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Sustainability Transitions Research

An Introduction

ABE HENDRIKS AND JULIUS WESCHE

Imagine what could emerge from this: a world in which communities thrive on clean energy, healthy food systems nourish diverse populations and sustainable transportation connects people equitably. Picture societies where societal prosperity aligns with ecological balance, where cultural traditions evolve to embrace sustainable practices and where social justice is woven into the fabric of everyday life. But how do we navigate the complex journey from where we are to where we need to be?

As society grapples with unprecedented environmental and social challenges, from climate change to resource depletion, the need for change has never been more urgent. As a response, we see many transitions (e.g. in energy, food, mobility and industry) unfolding as we speak. It is important to understand present transitions (e.g. to influence them), past transitions (e.g. to learn from them) and future transitions (e.g. to better understand their consequences). Over the past two decades, the field of sustainability transitions research has emerged as an important area of study in response to this.

Sustainability transitions research explores how societies and systems can shift towards more sustainable practices in response to environmental and social challenges. The transition to sustainable food systems illustrates this complex process. It aims to address various environmental challenges (e.g. climate change, biodiversity loss and resource depletion) as well as social dimensions such as food security, healthy diets and cultural practices. The sustainable food transition requires systemic changes in agriculture, food processing industries, distribution systems, consumption patterns and waste management. For instance, moving from industrial monoculture farming to regenerative agriculture does not just involve new farming techniques but also changes in land use, supply chains, consumer behaviour and policy frameworks. As transitions progress, they may lead to societal tensions (Grin et al., 2010), such as conflicts over land use or cultural resistance to changing diets. Related sectors (e.g. energy, water and transportation systems) have to deal with similar challenges.

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Sustainability transitions research engages with 'wicked problems' – issues that are deeply entrenched, fiercely debated, open-ended and incompatible with simple solutions. These challenges permeate systems such as energy, transport, water and food. The field examines how fundamental transformations towards sustainability can be achieved, investigating questions of justice, equity and effectiveness in system-wide changes. At the basis of sustainability transitions research is an approach that transcends individual disciplines as it embraces insights from a variety of disciplines, including innovation studies, sociology, political science, engineering or management (e.g. Truffer et al., 2022). In this handbook, authors working on sustainability transitions provide their perspectives on how to understand and study transitions.

1.1 Defining Sustainability Transitions

Sustainability transitions research emerges from a diversity of backgrounds and perspectives, each contributing insights to our understanding of socio-technical change. At its core, sustainability transitions research examines processes of long term, structural shifts in socio-technical systems towards more sustainable modes of production and consumption. In line with Markard et al. (2012), this field can be understood through breaking it down into its three main components: (1) socio-technical systems, (2) transition processes and (3) the contested character of sustainability.

First, socio-technical systems encompass not just technological artefacts but also the social structures, power relations and cultural norms that shape their use and development, like regulations, user practices and financial networks (e.g. Geels, 2002; Markard et al., 2012; Smith et al., 2005). For instance, a city's transportation network comprises roads and vehicles as well as traffic laws, economic interests, political decisions and user practices. Within these systems, certain configurations are dominant, forming *socio-technical regimes*. For example, in many cities, the private car-based transportation regime has dominated for decades, characterised by car-oriented urban planning, strong automotive industries, cultural associations between car ownership and freedom/status and policies favouring car use over public transit. These regimes are typically very resistant to change, but they may also be challenged by exogenous developments or various actors with different interests and levels of influence (e.g. Rip and Kemp, 1998).

Second, transitions have been conceptualised as fundamental, multi-dimensional changes of socio-technical systems over long timespans (e.g. Geels, 2002; 2004; Kemp, 1994). Socio-technical transitions unfold as non-linear, contested processes of change and there are no predetermined paths (e.g. Grin et al., 2010; Markard et al., 2012). Transitions involve shifts across multiple dimensions: technological,

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organisational, institutional, political, economic and socio-cultural. As new practices emerge, they may complement, compete with or gradually replace existing ones (see Chapter 2). Transitions require actors to create joint visions of the future and use their collective power to advocate for them. There will be resistance from incumbent actors with vested interests who perceive changes as threats to their established positions and business models, leading to struggles and negotiations as different actors – from grassroots innovators to powerful incumbents – vie to shape the direction of change according to their interests and values (e.g. Leach et al., 2012, Smink et al., 2015; Smith & Stirling, 2010)

Finally, sustainability transitions are a particular type of socio-technical transition. They are associated with sustainability goals. These goals can be about environmental issues such as greenhouse gas emissions, biodiversity or circular economy and about social goals such as poverty, social equity or health and well-being. The understanding of what constitutes sustainability is not fixed and evolves over time as new priorities and challenges emerge (see Chapter 27). As sustainability transitions research focuses on understanding processes of change, or resistance, it inevitably engages with normative questions about what is considered sustainable. This reflects a growing recognition that researchers both analyse transition processes and participate in shaping understandings of sustainability through their work (see Chapters 26 and 27). Since sustainability is inherently normative, its definition must be continuously negotiated through governance processes across different contexts and time periods. What societies consider 'sustainable' varies not only between places but also evolves over time, reflecting changing values, knowledge and priorities that require ongoing reflection and deliberation. Long-term goals such as missions (see Chapter 4) may play a key role in guiding transitions (e.g. Stirling, 2024), and many different actors may engage around the envisioned transition (see Chapter 3).

In short, **sustainability transitions** can be defined as the comprehensive and systemic transformations that move socio-technical systems towards collectively envisioned sustainable futures, which themselves are continuously negotiated and redefined. These transitions emerge through the co-evolution of various societal subsystems, including economic, cultural and institutional frameworks, and typically unfold over extended periods, often taking 25–50 years to complete.

1.2 Why Does Sustainability Transitions Research Matter?

Sustainability transitions research is crucial in today's world as it addresses some of the most urgent global challenges, including climate change, biodiversity loss and resource depletion. These issues, often referred to as 'wicked problems', are characterised by their complexity, persistence and contested character, affecting

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sectors such as energy, transportation, agriculture and water management (e.g. Levin et al., 2012; Rotmans, 2005). Unlike simpler problems with clear solutions, wicked problems require systemic changes that involve multiple stakeholders, diverse interests and long-term perspectives. Sustainability transitions research provides conceptual and methodological tools to understand these complex processes and to explore how to guide the shift of societies towards more sustainable modes of production and consumption.

At the core of sustainability transitions research is the acknowledgement that the global push for sustainability is not merely a technical or environmental concern but a profound societal challenge. It demands the transformation of existing socio-technical systems, which are deeply embedded and locked into established economic, political and cultural practices and values. Sustainability transitions research matters as it offers approaches for analysing how these complex systems can be reconfigured to achieve sustainability goals.

While incremental improvements have an important place, sustainability transitions research argues that they are on their own insufficient to address our most pressing environmental and societal challenges. Instead, it advocates for radical, multi-level changes that can truly shift our societies onto sustainable pathways. The Multi-level perspective (MLP), explored in Chapter 2, provides a fundamental framework for understanding these dynamics. The interactions between niches and regimes (Chapter 9) help explain how innovations can either be absorbed by or transform existing systems. This approach, combined with insights on politics and policy (Chapter 14) and political economy (Chapter 15), helps policymakers identify effective intervention points – whether supporting niche innovations, creating regulatory frameworks to destabilise unsustainable regimes or leveraging landscape pressures such as international climate agreements.

Moreover, sustainability transitions research emphasises the importance of societal and political dimensions. It does so through examining aspects such as transition governance (Chapter 3), power dynamics (Chapter 12) and the diverse roles of actors (Chapter 17). The field pays particular attention to intermediary organisations (Chapter 18) that facilitate connections and knowledge exchange between different stakeholders, helping to bridge institutional and cultural gaps in transition processes. It also recognises the importance of individual behaviour in driving change (Chapter 19), while acknowledging that transformative impact often emerges through collective action and strategic coalitions (Chapter 20). These elements combine in complex ways, as transitions are inherently political processes involving negotiations and conflicts among various stakeholders – a theme deeply explored in the analysis of expectations and visions (Chapter 13). The field's focus on just transitions (Chapter 16) emphasises the importance of ensuring that sustainability transformations are equitable and socially inclusive. By highlighting these political

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dimensions, the field equips practitioners and decision-makers with the knowledge to manage and navigate the contested terrain of sustainability governance more effectively. The significance of sustainability transitions research also lies in its contribution to expanding theoretical and methodological approaches for studying long term, systemic change. The field draws on and integrates insights from various disciplines – such as sociology, economics, political science, environmental science and innovation studies – creating a rich, interdisciplinary research agenda. The development and application of frameworks like the MLP (Chapter 2) provide a cornerstone, particularly in its analysis of interactions between niches and regimes (Chapter 9). This is complemented by other key frameworks such as Technological Innovation Systems (TIS, see Chapter 4), which examine innovation processes in detail. The field has further evolved to consider multi-systems interactions (Chapter 10) and how everyday practices both shape and are shaped by transition processes (Chapter 11).

The temporal and geographical dimensions add further depth to our understanding. Changes occur across different timescales (Chapter 8), from rapid technological shifts to long-term Deep Transitions (Chapter 7) that reshape industrial societies over centuries. Spatially, transitions manifest differently across scales (Chapter 21), from urban environments (Chapter 22) to distinct patterns in the Global South (Chapter 23). This multifaceted perspective helps ensure that transition strategies can be appropriately tailored to different contexts while addressing overarching sustainability goals.

These frameworks help disentangle the processes by which niche innovations emerge (see Chapter 5), disruption takes place (see Chapter 6) and new socio-technical configurations are stabilised. By doing so, sustainability transitions research pushes the boundaries of traditional academic fields and fosters novel methodologies for studying change, providing a more nuanced understanding of how societies can move towards sustainability.

Additionally, this field has drawn upon a variety of methods, from qualitative case studies to network, discourse and socio-technical configuration analyses (Heiberg et al., 2022; Yap et al., 2023), quantitative modelling, scenario-building techniques (Hirt et al., 2020; Hof et al., 2020) and techniques of futuring (Hajer & Pelzer, 2018; Hawxwell et al., 2024), which are crucial for exploring transition pathways, assessing sustainability impacts and informing policy decisions. This methodological diversity allows researchers to capture the complex character of transitions and to produce actionable knowledge that can guide real-world sustainability efforts.

1.3 Development of Sustainability Transitions Research Over Time

The emergence of sustainability transitions research can be traced back to growing awareness in the late twentieth century of the need for systemic change to

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address complex sustainability challenges (e.g. Kemp et al., 1998; Rotmans et al., 2001; Grin et al., 2010). Traditional approaches to environmental problems, which often focused on incremental changes or technological fixes, were increasingly recognised as inadequate for dealing with the scale and urgency of issues such as climate change, biodiversity loss, resource depletion and social inequalities. This led to a growing consensus that these challenges were not isolated problems but were deeply embedded within broader socio-technical systems that needed transformation to achieve sustainability (Loorbach et al., 2017). Sustainability transitions research involves studying interplays between objective material realities and socially constructed meanings, requiring both systematic analysis of processes and critical reflection on how knowledge about these processes is produced and shapes transition processes themselves (see Chapter 24).

In the 1990s, researchers from diverse fields – such as evolutionary economics, innovation studies, political science, science and technology studies, engineering & environmental studies and sociology – began to converge on the idea that fundamental changes were necessary in the organisation of societal systems, including energy, mobility, water and food. This period laid the groundwork for what would become the field of sustainability transitions research, where the interdisciplinary convergence allowed the field to develop a comprehensive approach to studying complex and context-dependent change processes. Specifically, during the 1990s and early 2000s, sustainability transitions research was still a niche area within the social sciences. One could see that the 1990s were the time where some of the foundational concepts of sustainability transitions emerged, emphasising systemic changes rather than incremental improvements. Thereafter, between 2002 and 2007, the seminal publications laid the groundwork for contemporary research and debates (Bergek et al., 2008; Geels, 2002; Geels & Schot, 2007; Hekkert et al., 2007; Raven, 2005; Smith et al., 2005; Smith, 2007; Truffer et al., 2008). At the end of the decade, in 2009, the first International Sustainability Transitions (IST) Conference marked a significant milestone, fostering international collaboration.

This expansion of the field is evidenced by a rise in scholarly publications and special issues on various subtopics, particularly in the last decade, also including the establishment of research networks such as the Sustainability Transitions Research Network (STRN) and the Network for Early Career Researchers in Sustainability Transitions (NEST). The involvement of international policy bodies like the Organisation for Economic Co-operation and Development (OECD) and the United Nations Environment Programme (UNEP) further illustrates the increasing policy relevance of the field (OECD, 2011; UNEP, 2015). The OECD's engagement with system innovation and transition theory signals growing acceptance among policymakers, as seen in early programmes like the Dutch Sustainable Technology Development (DTO), which emphasised system

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transformation through socio-technical experimentation and multi-stakeholder involvement (Markard et al., 2012; Truffer et al., 2022).

Traditionally, the focus was heavily on niche-induced transition processes – those emerging innovations that challenge and eventually replace established systems. However, as the field has matured, researchers have also turned their attention to the dynamics within the regimes themselves. This includes understanding how destabilisation occurs within dominant socio-technical orders, leading to their decline and opening pathways for new configurations to emerge and diffuse. Despite these advancements, the field faces several persistent challenges and tensions. One significant issue is its reliance on foundational frameworks like the MLP and Strategic Niche Management (SNM). While these frameworks have been instrumental in shaping the field, their dominance can sometimes result in conceptual rigidity, making it harder for new perspectives to flourish. This reliance also connects to a broader methodological narrowness; the field's heavy use of case studies, while insightful, raises questions about the robustness and generalisability of its findings. To counter this methodological narrowness, it is encouraging to see that other methods have also been adopted to better understand transition processes, such as transition-specific networks analyses, especially related to socio-technical configuration analysis (e.g. Heiberg et al., 2022; Miörner et al., 2021), discourse networks analysis (e.g. Markard et al., 2021; Yap et al., 2023) and modelling approaches (Mercure et al. 2016, Safarzynska et al. 2012, Köhler et al. 2018).

As highlighted in Chapter 28, it is important to recognise the limitations of what sustainability transitions research can do and where further conceptual development is needed. It remains important to continue being reflexive, urging a need for greater engagement with alternative perspectives, as the field is on its way to embrace new and critical viewpoints. This challenge reflects a two-sided tension in the field: engagement with policymakers (EEA, 2019) is crucial for practical impact but can risk overalignment with specific framings. Simultaneously, the field's systemic and often abstract theoretical frameworks can prove challenging for practitioners to implement in their daily work, potentially limiting their practical application. Finding the right balance between theoretical rigour, systemic understanding and actionable insights remains an ongoing challenge for the field. Another limitation lies in the spatial focus of the foundational theories. Many of these were developed primarily in Western European contexts, which may limit their applicability when trying to address sustainability challenges in other regions with different socio-political and cultural settings. This geographical limitation points to the need for a more globally inclusive approach. Over the last years, there has been increasing attention within the sustainability transitions research community to address this.

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1.4 Scope and Structure of This Book

The volume is organised to provide a comprehensive overview of current research, structured to appeal to early-career researchers, policymakers, practitioners and students. The objective is to provide a starting point for embarking on a research journey that includes the contributions of sustainability transitions research. This volume is divided into four thematic sections. In the first section, the foundational concepts and approaches are presented, highlighting how the MLP, TIS and transition governance, including Transition Management (TM) and Deep Transitions, provide fundamental insights into the dynamics of sustainability transition processes. The second section dives deeper into key dimensions of socio-technical change processes, such as the dynamics of transitions, power and politics in transition processes, actors and agency and geographies of transitions. The third section will be diving into how sustainability transitions can be studied. This is not a section where specific methods are being outlined, but much rather where different stances and perspectives are being brought together. The fourth and final section looks forward to the future, to open up the discussion about where sustainability transitions research could go. This reiterates the aim of this book to not be an end point, but a temporary milestone of taking stock and looking forward.

As will be highlighted throughout the volume, the field of research has changed, where there is a growing emphasis on engagement with practitioners and civil society through innovative approaches like action research and knowledge co-production. Similarly, localised approaches to sustainability transitions have gained traction, with a focus on how urban and regional stakeholders can implement transitions on the ground. This trend includes discussions on urban futures, local governance and the role of cities in driving broader socio-technical transformations.

1.5 Conclusion

Sustainability transitions research represents a response to the grand sustainability challenges of our time. While the field has made substantial progress in understanding these transitions, many complex issues remain, especially as transitions accelerate, overlap and interact with one another. The path forward for sustainability transitions research requires continued analysis and investigation, interdisciplinary collaboration and a deep commitment to fostering meaningful, long-term changes. As the field evolves, it will need to address the ongoing challenges of scaling sustainable innovations, managing diverse stakeholder interests and avoiding new forms of technological and social lock-in (where societies become dependent on and 'locked into' certain technologies or practices that are difficult to change, even when better alternatives emerge).

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Despite significant advancements in the field, this book is not merely a summary of what has been done. Instead, it is an invitation to engage with sustainability transitions research and to critically reflect on its concepts. We live in a complex and dynamic world, where numerous challenges are present and where futures are being shaped, also through new research. Hence, while this volume serves as an introduction to the field, there remains a vast body of academic literature that developed in the last two to three decades that can and should be further explored.

Political inertia, economic lock-ins and societal resistance can all impede progress. However, there are also substantial opportunities driven by technological advancements, policy innovations and increasing public awareness. This volume aims to highlight these challenges and opportunities, providing a balanced perspective on the pathways to sustainability. Thus, this book hopes to offer a valuable contribution to the discourse on sustainability transitions, providing insights and inspiration for continued research, innovation and action. By fostering a deeper understanding of the dynamics and drivers of sustainability transitions, we aim to support the collective efforts needed to achieve sustainable futures. The transformation to sustainability is complex and demanding, but it is an imperative that we must pursue with urgency and determination.

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