A research agenda for the Sustainability Transitions Research Network, STRN Working Group

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Preface

The Sustainability Transitions Research Network (STRN) was inaugurated in 2009 at the 1st European Conference on Sustainability Transitions in Amsterdam with the purpose of creating a new inter-disciplinary academic community. Since then, STRN-membership has not only grown (from about 200 in 2010 to almost 1500 in December 2017), but also diversified to become very international, now including not just European researchers, but also scholars from Australia, Asia, Africa and the Americas.

In July 2010, STRN published its first mission statement and research agenda (STRN, 2010). Since then, sustainability transition scholarship has:

- grown rapidly in terms of the numbers of books and articles
- diversified in terms of journals: while early papers often appeared in innovation journals, STRN-scholars now also regularly publish in sustainability, energy, transport, agro-food, geography, organization, political science and sociology journals
- deepened intellectually, particularly through more systematic mobilization of ideas from various social sciences to better understand particular themes, mechanisms or dimensions
- broadened empirically: while early papers often focused on electricity or transport, transition scholars now also investigate other societal domains like heat and buildings, agro-food, and water and waste management
- extended geographically: while early papers often focused on Northern European countries, empirical studies increasingly also investigate transitions in other jurisdictions, which highlight new conceptual issues and questions (e.g. political economy, transnational networks, role of the state).

This renewed research agenda aims to take stock of the research over the last 7 years, during which period the collective research endeavour has become highly cumulative and productive. The new research agenda is almost three times as long as the first one, which reflects the field's rapid expansion, diversification, and deepening.

An initial impulse for this renewal came from the 6th International Sustainability Transitions (IST) Conference in August 2015 in Brighton, where participants discussed new research directions in breakout sessions. In 2016, the STRN Steering Group created a working group, chaired by Jonathan Köhler, to lead the revision process. The working group first reviewed the ideas from the Brighton sessions and then invited all STRN-members to put forward ideas for the research agenda (supported with brief arguments). The working group subsequently collated, discussed and organized these ideas into different themes. Different author groups were then assembled for the different themes, which included members of the working group, STRN steering group and other STRN-experts. Draft texts were then discussed and partly rewritten by the working group to ensure a similar length, structure and style. The compiled report was then sent to the STRN Steering Group for further comments. Based on their feedback, the working group made further adjustments, which finally resulted in this report.

I want to thank all STRN members, contributors, the Steering Group and working group members for their contributions to this new research agenda. The report shows how far the transitions community has come in a relatively short period of time, and how many interesting topics and questions we can still address in future years. I hope you will enjoy reading the agenda and, more importantly, that it will inspire you to contribute to the development of sustainability transition studies.

Frank Geels, Chairman of STRN, December, 2017

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INTRODUCTION AND PURPOSE OF THIS RESEARCH AGENDA

The starting point for transitions research is the recognition that many environmental problems, such as climate change, loss of biodiversity, resource depletion (clean water, oil, forests, fish stocks), are grand challenges, which relate to 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, but require shifts to new kinds of systems, shifts which are called 'sustainability transitions' (Markard *et al*., 2012). Therefore, a central aim of transitions research is to conceptualise and explain how radical changes come about 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). Transitions research is therefore complementary to long-standing sustainability debates at the 'macro'-level (e.g. changing the nature of capitalism or nature-society interactions) and the 'micro'-level (e.g. changing individual choices, attitudes and motivations).

Sustainability transitions have several characteristics that make them a special (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 forces of stability and path dependence. Transition research mobilizes insights from different disciplines and theories to understand the dialectic relationship between stability and change.

- *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, takeoff, acceleration, and stabilization (Rotmans et al., 2001). A potential drawback of phase models (particularly S-shaped diffusion curves) is that they can be seen as portraying transitions as relatively linear and teleological processes.
- *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 (Rosenbloom et al., 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, disagreement*: The notion of sustainability is, of course, highly contested, so different actors and social groups also tend to disagree about the most desired 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, cars, electric utilities, agro-food), such incumbents are likely to protect their vested interests and contest the need for and speed of transitions.
- *Public policy*: 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.

These characteristics make sustainability transitions research quite different from other sustainability approaches, which often 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 is broader and more inter-disciplinary than existing sustainability approaches. It is arguable that precisely *because* sustainability transitions research asks 'big picture' questions, it has sparked such enthusiasm and creativity. This updated research agenda takes stock of that research. 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).

1. Understanding transitions
2. Power, agency and politics in transitions
3. Governing transitions

4. Civil society, culture and social movements in transitions
5. Organizations and industries in sustainability transitions
6. Transitions in practice and everyday life
7. Geography of transitions: spaces, scales, places
8. Ethical aspects of transitions: distribution, justice, poverty
9. Methodologies for transitions research

The first theme addresses conceptual frameworks that aim to capture the complexity and multi-dimensionality of sustainability transitions. Themes 2, 3, 4, 5 and 7 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 6 addresses the spatial dimension of transitions, which raises interesting new issues including the role of cities and transitions in low-income and developing countries. Theme 8 and 9 are new compared to the 2010 research agenda, with the former addressing ethical issues and the latter expanding the discussion to methodological questions, including process methods, modelling, systematic comparison, and participatory and action research. Each of the respective chapters starts with a brief introduction of the relevance of the theme, followed by a discussion of the current state of the art, and an indication of interesting directions for future research. Links between the themes are indicated.

1 UNDERSTANDING TRANSITIONS

1.1 Introduction and relevance

The past two decades have produced a few distinct analytical frameworks that address the characteristics of sustainability transitions as described above (Markard et al., 2012). These are the *Multi-Level Perspective (MLP),* the *Technological Innovation System* approach *(TIS), Strategic Niche Management* and *Transition Management*. These frameworks are relatively broad and encompassing, because they aim to conceptualise transitions as longitudinal, multi-dimensional, multi-actor processes. Other contributions to the research agenda focus on particular dimensions or social groups (e.g. firms, consumers, policy makers, civil society) and such specialization is to be expected for a growing research community. However, it is also important to have frameworks that address the broader characteristics of transitions, as described above. The inaugural issue of the EIST (Environmental Innovation and Societal Transitions) journal summarised the literature (van den Bergh, Truffer and Kallis, 2011).

Most of the analytical frameworks in this section derive from the field of innovation studies, which is where transitions research initially started (Smith et al., 2010). The focus on innovation has the advantage of drawing analytical attention to novelty and existing structures which tend to privilege particular kinds of actors. The field of innovation studies is also quite broad and heterogeneous and includes (evolutionary) economic, sociological, and organizational approaches, which enable the study of multiple dimensions and actors.

1.2 Current state of the art: existing analytical frameworks

One of the most prominent approaches 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 pioneers and entrepreneurs nurture the development of an alternative socio-technical configuration by experimenting with new business models, technological artefacts or user practices (Kemp et al., 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., 2008; Negro et al, 2008, Markard et al., 2015), which mobilizes ideas from innovation systems theory (Lundvall, 1992; Malerba, 2002) and industrial economics (Carlsson and Stankiewicz, 1991). A technological innovation system comprises technologies, actors and institutions. It is defined as a network of agents interacting in the economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology. 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., 2008). 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) (Kemp et al., 1998; Geels and Raven, 2006; Schot and Geels, 2008) is another framework widely used for analysing the emergence of radically new innovations. Combining ideas from the sociology of innovation and evolutionary economics, SNM focuses on interactions between learning processes (on various dimensions), social networks, and visions and expectations.

Transition Management (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 (understood to follow an S-curve development) 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 theme 3 (governance).

Sustainability transitions research has exploded in the last 10 years, giving rise to the differentiation of existing analytical frameworks, the mobilization of insights from different fields and theories, and the investigation of new (sub) topics. MLP elaborations include the following:

- More differentiated views of the *interactions between niche-innovations and existing regimes* going beyond substitution dynamics. These include: the selective trans-

lation 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), and empowerment activities adjusting existing regimes so as to create space for niche-innovations (Smith and Raven, 2012).

- While many transition scholars initially studied niche-innovations, more attention is now also dedicated to *incumbent regime actors*, including active resistance to transitions (Geels, 2014a), institutional strategies aimed at shaping regime rules (Smink *et al*. 2015b; Fuenfschilling and Truffer, 2016), incremental reform activities to placate policy makers and publics (Penna and Geels, 2015), and strategic reorientations of incumbent firms towards radical niche-innovations (Bergek et al., 2013; Geels *et al*., 2016).

- More differentiated views of *transition pathways*. While the dominant understanding remains the substitution pattern, scholars have increasingly developed alternative transition pathways. 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. De Haan and Rotmans (2011) discuss a range of dynamic patterns, that combine in different ways to produce multiple pathways. Various scholars have suggested the need to move beyond the Schumpeterian pattern (in which new entrants produce radical innovations and incumbents incremental innovations). Instead, they suggest that incumbent actors can also reorient towards radical niche-innovations (Berggren et al., 2015; Penna and Geels, 2015), that incumbents and new entrants may work together in alliances (Geels et al., 2016), or that incumbents from different sectors move in to engage with niche-innovations (Hess, 2013).

- 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, 2015), 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 (see Markard et al. 2015 for an overview):

- Interactions of TIS with broader technological, sectoral, geographical and political context systems (Bergek et al., 2015) to capture, e.g. complex technology dynamics including competing and complementary technologies (Markard et al., 2009; Magnusson, Berggren, 2017.), or the dependency of TIS dynamics on institutional contexts (Dewald, Truffer, 2011; Wirth, et al., 2013).

- System building: analysis of the strategic actions of different kinds of actors, and actor networks towards the creation of system resources (Musiolik, et al., under review; Musiolik,et al., 2012; Planko, et al., 2016; Kukk, et al., 2015).
- Technology legitimacy: elaboration of legitimacy dynamics and legitimation strategies for technological innovation systems (Bergek et al., 2008; Binz et al., 2016; Markard et al., 2016).
- Differentiation of TIS development in spatial terms, including 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., 2015) or global innovation systems (Binz and Truffer, 2017).
- Development of a TIS life cycle model to accommodate the later stages of maturation and decline and the dynamics of sustainability transitions (Bergek and Jacobsson, 2003; Bento and Wilson, 2016; Markard, under review).
- More differentiated patterns of change, 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).
- Conceptual interactions between TIS and MLP (Markard and Truffer, 2008).
- The development of systemic policy instruments aimed at improving how innovation systems function (Wieczorek and Hekkert, 2012).

SNM research has also been elaborated along several lines:

- A different typology of core processes such as sheltering, nurturing, and empowerment (Smith and Raven, 2012; Raven et al., 2015). Two patterns have also been developed to describe the relation of niche-innovations to existing regimes: fit-and-conform and stretch-and-transform (Smith and Raven, 2012).

- A vibrant literature on learning and experimentation with regard to radical innovations (Van Mierlo et al., 2010; Sengers et al., 2017).

- A literature on the role of expectations in technological development (Brown and Michael, 2003) and how this may trigger hype-disappointment cycles (Bakker and Budde, 2012; Van Lente et al., 2013; Konrad, 2016).

- Research on grassroots innovation, activists, and local communities (Seyfang and Smith, 2007; Seyfang and Haxeltine, 2012; Hargreaves et al., 2013).

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

1.3 Research directions

New, but under-addressed topics on the research agenda include the following:

- The destabilization, decline, and phase-out of existing systems and regimes (Karltorp and Sandén, 2012; Turnheim and Geels, 2012; Markard, under review) represent the flipside of transitions. Existing systems may decline *because of* pressure from niche-innovations, but systems may also be phased-out deliberately (Stegmaier et al., 2014), which creates space for the accelerated diffusion of niche-innovations.

- There has been much work done in transitions research (in TIS and SNM) on the *emergence* of green innovations. It is time, however, to pay more attention to *breakthrough, diffusion, tipping points, and thresholds*, firstly because this is happening in the real world in some domains (e.g. electricity, transport), and secondly, because problems like climate change require accelerated transitions.

- A related aspect is the complementary and competing interaction of multiple emerging and existing technologies (Sandén and Hillman, 2011) or niches (Raven, 2007; Verbong et al., 2007; Papachristos et al., 2013; Markard and Hoffman, 2016), and the repercussions these dynamics have for the 'functioning' of the larger system (Markard and Hoffman, 2016). This also includes the consequences of transitions in one sector for the development of adjacent sectors (e.g. electricity and transport) in the sense of multi-regime dynamics (see below, Raven and Verbong, 2007; Konrad et al., 2008; Sutherland et al., 2015).

- The speed of transitions and how can they be accelerated is therefore also 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?

- Some scholars are 'zooming out' to develop an even 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 begun to investigate how multiple regime shifts can shape landscape developments and thus societies as a whole (Schot, 2016).

- While path dependence is crucial to understand the stability of existing systems, new research has begun to probe deeper and investigate the strengths of lock-in mechanisms, and how they vary over time or between sectors (Klitkou *et al*., 2015). The strength of socio-technical regimes has also been theorized and assessed from an institutional perspective (Fuenfschilling and Truffer, 2014). Such studies could enable more precise assessments of the degree of path dependency as well as tensions/cracks in regimes.

- Another important research direction is to move beyond the existing frameworks by mobilizing insights from other 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), organizational theories (Farla et al., 2012; Markard, 2017), and economic geography (Hodson and Marvin, 2010; Coenen and Truffer, 2012; Truffer and Coenen, 2012; Bulkeley et al., 2013).

- It is also striking that transitions research has had so far 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 could also contribute to the debate on limits to growth (van den Bergh, 2017).

2 POWER, AGENCY AND POLITICS IN TRANSITIONS

2.1 Introduction and relevance

In and around the field of transition research, the issues of *power*, *agency* and *politics* in transitions are receiving increasing attention. This is a response to several critiques that these aspects had been neglected in the early work on transitions and their governance (Shove & Walker 2007, 2008, Hendriks 2009, Meadowcroft 2009, Smith & Stirling 2010, Stirling 2010, Smith et al. 2010, Scoones et al. 2015, Gillard et al. 2016; Kern 2015). These critical discussions can be contextualized within a broader debate about the politics of sustainable development (e.g. Meadowroft 2007, Scrase and Smith 2009, Swyngedouw 2010), particularly the tensions between democratic governance and the radical steps deemed necessary for sustainable development (Langhelle, 2000; Stirling 2011; Blühdorn 2013; Røpke 2012). These critiques have led to a series of theoretical and empirical studies of power and politics in transitions (Kern & Howlett 2009, Voß et al. 2009, Kern 2009, Avelino 2009, Grin 2010, Hoffman 2013, Paredis 2013, Stirling 2014; Geels 2014, Pel et al. 2016, Avelino et al. 2016) 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 theme 3.

2.2 Current state of the art (established and emerging topics)

It is now well established in the literature that transitions involve various aspects of *power*. This is often thought of in terms of who has the power to affect change, but also in terms of the outcomes of transitions representing shifts in power away from incumbent actors and regimes. One can distinguish between three main perspectives on power: a socio-technical perspective, a governance perspective, and a political sociology perspective.

- In the socio-technical perspective on transitions (Geels & Schot 2010), power is primarily understood in terms of the regulative 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 on hegemonic power regime 'resistance' (Hess 2013).

- 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' (in reference to Healey). Moreover, Grin links the MLP to an existing multi-levelled power framework by Arts and Van Tatenhove (2005). Grin ar-

gues 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 & Rotmans (2009) build on sociological and political theories of power to propose a complementary, 'horizontal' understanding of power. Rather than the vertical interaction between actors, structures and systems, they focus on how actors engage with resources, structures and systems in *different ways*. Based on this, they complement the MLP with a *horizontal, qualitative* distinction. They characterise 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) (Avelino 2011).

In addition to the work on power dynamics, there is also a broader tendency in the transitions literature to focus more explicitly on the *agency* of the various actors involved in transition processes. A special issue guest edited by Farla, Markard, Raven and Coenen (2012) was an early initiative that combined actor and agency-oriented work in the field of transitions studies. For instance, it is studied how different actors strategically join forces in networks or larger coalitions to achieve common goals. More recently, a special issue in Environmental Innovation and Societal Transitions edited by Raven et al. (2016) brought together a variety of contributions dealing with the concept of 'protective space'. The key claim is that there are important politics of creating protective spaces within which alternative practices can emerge. Contributions to the special issue draw on evolutionary, relational and institutional perspectives to conceptualise these processes. Another recent special issue in the Journal of Environmental Policy and Planning edited by Avelino et al (2016) brought together different perspectives on the politics of sustainability transitions.

Another strand of work focuses specifically on the *politics* of public policy processes in the context of transitions. Given that much of the thinking in transition studies builds on the recognition that public policy is key to enabling transitions, scholars in the transition field have started to move beyond simply analysing 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; Markard et al 2016; Normann 2015; 2017).

This strand of work draws on well-known policy process theories from the field of policy sciences including Sabatier's advocacy coalition framework, Hajer's discourse coalitions, Marsh and Rhodes's policy networks and Kingdom's multiple streams. These approaches have in common that they shed light on the key actors routinely involved in policy making. They differ in terms of how they conceptualise what holds these actors together (e.g. shared beliefs or shared discourses). Interestingly, it is not just the field of sustainability transitions that benefits from policy process theories, but also vice versa. An important contribution from transition studies is that technology and changes in

technology may affect and even facilitate policy change (Markard et al., 2016; Schmidt and Sewerin, 2017).

There is also an emerging strand of work which goes beyond analysing individual policy instruments and how they came about, and focuses instead on wider policy mixes (Flanagan et al., 2011), arguing that these are be required for sustainability transitions (Kern and Howlett, 2009; Reichardt et al., 2016; Kivimaa and Kern, 2016; Rogge and Reichardt, 2016).

However, analysing the politics of transitions not only concerns studying government-led policy processes, but also unpacking the 'micro-politics' of transition processes (Hess, 2014; Pel, 2016; Chilvers and Longhurst, 2016; Avelino and Wittmayer, 2016; Hoffman and Loeber, 2016). Transition politics are also manifested as futures are envisioned (Gaede and Meadowcroft, 2016; Hoffman and Loeber, 2016), spaces visualized (Castán Broto, 2016), economic paradigms reproduced (Swilling et al. ,2016, Kenis et al., 2016), novelties captured (Pel, 2016), participation procedures take shape (Chilvers and Longhurst, 2016), and actor roles framed (Avelino and Wittmayer, 2016).

2.3 Research directions

In summary, there has been much research on various aspects of the power, agency and politics of transitions over the last decade in response to criticisms that such aspects were underplayed in the early literature. However, given the vastness of this agenda, many interesting and diverse future research directions are still emerging. These include:

- Drawing on classical political science theories (e.g. different variants of institutionalism) to better understand formalised decision-making processes and the institutional contexts within which transitions unfold (e.g. see Hall and Taylor, 1996; Schmidt, 2008).

- Building on political economy theories (e.g. realism, liberalism or Marxism, see Van de Graaf et al., 2016) to better understand the role of geo-political struggles in transitions (Kern and Markard, 2016). This is highly relevant and there has been little research on this aspect to date (e.g. Schmitz, 2013 raised the question of how the global power shift from the West to the East will affect the low carbon transition).

- Drawing on comparative political economy frameworks (such as varieties of capitalism) to explain the large variation of transition pathways and dynamics across countries (Ćetković and Buzogány, 2016; Kern and Markard, 2016).

- Drawing on policy process theories to better understand policy processes and how actors involved in transitions try to shape the content of policies (e.g. Sabatier's advocacy coalition framework), which then in turn influence further socio-technical developments (e.g. Pierson's policy feedback theory, 1993). It has already been pro-

posed by Markard et al. (2016) and Schmidt and Sewering (2017) that such feedbacks deserve more attention.

In addition to political science frameworks, research on the politics of transitions can also benefit from other relevant perspectives that include, inter alia:

- 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 2014, 2016; Avelino and Wittmayer 2016). The emerging literature on strategic action fields (Fligstein and McAdam, 2011, Kungl, 2015) may also be of particular relevance in this regard.

- 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 niches-regime interactions.

- Social movement theory can help to conceptualise the role of bottom-up pressure for transitions (see Theme 4; Sine and Lee, 2009; North 2011).

- Development studies (Swilling et al., 2016) provide perspectives to reconsider 'socio-technical' regimes as 'socio-political' regimes.

- Critical geography employs Foucauldian concepts of 'political technologies' to analyse how the politics of geographic boundaries and national identities 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 in transition governance, drawing on insights from critical political theorists such as Mouffe (2006), Swyngedouw and Żiżek to highlight how conflict and contestation are suppressed.

3 GOVERNING TRANSITIONS

3.1 Introduction and relevance

At the heart of the research agenda in the STRN community is understanding how transition processes have unfolded in the past, and are unfolding in the present. From the beginning, however, scholars in this field were also very interested in how transitions can be consciously directed towards more sustainable directions. Therefore, early on, various approaches were developed that aim to produce analyses of transitions, but also prescriptive advice on how to steer transitions, including work on Transition Management (Rotmans et al., 2001; Loorbach, 2010), Strategic Niche Management (Kemp et al., 1998; Hoogma et al., 2002), and Reflexive Governance (Voss et al., 2006; 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. The challenges of how to steer transitions in desirable directions, but also of how to do so within timescales that help avoid dangerous environmental change (e.g. Sovacool, 2016) are still very much at the forefront of research interest in the STRN community. As well as the close ties to power and agency discussed in theme 2, governance is also part of several other themes: geography and scales (theme 7) , as well as ethics and justice (theme 8). The need to improve quantitative methods has also been identified, which has links to theme 9.

3.2 Current state of the art

Governance scholars emphasise that while public actors, such as policy makers, are of course important for governance processes, governing also involves a range of private actors. Much of the work on governing transitions therefore starts by recognising that transitions cannot be governed from a top-down perspective, that a plurality of actors not just governments are involved, that it has to deal with uncertainty, and that appropriate interventions may change over the course of a transition depending on the respective phase (see e.g. Grin et al., 2010). Classic work on governance (Kooiman, 2003: 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 is a very suitable definition in the context of discussing the governance of sustainability transitions (Grin et al., 2010). This definition acknowledges the multi-actor nature and normative ambition of the project as well as indicating the importance of existing institutional structures. There has been work looking at the role of institutions in shaping transition policies (Kern, 2011) and at how institutional logics shape transition processes (Fuenfschilling and Truffer, 2014).

Governance scholars often distinguish between different modes through which governance takes place: hierarchy, competition and cooperation. The existing literature on the governance of transitions adopts many of these broad perspectives. For example,

the core idea of the transition arenas featured in Transition Management is to bring together actors from science, policy, civil society and businesses and develop cooperative rather than competitive relationships between them. However, early on, TM scholars warned that so-called 'control policies' (such as carbon pricing) are also required to promote transitions. Also in the latest work on strategic niche management, some attention has been paid to how niche actors may be able to change existing regulations favouring the current regime towards rules favouring their preferred niches (Smith and Raven, 2012; Raven et al., 2015).

Given that transitions are highly complex and uncertain processes, the notions of experiments and experimentation have received much attention in both TM (transition experiments) and SNM (niche experiments) literatures. Experiments have been a core part of transition studies from the start (Hoogma et al., 2002), but have recently gained increasing traction (e.g. Bulkeley et al., 2014; Luederitz et al., 2016; Sengers et al., 2016a; Matschoss and Heiskanen, 2017). Experiments are one tool that can be used to implement transitions in practice (Hoogma et al., 2002), but relatively few analyses have been made of their longer term influence on transitions through outcomes (Kivimaa et al., 2017a). Recent research has systematically reviewed the literature on transition experiments (Sengers et al., 2016b; Kivimaa et al., 2017a) and points out several avenues for future research: (1) analysis of the different forms of micro-politics, power and agency in experimentation; (2) moving beyond case study approaches; (3) geography of experimentation; (4) role of businesses in experimentation; (5) empirical accounts that examine governance and policy experiments from a transition perspective, and; (6) long-term aggregate evaluations of experiments - what happens after the experiment and how societies can reap the benefits of an 'experimental society' for sustainability transitions. This indicates the need to move beyond experimentation as a key transition governance tool. It could be argued that, while variety creation through experimentation is very valuable in the early phases of transitions (what Stirling (2008) called 'opening up'), there is also a case for 'closing down' certain avenues and making choices when the transition is further advanced and, for example when important infrastructural investment decisions need to be taken.

An emerging debate in transition studies with implications for how transitions can be governed concerns the role of intermediary actors who can actively facilitate and speed up transitions (Hargreaves et al., 2013; Kivimaa, 2014; Barnes, 2016). While many of the early studies focused on intermediaries in niche development (e.g. Geels and Deuten, 2006; Hargreaves et al., 2013; Kivimaa, 2014), new contributions have highlighted the lack of research on how intermediaries can interact in the niche-regime interface, destabilise incumbent regimes and operate in later phases of transitions (Ingram, 2015; Bush et al., 2017; Kivimaa et al., 2017b). There is scope for future research in these areas.

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., 2007b). Recently, there has been increased interest from international organizations like the OECD with its 2015 report on system innovation and the European Environment Agency (2016). This provides much scope for thinking about how research on transitions can be relevant for policy makers and applicable to policy analyses. This interest from policy makers challenges transition scholars to focus more on forward-looking analysis. It calls for 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. In addition, studies that have utilised TIS or MLP frameworks to analyse current policies have attracted interest from national and European policy makers, in particular.

3.3 Research directions

- While 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 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., 2017).
- An important issue is to engage with more traditional policies such as price instruments (taxes, subsidies, capital grants, loans, exemptions) and regulations (standards, bans, institutional reform). The transitions community has for long time emphasized the role of 'processual' instruments (networks, experiments, visioning, intermediary actors), as the above review shows. While these instruments remain important, we should also investigate the role of more traditional instruments in transitions, which may be especially relevant for diffusion, acceleration, and upscaling, while also affecting the speed and direction of innovations critical to sustainability transitions.
- Forward-looking analysis: Understanding the governance challenges of transitions calls for more explicit recognition of barriers and reconfigurations of regime and niche actors in the future (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; Hillman et al., 2011; Nilsson, Hillman, and Magnusson, 2012). Methods for forward-looking analyses such as backcasting or scenario studies (Wangel, 2011; Hughes, 2013, 20; Kriegler et al., 2012) should be developed further to better incorporate governance considerations.
- Widening the use of quantitative methods: Given its strengths in providing forward-looking policy advice, quantitative systems modelling can provide complementary methodologies to understand how to steer sustainability transitions in practice (Turnheim, et al, 2015). To further integrate these approaches to studying transition pathways requires the development of quantitative scenarios that draw on existing socio-technical analyses and the formulation of explicit quantitative goals based on this understanding (e.g. Köhler et al., in review).

- Extending transition studies to include multiple levels of governance: Analyses of governance processes and concrete policy interventions at different levels are needed to remove barriers to transitions or to nurture further niche and regime change (Nilsson and Nykvist, 2016). There is therefore a need for research on the multi-level nature of transition governance that spans global, international, national and local scales. For example, Ehnert et al (2017) have recently looked at acceleration dynamics in different European city regions as influenced by wider European, national and state level governance processes.
- Further development of the analysis of transition experiments in several directions: 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 to more generalised assessments.
- There is also the question of long-term aggregate evaluations of experiments - what happens after the experiment and how can societies reap the benefits of an 'experimental society' for sustainability transitions?

There is also an increasing interest in studying not only how governance can facilitate the emergence of alternative socio-technical configurations, but also how pressure can be exerted on existing regimes to provoke processes of destabilisation (Turnheim and Geels, 2013) and creative destruction (Kivimaa and Kern, 2016). Which governance interventions and policy mixes (Rogge and Reichardt, 2016) are suitable in different phases of transitions is therefore an exciting research agenda.

4 CIVIL SOCIETY, CULTURE AND SOCIAL MOVEMENTS IN TRANSITIONS

4.1 Introduction and relevance

The sustainability transitions literature has increasingly recognized the importance of civil society and social movements in facilitating the transformation of energy, transport, or food systems, and more generally our social systems of production and consumption towards greater sustainability. In a programmatic article by of leading sustainability and global change research centres, Leach et al. (2012) call for greater recognition and empowerment of grassroots innovation actors and processes to achieve transformative innovation.

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. As such, they have a particular role in the debates on governance (see theme 3). Examples of civil society organizations (CSOs) include those representing geographical communities, religious and ethnic identities, leisure activities, occupations, and nongovernmental political action. In contrast with civil society, social movements are grassroots mobilizations with the goal of changing established institutions in the state, private sector, and/or civil society (Schneeiberg and Lounsbury, 2008). They therefore represent an alternative form of power and agency (theme 3). Some social movement organizations (SMOs) can be considered a type of CSO, but social movements generally include coalitions with actors from the public and private sectors as well. Furthermore, in contrast to the idea of a subsector of civil society (such as religious or community organizations), social movements include a broad range of heterogeneous organizations that coordinate multiple campaigns over several years if not decades. There are frequently parallel and interacting mobilizations of protest-based movements that use extra-institutional repertoires of action, and reform-based movements that operate within existing institutional channels of change.

4.2 State of the art

The research to date on the role of civil society and social movements in sustainability transitions can be classified into three main groups: the politics of transitions (see above), grassroots innovation (Seyfang and Smith, 2007), and cultural change (Geels and Verhees, 2011). With respect to the politics of transitions (e.g., Avelino et al., 2016), CSOs and social movements can affect the public support for policies that lead to the decline of some technologies and the uptake of others. CSO activities are often motivated by an alternative vision for society as a whole (Smith, 2012) and thus help to articulate new directions of societal change (Leach et al., 2012). Although there is substantial general social science work on industrial opposition movements (e.g. grassroots mobilizations against genetically modified food or fossil fuels), their effects on societal innovation is only beginning to attract attention in the transition studies literature (e.g.

Elzen et al., 2011, Geels and Verhees, 2011; Penna and Geels, 2012). One fruitful avenue of research has been to explore the role of CSOs and SMOs as part of broad advocacy coalitions that support transition policies (Markard et al., 2016). With respect to the private sector, SMOs can also create new market opportunities, for example in the emerging U.S. wind energy sector, by propagating new cognitive frameworks and calling for new regulatory structures (Sine and Lee, 2009). SMOs and CSOs also draw attention to justice, fairness, and distributional issues that can affect public support for transition policies and inclusive innovation (Smith et al., 2016, Sovacool and Dworkin, 2014). This is linked to the ethics theme in theme 8. In addition to serving as drivers of change, CSOs can also become part of powerful actor coalitions that stabilize existing regime structures (e.g. Avelino and Wittmayer, 2016).

4.3 Research directions

Of the many research questions that emerge from this line of research, three examples are shown below:

- What is the role of SMOs and CSOs in developing public support for regime destabilization and sustainability policy development (Turnheim and Geels, 2012)? What role do SMOs and CSOs play in overcoming regime resistance to sustainability transition policies, and how do social movements affect the attention paid to the justice and inclusion aspects of innovation and sustainability?
- A second area of research draws attention to the direct effects of CSOs on industrial innovation by providing protective spaces for grassroots innovation (Hossain 2016, Seyfang and Smith 2007, Smith et al. 2016). These reform-based movements are often anchored in CSOs such as community organizations, but researchers, local governments, and entrepreneurs can play a significant role, too. A substantial strand of this literature examines innovation in "energy communities" (Dóci et al., 2015, Seyfang et al., 2014, Seyfang and Haxeltine, 2012), such as the UK transition town movement (Stevenson, 2012). 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). As with the other two categories of civil society contribution, CSOs may not only be a force to shape and facilitate sustainable innovations, but can also resist innovations, for example, by generating opposition to the introduction of wind farms or linking up with the industrial interests of incumbent actors. Furthermore, research on grassroots innovations identifies various challenges that such organizations are facing in relation to transitions. For example, there are tensions between being locally-specific, which is the focus of many community-based organizations, and at the same time generating scalable and widely applicable innovations;

between fitting into and gaining acceptance from existing institutions versus transforming them; and between having a project- and programme-orientation while seeking structural change (Smith et al., 2014). Various research questions emerge from this line of research. For example, how do CSOs and social movements enable grassroots innovations to achieve scale shifts and escape niche stasis, and in what ways do they constrain this process (Ornetzeder and Rohracher, 2013)? How do the "stretch and transform" aspirations of societal transformation and the goals of "deep transitions" (Schot, 2016) change as grassroots innovations become absorbed into industrial regimes? How do these aspirations become institutionalized; and how are reform-based movements for grassroots innovation connected with protest-based social movements?

- A third area of research involves how civil society and social movements bring about broader cultural changes that can shift the societal landscape and political and industrial opportunity structures for sustainability transitions. By cultural change, we mean shifts in the collective but contested systems of meaning, both cognitive and normative, which orient action. By challenging taken-for-granted systems of meaning, CSOs and broader social movements can affect public opinion and policy preferences as well as consumer preferences and everyday practices. Examples include Balsiger (2010) and Holzer, (2006) on political consumption and consumer boycotts, and Chilvers and Longhurst (2016) on public engagement in transitions. Reform-based movements create new semiotic maps of the possible and desirable, but protest-based movements can also drive shifts in political and consumer awareness and values. Much of the literature that examines the effects of CSOs and SMOs on culture change is still generally restricted to social movement studies, and opportunities exist to integrate this field into transition studies. This integration could also help to develop the analysis of "socio-technical landscape" structures within the multi-level perspective on transitions. 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., Feunfschilling and Truffer, 2016). Another approach is to draw on frame analysis, but connect this with design innovation and with changes among broader political ideologies that orient policy change (Elzen et al. 2011, Hess 2016b). A third approach examines the relationship between changing everyday practices and the mobilizations of CSOs and social movements (Spaargaren et al., 2012). The following questions are just some of those emerging from this line of research: How can the institutional logics perspective and frame analysis be integrated into research on the role of CSOs and social movements in transition studies? How can the study of transitions and everyday practices be connected with CSOs and social movements?

In summary, the integration of civil society and social movements into transition studies, especially when including variations in scale and across geographical regions, offers enormous opportunities for understanding the conditions under which sustainability transitions advance or face stasis.

5 ORGANIZATIONS AND INDUSTRIES IN SUSTAINABILITY TRANSITIONS

5.1 Introduction and relevance

Organizations play critical roles in sustainability transitions. Among others, they develop new products, services and business models (Bergren, 2015; Schaltegger et al., 2016; Wells, 2017), contribute to market formation for novel technologies (Musiolik et al., 2012; Binz et al., 2016; Planko et al., 2016), lobby for regulatory support (Jacobsson and Lauber, 2006; Sühlsen and Hisschemöller, 2014; Hess, 2016a), work toward common industry standards (Smink et al., 2015b; Markard and Erlinghagen, 2017), engage in societal discourses and problem framing (Geels and Verhees, 2011; Penna and Geels, 2012; Rosenbloom et al., 2016) or and shape collective expectations (Konrad, et al., 2012; Bakker, 2014). Organizations can support or oppose ongoing transitions (Kern and Smith, 2008; Geels, 2014b; Lauber and Jacobsson, 2016; Smink et al., 2015b). As a consequence, new industries emerge and existing industries transform – incrementally or fundamentally – thus contributing to socio-technical transitions (Bergek and Jacobsson, 2003; Wittneben et al., 2012; Turnheim and Geels, 2012; Geels, 2014a; Berggren et al., 2015; Dijk et al., 2016).

Transition scholars are paying increasing attention to the roles of firms and industries in sustainability transitions (Farla et al., 2012). From 2012 onwards, research related to firms, strategy and business in the field of sustainability transitions has expanded rapidly with about 30 new articles appearing every year.

At the same time, an increasing number of management scholars are engaging with fundamental sustainability challenges such as climate change (Lefsrud and Meyer, 2012; Wittneben et al., 2012) or the energy transition (Sine and Lee, 2009; Garud et al., 2010; Hoppmann et al., 2013), and mobilizing established frameworks in management studies such as institutional entrepreneurship (Garud and Karnoe, 2003; Wijen and Ansari, 2007; Buhr, 2012) or institutional theory (e.g. Lefsrud and Meyer, 2012; Ferraro et al., 2015; Bohnsack et al., 2016). More importantly, management scholars are expressing concern that sustainability issues have been marginalised for too long (Goodall, 2008; Patenaude, 2011) and are asking to what extent established concepts and theories in management studies are suited to dealing with the challenges of grand sustainability problems (Gladwin et al., 1995; Hahn et al., 2010; Bansal and Song, 2016; Markard, 2017).

Therefore, there is significant potential for both transition and management scholars to intensify research at the intersection of both fields and to improve our understanding of the roles of organizations and industries in sustainability transitions. This theme of the research agenda takes a ‘business perspective’ on sustainability transitions. It focuses on for-profit organizations such as firms, industry associations, or inter-firm networks and their role in the formation, change and decline of industries. Firms as a source of innovation are influenced by governance structures and policy (themes 2 and 3). They also play a pivotal role in transitions dynamics in the frameworks discussed in theme 1.

5.2 State of the art

Incumbents vs. newcomers: Many studies find newcomers driving radical innovation while incumbent actors obstruct major technological and institutional changes (Rothaermel, 2001; Kern and Smith, 2008; Penna and Geels, 2012; Smink et al., 2015b; Wesseling et al., 2014). 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), horticulture (Kishna et al., 2016) or power transmission (Andersen and Markard, 2016). A closely related theme concerns incumbents from adjacent sectors such as IT or telecommunications driving innovation (Dolata, 2009; Erlinghagen and Markard, 2012; Berggren et al., 2015). Future research along these lines could address: i) the characteristics (e.g. disruptiveness) of incumbent-driven innovation. ii) The challenges of collaborations between incumbents and newcomers. iii) The consequences for system building and transition pathways. iv) The challenge for incumbents to foster radical innovation while maintaining or phasing out established business. v) The relevance of complementary resources and how newcomers gain access to these. vi) How different emerging technological innovation systems and niche actors both compete and cooperate and how they engage with both incumbent systems (regimes) and future ideals to form 'hybrid systems' or 'bridging technologies' (Andersson and Jacobsson, 2000; Bergek et al., 2008; Raven, 2007; Sandén and Hillman, 2011; Suurs and Hekkert, 2009; Wirth and Markard, 2011). vi) How 'actors from adjacent sectors affect transition pathways.

Emergence and decline of industries: The emergence of new industries is often studied from a technological innovation systems perspective, which highlights the interdependent development of technologies, institutional and organizational structures (Bergek et al., 2008; Markard et al., 2015). A host of studies has concentrated on clean-tech and new energy technologies such as solar (Dewald and Truffer, 2012; Hoppmann et al., 2013; Quitzow, 2015; Bohnsack et al., 2016), wind power (Bergek and Jacobsson, 2003; Garud and Karnoe, 2003), biogas (Wirth et al., 2013) or fuel cells (Musiolik and Markard, 2011; Budde et al., 2012). To a much lesser extent, transition scholars have also studied industry decline (Dolata, 2009; Karltorp and Sanden, 2012; Turnheim and Geels, 2012; Penna and Geels, 2012; Kivimaa and Kern, 2016). Especially for the latter topic, we see much potential for future research. Scholars may want to explore: i) patterns of industry decline; ii) sailing ship effects and incumbent strategies to cope with decline; iii) life cycle models of industry emergence, maturation and decline; iv) the interplay of emerging and declining industries; or v) the governance and politics of industry decline.

Organizations and institutional change: Another central topic concerns organizations involved in institutional change. Institutional change is at the core of sustainability transitions, which is why transition scholars have studied the strategic activities of firms and other actors targeting different kinds of institutional structures. Organizations shape

their institutional environments, e.g. with the help of discursive strategies or framing (Geels and Verhees, 2011; Penna and Geels, 2012; Rosenbloom et al., 2016), through political coalition building and lobbying (Hess, 2014; Sühlsen and Hisschemöller, 2014; Markard, Suter, et al., 2016), system building activities (Musiolik et al., 2012; Planko et al., 2016), or by strategically influencing collective expectations (Borup et al., 2006; Bakker et al., 2012; Konrad et al., 2012). A closely related issue is the creation (or disruption) of legitimacy, which has been observed as an essential element in the struggle for public policy support of new technologies (e.g. Bergek et al, 2008b; Binz et al., 2016; Bohnsack et al., 2016; Markard, Wirth, et al., 2016). The topic of organizations and institutional change has a strong link to institutional theory (e.g. Greenwood et al., 2008; Battilana et al., 2009; Fligstein and McAdam, 2011), which is widely used by scholars in management studies and sociology.

5.3 Research directions

- Industrial convergence: In the course of transitions, new industries emerge at the intersection of existing ones, but existing industries also converge (Hacklin et al., 2009). One historical precedent is the convergence of computers and telecommunications (ICT) via digitalization. Now we see the extension of ICT itself into multiple industries including transport, energy, manufacturing, banking or music via apps, and the Internet of things, etc. (Dolata, 2013; Erlinghagen and Markard, 2012). And in mobility, for example, we are currently witnessing an ongoing convergence with ICT and electricity (Dijk et al., 2016). *Research questions:* What are the consequences of industry conversion for sustainability? How can existing transition frameworks deal with the complexity of convergence? How do firms handle the combined challenges of convergence and sustainability?

- New ways of organizing: In recent years, business has witnessed 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 (Von Hippel and Von Krogh, 2003; Dahlander and Gann, 2010; Belk, 2014; Bogers et al., 2017; Kivimaa, 2014;), all of which could 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.

- Sustainable business models: The concept of business models has gained increasing currency in the mainstream management literature, albeit with some uncertainty over conceptual definition and methodological rigour . While some in the field have studiously ignored the relevance of business model innovation to sustainability in general or to socio-technical transitions (Wirtz et al., 2016), there is a growing number of scholars concerned with such interactions (Gambardella and McGahan, 2010; Schaltegger et al., 2016; Wells, 2017). Research on business models for sustainabil-

ity provides a strong platform from which to understand how organizational innovations may contribute to or militate against wider socio-technical change. Research into the 'victims' of disruption is less prevalent but still has potential in advancing the understanding of how socio-technical transitions involve processes of industrial change (Lucas and Goh, 2009). Moreover, it is notable that 'hybrid organizations' might seek to enact a broader vision of the contribution of business beyond profit maximizationin ways that might speak to the transitions agenda. Potential avenues for future research include flexible business models in rapidly changing environments, business models in the sharing economy, business models based on sufficiency, or servitisation and sustainability.

- Finance: While the focus is on organizations themselves, there is a profound neglect of the role of finance capital (private equity, hedge funds, pension funds, sovereign wealth funds etc.) in stimulating or restricting change, or promoting change in a certain direction. A recent UNEP report points to the relevance of changes in the financial system for sustainable development (UNEP, 2015). The transition community has identified this issue as critical Geels, 2013). A variety of approaches indicate that issues such as economic crises and long-term growth Swilling, 2013, income disparities (Vergragt, 2013) and financial regulation (Foxon, 2013) need to be addressed when thinking about sustainability transitions.

- Organizational change and time: An observable strategy of many organizations is to defer change, or to slow down the pace of change (Wells and Nieuwenhuis, 2012; Smink et al., 2015b). The transitions community should consider this since the (slow) pace of change represents an area of increasing concern. Research questions include seeking a better understanding of the expression of path dependency in organizational structures, and the factors that accelerate or slow the pace of change. In the political realm, this strand relates to the ability of organizations to influence debate (Geels and Penna, 2015).

6 TRANSITIONS IN PRACTICE AND EVERYDAY LIFE

6.1 Introduction and relevance

A "founding assumption in the literature on sustainability transitions" (Raven et al, 2016:164) is the importance of understanding transformation across "*the entire* production-consumption chain, its flows, its multi-level architecture, its institutions and structures, and – not least – the behaviour of the actors involved in it, from resource extraction to the final consumption of goods and services." (Weber and Hemmelskamp, 2005:1, *emphasis added*).

The topic, "Sustainable Consumption: Transitions in practice and everyday life" was introduced in the STRN 2010 Manifesto, with a brief outline of the then recent application of theories of practice to questions of sustainable transition. Progress since 2010 has been mixed. Overall, interest in consumption and everyday life has remained marginal in IST conferences and publications from the STRN community (as reported in the STRN newsletter). There has been some renewed interest in the science and technology studies (STS) focus on 'users' and several calls for better integration between approaches, especially between theories of practice and the MLP (McMeekin and Southerton, 2012; Hargreaves et al, 2013; Geels et al, 2015). A parallel stream of scholarship has continued to study everyday life through the lens of theories of practice, but this has proceeded largely beyond the STRN community; this work has tended to isolate everyday practices from the wider socio-technical systems that service them. This indicates a need to develop the theoretical frameworks reviewed in theme 1, but also connects to the question of agency as discussed in theme 2. Civil service organizations are also influential in this context, as discussed in theme 4.

6.2 State of the art

Everyday life, consumption and theories of practices

Building on Giddens, Bourdieu, Schatzki and others (who proposed significantly different variants of practice theory), early practice theory work on *sustainable consumption* emerged as offshoots from ecological modernisation theory (Spargaaren 2003, 2006), 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. They share a commitment to foreground *practice* as the central unit of social scientific analysis, with the aim to go beyond the dualisms of agency/structure and holism/individualism. 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).

Practice theories have been adapted to inform policy directly in the area of sustainable consumption (e.g. Darnton et al., 2011; Southerton et al, 2011, Darnton and Evans 2013). However, somewhat ironically, their impact so far has largely been restricted to the areas traditionally falling under the ambit of 'behaviour change' that they seek to

critique. In contrast, Spaargaren's intellectual project (e.g. 2003) emphasised the crucial role of organized citizen-consumers in environmental governance processes, and the systemic interactions between consumption and production (Welch and Warde, 2015). While different strands of practice theory have different implications for processes of socio-technical change, the broad implications for interventions are inter alia:

- Practices and their configurations are moving targets. Interventions take place within the processes that they seek to change, rather than intervening from the outside (Shove, 2010). This suggests a reflexive approach to governance.
- Interventions should not focus on individuals, but on changing collective routines, which includes processes of de-routinization or second-order learning

Users, consumers and citizens in transition

The understanding of users in innovation studies, consumption studies and science & technology studies has shifted from passive consumers to active and crucial players in socio-technological change (Hyysalo, Jensen & Oudshoorn, 2016; Schot et al., 2016; von Hippel, 2017). Innovation activities by citizen users were key to the early formative stages of many of today's most important renewable energy technologies. Citizens' roles were also crucial in the formative stages of technology development, giving birth to many entrepreneurial ideas (Ornetzeder and Rohracher 2006), trials and gradual improvements in understanding how technical systems and their interplay with everyday life plays out (Ornetzeder and Rohracher 2006; Seyfang 2010). Grassroots movements and innovations have remained a persistent alternative form of how to seek solutions for both perceived social injustices and environmental problems (Hargreaves et al. 2013; Smith et al. 2014). These movements consist of a diverse set of activities, including the adoption and adaptation of renewable energy systems, improving energy efficiency, and behavioural change of locally novel configurations and adjustments to existing technologies (de Vries, Boon, and Peine, 2016). Users adjust, innovate and advocate transition technologies, in addition to merely adopting them (Hyysalo, Juntunen, and Freeman, 2013a,b; Ornetzeder and Rohracher, 2006; Seyfang and Smith, 2007). Users typically need to adapt their routines to suit new innovations in their particular contextual settings (Judson et al., 2015; Juntunen, 2014; Nyborg, 2015).

Schot et al. (2016) and Kanger & Schot (2016) propose a typology of important user roles in transitions. They suggest that user producers and user legitimators contribute to the available technological variety and discourse in the start-up phase (e.g. Ornetzeder & Rohracher, 2006; 2013; Smith, 2012: Smith et al., 2014; Nielsen, 2016). In the acceleration phase, user consumers emerge as important in making choices that favour niche innovations and expand their markets. Schot et al suggest that user intermediaries are crucial for building socio-technical systems. As intermediaries, they can become system builders aligning producers, users and regulators. Users can also affect the acceleration phase as active citizens who mobilize against the existing regime, hollowing out its legitimacy and commercial strength (Smith, 2012; Schot et al. 2016).

Users' capacity to further transitions has been found to be amplified through peer interactions and communities (e. g. Walker & Devine-Wright, 2008; Hargreaves et al., 2013; Ornetzeder & Rohracher, 2006; 2013; Smith et al., 2014; Nielsen, 2016; Durrant, 2016). Communities and movements create solutions that can be adopted into the mainstream, inflict change upon dominant regime actors and foster critical discourse on and the practice of technological and social alternatives (Smith et al. 2016).

Analysis across the entire production-consumption chain

The importance of studying of the co-evolution of production and consumption is evident in the context of transition research, and there are unrealised opportunities to study this seriously. Studies of users already have the potential for making such links, but the attempts to draw together production and consumption dynamics within single studies remain marginal and underdeveloped. At the level of systems, some historical studies bridge the production and consumer sides such as those exploring the development of automobility by Kanger & Schot (2016). At the level of technologies, a number of studies of Danish wind turbine development began to cover and bridge consumers and production (e.g. Karnøe & Garud, 2012; Ornetzeder & Rohracher, 2013; Nielsen, 2016). When it comes to more current developments and the details of innovation and consumption, the reliance on historical data faces limits. There are few studies at the level of products that bridge the cycles of development and consumption of particular innovations, even though their importance is well recognised in innovation studies and science and technology studies (Oudshoorn & Pinch, 2003; Hyysalo, Jensen & Oudshoorn, 2016). New concepts such as the circular/sharing economy require an understanding of consumption dynamics within wider systems and a focus on changes in the way that goods and services are provided (within households, communities, markets and via state redistribution).

6.3 Research directions

Deepening the understanding of the key social mechanisms and dynamics underpinning transitions in everyday life.

- These include the role of agency and collective action in processes of social change (Spaargaren, 2013), of discourse and large discursive formations (Schatzki, 2017), widespread cultural understandings (Welch and Warde, 2017), as well as the conceptualisation of power (Watson, 2017) and of large-scale phenomena (Nicolini, 2017).
- Empirical research on alternative social mechanisms that constitute change in everyday life. This includes collective political projects seeking change in everyday life and processes through which purposive collective action (e.g. of social movements) becomes part of everyday life (e.g. gendered domestic divisions of labour). It also concerns, processes through which collective actors emerge from everyday life practices

(e.g. consumer associations and other 'user groups' as discussed below) and, how shifts in modes of provision (state, market, community) shape the dynamics of everyday life.

Future research approaches focusing on users should consider the following aspects and approaches:

- Studies of users and user communities are needed across the entire transition process and this is accentuated by the fact that sustainability transitions are increasingly beyond the early start-up phases – user roles need to be compared across systems and spaces, and include gender, class, and ethnicity.
- More research is needed on user innovation and peer intermediation in transition technologies and social innovation.
- Geels et al. (2015) conclude that, while revolutionary forms of sustainable consumption risk being politically difficult and elitist, there are instances where users choose/or have to choose non-consumption for various reasons (e.g. poverty, ideology, religion). Research would be useful on this type of behaviour and its relationship to the transition process.
- When researching users, concepts such as individualisation (Middlemiss, 2014) can shed further light into everyday practices. Furthermore, issues such as scale, geography, context and cultural norms play a part (see also section 7). There are large variations in consumption between nations and cultures. There is thus a role for comparative research across the world.

Bringing the study of transitions in everyday life into a broader framework for the study of whole systems (that span the entire chain from production and consumption):

- New research that bridges production and consumption is needed at systems, technology and product levels. Such research needs to overcome the challenges that result from the common temporal and geographic separation of production and consumption, different study set-ups and the access required to study consumers and producers (Heiskanen et al. 2014; Hyysalo et al. 2016).
- While much practice theoretical work to date has focused on specific practices such as sites for intervention, more recent developments in practice theory are moving towards deploying a practice lens to study wider configurations (Welch and Yates, forthcoming), complexes (Blue and Spurling, 2017) or systems of practice (Watson, 2012). It is here perhaps that the greatest potential lies for links to the work on sustainability transitions.

Methodology

- There is scope to develop longer term historical analyses of changes in everyday life to align with transition timescales. 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 geo-

graphical regions to understand contrasting trajectories and dynamics of change in everyday life (see also section 9).

7 GEOGRAPHY OF TRANSITIONS: SPACES, SCALES, PLACES

7.1 Introduction and relevance

Until recently, the spatial dimensions of sustainability transitions have not been explicitly treated in this literature (Smith et al., 2010; Coenen et al., 2012; Raven et al., 2012). The 2010 STRN manifesto called for more attention to these issues and identified two major challenges. Firstly, analyses drawing predominantly on single or comparative case studies failed to explain if and how (spatial) contexts matters. An explicit geographical perspective was needed to disclose the contingencies and particularities of the various contexts where transition pathways evolve in order to develop a better theoretical understanding of the factors enabling or impeding these processes. Secondly, the usage or lack of scale in existing transition analyses was criticised and, in particular, the absence of concrete scalar territoriality in the levels of transitions (the global being ubiquitously 'out there' and accessible). This suggested that transitions can take place anywhere, thereby neglecting the advantages, conflicts and tensions of the spatial realities within which transition processes are embedded. Transitions are recognised as unfolding over multiple scales (theme 1) and theme 9 identifies the need for comparative studies across different locations. Cities have particular importance as a setting for both (local) niches and centres of socio-technical systems. The discussion of governance in theme 3 also identifies the importance of differentiating between political and geographical scales and the interactions between different scales.

7.2 Current state of the art

Research on the geography of sustainability transitions has expanded rapidly since the 2010 research manifesto, exploring different questions around space, place and scale in transition processes, and drawing on economic, institutional and evolutionary geography (e.g. Coenen et al., 2012; Coenen and Truffer, 2012; Raven et al., 2012; Lawhon and Murphy, 2012; Binz et al., 2014; Truffer et al., 2015; Hansen and Coenen, 201). Recognition of the spatial dimension of transitions led to unpacking this phenomenon and a better understanding of how space, place and scale matters. This body of work has produced two prominent advances: the importance of place specificity, and the spatial dimensions of inter-organizational relations (Hansen and Coenen, 2015).

Given that place can be defined on various scales, multiple dimensions of place specificity have been researched on local, regional and urban scale. The dimensions include: (i) Urban and regional visions and policies that can mobilize heterogeneous actors and facilitate the diffusion of niche processes. Here, authors emphasise that the visions are often an outcome of contestations and struggles rather than a consensus among multiple stakeholders (Shove and Walker, 2007; Smith, 2007a; Hodson and Marvin, 2009, 2010, 2012; Späth and Rohracher, 2010, 2012; Bulkeley et al., 2011; Truffer and Coenen, 2012; Carvalho et al. 2012; Dewald and Truffer, 2012; Essletzbichler, 2012; Bulkeley

and Castán Broto, 2013; Rohracher and Späth, 2014). (ii) Informal localised institutions (territorially bound values, norms and practices) that determine different socio-technical configurations. The configuration can facilitate niche formation processes, the diffusion of environmental innovations and regulatory push for the development and adoption of environmental regulation. Although place-specific, authors warn that informal institutions can differ even within local and urban territories, which may result in conflict concerning the sustainability vision (Coenen et al., 2010, 2012; Späth and Rohracher, 2010, 2012; Dewald and Truffer, 2012; Maassen, 2012; Truffer and Coenen, 2012; Bridge et al., 2013; Murphy and Smith, 2013; Ornetzeder and Rohracher, 2013; Wirth et al., 2013; Shove et al., 2014). (iii) Local natural resource endowments and a positive impact of resource scarcity on investments in renewables (e.g. Bridge et al., 2013; Carvalho et al., 2012; Essletzbichler, 2012; Murphy and Smith, 2013; Späth and Rohracher, 2010, 2012). (iv) Local technological and industrial specialisation that conditions the development of innovations needed for sustainability transitions (Coenen et al., 2010; Binz et al., 2012; Carvalho et al., 2012; Essletzbichler, 2012; Bridge et al., 2013); Monstadt, 2007; Smith, 2007a; Ornetzeder and Rohracher, 2013). (v) Consumer and local market formation that facilitates end-user engagement and feedback on emergent niches (Binz et al., 2012; Dewald and Truffer, 2012).

The most studied spatial dimensions of relations are those of inter-organizational type: within and outside the value chain, between users and producers, among policy makers, and between donors and recipients. Relations are found to be relevant for vision formulation, learning, or for collaborative innovation projects. Relations can occur on various scales and can concern geographical levels of different size (Angel and Rock, 2009; Berkhout et al., 2009, 2011; Coenen et al., 2010; Binz and Truffer, 2011; Dewald and Truffer, 2012; Truffer and Coenen, 2012; Carvalho et al., 2012; Hansen and Nygard, 2014). Two trends can be identified in this work regarding the perspective on the spatial dimension of relations between actors. The first concerns the positive influence of geographical and other forms of proximity in stimulating niche formation and the emergence of innovation systems more generally (Coenen et al., 2010). The second sees space as socially constructed by a network of actors (Raven et al., 2010).

Attention has also been paid to the non-local scale and the relations between developing and developed countries, donor interventions and their impact on sustainability transitions (Angel and Rock, 2009; Berkhout et al., 2009, 2011; Hansen and Nygaard, 2014). Specifically, research on latecomer countries' transitions shows transnationally-layered sustainability experiments (Wieczorek et al., 2015; Sengers et al., 2017) emerging in the context of the growth of new socio-technical regimes in key sectors (Berkhout et al., 2010). Sustainability experiments are considered to represent a significant new source of innovation and capability-formation in emerging economies, mainly due to more heterogeneous actor networks operating at various scales. Through transnational linkages that enable flows of knowledge, capital, institutions, people or technology, transition actors in emerging economies complement missing resources (Wieczorek et al., 2015a,b). This points to a broader, more socially-embedded model of innovation. Together with an increase in innovation for and by the poor and with a lower environmen-

tal footprint (a 'shift in innovation from the West to the rest', Jolly et al., 2012), this process has the potential to challenge the traditional models of development that are based on catch-up and convergence theories (Berkhout et al., 2011).

7.3 Research directions

What the current advances have in common is their focus on explaining the geography of niche development, exploring the geography of inter-organizational relations, proving relevant insights that place specificity matters, and spatially extending the key transitions frameworks such as MLP, TIS or SNM. Less attention is given to the geography of regimes, non-local, intra-organizational relations, alternative frameworks that move beyond the conventional transition frameworks, and in particular, those with explanatory power for understanding how place specificity matters (Hansen and Coenen, 2015). Moreover, given the increasing interconnectedness of globalisation and urbanisation processes, there are two themes that embed a variety of unexplored and challenging topics relevant for better understanding the geography of transitions: *urban transitions* (Hodson and Marvin, 2009, 2010; Bulkeley et al., 2011; Rutherford and Coutard, 2014; Rohracher and Spaeth, 2014), and *transitions in developing countries* (Berkhout et al., 2009, 2010, 2011; Byrne et al., 2011; Lawhon, 2012; Sengers and Raven, 2014; Hansen and Nygaard, 2014; Wieczorek et al., 2015; Baker, 2015). Examples of possible research avenues here include:

- Unpacking *the geography of regimes* and *regimes' stability, change and heterogeneity,* especially in the context of developing countries, where people may have no, sporadic, and/or poor quality service (Furlong, 2014). 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, 2014). Regimes that participate in global value chains may also create uncertainty (Berkhout, et al., 2011). They call for governance strategies that promote regime stability and give investors and end-users some security (Verbong et al., 2010). Does the definition of a regime need to be expanded to encompass differing grades of uniformity, stretching from highly monolithic to highly hybrid configurations? What are the possible transformation pathways in different geo-political contexts? How does the multi-scalar and fractured character of regimes influence the opportunities for its transformation? Do sustainability transitions in developing contexts always mean the destabilisation of regimes and technological substitution? How does the place specificity of developing contexts influence transitions? How to govern transitions of highly diverse regimes?
- *Normative orientation of transitions:* The understanding of sustainability can differ between poor rural contexts and industrialised regions. Social inequality poverty and lack of access to modern services that fulfil societal needs (such as sanitation or education) might dominate the environmental agenda at local level over environmental challenges of a more global nature, such as climate change (Sengers and Raven, 2014; Raven et al., 2017). There is confusion about what concepts such as sustaina-

bility or resilience may entail in practice (Romero-Lankao and Gnatz, 2013). How to utilise the potential of place specificity and especially the lack of established western-type infrastructure as an opportunity to stimulate transitions to more sustainable systems? How do different path dependencies (infrastructural, institutional, cultural, economic) affect alternative development trajectories across a range of places and scales? How to reconcile the divergent place-specific views of sustainability for the purpose of stimulating transitions? How to govern transitions to such a contested and context-specific normative end point?

- *Challenging convergence theories* - Do alternative, more sustainable, development pathways building on place-based sustainable experimentation have real potential? What are their drivers? Do the bottom-up sustainability-oriented local activities in developing countries provide reliable sources of more sustainable pathways and a new model of innovation? How to design and embed sustainability-oriented projects in various geographical and political contexts, so that they provide the seeds of radical change? Which mechanisms can stimulate the upscaling of such initiatives and is this a place-determined process? What role does transnational, local-global connectivity play? How to govern this globally connected process? How do the strategies differ depending on context?

- Currently, cities are far from carbon neutral, and splintered urbanism and urban inequalities continue to obstruct sustainable urban development (Graham and Marvin, 2001). Scholars have started to pay attention to urban experimentation as a recent but quickly expanding discourse and practice in urban sustainable development (Castan Broto and Bulkeley, 2013; Evans et al., 2016; Bulkeley et al., 2017). Future research could focus on questions concerned with the *conditions, processes and pathways* through which urban living labs and experiments emerge, and what happens after experimentation. How do experiments 'scale up' and shape wider institutional change beyond their initial geographies? How do ideas and innovations circulate and how do they transform as they circulate? Are urban living labs *a form of governance and political arena?* How can urban living labs and urban experimentation become a productive form of urban governance by enabling transitions in socially desirable directions? Are urban living labs a suitable *research method?* What role do academic researchers and critical social science play in the transdisciplinary approach often assumed necessary and productive in living lab processes? What are the benefits, but also tensions and limitations of transdisciplinary research in urban living labs?

- *Smart cities* have quickly emerged as the new kid on the block of urban imaginaries, in particular since 2009 (Jong et al., 2015). The general premise of smart cities is that ICT technologies such as sensors, computer code, big data and urban dashboards contribute to solving urban challenges, including sustainability ones. Smart city discourse has received major criticisms from social scientists for being technologically optimistic and deterministic, politically naïve and uncritically promoting private interests in urban public spaces. Nevertheless, smart cities and more generally the digitisation of urban flows such as resources, cars, people and energy continue

to drive urban agendas world-wide. This provides transition scholars with an opportunity to engage critically with these developments, building upon and extending the socio-technical frameworks developed in this field. A key line of research is to understand how ideas of the smart city have been nurtured, how they diffuse and how they are contextualised in different places. What are the political, institutional and material implications of the emerging smart urban agenda for sustainable urban development? How can the 'smart' agenda contribute productively to challenge-led urban transitions? What are the different socio-technical configurations and ways of governance of smart urban transitions? What kind of governmentality may have been fostered together with the digitisation agenda? What are the more bottom-up, citizen-led smart initiatives as well as more hybrid forms of smart city systems? What kind of knowledge about urbanism is constructed under different governance arrangements and what are the political and social implications for urban sustainability transitions?

- *Urban infrastructures and obduracy:* There is also a need to consider the work involved in maintaining and sustaining existing urban socio-technical networks and the infrastructures produced – in short, in engaging with the ways in which *urban obduracy* is actively constituted. 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 is relatively limited of how such obduracy is produced, and of the junctures and openings within the urban fabric that enable transitions to occur. As a starting point, the multiplicity of regimes that occupy the urban arena and infrastructural space need to be recognised 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). In their recent account of the transition of Copenhagen's waterways, Jensen and colleagues (2016: 557) argue that such work is animated by 'navigational actions' as actors encounter specific junctures in the urban assemblage, where "the established order and identity of the urban fabric has become unstable." Navigational actions are undertaken as forms of "sociomaterial repair work aimed at addressing such junctions" and reconfiguring particular urban assemblages.

8 ETHICAL ASPECTS OF TRANSITIONS: DISTRIBUTION, JUSTICE, POVERTY

8.1 Introduction and relevance

In this theme, we draw the STRN community's attention to the need to engage explicitly with ethical considerations that arise from sustainability transitions. In introducing this theme to the research agenda, we advocate a broader normative orientation of transition studies that, in addition to environmental concerns, explores transition dynamics geared towards sustainable development, i.e. embedded in notions of justice, and necessitating attention to alleviating poverty and promoting popular participation in development processes, echoing Meadowcroft (2000). There is also the need for more reflexivity within the transitions community in highlighting and dealing with social justice issues that are otherwise below-the-radar outcomes of transition processes, and explicitly engaging with the ethical dilemmas of the trajectory of socio-technical change. This connects to the themes of power and agency (theme 2) as well as governance and policy (theme 3). Ethical aspects are also critical in the role of civil society and social movements (theme 4). There is also an important question of how ideas of justice are incorporated into the analysis frameworks (theme 1) and the distribution across geographical and political scales (theme 7).

8.2 Current state of the art

Poverty, inequalities or disparities in gender, race, age and ethnicity among others, unemployment, disenfranchisement and social injustice are among the developmental challenges facing contemporary societies. In fact, many empirical cases of sustainability transitions highlight these phenomena as part of the backdrop of pre-existing socio-technical systems (e.g. Bai et al., 2009; Hamann and April, 2013). Even though the literature suggests that such problems—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 is lacking to analyse the distributional consequences of transitions, during and ex post, revealing a moral vacuum in transitions research (Newell and Mulvaney, 2013; Sovacool et al., 2016). So far, several studies only highlight some ethical implications or dilemmas, for instance, the marginalisation of the poor and their livelihoods in developing countries as large companies grab common land for commercial production (Byrne et al., 2011), or food-versus-bio-fuel conflicts (Raman and Mohr, 2014), and the unequal distribution of biofuel benefits in LDCs (Romijn and Caniëls, 2011). 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 (see theme 3 and 9).

Conceptually, distributive and participatory struggles within sustainability transitions can be explored using insights from the following streams of literature:

- The neo-institutional approach to operationalise system change (e.g. Fuenfschilling and Truffer, 2014) in a way that captures formal and informal institutional configurations that engender poverty, inequality and exclusion, and the institutional shifts thereof associated with technological development.
- New models of 'innovation for inclusive development' such as inclusive innovation (Heeks et al., 2014), frugal innovation (Rosca et al., 2016) 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 these innovations (Jolly et al., 2012) to new technological pathways (Romijn and Caniëls, 2011b).
- The transitions management literature (e.g. Loorbach, 2010; Grin et al., 2010) to explore 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).

Examples of explicit attempts to deal with these themes 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 addresses the developmental aspects of transitions to different degrees. For example, 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).

There is also a literature that considers justice issues in the context of specific products or sectors. The energy sector has received the most extensive consideration. Within the energy transitions literature, the concept of energy justice has received increasing attention as scholars explore where injustices emerge, which sections of society are ignored, and what processes exist for their remediation (Jenkins et al. 2016). Topics of interest include ethical energy consumption (e.g. Hall 2013), fuel poverty (e.g. Walker and Day 2012; Sovacool 2015) and energy justice applied in policy-making. Energy justice is increasingly characterised as an analytical tool. For Heffron et al. (2015), this tool can achieve a just balance between the three dimensions of the energy trilemma. There is a connection to economists here through the quantitative analysis of energy justice, allowing it to be evaluated in monetary terms.

Concerning 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 legitimising electric boating in Amsterdam. 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.

8.3 Research directions

In advancing this new agenda, future research could explore:

- Transition dynamics that induce, reinforce, exacerbate or mitigate poverty, inequality and exclusion. In what ways do these phenomena influence or mediate societal change processes and the trajectory of technological development?

- How the ethical consequences of sustainability transitions can be anticipated and mitigated at an early point during innovation journeys. Learning is important to recognise 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?

- How to conceptualise or operationalise 'inclusive forms of transition'? Questions concerning 'who wins, who loses, how and why' (Newell and Mulvaney, 2013; Moss et al., 2015) could be considered here.

- More explicit consideration of agency, power and politics in transitions (Geels, 2014) could be applied to sector analyses of social justice in, e.g. energy, accessibility, health or food systems.

- The role and agency of non-traditional actors in transitions, including the role of users (Schot et al., 2016), with due consideration given to marginalised groups as (non-) users, non-dominant and non-state-based actors in shaping transition processes (Seyfang and Smith, 2007).

- Normativity in sustainability transitions through the 'pathways approach' (Leach et al., 2010) that attempts to link environmental sustainability with poverty reduction and social justice, taking into account dynamics, complexity, uncertainty, differing narratives and the value-based aims of sustainability, for instance, bridging the pathways approach and SNM.

- Conceptual bridges between sustainability transitions literature and developmental state literature, complexity theory, and ecological economics are being pursued with relevance to developing economies (Swilling and Annecke, 2012). More case studies of developing economies in the global South, where developmental and sustainability goals could crystalize these approaches.

9 METHODOLOGIES FOR TRANSITIONS RESEARCH

9.1 Introduction: interrogating and developing the methodological basis of transition research

As transitions research matures as a field of research and as a set of particularly influential policy concepts (Voß, 2014), transitions scholars have started to interrogate the epistemologies and methodologies currently in use. This is demonstrated by the recent debates on the need for 'transformative science', but also the ongoing debates about the scientific adequacy of prevailing methodologies in transitions research. Some transitions scholars have started to consider methods that are tailored to transitions research, and its underlying ontological assumptions (Byrne, 2005; Vasileiadou & Safarzynska, 2010; Geels, 2010). Others explicitly target methodological and normative considerations when seeking to address substantive questions, such as the need for 'microfoundations' (Almudi et al., 2016; Mercure et al., 2016), the role of politics (Avelino et al., 2016), or the normative consequences of the temporal diversity of transitions (Sovacool and Geels, 2016). Each in their own ways, the aforementioned lineages of methodological interrogation and development address the following question: *How should existing (and newly developing) methodological approaches[1] be tailored to fit the (various) theoretical and transformative ambitions of the transition community?* In the following, we first discuss the methodological challenges to be addressed (section 2), after which we present promising methodological advancements (section 3), and some specific proposals for future research (section 4).

9.2 Challenges to be addressed: Strengthen the scientific rigor

As the most widely used transition research framework, the MLP has the advantage of being generic and flexible, facilitating the construction of narratives of transitions with high real-world accuracy. As a result, there now exists a vast archive of in-depth single case studies on transition dynamics and mechanisms. Theoretically, first steps have been made to systematically synthesize those insights across cases for theory development, resulting in various typologies of transition pathways (Geels and Schot, 2007; Boschma et al, 2017). These typologies invite more systematic comparative analysis of the key characteristics and conditions of transition processes (see also theme 6).

In order to bring greater analytical rigor to the analyses whilst maintaining broadly applicable frameworks, transitions research needs to develop approaches for "*structured navigation*" between broad transition frameworks and more precise theories and concepts for studying more confined phenomena (Holtz, 2012). There is therefore the need

[1] In this regard, we use the term 'methodological approach' as a shorthand for a congruent epistemological position with associated choices for research design and tools for data collection and analysis. This definition takes into account that research need not be restricted to academics, and that analysis can serve diverse knowledge interests.

to define intermediate levels of abstraction and procedures for relating phenomena on the various abstraction levels. Structured navigation between levels of analysis makes it possible to include theoretical insights and methodological approaches from other disciplines, to underpin the broad frameworks with the micro mechanisms that influence change dynamics, and to interpret particular sub-processes from the perspective of the overarching transition without "getting lost in the details". So far, this connection has often been implicit and case-based and presents a challenge for the analytical frameworks used (theme 1).

Structured navigation should also address another 'frontier' of knowledge development: the growing awareness of the *multiplicity of transitions*. The MLP tends to focus on particular systems of provision. However, recent research focuses more on how transitions occur as processes of co-evolution across systems of provision, how they are strengthened by other transitions, or hampered by innovation lineages that compete for the same resources.

Furthermore, in order to monitor the progress of transitions and to assess rates of change, *indicators for measuring transition dynamics* need to be developed that consider the multi-dimensional nature of transitions. Indicators are also discussed in theme 3 for the quantitative analysis of policy, and in theme 8 for energy justice. In fact, indicators are relevant for all the themes of transitions research. However, it does not seem feasible to develop a single set of indicators for measuring transitions. The choice of the most appropriate indicators (quantitative, semi-quantitative or qualitative) depends on the analysed system of provision, the transition phase, observed time and spatial scales, and partly on the specific case. Therefore, a nested approach is suggested in the spirit of the structured navigation between levels of analysis discussed above. The development of broadly agreed transition dimensions to be measured (e.g. technology, infrastructure,…) and indicator categories (e.g. market shares, industry structure, consumer preferences,…) would foster comparability. The operationalisation into precise indicators can then still be tailored to the specific case. It is thereby essential to address some of the critiques against traditional innovation indicators, such as their neglect of pivotal social and institutional factors, their narrow focus on product and process innovation, and their overlooking innovation by non-firm actors. In particular, we argue that traditional indicators have difficulty capturing innovation processes in the emerging economies of Asia and BRICS, regions that are pivotal for sustainable development.

9.3. Promising directions of methodological advancement

The above challenges are broad in scope and not linked to specific methodological 'solutions'. Furthermore, the interdisciplinary nature of transition research allows the adoption of methodological approaches from many other areas of study. The following list of promising methodological approaches is therefore far from exhaustive:

Process approaches.

Up to now, transitions research has mostly used qualitative approaches to study transitions. In particular, narrative approaches are able to describe the complex and contingent multi-level and multi-sectoral causation of transitions. In related fields, processual approaches are gaining traction in response to more informal narrative approaches. Narrative explanation is a viable epistemological approach (Abell, 2004; Klauk, 2016), and there are an increasing number of well-developed research designs and methodological tools available (Langley et al., 2013; Spekkink and Boons, 2016). In light of the inherently processual character of transitions (Geels & Schot, 2010), methodological reflection is called for regarding the prevalence of static categories, mechanistic metaphors, unwarranted reifications, and lack of attention to longitudinal development. Garud & Gehman (2012) and Shove (2012) were important reminders and radicalizations of the process-theoretical character of transitions research. Hoffman & Loeber (2016) and Pel (2016) are two recent examples of dialectical process theory.

Transition research as a process also raises the question concerning the role of transitions scientists in transitions processes, such as transitions management (theme 1). Many transitions researchers seek to develop transitions research into transdisciplinary science that that goes beyond the integration of different types of knowledge and plays a stronger role in the active engendering of societal change, i.e. research that not only describes societal transformation processes, but initiates and catalyses them (Schneidewind et al., 2016). Such research builds on the experimental turn in the social sciences and makes use of research approaches that focus on knowledge co-production and experimentation.

Modelling

Formal models offer an alternative approach to understanding dynamics in complex systems. They have distinct advantages when assessing transitions (Holtz et al., 2015). (i) They provide explicit, clear and systematic system representations. (ii) They help to make inferences about complex dynamics and to generate emergent phenomena from underlying elements and processes. (iii) They facilitate systematic experiments. It is debated to what extent modelling approaches are able to capture transitions as unfolding processes of events (McDowall and Geels, 2017). Agent-based models and system dynamics models seem best suited to modelling transition dynamics (Köhler et al., 2009; Köhler et al, 2018).

Qualitative-quantitative combinations

As complex, multi-faceted longitudinal processes, transitions pose challenges to both modelling approaches and qualitative approaches. Models have a poor track record in grasping the wider uncertainties that elude formalization. The limitations of narrative-based approaches surface when large numbers of interlinked elements are projected into the future. Against this background, models can be helpful to check the internal consistency of narratives, and narratives can help models to define scenarios for external

drivers that reflect societal development. Hence the proposals for qualitative-quantitative "bridging" (Turnheim et al., 2015), "linking" (Trutnevyte et al., 2014), "hybrid approaches" (McDowall, 2014) and "integration" (Holtz et al., 2015).

Systematic comparison

Comparative research designs (also for secondary analysis) are a promising tool for the systematic synthesis of insights for theory development. Approaches like Qualitative Comparative Analysis (QCA) were originally developed within historical sociology (Ragin, 2014) and public administration (Rihoux et al., 2011; Gerrits and Verweij, 2013), as well as organization and management sciences (Fiss, 2011). QCA can be used to uncover complex patterns (Byrne, 2005) in existing sets of case studies through secondary analysis. It can also provide a basis for comparative research designs. Systematic comparison will become more important as spatial embeddedness (see theme 7) becomes more prominent in transitions research (Truffer et al., 2015).

Multiplicity

In light of this general methodological challenge, it is logical to move beyond the single case and the isolated research object. Schot & Geels (2008) made this argument regarding SNM research, and since then there have been various studies of multiple regimes, multiple niches and their intersections (Hargreaves et al., 2013; Pel 2014). In general, multiple case studies and especially nested-case studies seem particularly appropriate to transitions research. Tailoring methodologies developed in historical sociology might be a fruitful avenue. The study of urban areas is promising in this respect, as these represent convergence points of multiple systems of provision and innovation lineages. Another example is the work on 'whole systems of provision', where the variegated set of niches and regimes in a system of provision is analysed (Hodson et al., 2017; Turnheim et al., 2015).

Critical approaches

In acknowledging the transformative nature of transition research, critical methodological approaches are helpful when interrogating the hegemonic discourses and mind-sets of regime structures. This systematic probing of underlying assumptions is a typical activity in research into transitions politics. It need not remain confined to this substream however, as the critical questioning of dominant assumptions can be considered fundamental to transitions research as a field (cf. Stirling, 2010; Pel et al., 2015; Avelino & Grin 2016).

Participatory & Action Research (PAR)

The integration of these methodologies into MLP-framed case studies, for instance, could be particularly useful to build up a stock of contemporary transition case studies. It is up for debate whether PAR requires the researcher to engage actively as a transition

actor, or if « fly on the wall » in-depth observation and informal knowledge sharing can also be considered PAR. PAR might facilitate the diffusion of transition concepts and systemic understanding and also enable iterative and action-based research processes. Although PAR is found in transitions research, it has not been brought together as a coherent topic in the research agenda.

Real-world labs

According to Schneidewind et al. (2016), real-world labs are an "ideal type" form of transformative research as contexts for experiments aimed at improved understanding as well as the support of transformation processes. The key idea is to develop, test and experiment in and with society. These experiments are expected to create situated yet socially robust and transferable solutions.

9.4 Proposals for future research topics

- More systematic comparative analysis of the key characteristics and conditions of transition processes. This will contribute to the systematic synthesis of insights across cases for theory development, and advance research on the typologies of transition pathways.

- Transitions research needs to develop approaches for "structured navigation" between broad transition frameworks, including the multiplicity of transitions and more precise theories and concepts for studying more confined phenomena.

- Indicators for measuring transition dynamics need to be developed that consider the multi-dimensional nature of transitions.

- Methodologies for combining quantitative and qualitative methods in the context of sustainability transitions research.

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