Technologies in Decline

Socio-Technical Approaches to Discontinuation and Destabilisation

Edited by Zahar Koretsky, Peter Stegmaier, Bruno Turnheim and Harro van Lente

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TECHNOLOGIES IN DECLINE

The central questions of this book are how technologies decline, how societies deal with technologies in decline, and how governance may be explicitly oriented towards parting with 'undesirable' technology.

Surprisingly, these questions are fairly novel. Thus far, the dominant interest in historical, economic, sociological and political studies of technology has been to understand how novelty emerges, how innovation can open up new opportunities and how such processes may be supported. This innovation bias reflects how in the last centuries modern societies have embraced technology as a vehicle of progress. It is timely, however, to broaden the social study of technology and society: next to considering the rise of technologies, their fall should be addressed, too. Dealing with technologies in decline is an important challenge or our times, as socio-technical systems are increasingly part of the problems of climate change, biodiversity loss, social inequalities and geo-political tensions. This volume presents empirical studies of technologies in decline, as well as conceptual clarifications and theoretical deepening. *Technologies in Decline* presents an emerging research agenda for the study of technological decline, emphasising the need for a plurality of perspectives.

Given that destabilisation and discontinuation are seen as a way to accelerate sustainability transitions, this book will be of interest to academics, students and policy makers researching and working in the areas of sustainability science and policy, economic geography, innovation studies, and science and technology studies.

Zahar Koretsky is post-doctoral researcher in STS and transition studies at the French Research Institute for Agriculture, Food and the Environment (INRAE) and Gustave Eiffel University in Paris. He works on sustainability transitions, focusing on a critical take on it. His current research lies within sustainability transitions in the extractive sector. Zahar has published on the history of various declined technologies across the world and on the EU's climate change mitigation.

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PREFACE

We started writing this book in a different world—one before the Covid-19 pandemic and before Europe saw war on its soil for the first time in the 21st century. Since that time the topic of technologies in decline has expanded its possible empirical subjects: from studying how to urgently address the climate crisis (movements to stop subsidising and to ban fossil fuels, for instance) to discontinuations of some industries during the pandemic lockdowns (for instance, aviation due to shortage of demand, food production due to a shortage of workers and the breakdown of supply chains) and war (namely, destruction in Ukraine, and, for that matter, what could be the beginning of a decline in the Russian aviation, military and IT technological fields as a result of international sanctions and an exodus of specialists). By the time this book is published, the readers will be in a better position to assess how these topics have evolved in real life. We, as editors, hope the lessons offered by this edited volume will be of use.

This book started with the conference panel on 'How are technologies abandoned?' initiated by Zahar Koretsky, Harro van Lente and Peter Stegmaier, at the European Forum for Studies of Policies for Research and Innovation (Eu-SPRI) 2020 conference. Having received ample first signs of interest from other science and technology studies and transitions researchers, we were approached by Routledge to consider turning the panel submissions into an edited volume. We decided to accept the invitation. As the book proposal was taking shape, Bruno Turnheim got increasingly involved and became a key part of the editors' team.

We may equally count the beginnings of this book from Zahar's PhD project on decline and phase-out (2017–2021) at Maastricht University; or from Peter's work on the governance of discontinuation of socio-technical systems in the Open Research Area project 'DiscGo' (2013–2016) with research partners from France (LISIS), the United Kingdom (SPRU), the Netherlands (STePS, University of Twente), and Germany (TU Dortmund), where the discontinuation governance

framework was developed. Likewise, the book may be said to have started several years prior when Bruno published his work on destabilisation. Or when Harro started engaging with the topic of Responsible Research and Innovation (RRI) and questions of sustainability and needs. The point is, for the past decade or so the topic of declining technologies, systems and practices has been with us in some way or another, in our experiences of the material world, in the expression of social claims related to impending crises, in our conceptual thinking, and in our puzzling about how the significant variety of approaches to decline may be brought together in a meaningful way. The four of us were impressed and happy to find like-minded scholars, the contributors to this volume, who were engaging with this important topic and grappling with similar puzzles, by their eagerness and by the quality of their contributions. With this book, we hope to have contributed to the identification of a community of scholars interested in the study of technologies in decline, and we look forward to seeing how this community will develop over time, including among the readers of this book.

The Editors
Zahar Koretsky, Peter Stegmaier, Bruno Turnheim, Harro van Lente

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1

INTRODUCTION

The relevance of technologies in decline

Zahar Koretsky, Harro van Lente, Bruno Turnheim and Peter Stegmaier

The central question of this book is *how technologies decline*. Surprisingly, this question is fairly novel. The dominant interest in historical, economic and sociological studies of technology has been to understand how novelty emerges and how innovation can open up new opportunities. This 'innovation bias' in the disciplines studying technology reflects how in recent centuries modern societies have embraced technology as a vehicle of progress. Indeed, the development and use of technologies have brought remarkable improvements in health, mobility and standards of living. In the last two centuries, technologies were figured as solutions to address societal problems. Yet, in a time of growing concerns related to the challenges of climate crisis, biodiversity loss, social inequalities or geo-political tensions, technologies increasingly figure as part of the problem, too (cf. Beck 1992; Douglas 1970). Technologies that once embodied progress, such as pesticides or coal-fired power production, now embody problems and stand in the way of better directions. It is timely, therefore, to broaden the horizon of technology dynamics and the technology-society relationship: next to considering the rise of technologies, we should also consider their fall, too. These are two sides of the same coin when it comes to how the relationship to technology is constantly re-negotiated in a social context. In this volume we present some outlines for the study of technological decline.

1.1 Limits to innovation

After WWII most industrialised countries adopted a techno-optimistic approach. The idea was that by stimulating scientific research and technological development, society would benefit from the boons of technology. This idea became known as the 'linear model' as it assumed a direct line from scientific discovery to the implementation and diffusion of technologies (Godin 2017). The techno-optimistic view of the linear model was emblematically captured in the 1933 Chicago World Fair motto: 'Science Finds, Industry Applies, Man Conforms'.

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But, of course, men and women do not readily conform. From the 1970s onwards, critical discourses about the problems of technology became more prominent. A landmark event for the public recognition that technologies can also put society at risk was the publication of the 1972 Club of Rome report on the *Limits of Growth*. The report indicated the depletion of resources and accumulation of pollution. It also announced that the general idea that economic growth would bring progress was misguided and not necessarily consensual. While such criticisms have changed the discourses and policies on technology, it is also clear that now, 50 years later, the problems flagged have only deepened. The climate crisis and the ongoing loss of biodiversity—as corroborated by a series of IPCC and IPBES[1] reports—indicate that widely used technologies, like the internal combustion engine, coal-fired power generation or the routine preventive use of pesticides, can pose serious threats for current and future generations.

The question of technology was broadened with the issues of reducing risks and increasing democratic control—questions linking to literature on critical theory of technology, where technology is seen as neither value neutral nor universal, and opposing the privileging of technical manipulation over other relations to reality (Feenberg 2017). How to stimulate technologies while avoiding unwanted side-effects? Can unintended effects be anticipated and avoided?

1.2 Critical discourses on technology

The set of questions broadened further with the economic crises of the 1980s that saw hampered industries and painful economic reshufflings in many parts of the world. Technology appeared as the stake in intensive global competitions; national industrial policies were set up to gain a favourable position in the innovation races. As with prior techno-optimism, as if part of a cyclical pattern, this was the era of strategic research and innovation, and of significant investment programmes in ICT, biotechnology and new materials. New regional specialisations emerged under technological and competitive pressures of global capitalism. Western countries faced the social consequences of deindustrialisation in heavy industry and sought to retain competitive edges by investing in R&D for advanced technological sectors. As emerging economies in the East and South became innovation powerhouses and expanding mass consumption markets, promises of growth and prosperity provided a counterpoint to problems associated with the decline of crafts and traditional industries (e.g., hand weaving in India, cf. Mamipudi 2016). Technology and innovation remained intimately and, again, techno-optimistically, tied to economic and social prosperity, but this time there was a more widespread awareness of the downsides, and particularly the social costs of regional decline in technological races.

During the last few decades, various political initiatives have been proposed to address the removal of certain technologies. Compared to efforts to stimulate technology these initiatives are modest, but there have been some successes: for instance, the ban of chlorofluorocarbons (CFCs) under the Montreal Protocol in

1987, the chemical substances responsible for ozone depletion which were used, for instance, in refrigerators. Various forms of technology assessment are now being used in policy settings and in firms to evaluate the desirability of technologies. In EU research, the notion of 'responsible research and innovation' has become commonplace, indicating an ambition to have more public control on technologies. Currently, there is a renewed emphasis on technological sovereignty (Edler et al. 2020), to gain independence from energy sources from warring states on the occasion of the war in Ukraine, or to be less dependent on supply chains that suffered from the Covid-19 pandemic.

In recent decades, environmental, health and social concerns have begun to assume more central roles in studies on technology, innovation and economic development. The UN Millennium Goals and their extension into the UN Sustainable Development Goals are important milestones signalling new long-term global orientations for economic and technological development. The rising interest in managing the concerns relating to technologies might be stemming from the economic stagnation of the global North in the last two decades (Streeck 2014; Albertson 2020) and dissatisfaction with the way institutionalised decision-makers have been handling economic and environmental issues (Oreskes & Conway 2010; Wille 2010). We can also observe a fatigue from current hyper consumerist societies and the unresolved environmental concerns (Gibson-Graham 2008; Escobar 2015; Hossain 2018; de Saille et al. 2020; Hickel & Kallis 2020) coming from both rich and poor regions of the world. Both types of concerns manifest in a new style of protest, one that not only frames a problem explicitly, but also articulates the need to change systems by taking them down. The actions of Fridays for Future, Black Lives Matter or Extinction Rebellion are cases in point. More societal and environmental problems such as climate change, biodiversity loss, unhealthy lifestyles, redistributive justice, privacy breaches or the spread of fake news are galvanising a return to critical discourses about technology. Against this background, calls for more desirable alternatives (e.g., eco-innovation, responsible innovation) are being complemented by calls for deliberately discontinuing existing systems deemed undesirable. Phasing out coal and fossil fuels has, for instance, become an important priority for climate action. Similarly, we are witnessing the emergence of policy objectives and programmes seeking to shift food production systems towards pesticide-free agriculture. Problems around nuclear decommissioning have been around for decades, but haven't yet found widely accepted solutions.

One of the difficulties is that attempts to discontinue technologies tend to remain largely translated into new agendas and horizons for innovative activity without fundamentally challenging its underlying logics (e.g., the 'green growth' oxymoron) or established systems. Significant R&D funding is being spent to invent ways to maintain and improve lifestyles without causing deterioration of the environment. Such eco-innovation optimism is, however, struggling to deliver fully on its promises: despite significant deployment of renewable energy, electric mobility or organic agriculture in some countries, these remain a far cry from the

'fundamental system transformations' called for (IPCC 2018; EEA 2019; UNEP 2022). Meanwhile, existing technologies and underlying systems remain relatively stable (e.g., empty passenger planes flying during pandemic) or even expand (e.g., SUVs, re-opening of coal mines in Europe due to the war in Ukraine, LNG extraction plus terminals to replace natural gas shortages), while new industries that are neither ecologically sustainable nor economically necessarily viable continue to emerge (e.g., space tourism) (Markard et al. 2021). Such examples can also show how much discontinuation has to contend with contradictory or competing rationales, interests, opportunities and framings (Turnheim 2023; Stegmaier 2023; Koretsky 2023).

In short, the prominent techno-optimistic discourses are under pressure, and existing socio-technical systems, ranging from energy production, to mobility, to agri-food, are increasingly under critique. As a result, many questions come to the fore: Is it possible to do away with undesirable or unsustainable technologies? If so, how? Does this necessarily involve substitution or does it involve other shifts, too? What societal, political and industrial strategies may help to reduce our dependence on harmful technologies and socio-technical systems? Should specific products or larger systems be targeted? How can investment patterns related to harmful and polluting production be discontinued? These questions require another approach to technology: exits and divestments, destabilisation and discontinuation are high on the agenda.

1.3 Studying technology beyond innovation

In the scholarly fields of innovation studies and science and technology studies, the emergence of technologies has traditionally been the focus of study. Even a decade ago Elizabeth Shove noted that '[w]ithin the fields of innovation studies and transitions theory, processes of emergence and stabilisation are better documented and more widely discussed than those of disappearance, partial continuity and resurrection' (Shove 2012: 363). Yet, the attempts to abandon undesirable technologies have been hampered by insufficient insights into how such processes unfold—whether they are deliberately pursued or not. The question of how technologies decline, which we are concerned with in this book, is timely and differs markedly from earlier questions about technology in society.

Of course, the recognition that technologies may be disruptive is not new. A century ago, the founder of innovation studies Joseph Schumpeter coined the phrase *creative destruction* to characterise the role of technical change in economies. Technologies do not just bring an accumulation of improvements, he argued, but will necessarily destabilise economic sectors, too. This still holds today: think about the woes of the postal services, which suffer from the popularity of e-mail. Before Schumpeter, Karl Marx analysed the exploitative and alienating nature of capitalism and its mobilisation of technology for this, and pointed to the fundamental disruption of social structures. The destructive character of technology, the destabilisation and eventual decline of industries or organisations, the social and

environmental costs of capital accumulation around technology and its use have a certain regularity and genericity that makes them observable in different geographical, sectorial or temporal settings.

The main starting point for this book is the observation that (desirable) exit or reduction objectives informed by critical discourses on technology are qualitatively different from fostering desirable innovation. They involve a different kind of phenomenon, requiring different skills, different interventions and different kinds of thinking: *decline is not just the reverse of innovation*. Moreover, deliberate decline is likely to face resistance from significant vested interests, which may be powerful incumbents as well as more vulnerable populations and communities facing to lose significantly from the end of systems they depend on. Deliberate decline entails significant challenges, such as those associated with regulating or restricting activities and livelihoods associated with 'undesirable' technologies, related political contestation and struggles, but also dealing with the fact that there will be winners and losers as a result of decline. Decline is likely to be as much about setting directions and objectives as it is about managing a process and handling its aftermath—including loss (Elliott 2018). The difficulty and, at the same time, opportunity is that technologies neither persist, nor disappear into oblivion automatically: they require work to do so (Callon 1987; MacKenzie and Spinardi 1995; Russell and Vinsel 2018). Moreover, formerly established systems may still be needed for very specific purposes (DDT for vector control, special purpose incandescent light bulbs, special purpose vehicles with internal combustion engines that are fossil-fuelled). At least for a transitional period, they may leave traces that outlive the discontinuation of their active use (e.g., dealing with nuclear waste long after the disconnection and dismantling of nuclear power plants) and require dedicated infrastructures. Sometimes they also threaten to come back as zombie technology because strong interests want to push them back into the market and effectively revert phase-out programmes (e.g., the revival of coal power generation) or critical discourses are shifting (e.g., nuclear energy framed as green and CO2-neutral or dirty and life-threatening). Thus, decline is neither a linear nor an irreversible process. This is new territory for policy and research alike, and calls for revisiting concepts, methods, capabilities and means for intervention.

1.4 Perspectives and concepts

This book proposes to ask what kind of processes are involved, what forms of decline can be observed, what lenses and concepts can be usefully applied and what questions remain unanswered. In this volume on technologies in decline, we seek to draw on a rich empirical base, which is diverse in terms of technologies, geographic locations and political settings. We intend to explore and use various intellectual starting points and concomitant concepts. The study of technologies in decline is necessarily *interdisciplinary*, drawing from multiple disciplines such as sociology, history, management and economics. Yet, this diversity can only be productive when there is also some common ground, which allows us to compare and contrast empirical findings and to connect conceptual claims.

Overall, the meta-theoretical lens of this book is *socio-technical* and we should clarify what this means, what it entails and what it requires. Firstly, 'socio-technical' refers to the insight that the social and the technical are deeply interwoven. They do not exist in separate domains, but are *mutually embedded* in tight relationships (Hughes 1983; Callon 1984; Latour 1999). As a consequence, socio-technical decline includes at least a partial dis-embedding of society-technology relationships. Secondly, a 'socio-technical' perspective implies that technological artefacts do not exist in and of themselves but only as a part of networks, configurations or systems. They can be seen as *configurations that work*, as Rip and Kemp (1998) phrased it. Consequently, technology removal or technology substitution is not the appropriate unit of analysis: technologies in decline is a matter of transformations in networks, configurations or systems. Finally, the socio-technical perspective points to the *interplay of social and technological dynamics*. The processes of technologies in decline then involve co-evolving social processes (political, cultural, psychological) and technical processes (in design, standardisation, manufacture, etc.).

The notions and terms mobilised in this volume showcase the varying foci and interests of its various contributors. Some of the notions point to emergent and long-term processes and mechanisms, such as 'destabilisation'. Others, such as 'discontinuation' or 'phase-out', help describe policy or policy goals and the related policy processes. Using past and contemporary examples, the contributions put forward different kinds of explanations, illustrate which strategies might work and which might not, and how decisions to turn away from a questionable technology could be initiated and navigated.

Judging just by the topics of the contributions and the theoretical constructs employed, we may sketch a preliminary frame of reference for various forms of technology decline, see Figure 1.1. The contributors of this volume are preoccupied with

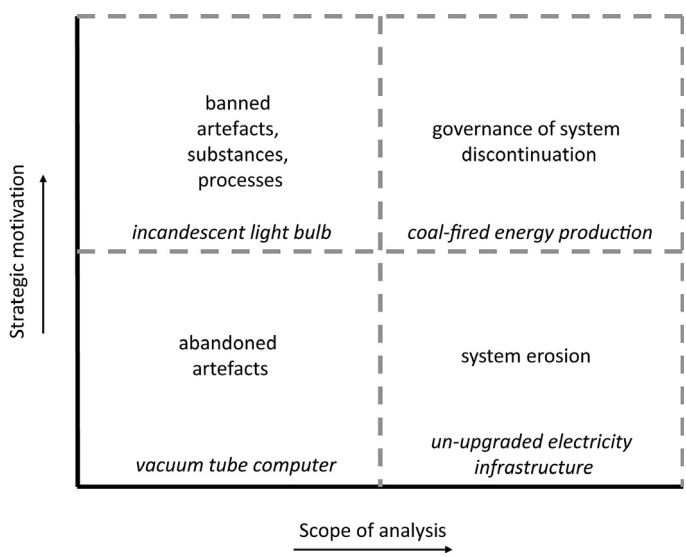

FIGURE 1.1 Varieties of technological decline

the particular processes of decline and adjacent concepts and how they unfold over time, their relevant characteristics, phases, trade-offs and dimensions. Two dimensions appear particularly relevant to make sense of the variety of perspectives: the scope of analysis (i.e., the perimeter of the technology, system or configuration in question) and the strategic motivations vested in a decline process (i.e., the extent to which decline is actively pursued or on the contrary a more emergent process). Of course, these dimensions are to be seen as gradients rather than binary categories, but they already allow us to qualify some archetypical foci along which *technologies in decline* are being thought up. Decline can range from the abandonment of a particular artefact or substance (say, a specific product model) or the erosion of a socio-technical system's relevance and centrality, to the more purposive ban of specific substances or products, or attempts to actively discontinue entire systems.

1.5 Outline of the book

We structure the volume in three Parts: from conceptual explorations, to empirical ones and, finally, to governance explorations. Table 1.1 provides an overview of the chapters, and bears witness to the significant variety of key notions deployed, analytical scale and contexts, focal context and primary research focus.

The conceptual Part of the book deals with three notions. The first one is decline, or *technological decline*, which in Zahar Koretsky's chapter is reconceptualised away from its colloquial, umbrella-term status in the book's title (and this introductory chapter) to a more specific and empirically supported characterisation: a measurable trend and a socio-material process of scaling down of production and/or use of a given product or process. In the chapter, Koretsky presents an overview of literature trying to understand the mechanisms of technological decline and offers, based on it, a socio-material characterisation. From a distinct conceptual starting point, Bruno Turnheim in his chapter focuses on the notion of *destabilisation* next to decline and phase-out. Destabilisation is understood as an emergent process of exposure of socio-technical orders to pressures significant enough to threaten their continued existence and 'normal' functioning, but also strategic responses of affected actors to this exposure and changing commitment to core productive engagements. Turnheim maps the theme of destabilisation in the transitions literature and proposes a research agenda. The third notion, central for Peter Stegmaier's chapter, is *discontinuation*, seen as a property of a technological trajectory in which its constituting relations become misaligned to such an extent that its distinctive character is lost, and also seen as a possible result of various permutations of distributed agency, contingency, emergence or deliberate governance. In this chapter we find a discussion of how the actions of groups of actors affect both the discontinuation of a trajectory itself and of governance practices that help stabilise it. These three notions—decline, destabilisation, discontinuation—provide lenses for the exploration of the problems around passive and active withdrawal of technologies from societies. As is discussed throughout the book and returned to in the Conclusions (Koretsky et al. 2023), these notions are interrelated and provide

entry points for dealing with the challenges that come with re-negotiating our relationships with technology.

A Part focusing on empirical studies continues the book's inquiry. To characterise their focal phenomena, some contributors have mobilised a range of additional notions and frameworks. Jochen Markard, Karoliina Isoaho and Linda Widdel (2023) study discursive destabilisation in a comparative setting, by examining framings of coal phase-out in mainstream press outlets across Europe. They adopt the conceptual lens of Technological Innovation Systems (TIS) to study the case of coal power generation in three countries. Daniel Weiss and Philipp Scherer (2023) mobilise the notion of 'phase-out' and approach it as an outcome of processes of decrease in production or consumption. They study the phase-out of the internal combustion engine also through the TIS framework, discussing the role of geographical context in phase-out and decline, focusing on divergent responses to phase-out pressures in the US and the EU. Frédéric Goulet (2023) studies decline as a process of innovation through withdrawal, and examines its relationship with processes of novelty creation. Using an illustrative case of bio-pesticides as alternatives to synthetic pesticides, his chapter explores how the development of substitutes can contribute both to the decline and continuity of problematic technologies. Dirk van de Leemput and Harro van Lente (2023) study the duality of decline of and care for a technology, framing care as 'aftercare' (cf. Stegmaier et al. 2014). Using the example of the 16 mm film as an object of art, they draw from museum studies and care studies. They show how actors can preserve and care for declining technology in pockets of resistance to decline, and how these processes are often invisible.

In the third Part of the book, we turn to governance-related perspectives. Adrian Rinscheid, Gregory Trencher and Daniel Rosenbloom (2023) focus on phase-out, which they see as a policy intervention for a stepwise decrease and termination of production or consumption of a product or process. They offer a systematic review of academic literature on the notion of 'phase-out' since the 1970s. They observe the changing attention to this notion in the literature and comment on the travels of this concept across environmental and societal challenges, policy efforts and instruments. The chapter by Ela Callorda Fossati, Bonno Pel, Solène Sureau, Tom Bauler, and Wouter Achten (2023) mobilises the concept of 'exnovation', where the authors seek to advance empirical knowledge on this notion adjacent to decline and discontinuation. The study focuses on the efforts of the Brussels-Capital region to establish and maintain a low-emission zone. The authors discuss political, jurisdictional and epistemic issues with the implementation of an exnovation policy, and highlight contestations and concomitant discourses of discontinuation in a complex governance setting. A captivating activist/academic testimony by Peter Newman (2023) on the end of leaded petrol complements the prior chapters with a powerful and, ultimately, hopeful account of, and reflection on, the possibility and reality of decline of an undesirable technology.

The concluding chapter by Zahar Koretsky, Bruno Turnheim, Peter Stegmaier, and Harro van Lente (2023) brings the three Parts together by returning to the

TABLE 1.1 Overview of the contributions to the present volume

		Core notions ○ Side notions •						Analytic scale			Focal context					Research focus					
Book section	**Book chapter**	Decline	Destabilisation	Discontinuation	Phase-out	Exnovation	Withdrawal	Domain	Country	Number of	Organisational	Municipal	Regional	National	Supranational	Transition	Governance	Innovation	Socio-technical	STS	Sectorial
Conceptual explorations	Koretsky	○			•			Energy, IT, Meteorology	USA, EU, RU	3	•			•	•	•			•	•	
	Turnheim	•	○		•			-	-	-	•		•	•		•			•		
	Stegmaier	•	•	○	•	•	•	-	-	-	•	•	•	•	•	•	•		•	•	
Empirical explorations	Markard et al.	○	•		•			Coal	UK, D, FIN	3	•			•		•			•		•
	Weiss & Scherer	○			•			Car	EU, JP, USA	1				•	•	•		•			
	Goulet	○		•				Agriculture, Pesticides	ARG, BRA	2				•		•		•			•
	Van de Leemput & van Lente	○						Media	UK	1	•									•	•
Governance explorations	Callorda Fossati et al.		•		•	○		Mobility	BE	1		•					•	•			•
	Rinscheid et al.				○			Sustainability	-	-				•	•	•	•				•
	Newman				○			Fuel	Several	1	•			•	•	•	•				•

question what the study of technologies in decline entails and requires. The chapter reflects on the progress made in this volume and delineates a research agenda for further study and reflection. In this way, with the book we hope to inspire more efforts to move to a next step in the relationship of current societies to technology as questions of *decline* become more prominent.

Note

1 The Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, both organisations of the United Nations.

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3

DESTABILISATION, DECLINE AND PHASE-OUT IN TRANSITIONS RESEARCH

Bruno Turnheim

3.1 Introduction

How do fundamental transformations of socio-technical systems occur? What kinds of difficulties are associated with shifting away from undesirable systems of provision? How might such processes be accelerated or oriented?

The socio-technical transitions and innovation literatures ascribe difficulties to set in motion fundamental system transformations to various lock-in mechanisms (Klitkou et al. 2015; Seto et al. 2016; Unruh 2000; Walker 2000), but have so far primarily addressed this question from the perspective of the emergence and development of novelty, examining the systemic obstacles that such "emergent" and positively connoted processes may face. An equally valid way to address this question consists in shifting the gaze away from novelty creation in order to focus on established systems, practices and institutions, and the role of various forms of incumbencies in reproducing existing orders or actively resisting change (Stirling 2019; Turnheim and Sovacool 2020), as well as how these incumbencies may be challenged.

Focusing on *existing* (i.e. already and lastingly stabilised) socio-technical systems enables a closer inspection of the phenomenon of lock-in and inertia, and its incidence on broader patterns of stability and change in socio-technical transitions processes. Starting from the discontinuation of the existing, rather than the emergence of the new, affords alternative lines of reasoning with respect to the core problems of transitions.

According to authors concerned with transitions, such a shift of focus is long overdue:

> Within the fields of innovation studies and transitions theory, processes of emergence and stabilisation are better documented and more widely discussed than those of disappearance, partial continuity and resurrection.
>
> *(Shove 2012)*

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> policy mixes favourable to sustainability transitions need to involve both policies aiming for the "creation" of new and for "destroying" (or withdrawing support for) the old.
>
> *(Kivimaa and Kern 2016: 206)*

> current policies are not enough to affect global emissions, or are slow to have a detectable effect, or simply fail to directly address the root cause of the problem: phasing out CO2 emissions from the use of fossil fuels.
>
> *(Peters et al. 2020: 6)*

The destabilisation of existing systems is an emerging research and policy concern related to socio-technical transitions (Bergek et al. 2013; Johnstone and Hielscher 2017; Kivimaa and Kern 2016; Kungl and Geels 2018; Rogge and Johnstone 2017; Turnheim 2012; Turnheim and Geels 2013, 2012). Accelerating socio-technical transitions requires not only the deployment of alternative options, but also breaking away from patterns of inertia and lock-in (Unruh 2002, 2000) that lead existing systems and actors to resist, slow down or prevent transition efforts, i.e. the active phase-out of deeply entrenched systems and related activities (Langhelle et al. 2019; Roberts et al. 2018).

Research about the destabilisation, decline, discontinuation and phase-out of existing systems in the scope of socio-technical transitions has developed significantly in recent years. A number of research orientations can be identified, addressing conceptual, empirical, policy and societal challenges in different ways. This chapter seeks to explore this variety, as a means to reflect on current and future research directions. It contributes to this recent development but also seeks to open up new perspectives.

Indeed, in their review of research on deliberate decline, Rosenbloom and Rinscheid (2020) identify three main strands (destabilisation, phase-out, divestment), but the scope of their exploration leads them to only consider contributions directly relevant to policy and dealing with climate change or carbon-intensive activities. The present contribution seeks a broader engagement with the *process* of socio-technical destabilisation. This leads to considering relevant contributions beyond the scope of transitions studies, climate policy or energy-intensive industries. For instance, the understanding of destabilisation as a process has much to gain from insights concerning harmful substances and socio-technical activities related to food and agriculture or from social science literature beyond transitions studies.

Section 3.2 offers a clarification and disambiguation of related terms: destabilisation, decline, phase-out. Section 3.3 reviews contributions to destabilisation research within transitions studies, structured around six salient themes as entry points for destabilisation research. For each of these themes, I discuss distinct research questions, conceptual elaboration and empirical strategies, as well as ongoing research puzzles. In section 3.4, I return to the themes identified

in section 3.3 to formulate six conceptual propositions about destabilisation. The chapter concludes by formulating unanswered questions as avenues for future research endeavours.

3.2 Terminological disambiguation

Before examining the notions deployed around destabilisation in detail, definitional considerations are in order. Indeed, ambiguities exist in research about decline, destabilisation and phase-out of socio-technical systems. These largely relate to boundary conditions and analytical choices, some of which are too often implicitly assumed rather than explicitly formulated. A first necessary step appears to be one of qualifying differences between these concepts and ensuing analytical choices.

Socio-technical *destabilisation* can be understood as a *longitudinal process* by which otherwise relatively stable and coherent socio-technical forms (systems, regimes, institutional arrangements, sets of practices or networks) become exposed to challenges significant enough to threaten their continued existence and their "normal" functioning, triggering strategic responses of core actors within the frame of existing commitments (preservation) and in certain circumstances away from such commitments (transformation). Destabilisation can hence be understood as a *process* involving pressure fronts, strategic responses, and varying commitments to prevailing frames of operation (rules, endowments, etc.). Destabilisation can also be understood as a dynamic *context* for action, involving changing opportunities for navigation and steering from within existing systems (e.g. strategic management of destabilisation contexts by incumbent actors) or from without (e.g. societal contestation or technological alternatives as destabilisation pressures, active destabilisation governance).

System *decline* relates to often a more objectifiable or quantifiable degradation of system performance (e.g., size, economic viability, population, hegemonic power, legitimacy), which can (but rarely does) lead to total decline.[1] Depending on its qualification, decline can hence be understood as a *trend* (e.g., declining performance), a *process* (e.g., system in decline), a possible *outcome* (e.g., decline as consequence of destabilisation) or a *context* (e.g., declining industry as warranting particular kinds of strategies).

Phase-out refers to deliberate (governance) interventions seeking the partial or total discontinuation of a socio-technical form that is deemed undesirable.[2] In practice, phase-outs have largely been restricted to specific products or substances (e.g., DDT, asbestos, mercury, plastic bags, alcohol, class A drugs) and practices (e.g., farm-site slaughter, inner-city driving, indoor smoking),[3] though there are relevant exceptions (e.g., dismantling of tramways, whaling ban). Phase-out is hence a governance *objective*, a form of *intervention*, and a *process* inscribed in a temporal sequence of active discontinuation in phases.

3.3 Core notions deployed within transitions studies

Destabilisation is related to several notions assuming relative centrality within studies of socio-technical transitions: 1) multi-dimensional sources of stability (inertia and lock-in), 2) multi-dimensional sources of change, 3) incumbents as focal actors, 4) processes, pathways and mechanisms, 5) deliberate or purposeful governance, and 6) vulnerability and politics.

3.3.1 Lock-in as structural and *enacted form of stability*

Destabilisation is essentially a process of departure from or challenge of system stability. Within transitions studies, established socio-technical systems are taken to be relatively stable and coherent. System stability is linked to the notion of lock-in and path dependency, which tend to foreclose opportunities for radical innovation and fundamental reconfigurations in favour of more incremental adjustments to existing socio-technical trajectories. For this reason, transitions remain relatively rare phenomena.

On the one hand, *structural* determinants of lock-in are rather well understood from the perspective of economic rationalities (Seto et al. 2016) and cognitive routines (Nelson and Winter 1982), which include sunk investments (e.g., infrastructure, production facilities), increasing returns from economies of scale (Arthur 1989), industry standards, user externalities, network effects and other positive feedback mechanisms reinforcing asymmetrical advantages accruing from cumulative socio-technical development processes. Non-economic dimensions (e.g., institutional and political) are increasingly being considered (Klitkou et al. 2015; Pierson 2000), but are also admittedly more ambiguous due to the "complexity of the goals of politics as well as the loose and diffuse links between actions and outcomes" (Pierson 2000: 260). They include enduring the unusual obduracy of political arrangements, public policies and formal institutions (Pierson 2000), powerful strategic alliances and coalitions with asymmetric access to rule-setting (Roberts et al. 2018), normalised discourses, ideologies and socio-cultural repertoires, and the deep societal embeddedness of user practices and lifestyles. Together, these structural sources of lock-in have the cumulative effect of preventing, limiting or slowing down the development of alternative innovations and socio-technical configurations. Lock-in is an inherently path-dependent process (Arthur 1989; Pierson 2000) resting on self-perpetuating event sequences (Mahoney 2000): past design choices constrain current and future options of system development in ways that favour incremental over radical forms of change and appear as irreversible.

But lock-in is neither permanent nor inevitable: system *un*locking does and has happened. Understanding and characterising structural lock-in requires 1) longitudinal approaches to *how socio-technical configurations have stabilised* along particular trajectories to take on specific forms and shapes, and 2) evaluative-descriptive approaches to *how stable socio-technical configurations actually are* (Klitkou et al. 2015)

and *how socio-technical stability may change over time*—notably as alternatives are developed or windows of opportunity for change open up. In practice, the situated analysis of lock-in needs to be cognisant of the variety of relevant dimensions and mechanisms (economic and institutional), their relative importance (e.g. structure depth, interlinkages) and their transient nature.

On the other hand, socio-technical stability is also *enacted* by established actors enjoying central or dominant positions within existing systems that tend to reproduce the conditions of their incumbency (Stirling 2019; Turnheim and Sovacool 2020). Firstly, incumbent actors contribute to the continuity of existing systems, structures and practices through tacit and routinised activity, including maintenance, care and repair, continued investment, service improvements, incremental innovation, or the reproduction of underlying (regime) rules. Such continuation, maintenance and improvement activities may confer sustained relevance and legitimacy to the actors involved and contribute to further entrenching related socio-technical practices, arrangements, infrastructures. They are carried out at various levels, from mundane and invisibilised maintenance work to more strategic (and often framed as remarkable) programmes. Secondly, more active forms of stability enactment include strategic activities aimed at defending and protecting current arrangements and advantages (e.g., favourable policy conditions), notably by incumbent actors (see section 3.3.3) in the face of contestation and other challenges to socio-technical stability (e.g., delegitimation). The repertoire of regime resistance and defence strategies can be approached by distinguishing forms of power available to incumbent actors (see Table 3.1).

It hence appears relevant, as a preliminary step to better understanding destabilisation processes, to develop the means to evaluate system stability and coherence over time. To do this, it is important to identify markers of system stability and coherence, processes of system stabilisation, and the mechanisms—structural and enacted—that contribute to system lock-in and stability. It then becomes possible to evaluate destabilisation as a process involving the waning of stabilisation mechanisms (erosion of structural forms of stability), difficulties to maintain stability in the face of challenges (failure to actively resist pressures) or intended departure from system preservation objectives and rationales (transformation). The interplay between stabilisation and destabilisation is further discussed in section 3.3.4.

3.3.2 Multiple and mutable sources of change

While established socio-technical systems are characterised by lasting stability, they are also exposed to pressures and challenges of varying kinds, which may call into question their normal functioning, expected performance, continued relevance or legitimacy. Such pressures for change may be deflected entirely (e.g., operations resuming after temporary disruption of service), orient incremental improvement and optimisation strategies (e.g., more efficient production modes, substitution of harmful substances), trigger significant adjustments (e.g., new business models,

TABLE 3.1 Types of power harnessed by incumbent actors for resistive purposes

Types of power	*Related incumbent resistance activities*
Instrumental	Mobilising resources (e.g. finance, capabilities, authority, access to decision-making) in immediate interactions with other actors to achieve their goals and interests
Discursive	Mobilising authority and legitimacy to shape what issues are being discussed (agenda-setting) and how they are being discussed (issue framing)
Material	Leveraging technical capabilities and financial resources to promote incremental improvements of existing options over more radical alternatives
Institutional	Reinforcing prevailing political cultures, ideology and structures (e.g. economic liberalism, technocratic styles) to downplay alternative paths and decision rationales

Based on Avelino and Rotmans (2009) and Geels (2014a)

reconfigurations) or eventually make existing systems obsolete. It hence appears important to develop the means to better characterise these sources of pressure, determine and trace their influence over existing systems, namely in order to better qualify *what makes for a destabilising source of change* (as opposed to other sources of change), and *whether specific sources of change may be associated with specific destabilisation patterns*.

Kinds and sources of (destabilising) change can be related to relevant socio-technical dimensions within which systems are embedded, the alignment of which confers stability or the de-alignment of which may generate destabilising conditions. The specific dimensions considered vary according to approaches and are largely a matter for analytical choice. These include usual distinctions between techno-economic dimensions (e.g., significant changes in markets, technologies, infrastructures, scientific knowledge), and socio-political dimensions (e.g., significant changes in ideas, policies, politics or cultures) (Geels 2014b; Turnheim and Geels 2013). Socio-technical approaches make a distinction between three interrelated and partly overlapping ontologies (Geels 2004; Geels and Turnheim 2022): that of technical components and systems (artefacts, technical systems, infrastructures), that of institutions (regulations, conventions, cultural values and beliefs, symbolic meanings, and so on), and that of actors and networks (their actions, motives and interests, forms of organisation and interaction). Accordingly, sources of destabilising change include 1) technical dysfunctions, technological discontinuities or performance erosion, 2) social and political mobilisation, delegitimation, the emergence of new rules or the breakdown of existing rules, and 3) challenges by new actor coalitions, the disbanding of existing coalitions or the accumulation of poor strategic choice. Practice theory distinguishes between three kinds of elements that are tied together in stable practices: materials ("things"), meanings (social and symbolic signification) and competences (forms of understanding and practical knowledgeability)

(Shove et al. 2012). So, the decline, erosion or decay of practices can be understood as the unmaking or breaking of ties between such elements.

Regardless of the chosen frame of reference, a number of observations can be made. First, challenges to stability can emerge along various dimensions: significant change in one dimension may perturbate the relative stability experienced by established systems. Qualitatively distinguishing different sources of change can underpin the identification of ideal destabilisation processes, including technological disruptions and discontinuities, creative destruction (of economic entities), discursive destabilisation (of prevailing frames), delegitimation (of practices, behaviours or specific actors), de-institutionalisation (of rules and conventions), regulatory challenges and so on. Second, destabilisation is likely to result from a combination of sources of change, so it is more fitting to think in terms of *pressure fronts*. Third, destabilisation is not merely the result of threats and challenges but is related to the weakening of stability-conferring ties and alignments within socio-technical configurations. Destabilisation results from the combination of intensifying discontinuities (threats and challenges) and weakening continuities (erosion).

A related distinction concerns the location and distance of sources of change vis-à-vis the definition of an established system's boundaries, i.e., whether sources of change are exogenous or endogenous. Exogenous sources of destabilising change typically relate to challenges outside of existing systems and beyond their immediate environment, such as external threats, uninvited challenges or unforeseen discontinuities (e.g., surprises and shocks). Exogenous pressures tend to be less anticipated and not to be the object of dedicated monitoring or intelligence than their endogenous counterparts. "Landscape changes", such as demographic patterns (e.g., urbanisation), macro-economic trends, geo-political swings, crises and disruptive events (e.g., wars, shocks) are typical exogenous changes. But exogenous changes are not necessarily macro in scale, as with competition from socio-technical alternatives, social movement contestation, or practice and consumption changes, which can start as relatively isolated and follow more gradual emergence patterns yet come to exert significant pressures for change. Endogenous sources of change, by contrast, are more closely linked to established systems and activities or in their immediate vicinity. They tend to be the object of monitoring (through for example performance indicators); regime actors tend to be more knowledgeable about them and so in a better position to anticipate them or perceive them as immediate threats. Endogenous changes include worsening economic performance (e.g., at product, firm or industry level), declining income, slack (which reduces the ability to manage change) or resources, weakening ties between key socio-technical components, changes in political support and coalitions, degraded infrastructures (e.g., material, knowledge), and divergence within organisational fields. Furthermore, endogenous sources of change are likely to materialise as conflicts and contradictions between otherwise aligned elements in configurations. However, the distinction between exogenous and endogenous change is not entirely clear cut: it

depends on system boundaries, is a matter for interpretation, and exogenous changes can turn into endogenous pressures for change as they become translated into more concrete concerns and pervade socio-technical configurations.

Lastly, considerations about sources of change in destabilisation processes raise issues about the explanation of change, and the mechanisms by which sources of change can trigger, reinforce or orient destabilisation processes and patterns (see also section 3.3.4). Since destabilisation rarely results from a single pressure or source of change, its analysis calls for representations of the complex causal chains involved: the temporal interaction of sources of change in the formation of *pressure fronts* and related destabilisation patterns.[4] With regard to temporality, a variety of possible destabilisation patterns may be identified according to the intensity, speed, scope and sustained nature of pressure fronts. Suarez and Oliva (2005), focusing on changing industry environments, suggest a distinction between regular change, hyperturbulent change, specific shocks, disruptive change, and avalanche change. Stirling (2014), focused on the interpretation of system vulnerability threats, distinguishes between short-term episodic perturbations (shock interpretations) and long-term enduring pressures (stress interpretations).[5] In practice, destabilisation processes are likely to deviate from such ideal-types with interrupted, cycling or reversing patterns.

With regard to causation, it is useful to distinguish different levels: proximate causal forces, intermediate causal forces and distal causal forces. The shock/stress distinction illustrates the importance of differentiating causes in practice: the 2008 financial crisis may be interpreted as a shock, the primary cause of which is attributable to the "bursting" of a housing market bubble (subprime mortgages) and of a dependent financial bubble in its wake. But beyond this proximate causation, it is also possible to interpret the crisis as resulting from a long-term stress linked to more remote causes: the accumulation of solvency imbalances (between debt obligations and cash flow), the multiplication of financial innovation, lax monetary policy and an increasing disconnect between the financial system and the real economy. Furthermore, the hysteresis-like pattern of many shocks, while influenced by identifiable feedback loops, is largely emergent and contingent in character. Consequently, it is relevant to approach such processes through the analysis of sequences of events, the identification of critical turning points and possible cascading dynamics of change.

So, given that the emergence, evolution and endurance of pressure fronts are an essential source of destabilisation, it is important to develop the means to better characterise, distinguish and evaluate them and their incidence on established systems.

3.3.3 Incumbents as focal actor

Destabilisation is intimately tied to the roles, motives and actions of particular social actors, notably those assuming a *de facto* position of centrality in established socio-technical configurations and those willing to challenge these positions for various

motives. Many studies adopt a particular focus on "incumbent actors" and their responses to destabilisation challenges (Andersen and Gulbrandsen 2020; Bergek et al. 2013; Berggren et al. 2015; Bohnsack et al. 2020; Dijk et al. 2016; Hess 2019; Hörisch 2018; Isoaho and Markard 2020; Kungl 2015; Lee and Hess 2019; Lockwood et al. 2020, 2019; Mylan et al. 2019; Raven 2006; Smink et al. 2015; Steen and Weaver 2017; Turnheim and Geels 2013; van Mossel et al. 2018), often portrayed as villains to be dethroned or transformed for system change to occur. While the notion of incumbency denotes particular attributes such as a position of centrality, power, mastery over resources in connection to established system, it is important to move beyond simplistic, monolithic and static portrayals of incumbency attributes and the actors that come to incarnate them (Turnheim and Sovacool 2020), to examine a plurality of forms of incumbency at play and the depth of related socio-technical entanglements (Stirling 2019).

First, "incumbent actors" is often used as shorthand for large firms or multinational corporations, with little consideration for incumbency, centrality and power in other societal spheres (e.g., policy and politics, civil society, knowledge production). Important questions for destabilisation research remain concerning these other forms of incumbency and how they relate to one another, for instance in incumbent coalitions or constellations perpetuating prevailing paradigms.

Second, because incumbency connotes significant vested interests in existing systems, practices and arrangements, it is commonly assumed to exclusively lend to the adoption of resistive postures with respect to radical change, i.e., incumbency as calculated conservatism. In practice, however, the strategic repertoire of incumbents may be broader (e.g., from purely resistive stances to more proactive diversification through various means) and vary significantly from actor to actor. This suggests important questions concerning the range of strategic positions and stances available to and performed by incumbent actors.

Third, incumbent strategies are likely to change over time, as the nature of destabilisation contexts changes (e.g., mounting pressures), as specific opportunities arise or as new frames of reference become available to those actors. This raises questions about the changes in incumbent strategies in various contexts and their determinants.

Fourth, there is a need for greater clarity as to how the notions of "regime" and "incumbency" are related and intersect. Indeed, certain incumbent actors may "disband" from existing regimes and so contribute to their fragmentation (Steen and Weaver 2017), incumbent actors from neighbouring regimes can significantly contribute to niche construction (Berggren et al. 2015; Späth et al. 2016; Turnheim and Geels 2019), and regime rules are reproduced by all sorts of actors—some of which are not considered as particularly powerful, dominant or central to said regime. So, socio-technical regimes and incumbency only partly overlap.

For incumbents, destabilisation ultimately comes with the threat of losing a dominant status, position, sustained relevance or legitimacy (e.g., social licence to

operate) but can be met with a broad range of tactical moves and response strategies. Following incumbent actors along destabilisation processes is a relevant analytical entry point, particularly as it enables us to better understand how particular organisations experience, interpret and handle such challenging processes. Correspondingly, incumbent destabilisation processes are being approached from various perspectives deployed at the organisational level, including cognitive and learning approaches, strategic change approaches (e.g., diversification, renewal, ambidexterity), organisational decline, organisational capabilities (Ottosson and Magnusson 2013) or power (Avelino and Rotmans 2009; Geels 2014a). Organisation-centric approaches may further be distinguished according to two dimensions: 1) the depth of challenges and changes (e.g., change in activities, routines, models or core beliefs), and 2) the nature of challenges and changes (e.g., competitive, technological, reputational/legitimacy, socio-political) (see also section 3.3.2).

While incumbents are a relevant entry point to study the destabilisation process, other actors warrant attention and dedicated research, including 1) social groups with no or weaker prior links with existing systems and regimes which may actively contribute to destabilisation (e.g., civil society, new entrants organisations, alternative political alliances) notably due to their interest in challenging positions of power for various motives, 2) vulnerable groups with potentially less agency in destabilisation processes such as workers and local communities (Johnstone and Hielscher 2017) and less visible groups directly affected by decline or phase-out interventions (see also section 3.3.6).

In other words, there is significant scope for conceptual, analytical and empirical elaborations on agency and power in destabilisation processes.

3.3.4 Destabilisation processes, patterns and mechanisms

Destabilisation implies challenges to system stability (see section 3.3.1), is related to different sources of change (see section 3.3.2), and centrally involves actors with strong ties to existing configurations (see section 3.3.3). But at heart, destabilisation is a complex process involving non-linearities, indeterminacies and contingencies. *How to make sense, then, of destabilisation as a process, its generative mechanisms, and variety of possible trajectories and outcomes?*

First, understanding destabilisation as a *process* requires adopting a mode of enquiry that allows describing and explaining *how* and *under which conditions* destabilisation unfolds over time. This implies "understanding both the processes that reproduce durable configurations of social order and those that generate strains or produce events with the capacity to transform social structures" (Clemens 2007: 528), and in what ways the tension between inertial and change forces can evolve. Explaining change in terms of process requires particular attention to (sequences of) events and their enactment:

> Process research is concerned with understanding how things evolve over time and why they evolve in this way…, and process data therefore consist largely

> of stories about what happened and who did what when—that is, events, activities, and choices ordered over time.
>
> *(Langley 1999: 692)*

Certain events in destabilisation sequences may be more influential, while others may be particularly significant because of their location within a sequence or because they activate, orient, accelerate or inhibit key processes. Crises may have an accelerating or orienting effect on destabilisation, while the timely development and legitimation of alternatives may contribute to destabilisation by weakening claims about the need to maintain stability at all costs. Further, while the temporal ordering of relevant destabilising events in sequences and their narrative depiction can produce interesting and relevant stories, they also need to lead to generalisable explanations about the phenomenon at hand and hence come into conversation with theoretical arguments: "process theorization needs to go beyond surface description to penetrate the logic behind observed temporal progressions" (Langley 1999: 694)—following inductive or deductive strategies.

Process tracing offers a useful approach, empirically focused on individual or small-N cases and analytically oriented towards causal inference through the identification of mechanisms as intervening events (Mahoney 2016). Uses of process tracing vary significantly, and can be mobilised both for theory testing or theory development (George and Bennett 2004). In the case of overly complex and overdetermined processes like destabilisation, recourse to "analytical explanation", i.e., a "variety of process-tracing converts a historical narrative into an *analytical* causal explanation couched in explicit theoretical forms" (George and Bennett 2004: 147), appears as a particularly relevant form of process-tracing. The analysis of path dependences, trajectories and branching points along such paths is another useful way forward, provided it does not assume the inevitability of development outcomes (e.g., through consideration of interrupted or resurgent paths) and remains open to counterfactuals.

Second, if process tracing can enable the identification of events-as-mechanisms in individual cases, the comparison of multiple cases can improve knowledge claims and conditional generalisations about a given process, particularly if supported by the development of a typology. Typologies seek the identification of relevant causal mechanisms and pathways that influence the outcomes of a phenomenon by specifying its possible variants as ideal-types within a theoretical space. Again, this may follow an inductive logic (i.e., multiple cases allow the identification of different causal pathways), a deductive logic (i.e., theoretical dimensions inform the space of possible pathways), or an abductive logic (i.e. a combination of both in tentative iterations). The elaboration of a destabilisation typology can hence allow specifying the possible causal pathways that destabilisation processes may follow, with particular attention to conditions and contingent mechanisms. Specifying a variety of potential destabilisation pathways can also guide the selection of appropriate case studies, by maximising the variety of observed types or to search for

outliers. Importantly, while single-site studies have accumulated evidence of a variety of destabilisation patterns, a useful next step for the research community would be to comparatively locate these within a coherent repertoire of possible mechanisms.

Third, the temporality of destabilisation warrants particular attention. Similar to socio-technical transitions, destabilisation typically unfolds over multiple decades (Martínez Arranz 2017), although its duration, speed and pace may vary significantly across cases. In ways analogous to the *development* of socio-technical systems, destabilisation may be subject to acceleration phases which may wrongly convey an impression of overall speed, so determining the overall duration of destabilisation largely depends on "when one counts" (Sovacool 2016). Periodisation, whether calling upon ideal-typical phases of development or the identification of crucial events, appears as a useful but not unproblematic way forward. Identifying *when* destabilisation starts and ends is an analytical question. Further, destabilisation, though imprinted in the popular mind by the importance of singular events (e.g., a coal miners' strike, nuclear disaster, or food crisis), is a cumulative process involving layered temporalities. While tempting to focus only on the most dramatic surface events, those provide "the most distorting and unpredictable lens through which to view reality" (Braudel 1970: 148), and hence require attention to overlapping concomitant temporal processes and nested temporalities (e.g. short term, conjectures, longue durée). Under certain conditions, destabilisation processes might appear as particularly rapid, but in most cases they involve long pre-development phases in which contestation builds up without leading to dramatic struggles, because it is kept at bay or overshadowed by the inertia of incremental system developments. Beneath the highly visible surprises, conflicts and struggles are deep structural tensions, latent disagreements between social groups, and more gradual accumulative processes of problem framing, social mobilisation and political contestation, knowledge and innovation development, the articulation of alternative visions of the future, and so on, which contribute to socio-technical instability.[6] In yet other cases, destabilisation may be entirely uneventful (e.g., gradual erosion or drift) when resulting from a lack of maintenance, under-investment or fatigue.

So, destabilisation processes involve a combination of gradual cumulative change and their activation in particular events, which provide focusing devices around which to *a priori* centre empirical efforts, but require investigation of causal chains. Destabilisation is a social process inscribed in multiple temporalities, including long-term social trends, volatile political and public opinion swings, contingent surprises and accidents, medium-term strategic dependencies, abrupt decision reversals and cyclical fluctuations (Braudel 1970; Burke 2005; Sewell Jr 2005), which are combined in particular sequences of events at specific times and places. Understanding destabilisation as a process hence requires explicit analysis of the conditions under which different causal patterns (e.g., distal, intermediate and proximate causes) may accumulate or align. The specification of propositions about such alignments pathways (e.g., their nature,

articulation and timing) is key to crafting destabilisation typologies with significant explanatory power, notably as it allows making sense of varied observable temporal patterns such as gradual erosion (Shove 2012), accelerated destabilisation (Andersen and Gulbrandsen 2020), turning points (Abbott 1997), downward spirals or perfect storms (Hambrick and D'Aveni 1988; Kungl and Geels 2018), or interruptions and reversals (Haydu 2010; Sillak and Kanger 2020). Theoretical models of destabilisation may also attend to the cumulative character of the process by distinguishing different typical stages and outcomes, linked to propositions about expected observations: early stages of destabilisation may be characterised by low or divergent degrees of pressure that can be easily denied or deflected by regime actors (Geels 2014a; Lockwood et al. 2019); moving to later stages of destabilisation may require an accumulation and alignment of pressures as well as alternative path creation (Turnheim and Geels 2013). Such stages are likely to also reflect changes in the strategic positioning of actors involved—destabilisation may require increasing coherence of contestation forces and lead to increasing divergence within existing regimes. However, progression through such stages is neither predictable nor inevitable, and likely prone to pushback from collectives under threat. Destabilisation may hence lead to differentiated outcomes, including partial destabilisation, full decline, reorientation or re-creation (Turnheim and Geels 2012), but also continuity and persistence (Newig et al. 2019; Wells and Nieuwenhuis 2012; Winskel 2018), i.e., when destabilisation pressures are effectively deflected.

Fourth, destabilisation is tied to processes of stabilisation in multiple ways. Like stabilisation processes, destabilisation involves ongoing tensions between forces of stability and change, which may ebb and flow, but involves an overall trend away from stability. It can be dialogically related to stabilisation in broader transformation dynamics, particularly in the case of substitution patterns wherein the destabilisation of a given entity enables and requires the stabilisation of another and vice-versa.[7] Destabilisation and stabilisation can also be sequentially related, particularly within the processual logics of punctuated equilibrium (Tushman and Anderson 1986) according to which relatively long periods of stability and incremental change are punctuated by shorter turbulent episodes of radical change in which destabilisation can give way to re-stabilisation, and so on. Given that most transition cases, however, do not follow substitution logics, re-stabilisation is likely to occur at a different structuration level: while the delegitimation of DDT (a powerful and toxic pesticide) led to its subsequent ban (hence fully destabilising the substance's value and use chain), it however led to new forms of legitimation of pesticides concomitant to the regulation of their use (Joly et al. 2022). This example illustrates the importance of analytical considerations about *what* is being destabilised, as well as the potential distinction between destabilisation and "exnovation",[8] notably as they tend to operate at different levels of structure. It also illustrates how destabilisation may lead to the reinforcement of existing structures. Newig et al. (2019), focusing on various types of institutional decline and drawing on Streeck and Thelen (2005a),

suggest distinguishing functional change from structural change: 1) adaptation to crises (e.g., technical fixes or enhanced controls) and systemic learning can preserve function and structure, 2) the phase-out of particular substances (e.g., DDT) may alter the structure of underlying institutions but preserve or extend overall function (e.g., pest control) through substitution and adjustments, 3) the repurposing of outdated institutions (e.g., shift from military service to civil service) may be oriented towards new functions without fundamentally altering their structure, and 4) certain institutions may be abolished altogether (structure and function) with or without alternatives. Further, one regime's destabilisation may be tied to another's stabilisation: the stabilisation of a "climate regime" (e.g., the increasing structuration of the problem and solution space related to addressing climate change) is intertwined with the possible destabilisation of a fossil fuels regime.

Though interlinked, stabilisation and destabilisation cannot simply be understood as opposite, reverse or symmetrical processes. Contrasting destabilisation with stabilisation is a useful first step (see Table 3.2), notably as it points towards markers and handles for the evaluation of each process, but it tells us very little about how these unfold. Further, such efforts should be complemented by dedicated conceptual elaboration aimed at explaining and qualifying possible patterns in greater detail.

TABLE 3.2 Contrasting features of socio-technical stabilisation and destabilisation

	Socio-technical stabilisation	*Socio-technical destabilisation*
Processual features	Generative, accumulation, addition	Degenerative, erosion, removal
Structural stability (momentum and inertia)	Increasing: socio-technical embedding in configurations	Decreasing: challenges to parts or entire configurations
Functional stability (purpose and framing)	Oriented towards closure and standardisation: problems meet solutions	Oriented towards opening up: new or unsolved problems, search solutions
Innovation strategies	Focused: Incremental and cumulative system-building (within)	Multiple: radical alternatives (outside) and system transformation (within)
Institutional dynamics	Convergence, relative homogeneity and reproduction	Divergence, disbanding and delegitimation
Politics, controversy and normativity	'evacuated' through relative consensus or hegemony	Tensions and dissensus are central preoccupations and motors of change
Inclusion of relevant social groups	Increasingly selective (outsiders invisibilised)	Increasing visibility of dissenting voices
Infrastructure	Increasingly seamless, reliable, maintained	Increasingly seam-full, failure-prone, eroding

3.3.5 Deliberate, purposeful, intended governance

Within the scope of more pragmatic programmes (Abbott 2004) about destabilisation processes, notably those in search of means of interventions, questions arise concerning whether and how destabilisation can be *purposely* governed (Kivimaa and Kern 2016; Rosenbloom and Rinscheid 2020). Such considerations have been the object of a growing stream of literature under various terminologies, including deliberate destabilisation (Normann 2019; Turnheim and Geels 2012), deliberate decline (Rosenbloom and Rinscheid 2020), phase-out (Andersen and Gulbrandsen 2020; Johnstone and Hielscher 2017; Vögele et al. 2018), exnovation (David 2018; Davidson 2019; Heyen et al. 2017) and innovation through withdrawal (Goulet and Vinck 2017), creative destruction (Kivimaa and Kern 2016) and the governance of discontinuation (Hoffmann et al. 2017; Johnstone and Stirling 2020; Stegmaier et al. 2014).

The governance of socio-technical systems raises several questions. According to Borrás and Edler (2014), key considerations for anyone interested in the governing dynamics of socio-technical change can be appreciated around three pillars: 1) agents and opportunity structures (*Who and what drives change?*), 2) instrumentation (*How is change influenced?*), and 3) legitimacy (*Why is it accepted?*). For Kern (2011), indebted to notions from comparative political economy perspectives (Hall 1993; Hay 2004), ideas, institutions and interests are key dimensions shaping policy and governance processes, which are critical to explaining the tensions between continuity and radical change. Kivimaa and Kern (2016) mobilise three interrelated analytical dimensions of socio-technical change to distinguish policy instruments for "creative destruction" besides "control policies" focusing on changes to 1) regime rules, 2) support for dominant technologies, and 3) networks and actors. Smith et al. (2005: 1507), wary of depictions of policymaking as "coordinating the consensual introduction of elements that are self-evidently required for the smooth operation of a clearly more sustainable innovation system", insist on the importance of considering a variety of contexts and conditions for regime transformation which governance may sustain or alter, but also of attending to the central issues of 1) agency and power, 2) regime structures and membership, 3) uneven and distributed resources, and 4) the performativity of visions and expectations. Building on aforementioned distinctions, the following paragraphs discuss relevant issues arising with the governance of destabilisation.

First, as a social phenomenon, destabilisation is conditioned by the actions and interventions of different social groups—though their agency may be limited and facing important structural determinants. The extent to which destabilisation is purposefully governed varies significantly across cases. Untended destabilisation processes are those involving no *explicit* intention to trigger, slow down, accelerate or orient the difficulties and possible decline experienced by a particular regime. Streeck and Thelen (2005a), in their conceptualisation of institutional change, provide two relevant notions that may apply to cases of untended destabilisation. They define "institutional drift" as processes resulting from the lack of adaptive

maintenance in spite of changing external conditions, which may lead to shrinkage, erosion or atrophy of institutions (e.g., degradation of US health care coverage in the face of new risks). They define "institutional exhaustion" as another archetype of gradual breakdown, largely related to failures to anticipate changing conditions whereby institutions deplete the external conditions on which they rely to operate (e.g., revenue balance for social insurance systems). In both cases, what may appear as inaction in the face of destabilisation may more appropriately be understood as a particular form of intervention: neglectful or self-consuming governance. Such cases, however, tend to be viewed in the transitions literature as "unmanaged" or "spontaneous" (and relatively autonomous) forms (Newig et al. 2019), as opposed to more purposeful forms (Smith et al. 2005), which are underpinned by oriented and coordinated efforts. If purposive transitions are those "which have been deliberately intended and pursued from the outset to reflect an explicit set of societal expectations or interests" (Smith et al. 2005: 1502), purposive destabilisation has been defined as a process influenced by "deliberate political steering" (Newig et al. 2019: 17).[9] In-between these two extremes, a variety of destabilisation governance archetypes may be observable. The following paragraphs explore some relevant dimensions.

Second, destabilisation governance may be approached according to the motives and intentions involved. Leaving aside denial, doubt, and resistive stances that may drive action by incumbents, particularly in the early stages (see section 3.3.3), I suggest distinguishing reactive, active and emancipatory motives for destabilisation governance (see Table 3.3). *Reactive* motives are oriented towards mitigating the possible outcomes of destabilisation and decline, as and after it happens. Related actions include slowing down the contraction of declining industries or practices (e.g., protecting declining domestic fisheries or agriculture), reducing the effects of decline though financial assistance (e.g. bailouts) or extended social provisions (e.g., coal miners' fuel allowances), but also dealing with the lasting structural inequalities produced by decline (e.g., regional social policy, priority education zones), infrastructure decommissioning or socio-technical aftercare[10] (Stegmaier et al. 2014). *Active* motives are oriented towards the discontinuation of undesirable systems, with a more forward-looking orientation. Related actions include mobilisation and interventions seeking to trigger the phase-out of products, substances or systems, but also the anticipation of future transformations through increased preparedness (e.g., reskilling strategies, territorial conversion). *Emancipatory* motives are oriented towards opportunities for transforming existing social contracts that destabilisation (or avoided destabilisation) may afford. Related actions include ring-fencing "strategic" activities and sectors, challenging structural forms of power, oppression and neglected interests, delegitimising systems and activities on moral and ethical grounds (e.g., unsustainability, injustice, inequality, uneven access), and empowering alternative pathways of development. Such motives may present scope for complementarity as well as significant points of tension and contradiction.

TABLE 3.3 Motives for destabilisation governance

Type	*Commitment*
Reactive	Mitigating the possible outcomes of destabilisation and decline, as and after it happens
Active	Anticipating and supporting the discontinuation of undesirable systems
Emancipatory	Transforming existing social contracts

Further, motives for destabilisation governance may also be distinguished according to their core normative orientation (i.e., prescriptions about what is "desirable"). Destabilisation motivated by sustainability, justice or low-carbon objectives can be contrasted with destabilisation motivated by no less normative, but different, priorities (e.g., liberalisation transitions of the 1980s or productivity- and scale-oriented transitions in historic agricultural reforms). Similarly, motives for transitions governance may change depending on the position of actors involved vis-à-vis existing regimes and depending on destabilisation contexts. While incumbent actors are more likely to pursue a general orientation towards preservation, continuity and incrementalism, such orientations may change where and when path-insistence is interpreted as less feasible or tenable. Immediate response to acute crises are more likely to be reactive when those are largely unpredicted and unprepared for (e.g., response to Covid-19 in Europe, as opposed to some East Asian responses actively mobilising SARS precedents, related imagery and preparedness), leading to situations more akin to firefighting (Osterholm and Olshaker 2020), but may shift to more active motivations if underlying problems become more widely understood, particularly if combined with emancipatory orientations for transformative change.

Third, while deliberate destabilisation policy is politically difficult (Stegmaier et al. 2014) and relatively new in the context of sustainability and low-carbon objectives, the repertoire of available instruments is broad and extends well beyond policy interventions (Kivimaa and Kern 2016). Phase-out policy, for instance, is currently the object of much experimentation as well as rediscovery of existing instrumentation, as evidenced by the variety of coal phase-out interventions (Spencer et al. 2018) or "policy for incumbency" more generally (Johnstone et al. 2017). Considering the breadth of available instruments requires distinguishing policy interventions from wider governance means and constituencies, as well as how these may be articulated in policy mixes, layering and sequencing, or in changing governance contexts. I suggest a distinction between direct, indirect, experimental and civic interventions (see Table 3.4). *Direct* destabilisation interventions are relatively conventional forms of policy interventions seeking to contribute to phase-out by introducing control policies and altering frame conditions, such as formulating long-term reduction goals (e.g., zero-carbon, zero-pesticides), introducing restrictions (e.g., bans, regulated use), modulations mechanisms (e.g., incentives and disincentives), removing/dismantling undesirable support structures

and institutions (e.g., fossil fuel subsidies, R&D funding, decommissioning), reorienting resource flows away from existing regimes, and structural reform. Such interventions are rarely effective on their own, because they face oppositional backlash that tend to weaken and delay action (e.g., litigation, loopholes, exemptions, implementation failure) or lead to reversals, are often implemented as macro-level instruments at a high level of granularity (e.g., carbon emissions trading or regulation), unevenly affect certain actors and communities, and can hence generate all sorts of unintended effects (e.g., exacerbating poverty, affecting livelihoods). *Indirect* destabilisation interventions are those oriented towards addressing (legitimate) oppositions to destabilisation processes, increasing the preparedness of affected or vulnerable groups and overturning structural dependencies. They include compensations for losses and stranded assets (e.g., specific industries, social safety net for affected communities), changes in organisational ownership and control (e.g. nationalisation), reskilling and professional training programmes, regional development and labour adjustment programmes, or infrastructure development to support regional conversions. Such interventions, though providing buffers for the disruptive consequences of decline and increasing adaptive preparedness in certain cases, can have limited or perverse effects when not conditioned to transformative or redistributive outcomes (e.g., bailouts with limited obligations), not tailored to the needs of communities involved (e.g., regeneration programmes driving local residents out, reskilling programmes in the absence of employment opportunities), or not combined with the development of emancipatory opportunities and pathways (e.g. decent jobs, accessible public infrastructures, meaningful lifestyle changes). *Experimental* destabilisation interventions are more novel approaches oriented towards anticipating, triggering and navigating destabilisation as transformative opportunity for introducing lasting systemic change, as well as legitimising such objectives. Given that less practical experience exists with such interventions that do not neatly fit within existing policy roles and responsibilities, they require particular dispositions towards trialling new solutions, real-time evaluation and learning, flexible dispositions concerning rules (e.g., exceptions), tolerance for failure (Kuhlmann et al. 2019), and changes in decision-making procedures and representation to limit the power of incumbents (e.g., more participatory processes, co-production). The scope of experimental destabilisation interventions is particularly broad and systemic, and hence involves the combination of instruments (e.g., in policy mixes), while the perimeter of applications is likely to focus on particularly undesirable or vulnerable sectors and regions. Coal-dependent regions currently appear at the forefront of such experiences, owing to the relative societal and policy purchase that transitions away from coal have recently acquired (Spencer et al. 2018), but similar initiatives are likely to arise in the context of agri-food systems (e.g., zero pesticides), mobility (e.g., car-free cities) or manufacturing (e.g., zero plastics, zero waste). Further, relevant historic exemplars with experimental destabilisation interventions are not restricted to sustainability. Potential exemplars include experiences with tobacco and smoking restrictions, drugs and pharmaceuticals, restrictions on agricultural and fishing practices on ethical grounds (e.g., "humane slaughtering", whaling), polycentric cities (as

means to deal with structural trends and challenges arising from concentric, unfair and overspecialised urbanisation patterns) and regional specialisation (e.g., tourism- or knowledge-oriented development in former industrial or agricultural regions). *Civic* destabilisation interventions are those emanating from civil society, social movements and activists. They share a commitment to bringing new problems and issues to the attention of society, mobilising public and political forces around them, and ultimately undermining the continuation of practices and systems seen as undesirable, notably by delegitimising them and promoting alternatives. In terms of strategy, civic interventions may seek to weaken the semantic power and influence of lobby groups and vested interests, develop contesting forms of knowledge and invoke various forms of dissent, but also include material strategies seeking to obstruct or circumvent the normal functioning of socio-technical systems and infrastructures. Interventions vary and may include information campaigns, citizen knowledge and alerts, public protests, peaceful disobedience, boycotts (of products, companies, authorities), consumer opt-out or disconnections, financial divestment (e.g., fossil fuel divestment), the promotion of practices challenging economic paradigms (e.g., degrowth vs capitalist consumerism), as well as civil unrest, production site blockages or asset destruction. Civic interventions are a powerful means of raising attention and mobilising around particularly problematic socio-technical systems and practices.

Fourth, destabilisation governance likely involves a combination of different forms of intervention, different types of actors (policy, civil society, science, industry) and rationales, and their articulation over time. Two notions appear particularly relevant: policy mixes and governance contexts. Approaching destabilisation policy in terms of *policy mixes* enables the identification of complementarities between instruments for a given problem or objective and across policy domains (Rogge and Reichardt 2016), notably in terms of overall coherence, consistency and coordination. Another relevant dimension of policy mixes is their evolution over time (Kivimaa and Kern 2016; Rogge and Reichardt 2016) or issues of

TABLE 3.4 Types of destabilisation governance interventions

Type	*Features*
Direct	Relatively conventional forms of policy interventions seeking to contribute to phase-out by introducing control policies and altering frame conditions
Indirect	Oriented towards addressing oppositions to destabilisation processes, increasing the preparedness of affected or vulnerable groups and overturning structural dependencies
Experimental	Oriented towards anticipating, triggering and navigating destabilisation as transformative opportunity for introducing lasting systemic change, as well as legitimising such objectives
Civic	Emanating from civil society, social movements and activists, they are oriented towards bringing new problems and issues to the attention of society, mobilising public and political forces, and undermining the continuation of practices and systems seen as undesirable

temporal sequencing (Nilsson and Nykvist 2016). While it is too early to say much about the design of destabilisation policy mixes, it is useful to mobilise Streeck and Thelen's (2005a) institutional change typology to qualify possible evolution patterns from current arrangements in terms of their structure- and function-preserving qualities in search of evidence of institutional displacement, layering, drift, conversion or exhaustion. Kivimaa and Kern (2016) suggest that while evidence of policy layering is the most likely pattern, what is really needed for destabilisation policy mixes is a displacement and replacement pattern, notably concerning dominant technologies, key actors and rules.

Approaching interventions in terms of *governance context* broadens the perspective to include non-policy interventions, actors and dynamics, as well enabling conditions for destabilisation governance, i.e., the social, scientific, technical and economic dynamics making political projects of destabilisation possible at a given time and over time. *What are the conditions under which decisive and sustained deliberate destabilisation governance becomes possible, feasible or desirable?* Windows of opportunity for more radical interventions may open up and be seized by change entrepreneurs if problems, proposals and political agendas gain significant traction and become aligned (Kingdon 1984). The dynamic alignment of destabilisation contexts and governance spaces is likely to follow a range of different patterns and is a matter for empirical investigation. For instance, *under which conditions do crises become mobilised as opportunities for the deployment of radical phase-out interventions (as opposed to reinforcement of prevailing arrangements)?*

3.3.6 Vulnerability and politics

This section deals with some of the negative consequences of destabilisation and decline, their linkage to structural problems, and how they might be anticipated and avoided. Indeed, destabilisation raises significant human, social, political and ethical challenges, which may considerably weaken claims of "sustainability"[11] associated with socio-technical transitions if left unattended, and conversely enhance the emancipatory prospects of transition projects if justice, fairness and redistribution are brought centre stage.

Firstly, the destabilisation of socio-technical systems is likely to lead to the decline of certain industries and organisations, the closure of production sites, significant job losses and resulting individual hardships, particularly in communities and regions most dependent on conventional—"unsustainable"—activities. Indeed, by focusing on downfall, closure and abandonment, destabilisation research can usefully support the identification (and anticipation) of potential "losers" of socio-technical transitions. While economic and competitiveness losses in organisations and industries have led to the emergence of "managed decline" arguments and strategies (discussed in sections 3.3.3 and 3.3.5), it is essential to foreground often neglected human and local community perspectives in the process of change[12]—those of "people caught in the cross fire of industrial change" (Cowie and Heathcott 2003: 1). In the context of the British coal phase-out, scholars have pointed towards "the risk of insufficient attention

regarding the broader implications of such discontinuity processes around the impacts on local coal communities and future prospects of the workforce" (Johnstone and Hielscher 2017: 457), by highlighting the uneven impacts that closures have on regional economies, workers and deprived communities. Such concerns are manifest around historically declining activities and livelihoods such as farming or heavy industries, notably given important deindustrialisation and delocalisation trends, for which lived experiences of loss and marginalisation abound and tend to persist well beyond the generation directly exposed to such loss (Strangleman 2017). Further, such experiences take on a new form in the context of environmentally motivated transitions, because of their intentional character—ironically, "deliberate destabilisation" risks not involving much local deliberation[13]—and because of the speed of change called for (Newell and Simms 2020), likely to temporally intensify related challenges. Furthermore, while the material, human and social losses of destabilisation tend to be considered in relation to production systems, sites and jobs, it appears relevant to consider the effects of destabilisation in consumption systems and practices too. For instance, phasing-out certain types of foods deemed unhealthy or environmentally problematic may unfairly affect certain communities over others. Similarly, recent social and political backlashes against the introduction of carbon taxes on petrol (e.g., the Gilets Jaunes movement) illustrate the difficulties of imposing restrictions on daily practices without involving concerned users whose livelihoods may be disproportionately dependent on certain modes of consumption (e.g., car-based mobility in rural or peri-urban communities) in the absence of real alternatives (e.g., affordable and accessible public transport). So, destabilisation raises major social and human concerns, which tend to disproportionately affect communities most *dependent* on existing means of production and consumption. These communities are hence most *exposed* to the effects of destabilisation and *vulnerable* to the potential losses associated with such processes but tend to be less visible and represented in related policy debates.

Second, the structural determinants and impacts of destabilisation are tied to particular places, patterns of dependence, vulnerability and opportunity. Concerning social and human dimensions, communities most exposed and vulnerable to the impacts of destabilisation tend to be those with limited resources (income, opportunities, various forms of capital), relatively strong dependence on established systems as means of production and consumption, limited agency or means of representation concerning related strategic decisions, and relatively weak emancipatory prospects (i.e. social groups with little access to alternatives, mobility or relevant infrastructure). So, the human and social impacts of destabilisation are likely to exacerbate *existing* structural inequalities as well as produce *new* forms of disenfranchisement. The place-based character of such structural inequalities has been problematised within human geography perspectives (e.g., geographic political economy, evolutionary economic geography), notably in the context of deindustrialisation in highly specialised regions.

Deindustrialisation studies tell us two fundamental lessons that may be applicable to destabilisation: rather than an ineluctable process, deindustrialisation is related to 1) a rupture of a long-standing "social contract" between worker unions and

management, and 2) a process of capital mobility whereby productive activities are displaced to other localities, activities or forms of investment (Cowie and Heathcott 2003). Likewise, destabilisation can be seen as a process linked to mobility and displacement of local activities (which highlights the local, relative and uneven nature of destabilisation and its linkage to the stabilisation of other forms of activity, rather than viewing it as an irremediable and homogenous process), and a process involving struggles and fundamental changes in long-standing arrangements between relevant social actors (which highlights the political and social choices involved in handling destabilisation). So, the injustices related to destabilisation processes are likely tied to uneven power relations and access to capital between social groups, uneven ties and dependencies to places, and related tensions.

Concerning regional economies, sectors and industries, evolutionary economic geography has deployed the notions of regional lock-in (see also section 3.3.1) and relatedness to explain different patterns and outcomes of change in mature industry clusters facing significant challenges (Hassink 2010; Martin 2010). The focus on regional lock-in allows distinguishing adjustment patterns from renewal patterns, and explaining them according to the relative strength of political-institutional resistance to restructuring and to regional economic structure (Hassink 2010). The focus on relatedness (of activities, knowledge and skills in regional economies) enables inferences concerning the adaptiveness or resilience of a regional economy to external shocks: related variety of activities within a regional cluster enables specialisation and growth, but may reduce diversity and adaptability to pressures and shocks (for which unrelated variety may prove more versatile) (Balland et al. 2018; Boschma and Frenken 2011). So, a region's economic structure may determine its vulnerability to future challenges, regional lock-in may "explain the structural economic problems some old industrial areas face, as well as the related persistence of regional economic inequalities in some industrialized countries" (Hassink 2010: 454), and against observations of path dependence and "path insistence", it may be possible to engage more constructively with opportunities for regional path creation, path renewal or path development (Hassink et al. 2019). Blažek et al. (2020) have also suggested a need for greater attention to "negative" regional path developments, i.e., those involving the less appealing yet very likely paths of downgrading, contraction or delocalisation.

Geographical political economy perspectives highlight how the embedding of regional economies in wider political and economic relations generate interdependences and overflows with negative consequences. Regional destabilisation and decline can result in structural poverty and unemployment for place and people "left behind" (Rodríguez-Pose 2018), notably when alternatives are limited—stranded assets *and* stranded communities. Even "positive" regional path developments also have their "dark sides" (MacKinnon et al. 2019), indeed dark and bright sides of regional economic development are related in numerous ways (Phelps et al. 2018). New paths can create new forms of exploitation and inequality, because they lead to poor quality jobs (low value, low pay or precarious), dispossession, displacement or inequalities—notably in peripheries and enclaves within

global production networks. Interregional competition can also undermine regional development opportunities in other localities.

Third, there is an inherently political dimension to destabilisation because it raises questions about the representation of the most exposed and vulnerable social groups (i.e., those left behind) and because neglecting to do so can lead to knock-on effects on socio-political stability, collective hopes and the fabric of society.

Policy perspectives on low-carbon transitions tend to emphasise related innovation opportunities and job-creation potential and suggest focusing policy efforts on appropriate jobs and skills development. While sustainability transitions will indeed generate new opportunity pathways for certain sectors, businesses, and forms of employment (e.g., in low-carbon building renovation, renewable energy, or sustainable food production and distribution), they will inevitably also lead to significant job losses in particular sectors and regions (e.g., in extractive, energy-intensive industries or conventional high-input farming). Emerging questions, besides how to re-orient "unsustainable" jobs towards emerging "green" sectors to quantitatively maintain stable employment opportunities, thus concern the scope for 1) avoiding negative and most destructive effects of sustainability transitions on workers and communities historically tied to sectors facing destabilisation, and 2) harnessing transitions as a means to enhance the nature, quality, and decency of employment. Such questions have recently been picked up under the framing of "Just Transitions" (Heffron and Mccauley 2018; Jasanoff 2018; Schwanen 2021; UNRISD 2018), to which trade unions and worker organisations have been actively contributing—though such framing still remains peripheral to mainstream policy concerns (Steward 2015). Workers—unionised or not—though perhaps the largest, most vulnerable and exposed social group to the destructive impacts of destabilisation, remain largely invisibilised in related political debates and policy decisions. A worker perspective is however of central importance if we consider that the destabilisation of industries and organisations can lead to a rupture of the social contract between workers and management, that workers have legitimate concerns about how destabilisation is handled, and that worker intelligence about industrial change contributes to creative solutions. Relevant analytical entry points include the role of workers and trade unions 1) in the production of political discourse and framings of destabilisation, 2) in the crafting of strategic responses to destabilisation, and 3) as mediating forces in destabilisation processes.

The unequal impact of destabilisation on particular communities is also likely to exacerbate political tensions and fuel political discourses capitalising on forms of injustice. Destabilisation and industrial decline can generate material and symbolic grievances, which populist politics mobilises through place-based narratives (Lizotte 2019). The impact of globalisation, automation, and the weakening of trade union representation of manufacturing workers have contributed to the recent political success of right-wing populist (RWP) parties, with "particular appeal amongst [groups commonly referred to as] the 'losers of modernisation' [or] the 'left behind'" (Lockwood 2018: 718). While the electoral appeal of RWPs is by no

means restricted to industrial hinterlands, it is in such places that the more evident link with destabilisation can be observed:

> The places that don't matter are becoming tired of being told that they don't matter and are exercising a subtle revenge. They are voting down or threatening to vote down a system they perceive has quelled their potential and driven them down a road in which the future offers no opportunities, no jobs and no hope (Gros 2016; Rodrik 2017). It is as if the declining agricultural areas and rustbelts the world over have had enough of being patronised and have said, rightly or wrongly, that enough is enough: if we are being told that we no longer matter and that we are going down, the whole ship will sink with us.
>
> *(Rodríguez-Pose 2018: 199)*

The rise of global environmental issues as drivers of industry destabilisation have become a new element in this picture, most visible around the climate issue and resulting pressures exerted on high-carbon jobs. Indeed, climate scepticism has become a staple of RWP party discourse, which may be explained through structural arguments related to vulnerability and protection (e.g., hostility to climate policies seen as hitting workers and marginalised communities the hardest) or ideological ones related to anti-establishment and political distrust (e.g., hostility to climate policies seen as the product of a cosmopolitan elite) (Kulin et al. 2021; Lockwood 2018). Regardless, ensuing political discontent and tension around climate policies and "job-killing" arguments are a boon for carbon-intensive industries seeking to lobby more stringent targets and restrictions (Vona 2019).

While this arena currently seems largely captured by populist resentment and "places expressing their fear and outrage about potential futures in which they are economically and culturally irrelevant" (Lizotte 2019: 140), there are also reasons to believe that related conflicts and struggle about socio-environmental justice can spur more hopeful forms of political engagement with destabilisation futures.

3.4 Discussion: Conceptual propositions

This section builds on the six core notions introduced in section 3.2 and seeks to translate them into conceptual propositions. Together, these provide a synthetic reflection of where research debates stand and some pointers for further conceptual developments.

P1: Destabilisation can be seen as a form of challenge, reversal or erosion, of sources of socio-technical stability (lock-ins). Following a distinction between structural and enacted forms of stability, destabilisation involves 1) the breakdown of existing structural patterns, 2) divergence from prevailing action patterns, including a more active mobilisation of resistive power.

P2: Destabilisation is likely to result from a combination of multiple and mutable sources of change. Sources of change may vary in terms of

dimensions, intensities, scope or kinds of causation. The intensity of individual and combined sources of change is likely to change over time and, if sustained, may lead to escalating destabilisation pressures. Destabilisation patterns may be distinguished according to the configuration of pressure fronts and their evolution over time.

P3: Incumbent actors are central actors of destabilisation with major stakes in and resources for maintaining prevailing configurations. Incumbency is related to important power and resource asymmetries that tend to reinforce stability tacitly (through reproduction of rules, practices and advantages) and actively (strategic moves to resist destabilisation). However, incumbency is also a plural and potentially transient kind of attachment. Other frontline actors of destabilisation processes include those invested in challenging forms of incumbency and vulnerable groups.

P4: Destabilisation is a non-linear, indeterminate and contingent process calling for the analysis of causal mechanisms and the conditions of their activation. A process approach to destabilisation should consider how sequences of events and particular conditions can activate causal mechanisms. The development of a destabilisation typology, specifying causal pathways, is a useful way forward, particularly if it is combined with a comparative approach oriented towards the exploration of a variety of pathways empirically. The temporality of destabilisation processes needs to be deconstructed, namely to disentangle punctual crises from more continuous stresses and to make sense of a variety of temporal profiles. Critically exploring the linkages between destabilisation and stabilisation is a useful avenue for theoretical development.

P5: The deliberate destabilisation of undesirable socio-technical regimes appears as an emerging, yet politically thorny, horizon for governance. It raises important questions related to 1) limits to agency and coordination vis-à-vis destabilisation processes and their governance; 2) a broad array of (potentially countervailing) motives for destabilisation governance with important implications for what is to be governed and how; 3) a variety of governance instruments extending beyond the conventional remit of innovation policy; 4) the need for thinking through combinations of policy instruments (policy mixes, policy sequencing, policy layering) and the types of governance contexts that may constitute destabilisation as a legitimate object of governance.

P6: Destabilisation and phase-out have human, social and political implications, which are exacerbated by uneven patterns of dependence, exposure and vulnerabilities. While such implications are likely to become more visible as destabilisation pressures materialise, they need to be foregrounded and anticipated. Place-based losses are likely to exacerbate existing structural inequalities as well as produce new forms of disenfranchisement. Destabilisation research has much to gain from engaging with place-based accounts of vulnerability, dependence and opportunity. Destabilisation is inherently political, raising issues of political representation and expressions of political discontent.

3.5 Conclusion: Emerging and unanswered problems

To conclude, I would like to evoke several unresolved issues and emerging puzzles, as we take a sidestep to engage with the flipsides, the dark sides, the losses and less hopeful aspects of socio-technical transitions. These are what I see as crucial next steps for destabilisation research: my wish list for a collective and distributed research programme.

Elaborating typologies of destabilisation pathways. Typologies of transitions pathways have assumed a central role in transitions studies, as a heuristic to make sense of developments in historical cases and to shed light on transitions in the making. Taking destabilisation seriously as a process opens the way for similar typological development. Typologies of destabilisation pathways should be oriented towards the exploration of a variety of possible processes and outcomes, enable pattern recognition in cases, and specify key degenerative mechanisms. This chapter has offered a number of relevant dimensions that such typological work may foreground (see section 3.3.4).

Harnessing and expanding empirical variety. Destabilisation research needs to supplement rich single-site case studies with ways to draw comparatively on the growing number of existing cases. To some extent, such work is underway, but it may largely benefit from the specification of destabilisation pathways. Furthermore, it appears important that the comparison of destabilisation patterns extends transversally across sectors, contexts and time periods. A shift towards more systematic comparisons also raises issues about the appropriate unit of analysis and implies trade-offs with deeper engagement with the various scales and sites of destabilisation. So, systematic comparison should not be a substitute for single case studies, but rather go alongside a deep engagement with non-standard cases that can challenge existing concepts and frames.

Dealing critically with shocks and temporality. Shocks and crises play a central role in imaginaries, discourse and research related to destabilisation. Destabilisation and breakdown are often ascribed or confined to exceptional circumstances, disruptions and external shocks challenging the otherwise normal operation of systems. Sections 3.3.2 and 3.3.4 have however demonstrated how destabilisation involves multiple and mutable sources of change that may combine in a variety of patterns, ranging from the dramatic to the more gradual or seemingly uneventful. It therefore appears important to situate crises in longer developmental sequences, by attending to what precedes and what may follow crises and the particular circumstances that may lead crises to activate or enable fundamental reconfigurations (crisis/transformation) and those that may lead crises to reinforce prevailing logics and dynamics (crisis/preservation). Section 3.3.5 has further underlined a very fruitful distinction between the discontinuation of governance (in exceptional times) and the governance of discontinuation (Stegmaier et al. 2014), which is an invitation to critically reflect on tensions between preservation and transformation rationales in the face of crises.

Dealing with uncertainty, anticipation and imagination. Destabilisation is an inherently uncertain and unpredictable process. That being said, taking the symmetry argument seriously requires engaging with the types of futures that a

destabilisation focus may help envision. An obvious motive is that destabilisation scenarios may be a powerful tool to anticipate, and so possibly avoid, some of the direr consequences of destabilisation evoked in section 3.3.6. For this purpose, destabilisation research needs to engage more with modelling and other types of scenario techniques. Destabilisation futures are not necessarily hopeful and may be inhabited by more monsters than their Promethean counterparts, but there are possibly also joyous and enchanting aspects to future destabilisation, withdrawals and reductions waiting to be uncovered and engaged with. Living with less, without or in the ruins may also have its bright sides—or simply be necessary. Serious engagement with destabilisation imaginaries—dark and bright—appears as a crucial endeavour.

Dealing with vulnerability, justice and politics. Destabilisation comes with significant and lasting negative consequences on industries, regions, communities and individuals. To be sure, destabilisation is becoming a very current issue in the context of sustainability transitions, because an innovation-only approach is proving its limits to enable system-wide reconfigurations and because as sustainability innovations overflow out of their niches they are generating new forms of unintended consequences, backlash or resistance from incumbent actors. Transitions studies has always highlighted the role of struggles, but this new phase for transitions (Markard 2018; Turnheim et al. 2018) may be characterised by qualitatively and quantitatively different processes, notably ones in which struggles and politics take centre stage. By proposing a conceptual side-step, destabilisation research affords new ways of thinking about forms of dependence to existing systems, vulnerabilities to change, and the kinds of politics that emerge from situations of impending loss and marginalisation. The just transitions framing is one way forward (Jasanoff 2018), as is thinking through the emancipatory prospects of transitions (Stirling 2015), or thinking more seriously about the social determinants and implications of loss (Elliott 2018).

Dealing with expertise and knowledge. The way it has been framed here, destabilisation research involves an epistemological wager. Shifting the gaze to the existing and its challenges is already delivering significant insights as evidenced by the richness of existing conceptual elaborations (see section 3.2) and promises to bring STS traditions to new ground and debates. As destabilisation research and practice moves forward, it will no doubt spring up new matters of fact (what is destabilisation?) and matters of concern (how should destabilisation be handled?). One yet unaddressed question concerns what this new focus on destabilisation will do to knowledge communities and forms of expertise. Destabilisation bears promises of re-invigorating certain forms of knowledge and expertise around new questions as well as possibly destabilising epistemic communities currently less well equipped to think through its problems.

Notes

1 Indeed, in practice, there are very few historical examples of total decline of material or socio-technical systems, which instead tend to lose their centrality and significance as prime engines of socio-technical evolution.
2 Undesirability can be predicated upon various motivations, including environmental, aesthetic, cultural, economic arguments, and always a matter of perspective.

3 It is worth noting that practice bans usually take the form of restrictions on the modalities and locations of allowed use. The notion of perimeter (of use, of ban) hence appears relevant.
4 It is useful to distinguish between different forms of causation. Given the path dependent and contingent nature of socio-technical processes, *process theory* approaches are likely to be more useful than *variance-based* approaches, because they attend to the multiple and mutable causes involved in developmental process and event chains rather than attributing a specific outcome or event (e.g. the closure of a firm, the toppling of a political regime) to a set of variables via immutable forms of causation. Consequently, process tracing, event-sequence analysis and narrative analysis are relevant strategies to uncover the processes, contexts and conditions that can explain destabilisation and its outcomes (Smith et al. 2005; Yazar et al. 2020).
5 Stirling's analysis underscores the importance of interpretive schemes and heuristics as determining the style of action mobilised, with for example shock-interpretations tending towards conservative responses and stress-interpretations towards more radical changes in the underlying conditions.
6 In other words, and following a distinction between causal mechanisms according to the amount of energy (or pressure) they require posited by Bunge (1997), destabilisation may involve a combination of Type I causation (involving energy transfer) and Type II causation (wherein a very small cause may *trigger* a disproportionate effect). Type II causation hinges upon 1) triggering mechanisms or events, and 2) latent system instability.
7 Such metamorphic analogies can be found in the work of Joseph Schumpeter on the relationship of "gales of creative destruction" wherein industrial mutations involve the breakdown of industrial structures to create new ones—a perspective that has been heavily criticised for its pro-innovation bias (Joly 2019).
8 "Exnovation" (David 2017) or "innovation through withdrawal" (Goulet and Vinck 2017), initially developed as a principle for managing innovation within firms (Kimberly 1981) whereby organisations should devote more attention to divesting themselves of or discarding old innovations to make space for new ones, has become increasingly popular in debates about the deliberate phase-out of undesirable innovations (Davidson 2019; Heyen et al. 2017). While the focus tends to be on the removal of particular technologies or practices, rather than underlying systems and industries, it is pragmatically oriented towards the identification of particularly problematic, vulnerable or changeable elements with the intent to induce wider changes (Newig et al. 2019).
9 Stegmaier et al. (2014), focusing on *discontinuation as a purposeful action sui generis*, suggest another useful distinction between *enacted discontinuation*, which consists in setting change in motion, and *emergent discontinuation*, which consists in seizing prevailing developments of change.
10 Indeed, "abandoned socio-technical systems do not vanish completely and some continued governance effort is necessary long after their exit" (Stegmaier et al. 2014: 121–122). This raises the specific problem of "governing socio-technical aftercare", seeking to "control the loose ends of 'undead' regime and system parts" following decisions to phase-out, which may include dealing "legally, politically and technically" with remaining stocks and artefacts.
11 Notably by restricting them to environmental benefits, or by losing sight of distributive outcomes.
12 On this particular point, see Andy Stirling's advocacy of a "worm-eye" view on transition, focused on human experience and practice, as opposed to the more common "eagle-eye" view, focused on top-down management and governance (Stirling 2019).
13 I am indebted to Marc Barbier for intransigently pointing this out.

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