kalfagianni, 2017) are noteworthy. Originally developed within historical sociology (Marx et al., 2014) public administration (Zschoch, 2011; Gerrits and Verweij, 2013), and organization and management sciences (Fiss, 2011), QCA is gaining ground as a method for uncovering complex patterns (Byrne, 2005) in existing sets of case studies through secondary analysis. It can also provide a basis for comparative research designs, which

gain importance as spatial embeddedness (see section 8) becomes more prominent in transitions research (Truffer et al., 2015). Comparison could also be facilitated through case-study databases, supporting theory building using quantitative techniques and algorithms (Martínez Arranz, 2017).

10.2.2. Process analysis: historical vs. in-the-making

This methodological dilemma indicates that there is still ample room for deepening of process-methodological work in transitions research. The meta-perspectives by Garud and Gehman (2012) provide a useful starting point for making conscious choices within the abundance of research directions available. Examples are the explorations of the temporal diversity of transitions (Sovacool and Geels, 2016), attention to process patterns of decline and destabilization rather than breakthrough (Shove, 2012; Turnheim and Geels, 2012), elaborations of dialectical process models (Penna and Geels, 2015; Pel, 2016) and theoretical templates for analyses of policy processes (Kern and Rogge, 2018). More fundamentally, transitions research has been challenged to provide more systematically developed process explanations, beyond the construction of persuasive process narratives (Svensson and Nikoleris, 2018). This involves tighter linkages between sequences of events and the identification of critical conditions that causally link these events. In related fields, process approaches are gaining traction in response to more informal narrative approaches. Narrative explanation is a viable epistemological approach (Abell, 2004), and there are an increasing number of well-developed research designs and methodological tools available (Langley et al., 2013; Spekkink and Boons, 2016). Such approaches allow for the comparison of multiple cases using pattern matching, where patterns constitute distinct transition pathways.

10.2.3. Levels of analysis: micro vs. macro

Overall, a growing awareness of this methodological dilemma can be witnessed. This speaks from reflections on the difficulty in delineating transitions processes along the temporal (Grubler et al., 2016) and spatial (Coenen et al., 2012) dimensions, from methodological approaches involving alternative units of analysis (cf. section 10.1), and from conscious approaches to zoom either in or out. Next to the attempts to specify micro-level processes, analyses of 'deep' or transversal transitions (Schot et al., 2016) that reach for the very macro level can be appreciated as both conceptual and methodological advances. The 'whole system reconfiguration' theme of the IST 2018 conference re-asserted the importance of the levels of analysis issue. Meanwhile, much work remains to be done regarding the connection of micro and macro level analyses. A prominent example of such work is the development of 'structured navigation' approaches Holtz (2012), defining intermediate levels of abstraction and procedures for relating phenomena on the various abstraction levels. Such structured navigation between levels of analysis helps confront the typical transitions research challenge of grasping nested change phenomena.

10.2.4. Complexity: reduction and articulation

This dilemma has evoked significant efforts to move beyond the single-case embracing of irreducible complexity, involving modelling approaches and indicator development. This remains one of the main methodological frontiers for transitions research. Seeking to project large numbers of interlinked elements into the future whilst remaining attentive to the uncertainties that elude formalization, proposals have been made for qualitative-quantitative 'bridging' (Köhler et al., 2018b; Turnheim et al., 2015), 'linking' (Trutnevyte et al., 2014), 'hybrid approaches' (McDowall, 2014) and 'integration' (Holtz et al., 2015). Through such interplay, models serve to check the internal consistency of narratives, which in turn inform models to define scenarios for external drivers that reflect societal development.

Next to these formalization efforts, a second main direction for research consists in the methodological approaches oriented towards the multiplicity of transitions. The key argument is that single-case research designs and isolated research objects are at odds with the transitions ontologies of nested, composite systems, and that methodological approaches are required that allow the (co-evolutionary) interactions between processes to surface. (Schot and Geels, 2008) made this argument regarding SNM research, and since then there have been various studies of multiple regimes, multiple niches and their intersections (Raven, 2007; Hargreaves et al., 2013; Papachristos et al., 2013; Pel, 2013). In general, multiple case studies and especially nested-case studies seem particularly appropriate for transitions research. Urban areas have in this regard been identified as particularly salient convergence points of multiple systems of provision and innovation lineages. Multiplicity is also confronted in the work on 'whole systems of provision', where the variegated set of niches and regimes in a system of provision is analyzed (Turnheim et al., 2015; Hodson et al., 2017). As always, the sensitivity to complexity does come at a price: these advanced case study research designs entail particularly heavy duties of demarcation or the delineation of (sub-)system boundaries.

10.2.5. Transdisciplinarity: engaged vs. distanced research

The questions on the societal role of transitions research are clearly widely reflected upon. This is arguably inevitable for a field characterized by an attitude of 're-construction' (Avelino and Grin, 2017), i.e. combining elements of critical deconstruction with more positive, foundational and action-oriented elements. The earlier critiques of the 'distanced, voyeurist, managerial' inclinations of transitions research are still echoing in the various recent advances towards participatory action research, real-world labs, and other arrangements of co-produced transitions research (cf. section 10.1). This is likely to remain a major frontier for methodological advancement. The basic epistemological commitments to descending from the ivory tower raise many further methodological issues. These pertain not only to the procedures for increased societal value, inclusiveness and reflexivity. As transitions researchers seek to engage in evidence-based policy environments and argue the transferability of action research projects to other contexts, the development of adequate and relevant indicators and measurement techniques will be important.

As a highly interdisciplinary field, transitions research is shaped by a broad range of methodological approaches, often imported

through its constituent disciplines. Methodological pluralism is in that regard an arguable basic stance. On the other hand, the maturation of the research field speaks from the widespread reflection on the appropriateness of tools and strategies of investigation. The particular theoretical foundations and ontological assumptions of transitions research do encourage particular methodological approaches whilst advising against others. These considerations of appropriate methodological approaches have been expressed through five – in many ways interrelated - methodological dilemmas. Taken together, and recognizing their interrelations, these five dilemmas arguably capture much of the methodological challenges and methodological advances in the field. And while the identified research directions and methodological advances do not indicate generic recipes or single-best solutions to follow, they constitute examples of best practices.

11. Conclusions

This article provided an overview of existing research and emerging themes in the field of sustainability transitions. It is the result of an extensive consultation and collaboration process across the STRN community. We were impressed by the rapid development of the field, how many studies have been published and how the range of topics has widened since the first research agenda was published in 2010. Even though we tried to be inclusive, there might still be issues we have missed, perspectives we did not include or aspects that deserve more attention. We are confident, nonetheless, that this research agenda will be a helpful document to mark the current 'state of the art' and to further strengthen sustainability transitions research. In this final section, we share three general reflections on the development of the field before examining the challenges that lie ahead.

First, sustainability transition studies have diversified significantly, with new sub-themes emerging such as urban transitions, acceleration, system decline, system re-configuration and interaction between multiple innovations, ethics and justice, the role of users, power relations in governance structures, and transitions involving multiple sectors. These themes point to the field's continued expansion and demonstrate the usefulness of the broad transition framing when reflecting on the dynamics of radical socio-technical change.

Second, transitions research continues to build bridges to established disciplines such as political sciences, business studies, development studies, and science and technology studies. Transition scholars can draw on an increasingly broad range of social science theories, including institutional theory, corporate sustainability, actor network theory, practice theory, and approaches from policy analysis and political economy. We believe it is essential to continue the dialogue with more established disciplines, not just to promote transition ideas in these networks, but also to be challenged by 'outsiders', to benefit from new perspectives, and to further refine current transition approaches.

Third, while we embrace new approaches and perspectives, we believe that our core concepts and frameworks are still relevant, especially as we continue to develop them to address the new challenges ahead. As in other maturing fields, the risk is that new scholars are not necessarily familiar with the wealth of existing knowledge and fail to build on this/fail to integrate this when embarking on new strands of research. This calls for research that synthesizes and reflects on the state of the art from time to time, relates this back to the core challenges, and incorporates new developments, both in the 'world out there' and in our academic discussions. We hope this paper will be a major contribution in this regard.

Despite being an established scholarly field with a strong epistemological community, sustainability transitions also faces numerous challenges.

The sustainability challenges that provide a major rationale for transitions research are becoming more and more urgent. As the new IPCC report makes clear, society and policy are acting so slowly that climate risks seem to be increasing rapidly (IPCC, 2018). A similar urgency exists for other grand sustainability challenges. How can transitions research address situations in which time is running out so quickly? How can we support the acceleration of sustainability transitions? How can transition researchers react to the lack of progress towards sustainability?

We witness a changing political environment in many parts of the world as a reaction to globalization, social inequality, migration, poverty etc. What can sustainability transitions research say about current political and societal macro developments? Will these developments reduce our chances of swift global action on sustainability? Or will the mounting environmental pressure strengthen international collaborative efforts?

The social and environmental problems that require transitions are often pervasive, in the sense that they affect many different sectors. Transition studies are beginning to widen their scope from focusing on single systems (energy, mobility, water, food, and health) to 'multi-sector' transitions, and the interactions of various systems. How can our research address and conceptualize sustainability transitions across interconnected systems of provision? How can innovations that span different socio-technical systems be accelerated?

A further challenge concerns the next phase of transitions, including the phase-out of mature, unsustainable technologies and industries. For example, in the energy sector in some countries, we see an accelerating diffusion of renewables and the decline of existing technologies such as coal or nuclear. How can this decline be managed in a way that addresses social and economic sustainability as well as reducing environmental impacts? How can this decline be accelerated? How should society re-configure existing socio-technical systems; which regime rules should be abandoned, which maintained?

At a more general level, there are not only a multitude of sustainability challenges (see e.g. the UNDP SDGs), but sustainability as a concept is itself also heavily contested for several reasons: its holistic nature (it has environmental, social and economic dimensions), its temporal and spatial differentiation (its desirable characteristics change over time and space), the fact that it is strongly normative and driven by multiple interpretations and philosophical underpinnings regarding individuals' perception of the value of nature. Nonetheless, we tend to take sustainability for granted by looking at one dimension at a time, by not pausing to unpack it in

various contexts, thereby missing potential conflicts and trade-offs (e.g. greenhouse gas emissions vs. biodiversity and land use in the case of biofuels). How can we address sustainability in a more nuanced manner? How can we work with the inherent complexity and contestation?

There are other fundamental questions about sufficiency, limits to growth, alternative economic systems, and deep changes on the demand side. These topics have been part of the transition agenda for a long time, but are still difficult to address. How to study the interrelatedness of changes in supply and demand? How can we reduce demand and change prevailing lifestyles and consumption patterns? How can society support transitions to alternative social and economic systems, or embark on fundamentally different pathways to sustainability?

Finally, questions arise about the ambition of the sustainability transitions research community to have a practical impact and engage with real-world actors, systems and transitions. This also comes with challenges. How should research on sustainability transitions balance engagement with local initiatives, top-down policy making, and incumbent actors? Can and should researchers in the field be part of transition initiatives and apply ideas of transitions management in pilots, living labs and action research?

Sustainability requires drastic changes across a broad range of sectors, technology, policy making, business, and consumption. Research on sustainability transitions has made much progress in addressing key issues, but there is a lot more to be done. Given the pace of development, the current slow rate of change towards sustainability may seem like an insurmountable barrier, but the history of industrial revolutions shows us that social, economic and technological systems can and do transform, and that transitions can accelerate and generate impressive dynamics. Transitions studies hold the promise of creating new approaches and understanding in moving society towards sustainability.

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Appendix Alternative Justice Theories and Conceptualizations for Sustainability Transitions

Concept	Definition	Application to transitions
Ubuntu	Emphasizes the act of building community, friendship and oneness with the larger humanity.	Neighbourhoods efforts to promote energy efficiency, decisions about food resources within a community
Taoism and Confucianism	Emphasizes virtue and suggests that the means to an end is more important than the end itself.	Respecting due process in transition decisions, adhering to human rights protections when implementing infrastructural projects
Hinduism and Dharma	Carries the notion of righteousness and moral duty and is always intended to achieve order, longevity and collective well-being.	Seeking to minimize the extent and distribution of externalities, offering affordable access to technology help address poverty
Buddhism	Expounds the notion of selflessness and the pursuit of individual salvation or nirvana.	Respecting future generations, minimizing harm to the environment and society
Indigenous Perspectives of the Americas	Recognizes interdependence of all life and enables good living through responsibility and respect for oneself and the natural world, including other people	Technologies developed cautiously through long-term experience and sovereign cultural protocols, avoiding dramatic transformation of ecosystems, requiring restoration
imal-centrism	Values and recognizes rights of all sentient life	Promoting transition processes or practices such as veganism, vegetarianism, or waste reduction that avoids harm and provides benefits to all sentient animals
Biocentrism	Values and respects the will to live and the basic interest to survive and flourish	Promoting transitions that adhere to a fair share of environmental resources among all living beings
Ecocentrism	Gives moral consideration for human and nonhuman communities and the basic functioning and interdependence of the ecological community as a whole	Advocating technologies or transitions that preserve the integrity, diversity, resilience, and flourishing of the whole ecological community

Source: Modified from Sovacool and Hess (2017).

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