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Positive Tipping Points Towards Sustainability

Understanding the Conditions and Strategies for Fast Decarbonization in Regions

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Foreword

This volume takes up the necessary task of analyzing the forces that help bring about transformative change in carbon-intensive regions. In doing so, this collection addresses the key challenge of the need to better integrate diverse contributions from varied social sciences as part of navigating transformation pathways and sustainability solutions. This is a vital challenge because social-ecological futures are complex, unruly, and only partly predictable based on current trends and path dependencies. If we over-rely on a narrow set of instruments or single perspectives, we are more likely to pursue sustainability solutions that have unintended—and often harmful—social side effects or which have difficulty finding community buy-in. As this volume illustrates, creating spaces for dialogue across a broader range of disciplinary contributions can help us to better feel our way forward in the half-light of current trends and predictions toward meaningful and just social-ecological transformations.

A musical metaphor may be appropriate here: polyvocality, or music consisting of many voices. Whereas monovocality involves a solo voice that determines the melody—as when future pathways are envisioned from the narrow confines of a singular discipline—polyvocality embraces the potential of multiple voices to create harmonies and intersecting melodic lines or rhythms to create richer and more complex musical forms. A polyvocal approach to interdisciplinary assumes that increasing the range of players and perspectives adds value to the collective project of sustainability transformations. This is particularly relevant in trying to improve our social science understanding of the complex concept of positive tipping points, as this concept is often associated with the promise of creating the enabling conditions for accelerating deliberate sustainability transformations.

This notion of polyvocal interdisciplinarity is well aligned with the TIPPING+ project emphasis on transformative narratives as cultural drivers of positive tipping points for two reasons. First, because successful large structural and qualitative changes toward sustainability will need to translate across multiple political and social scales, from the local and regional to the national and global. Second, because in talking about positive tipping points we must repeatedly ask the question "positive for whom" to ensure that the benefits of positive tipping points are diffused throughout communities and across generations, while potential negative social side effects are adequately understood and mitigated.

Polyvocal interdisciplinarity is better suited to grapple with the complex issues of multiscalar governance and social equity and inclusion that are inherent to social-ecological transformations. There is a caveat, though. The shift from monovocality to polyvocality brings a valuable expansion of perspectives and instruments to our sustainability dilemmas. However, it also raises challenges of increasing complexity, as well as reconciling sometimes divergent or opposing viewpoints when a full consensus on solutions may be unachievable. It is worth pausing to acknowledge that increasing complexity will likely increase the time and costs of working through sustainability challenges, and so may be a harder sell for those who are guided by logics of maximum speed and efficiency.

In this period of cascading ecological crises—climate change, biodiversity, ocean health—it is imperative to work with the full suite of instruments for sustainability transformations, while being aware of their respective strengths and limitations. Polyvocal interdisciplinarity is well suited to identify a broad suite of possibilities for social, cultural, technological, economic, and political positive tipping points. This book serves as a proof of concept of the benefits of polyvocal interdisciplinarity. As is demonstrated by the rich chorus contained herein, this approach deserves to be further taken up and expanded as we collectively compose our way toward socially equitable sustainability transformations.

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As editors of this Book, we do hope that it will contribute to understanding positive tipping points toward a sustainable future.

Introduction

When one more modest alteration, action, or event triggers a self-propelling process of substantial qualitative change in a system, we say that the system has crossed a “tipping point.” It is important to note that tipping points are never the result of a single event, individual action, or policy intervention, but rather the result of several smaller events, trends, and shifting conditions that add up to something larger. Because these qualitative shifts can happen on a variety of scales and in a wide range of systems, identifying and characterizing tipping points requires taking into account the researcher's or practitioner's perspectives when deciding on a frame of reference, analytic approach, or normative criterion.

To better understand and explore policy consequences of deliberate rapid decarbonization processes in Carbon & Coal Intensive Regions (CCIRs), the European Commission-funded TIPPING+ project has investigated the crucial notion of tipping points. Using the insights of over 20 case studies in Europe and elsewhere, the project team has identified the types of dynamics, enabling conditions, and narratives leading to just regional transitions and systemic transformations across different sectors and scales.

TIPPING+'s overarching understanding is that rapid just energy transitions in CCIRs face obstacles beyond those specific to making the switch. To create the kind of just societies we envision (e.g., more socially just, open, and climate resilience-oriented), it is crucial to have a firm grasp on how to steer full-scale societal transformations involving multiple socio-economic and cultural dimensions and profound changes in governance mechanisms, individual capacities, economic arrangements, and collective visions. This Special Edition explores and brings to the fore the discrepancies between narratives and policies that focus on transition points within certain industries and those that focus on cross-sectoral and systemic changes.

Organization of the Book

The book's first section focuses on theoretical and interdisciplinary approaches to tipping points. The second section includes eight empirical case studies from around the world. The book ends with an outlook and future research challenges, acknowledging that although we might never be able to anticipate whether or when positive tipping points will happen, we can, however, create enabling conditions for their emergence.

The theoretical and interdisciplinary approaches to tipping points part opens with an introduction by **J. David Tàbara**, explaining the research background and methodological developments over two decades of interdisciplinary research in sustainable development that led to the TIPPING+ project proposal and its funding by the European Commission. The goal of this project was to further understand how coal and carbon-intensive regions can undergo rapid, sustainable transformations, using the boundary concept of tipping points from several social science and interdisciplinary viewpoints. The introduction also highlights the conceptual and methodological ideas in the project and emphasizes the importance of considering different ways of knowing and understanding fairness and justice as crucial drivers and outcomes in positive tipping points processes.

Sander van der Leeuw continues by clarifying the concept of tipping points using systems and anthropology perspectives and defines them as those moments in a system's trajectory where further evolution "as is" is not possible and structural change is needed and can be enabled by adopting fundamentally different dynamics, different cognitive perspectives and considering fundamentally different worldviews. Tipping points here are understood as the moments at which humans create the illusion of stability. Aspects of human cognition and decision-making, agents' collaboration, collective meaning, and narrative creation are crucial to understand processes of structural systemic change and permanence.

Mauro Sarrica *et al.*, using a social psychology approach, explore how tipping points relate to well-known concepts like "Insights and dynamics of field forces," "Cognitive dissonance," "Grievance," "Bounded rationality," "Coping," and "Socio-dynamical approaches to social representations." Noting the sharp definition provided by O'Brien, they observe that tipping points constitute transformations in perception, the moments in which "noise becomes signal" and therefore also become potential meaning for deliberate action. The authors emphasize the progress made in understanding tipping points through cognitive, socioecological, and systemic models. They describe and explain the processes that either encourage or impede significant changes, both in how they are perceived and how they happen.

Per Olsson & Michele-Lee Moore explore the connection between tipping points and transformative change underlying the importance of the resilience approach. They emphasize that resilience science helps us to better understand the dynamics of complex adaptative systems, their interdependence, and how they can adapt, persist, or undergo significant change when faced with uncertainty. The authors argue that "transformation" involves intentionally, distributed agency, and the deep restructuring of a system's configuration and its relationships. They clarify that "transformation research" is a broader field beyond identifying tipping points and emphasize the need to consider the shared roles of many actors and relationships, as well as the uncertainties that arise in response to shocks and disturbances surrounding tipping points.

Jennifer Hodbod *et al.* argue that the literature lacks compelling real-world examples of social tipping points due to the difficulty to identify them through data-driven methods. Accordingly, they provide a methodological framework and a series of criteria for identifying social tipping processes in case studies of social-ecological systems. The framework proposed relies on four critical elements: the presence of multiple stable states, self-reinforcing feedback loops, abrupt changes, and limited reversibility. They also outline seven principles that can be used as a step-by-step guide for analyzing social tipping points in any social-ecological system, along with highlighting the major difficulties that researchers might face when applying these principles.

Olha Lukash & Vasyl Namoniuk provide an assessment of Ukraine's emissions' profile before the 2022 war, primarily driven by fossil fuel-heavy industries and power generation. They also examine the impact of the war on the country's energy sector, which suffered damage, reduced industrial activity, and led to emissions due to fires and environmental loss. They suggest that reconstruction after the war offers a chance to rebuild in a more sustainable way. However, this necessitates a balance between immediate energy security needs and long-term goals, through the expansion of renewable energy sources, improving energy efficiency and interconnections, and aligning with European standards.

Diana Mangalagiu *et al.* introduce the interdisciplinary perspective used to investigate the transition process and to collect empirical evidence of tipping points in the case studies analyzed in TIPPING+. The interdisciplinary lens considers different modes of thought, frameworks, and multiple perspectives and interests from diverse stakeholders, a systems' understanding, and different culture considerations across the CCIRs. Notably, it combines insights from human geography, social psychology, regional socio-technical systems, and political economy perspectives on the various phases of low-carbon transitions and the justice component of the transitions. Subsequently, the authors provide an overview of how the eight CCIRs case study chapters in the book have applied the proposed interdisciplinary perspective.

Daniel Delatin Rodrigues & Marco Grasso examine the destabilization practices that eventually would lead to social tipping processes using a framework based on the analysis of agents of transformation (ATs) applied to the city of Civitavecchia in Italy and its transitioning to renewable energy sources. They explore how the concept of social tipping processes using such policy science analysis approach can further help understand and guide the transformations of the local socio-energy systems in Civitavecchia. They outline key directions toward achieving a sustainable future, based on the principles of social tipping processes that are being put into practice in this particular case study.

Anna Sveinsdóttir & **Brigt Dale** investigate the two-decade-long conflict over oil extraction in Lofoten, Norway, and the subsequent adoption of an alternative development trajectory to move away from oil and gas projects in the area. Their study aims to gain a deeper understanding of how regions heavily involved in carbon-intensive industries can quickly transition to decarbonization, to discover how different visions of the future become influential in places like Norway, which have traditionally supported carbon-intensive industries, and to examine how multiple tipping points events eventually influenced the decision to shift away from oil and gas development in Lofoten.

Francesc Cots *et al.* investigate how people's identities and their outlook for the future can either hold back or promote the shift of coal and carbon-intensive regions toward cleaner energy and sustainable development pathways. They stress that understanding how local residents perceive uncertainties about the future and examining views on inequality and relative deprivation are essential for creating effective governance arrangements and learning feedback systems, which are needed for swift transitions in energy and society. They show the shift from previous resistant place-based identities to potential transformative *project identities* with the symbolic effects created by the demolition of the cooling tower of the coal power plant in Andorra, in Spain.

Cynthia Juwita Ismail *et al.* use Integrated Sustainability Assessment (ISA) in combination with participatory narrative analysis, social-ecological network analysis, and Q-methodology to study how transformation is happening in the Banten and Bali coal and carbon-intensive regions in Indonesia. Their research tracks the links between stories and visions of transformation and the way these affect social networks finding out two distinct narratives on energy transformation, both with different implications for policy. They reckon that these narratives and network dynamics can serve as early or *anticipatory signals for transformation*. Ultimately, they indicate that mapping out and exploring different visions of sustainability on a same system of reference can encourage diverse social networks to learn from each other and create multiple strategies for transformation.

Elena Apostoli Cappello presents an ethnographic analysis focused on the small island community of San Pietro, in Italy. The goal is to investigate how local residents perceive and influence decision-making processes. This examination that also uses the notion of "Energyscapes," that often limits individuals and community perceptions of reality to their more immediate contexts, helps to explore their attitudes, willingness, and capacities to participate in large transformative and decarbonization process. Such cognitive and symbolic resources and relationships affect their capacity to engage in energy transformation discussions and processes at regional, national, and European Union levels, and how such transformations in energy practices are perceived as fair or worth being involved in.

Siri Veland *et al.* delve into energy changes happening in the Arctic, using the example of discontinuing coal mining in Svalbard, the last one operating in Norway. They explain that international agreements and discussions about sustainable transitions, along with fluctuating coal prices, have sparked different narratives about the future of the region, including adopting low-carbon practices for the local economy and finding alternative energy sources for people living on Svalbard. They examine these narratives by analyzing how demographic and socio-economic changes over the past two decades influence these energy-related developments and report systems where tipping points have been observed or remain to be observed.

Anne-Merrild Hansen & J. David Tàbara underline the policy and factual contradiction of narratives postulating for keeping the vast fossil fuel reserves of Greenland in the ground, arguably one of the most efficient ways to avoid a global climate negative tipping point, with the need to further extract new materials resources needed for a global transition toward energy decarbonization. The authors argue that the relatively unnoticed and small decision by the Inuit Government to halt the exploration of oil reserves, while having potentially large beneficial consequences for humanity, also faces difficult ethical dilemmas as those that have to with reconciling Earth System justice with local resource justice, cultural traditions and local governance arrangements as those that do not allow to own land privately across generations.

Jan Frankowski *et al.* investigate whether carbon taxation can be considered a tipping intervention for fast technological innovation and infrastructure development in coal and carbon-intensive regions, and what are its effects on the sectoral structure of the economy, and on key macroeconomic indicators such as GDP and unemployment. They use energy modeling to perform the assessment for two coal and carbon-intensive regions in Poland and Greece. Their conclusion is that it's more practical to view carbon tax as one of many tools in a broader toolkit for change. It should be part of a coordinated set of interventions aligned with a comprehensive transformation plan rather than being relied upon as the sole means to predict or trigger future tipping points.

Finally, a further literature review and outlook is provided by **J. David Tàbara *et al.*** mentioning that while the concept of social-ecological tipping points (SETPs) is still in need of further operationalization as a way to mark significant changes in regions transitioning toward sustainability, it is possible however to identify three main research challenges for transdisciplinary research and its implementation in their efforts to support regional transformative sustainability changes. These include: (1) being much more open to contributions from diverse social sciences (2) designing transdisciplinary processes able to represent and support transformative qualitative changes and capacities based on diverse ontologies, methodologies, and normative criteria, for which a reflection on researchers' positionality is needed, and (3) supporting the enabling social-ecological conditions that eventually can lead to positive structural changes through multiple deliberate tipping-oriented interventions.

Contents

About the Editors

David Tàbara is an independent researcher associated with the Global Climate Forum and with the Autonomous University of Barcelona and holds over 25 years' experience in international interdisciplinary research on knowledge integration for sustainability. He is a member of the Earth Commission Working Group on Transformations of the Global Commons Alliance and was appointed member of the EU Mission Assembly on Climate Adaptation and Social Transformation for the EU Research and Innovation Framework Programme—Horizon Europe. With over 100 scientific publications, his research interest has focused on socio-environmental sciences and participatory knowledge integration concepts and methods, with particular attention to questions of public perception, social learning, communication, and public engagement for sustainability. He contributed to the first book on *Public Participation in Sustainability Science* (CUP 2003) and his recent involvement in EU research transformations-oriented projects include GREEN-WIN, IMPRESSIONS, TIPPING+ (as P.I) and TRANSPATH. Together with Diego Galafassi, he was convenor of the Transformations 2021 Online Conference on *Enabling Positive Tipping Points in times of Uncertainty* held during the pandemic.

Alexandros Flamos is Full Professor at the University of Piraeus (UNIPI) and Director of the Technoeconomics of Energy Systems Laboratory (TEESlab) of UNIPI. He has a Degree on Electrical and Computer Engineering and a PhD in the area of Decision Support Systems (DSS) applied in energy and environmental policy and planning. He teaches Engineering Economics, Energy Management, Renewable Energy Sources Utilization & Technoeconomics of Energy Systems at graduate and post graduate level at UNIPI and the National Technical University of Athens (NTUA). He has over 25 years of working experience in the areas of DSS, Energy Management & Planning and energy modeling and their applications for analyzing energy policy scenarios, intra- and cross-sectoral interactions of energy and climate policies, security of energy supply, business models, and energy pricing competitiveness. He has held the position of scientific coordinator/senior researcher in more than 50 European Commission (EC)-funded projects (EC R&D FP5, FP6, FP7, H2020, Horizon Europe, IEE, etc.) related to energy systems management, appraisal, and planning. He has also worked as consultant in projects funded by international donors (e.g., the European Investment Bank and EuropeAid). He has significant experience working as Editor in Chief, Guest Editor, and Editorial Board for scientific journals. He also has published more than 150 papers in high impact international scientific Journals (peer reviewed) and international conferences and has been an invited speaker and moderator at major energy policy events (MENAREC, Euro-Asia meetings, EU-GCC, EUSEW etc.).

Diana Mangalagiu is Professor at Neoma Business School, France and Associate Fellow at Saïd Business School, University of Oxford, United Kingdom. She has a dual background, in natural sciences (Ph.D. Artificial Intelligence, Ecole Polytechnique, MSc Physics) and social sciences (MSc Sociology, MSc Management). She has over two decades of research, teaching and advising experience in sustainability, long-term planning, risk governance and articulation of environmental and economic policies in corporate and public policy settings, addressed through modelling, stakeholder-based inquiry and foresight approaches. She authored numerous scientific articles and books in fundamental and applied areas and has extensive experience working as Guest Editor for scientific journals. Her recent involvement in EU research projects include GREEN-WIN, IMPRESSIONS, and TIPPING+. She co-founded the Initiative for Science, Society and Policy Dialogue, co-chaired the Sixth Global Environment Outlook Assessment for the pan-European region for the United Nations Environment Programme, is a Coordinating Lead Author of the IPBES Nexus Assessment, a Member of the High-level Steering Group of the International Science Council, and a scientific board member of the Global Climate Forum. She leads and participates in advisory, research, and development projects with national and regional governments, companies, the World Bank, OECD, European Space Agency, and United Nations agencies.

Serafeim Michas is a research associate at the Technoeconomics of Energy Systems Laboratory (TEESlab) at the University of Piraeus (UNIPI). He has a M.Sc. degree on Mechanical Engineering from the National Technical University of Athens (NTUA). He teaches energy modelling at UNIPI. He has 7 years of research experience acquired through his participation in 6 European and national funded projects. His expertise is in the modeling of energy systems, the exploration of decarbonization pathways, the analysis of the socio-economic implications of energy transitions, and decision support for the assessment of policy measures' effectiveness under contextual uncertainties. He has also published 5 papers in peer-reviewed international scientific journals, and his work has been accepted for presentation at various international scientific conferences.

The TIPPING+ Project Journey

J. David Tàbara

Abstract This chapter introduces and provides the research background of the several contributions of this book. It does so first by briefly reviewing the previous conceptual developments that over the course of two decades eventually led to the EU-funded project TIPPING+. The goal of the project was to improve our understanding of the enabling conditions and complex processes for fast structural sustainable transformations in coal and carbon intensive regions (CCIRs) using the notion of *positive tipping points* as a boundary concept able to bring together the insights of various social science and interdisciplinary perspectives. The main challenge facing these regions is understood not only as sectoral energy transitioning challenge; but the extent to which multiple socio-economic, political and cultural dimensions for full-systems transformations are taken into account. Second, it presents some of the conceptual and methodological proposals generated by the project and argues for ontological and epistemological diversity and to understand equity and justice as a key drivers and outcomes of positive tipping points. As a research journey, however, the TIPPING+ project did not search for a destination. Instead, it looked for a point of departure, for an opportunity space in which different disciplines, researchers and interests could jointly develop their own ideas and start their own new research ventures.

Keywords The TIPPING+ project · Tipping points · Coal and carbon intensive regions · Sustainability transformations · Earth System Justice

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1 Introduction

The TIPPING+ project[1] was a 3-and-a-half-year EU project (2020–2023) that emerged from the identification of the specific unmet research need to address tipping points from a interdisciplinary social science approach. The theoretical and operational background of the TIPPING+ proposal was based on two decades of previous EU research efforts and in particular the MATTISSE, ADAM, GSDP, GREEN-WIN and IMPRESIONS projects.[2] In all these interdisciplinary efforts , the exploration of transformative visions and narratives played a key role as it was assumed that deliberate systems' transformations most often require, in the first place, alternative ways of framing socio-political, biophysical and economic realities. In particular, and during the MATISSE and ADAM projects, the four-step transition methodology of *scoping, visioning, experimenting, and learning* was further developed and then made operational for dealing with climate challenges in the form of a transformative Policy Appraisal Framework (PAF; Weaver et al., 2006, Fig. 1). It was then, from those discussions, that the idea of *Integrated Climate Governance* emerged with the explicit goal to *support agents' transformations for sustainable development* (Tàbara, 2011):

Visioning was therefore considered of central importance in transformations-oriented research. Consequently, within the GREEN-WIN project, a global dialogue was carried out bringing in empirical cases of win-win strategies at different levels of action (Jäger et al., 2018; Omann et al., 2019). These ranged from the assessment of micro-solutions to address energy poverty in rural areas to macro-economic modelling alternatives, as well as other strategies in diverse domains, such as in coastal adaptation or urban contexts. The aim of the dialogue being to identify a shared vision on 'which kind of economy we want for the kind of world we want'; and at the same time, that it would be based on the lessons learned from the empirical study of feasible and tested options that show both short-term positive effects on sustainable wealth creation as well as on climate adaptation or mitigation. In other words, to develop robust transformative visions and narratives (Hinkel et al., 2020) that were based not only on aspirational goals, but also that could be validated by empirical experiences and insights on systems transformations (see Sato et al. 2018).

In the case of IMPRESSIONS, the challenge focused on how to address the prospect of a world committed to high-end climate scenarios, that is, those that will go beyond the 2–1.5 °C UN Paris global warming threshold. Moreover, it intended to identify what kinds of alternative pathways, governance structures and integrated

[1] https://tipping-plus.eu/publications

[2] MATISSE (Methods and Tools for Integrated Sustainability Assessment; https://cordis.europa.eu/project/id/4059/es), ADAM (Adaptation and Mitigation Strategies: Supporting European climate policy; https://cordis.europa.eu/project/id/18476), GSDP (Global Systems Dynamics and Policy; https://cordis.europa.eu/project/id/266723), IMPRESSIONS (Impacts and risks from high-end scenarios: Strategies for innovative solutions; http://www.impressions-project.eu/), GREEN-WIN (Green growth and win-win strategies for sustainable climate action; https://www.green-win-project.eu/).

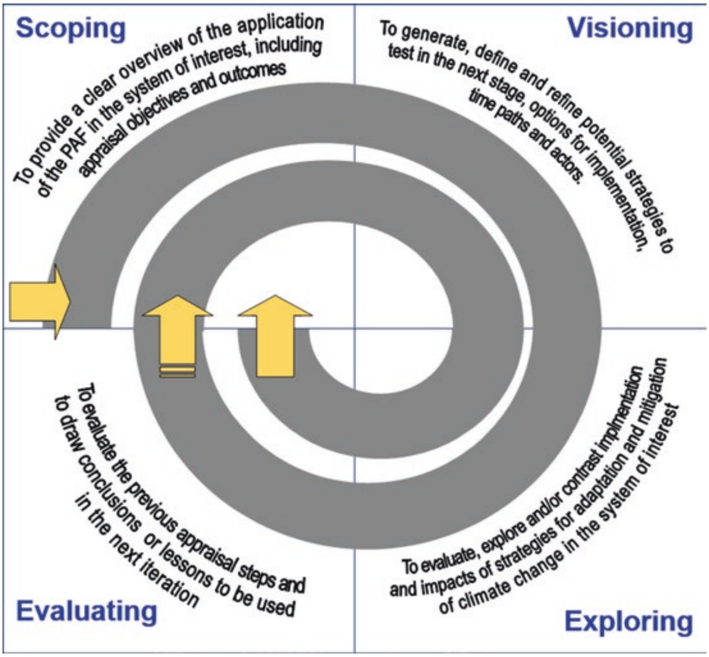


Fig. 1 The policy appraisal framework from the ADAM project (source: Weaver et al., 2006)

assessment interfaces would be needed to avoid the most negative outcomes of such futures. Assuming that conventional solutions would not be enough to address high-end climate change at the required speed and intensity to avoid potential catastrophic outcomes, a central concern was the call for developing science-policy integrated approaches to accelerate positive systemic change. This eventually led to proposing a check-list for transdisciplinary researchers to move towards *Transformative Climate Science* (Tàbara, Jäger, et al., 2018), and relatedly, the idea of positive tipping points emerged by acknowledging the fact that in complex social-ecological systems, it was not possible to know a priori whether or when deliberate positive rapid systemic changes able to cope with potentially catastrophic climate change and unsustainability would happen. It was recognised that robust solutions able to deal with to those high-end climate futures could not be fully known beforehand until explicit and situated transformative capacities aimed at developing such solutions were implemented in particular places and contexts. This, in turn, led to an original interpretation of the conditions for positive tipping points that moved towards a perspective focused on capacities (Fig. 2), and again, of those particular capacities to support *Transformative Climate Governance* (Hölscher & Frantzeskaki, 2020).

Therefore, an important aspect of the definition of positive tipping points in social-ecological systems, according to the IMPRESSIONS project, was that a

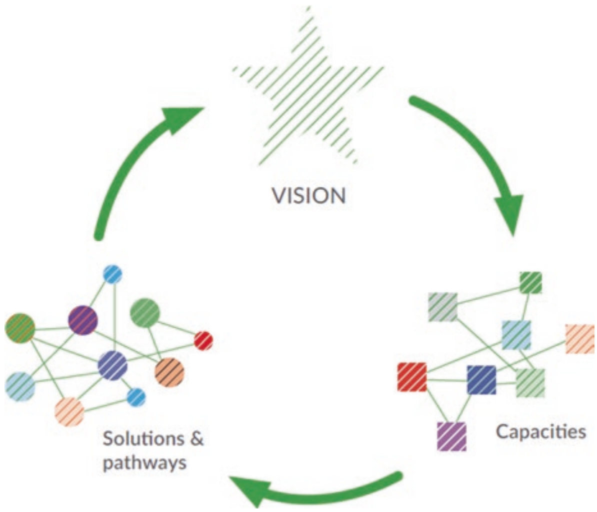


Fig. 2 Transformative solutions as emergent outcomes of transformative capacities derived from alternative visions of social-ecological systems

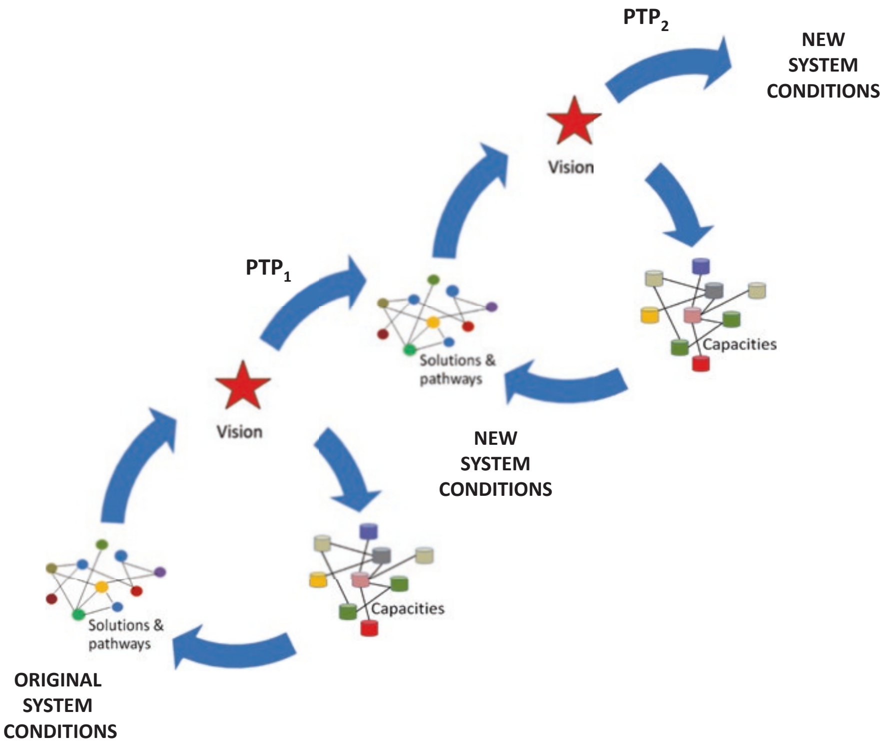


Fig. 3 Tipping points focusing as emerging outcomes of transformative visions, capacities and systems of solutions eventually changing original system conditions (source: Tàbara et al., 2018)

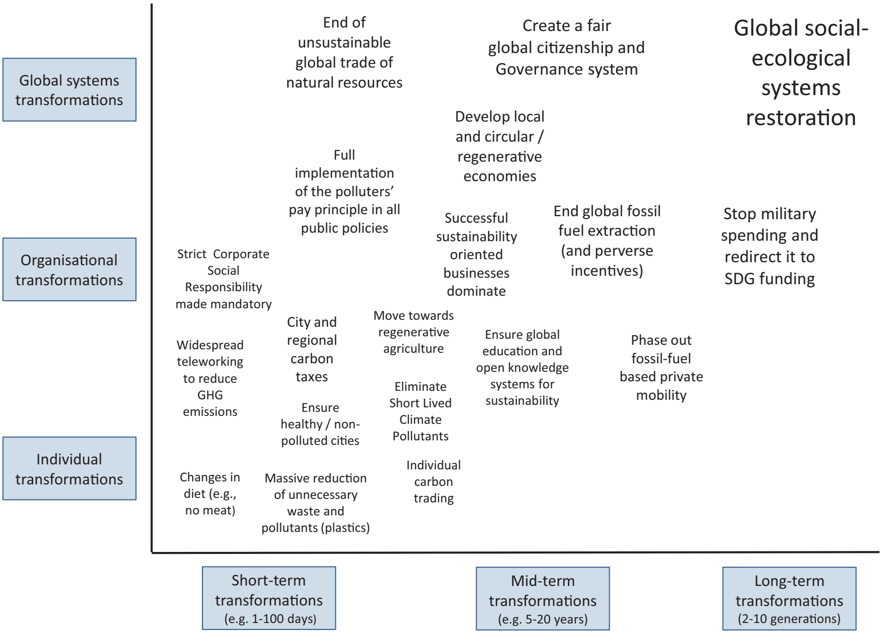


Fig. 4 The landscape of transformative solutions. Accelerating deliberate systemic change require combinations of multiple transformative solutions operating at different social and temporal scales (source: http://www.highendsolutions.eu/page/transformative_solutions)

tipping point would lead to fundamentally different configurations of the original social-ecological systems (Tàbara, Frantzeskaki, et al., 2018; Fig. 3).

Moreover, it was argued that the acceleration of deliberate transformations towards more sustainable development pathways would require *combinations of multiple systems of transformative solutions* able to move from additive to multiplicative strategies on systems' reconfigurations. Those outcomes would entail synergising the multiple wins and positive effects occurring at different scales of social action, from individual, organisational and systems levels; and also, to consider multiple time and space interlinkages, from short- and mid-term temporal scales to long-term ones (Fig. 4 shows some the possible examples, not tested, and were provided only for illustrative purposes):

Last but not least, the TIPPING+ project was also inspired by many years of interactions with the Transformations Community, collaborations that especially started with the series of international Transformations Conferences originally catalysed by Professor Karen O'Brien at Oslo University. In this line, the TIPPING+ project also co-convened the Transformations Conference 2021 (online, due to the pandemic) precisely on 'Enabling Tipping Points in an Uncertain World'.[3] An important concern of the Transformations Community has been to explore how to

[3] https://www.transformationscommunity.org/conference-2021

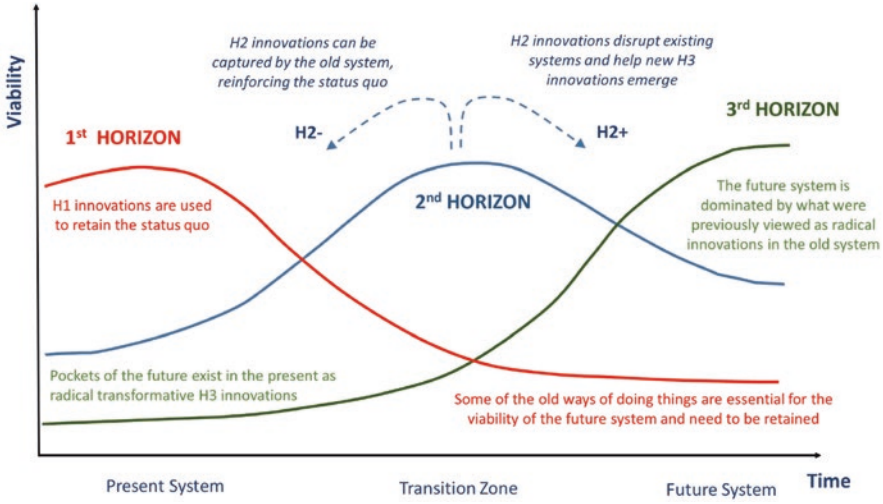


Fig. 5 The three Horizons methodology applied by the Transformations Community to explore alternative configurations of knowledge systems to address global challenges such as climate change (source: Fazey et al., 2020)

connect transformative changes at individual and organisational levels with large systemic ones (O'Brien, 2018) with especial emphasis placed on the management of knowledge systems. For instance, at the Transformations Conference 2017, held at the University of Dundee, the Three Horizons methodology was applied to explore the kinds of emerging knowledge systems needed to address global challenges such as climate change, as represented in Fig. 5 (Fazey et al., 2020).

However, and out of these broad conceptual approaches and theoretical discussions, it was clear that empirical research on the required conditions and processes leading to sustainable fast decarbonisations was still lacking. And the TIPPING+ project was to address this task by focusing on the identification of narratives as well as structural conditions for the fast decarbonisation of Coal and Carbon Intensive Regions (CCIRs).

2 Defining and Researching Positive Tipping Points: The TIPPING+ Approach

Tipping points are widely used and apparently widely 'understood' by many audiences. And in this sense, they operate as a boundary concept that helps to attract different disciplines and practitioners too. However, there are multiple understandings of tipping points as they are defined and used very differently by different social and natural science disciplines, which may lead to an overuse of the term (Milkoreit 2022). Moreover, the notion of Social-Ecological Tipping points (SETPs) integrating both biophysical and social interactions and feedbacks (see Franzke et al., 2022; Tàbara, 2023), and entailingl fundamental changes in original social-ecological system's conditions and relationships, made such discussions even more challenging.

Due to the fact that SETPs are the result of multiple complex processes and dynamics, it was assumed that positive tipping points cannot be fully predicted whether or when they will occur. However, in TIPPING+, we also assumed that the emergence of positive SETPs can deliberately be induced by tipping interventions (e.g., towards sustainable decarbonisation; Tàbara et al., 2024). In the context of regional decarbonisation, positive tipping points were defined as those relatively small additional actions or policy interventions that at one moment trigger and accelerate large, beneficial and self-propelling processes of deliberate qualitative change in a given social-ecological system (Tàbara et al., 2021). In particular, TIPPING+ identified two types of tipping points relevant for policy. On the one hand, *sectoral tipping points*, with are limited to deliberate changes within a particular domain of action, such as mobility or energy consumption, but which do not demand major and cross-cutting reconfigurations in power structures, individual worldviews or cultural beliefs. And on the other hand, *full-systems tipping points*, which also entail cross-scale and more profound and institutionalised changes in individual behaviours, economic organisations, power arrangements, knowledge systems, social-ecological interactions as well as in cultural values and identities. This can be represented in Figs. 6 and 7, in which sectoral tipping points relate mostly to *transitions tipping points* whilst the latter has to do with *transformations tipping points*. In both cases, these deliberate tipping processes result from the building of prior changing conditions and capacities derived from targeted deliberate interventions, and that at one threshold point, a relatively small additional action or disruptive event flips a social-ecological system towards a new sustainable trajectory or system's basin of attraction:

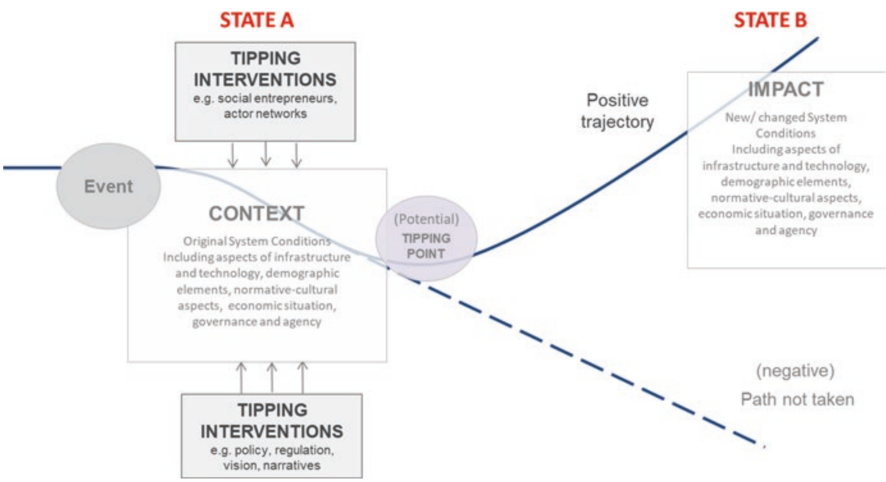


Fig. 6 Sectoral tipping point as trajectory discontinuity (source: Mey & Lilliestam, 2020)

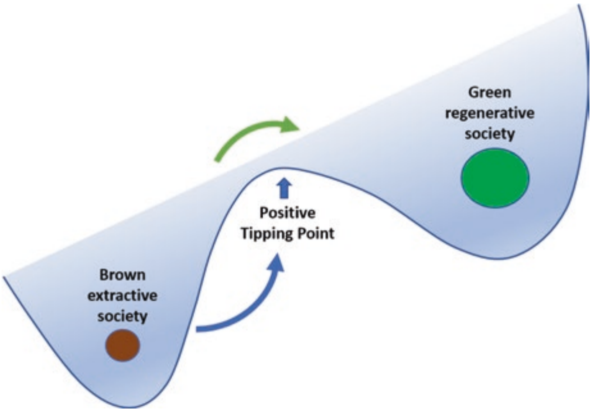


Fig. 7 Full system's tipping point, as a move toward a new basin of attraction (source: Tàbara, 2021. In search of a safe and just corridor for humanity. What kinds of transformations, agents and levers? Presented at the Earth Commission Working Group on Transformations, Global Common Alliance, 27th May 2021)

Tipping points necessarily refer to phenomena that occur over time. Hence, how temporal scales and dynamics are conceptualised is crucial in the research of deliberate positive tipping points in specific regional contexts. Concisely, the study of such phenomena can focus on three critical moments or stages in their development: (1) the building of the transformative conditions and capacities for systemic change that eventually enable and induce the emergence of desirable new system conditions; (2) the moment at which, provided that a critical window of opportunity for transformation exists, a sensitive intervention (Farmer et al., 2019) or tipping event (endogenous or exogenous) may trigger the tipping of a complex system toward its deep reconfiguration ; and (3) the passage of the system's dynamics toward new basins of attraction which in turn can provoke further effects on other systems. This complex phenomenon can be represented in a simplified form in Fig. 8.

Therefore, the governance of positive tipping points in CCIRs (Mey & Lilliestam, 2020) entails identifying four types of phenomena: (1) the social, political and economic contexts where potential abrupt changes may occur; (2) the possible tipping events that may accelerate or trigger fast structural change, such as closing a coal mine; (3) the feasible and more just interventions required to transform the system towards a desirable dynamic state and bring it towards a tipping point; and (4) the different kinds of impacts or courses of action after the tipping point. All these aspects are interrelated in the way that a tipping event or process qualitatively disrupts the initial social and economic structures of a region. However, and as pointed out by Eder and Stadelmann-Steffen (2023), current literature on tipping points does not yet adequately integrate, conceptualize or measure the role of the political with regard to social tipping processes. They argue that current research has conceptualised *the political either as context that provides the rules of the game or as part of the system that may tip itself* and trigger tipping cascades. Moreover, they contend that political complexity requires distinguishing between *policy* (as the set of political institutions), *politics* (in terms of decision-making processes) and *policy* regarding particular goals, interests and solutions and so they apply these ideas to

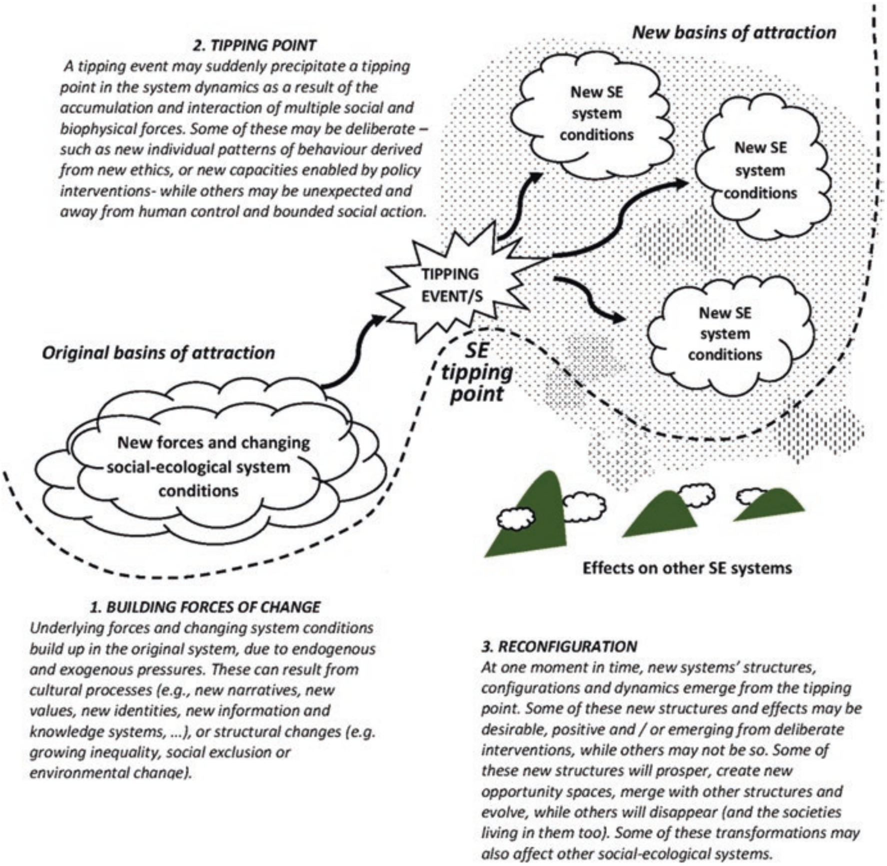


Fig. 8 Dynamics of social ecological tipping points (SETPs). In a given moment in time, tipping events accelerate the underlying forces of change and eventually provoke the emergence of new systems' reconfigurations and move its dynamics toward new basins of attraction (source: https://council.science/current/blog/enabling-positive-tipping-points-towards-global-sustainability-in-uncertain-times/)

examine the phase-out of nuclear energy in Germany and Switzerland. Hence, the political sphere can be understood as a domain that triggers social-ecological tipping points or as an element that can tip itself (Eder & Stadelmann-Steffen, 2023; see also Fesenfeld et al., 2022).

An important aspect of the cross-analysis of the empirical findings in TIPPING+ had to do with the study of narratives, and an adapted framework proposed by Lieu et al. (2020) was applied across the case studies to describe the dynamics of three main kinds of narratives within the different CCRIs (Mangalagiu et al., 2023; Martínez Reyes, 2022) as follows: (1) on-stream pathways, whereby dominant perspectives on the socio-energy pathways prevail; (2) off-stream

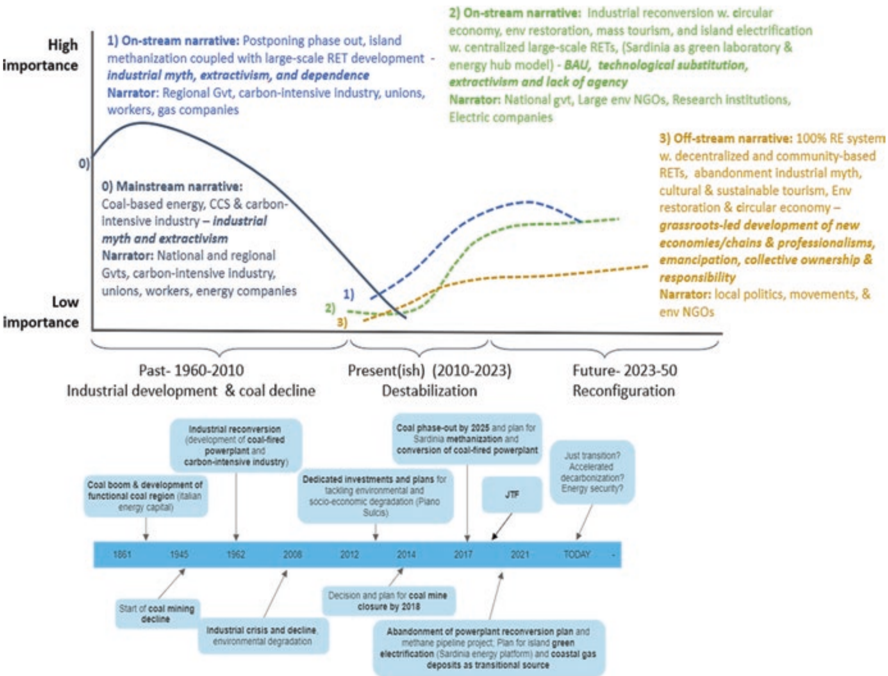


Fig. 9 Analysis of narratives and structural events in the Sulcis (Italy) case study (source: Biddau & Sarrica, 2022)

pathways, that depart from the mainstream socio-energy pathway and are open to social equity and technological innovations; and (3) transformative pathways, that are fundamentally different from previous mainstream pathways and include social dimensions and equity issues in the new socio-energy regimes. Figure 9 illustrates how this framework was translated and applied for the case of Sulcis in Italy:

Last but not least, the TIPPING+ project also engaged with various methodological discussions related to how to carry out research on tipping points in interdisciplinary contexts (see for an alternative perspective in this volume Hodbod et al., 2024). Among other contributions, these had to do with positionality. Researchers and change agents looking to identify and 'discover' potential positive tipping points in regional development processes may need to reconsider their own ideas, beliefs and attendant practices regarding the recognition and personal adherence to different ontological, epistemological and normative positions that affect the way they define, approach and assess their systems of reference. For this purpose, a simple methodology to assess positionality was proposed at early stage of the project and represented in Fig. 10.

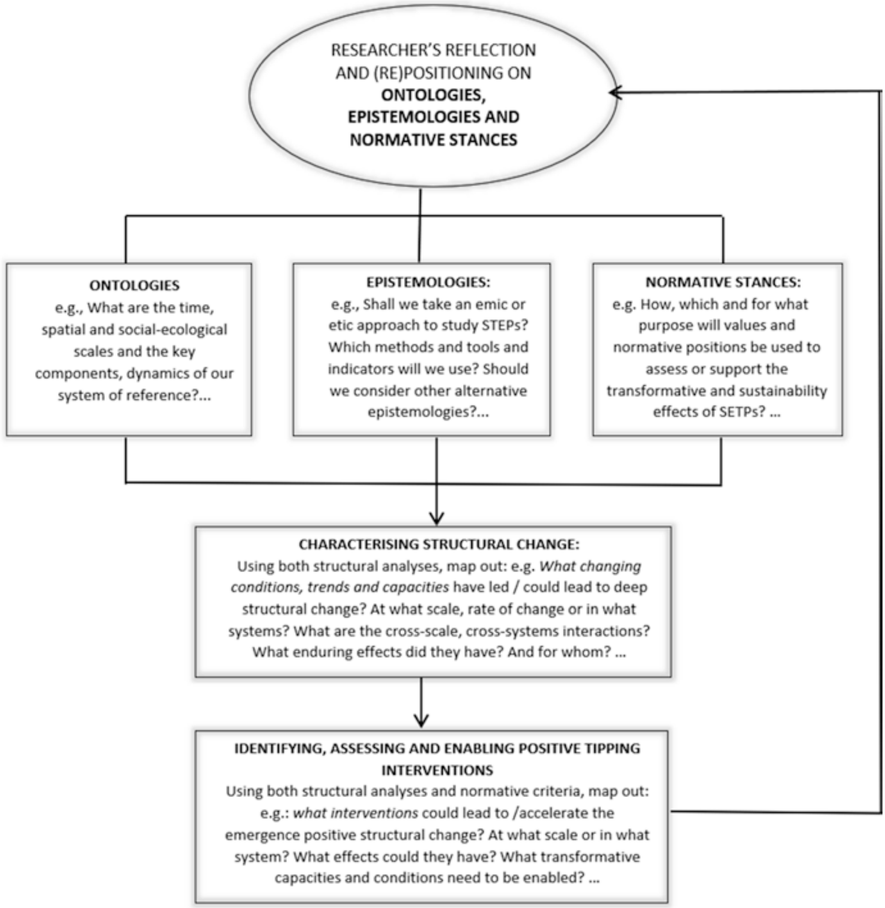


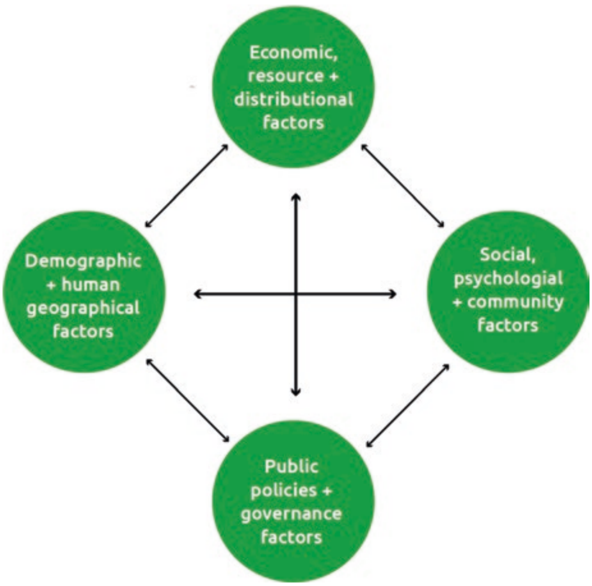
Fig. 10 The characterisation and enactment of positive tipping points depend on researchers' positionality, that in turn depends on critical ontological, methodological and normative questions (source: Tàbara et al., 2021).

3 The Multi-dimensional Challenge of Rapid Decarbonisation of Coal and Carbon Intensive Regions (CCIRs)

The regional energy transformation processes supported by EU and national policies and funds have created a window of opportunity for the reconfiguration of coal and carbon intensive regions (CCIRs) in a way that can be aligned with sustainable development goals. Such regions have in recent decades been affected by an array of negative trends, regarding loss of local jobs, population ageing, migration, lack of services as well as poor environmental quality conditions. In these socially complex contexts, systemic inertia, aversion to change and immobilism has often been paramount. To overcome this, several factors that have to do with realising the multiple dimensions that affect deliberate and fast change at the regional level need to be taken into account. These have to do not only with injecting structural funds to trigger technology innovations, but also with many other more intangible, cultural and perceptual dimensions related with the collective construction of meaning and action (see Apostoli Cappello, 2024; Cots et al., 2024; Sarrica et al., 2022, 2024; Van der Leeuw, 2024) and that affect the willingness and the capacities of different local agents and communities to collaborate actively in transformative governance processes. Harmonised policies need to consider all these cultural, identity, inequality and perceptual dimensions in order to foster the potential of local populations to contribute to systemic change in their own terms, which may eventually be expressed in more diversified, inclusive and resilient development pathways.

An important objective of the TIPPING+ project was then to underline the need to engage social scientists in the exploration of tipping points, given that this field had thus far been dominated by the natural sciences. Thus, the project wanted to underline the fact that tipping points occur as complex phenomena derived from multiple and intertwined socio-economic, political and cultural dynamics. These have to do, among others, with many structural factors, dimensions and disciplines including: (1) demography and human geography; (2) social psychology, ethnography and community studies; (3) governance and public policy science; as well as (4) economic, resource and distributional issues, for which a single work package was dedicated within the project (Fig. 11). Hence, from an interdisciplinary social science approach based on allowing for epistemic diversity, it was grounded on the recognition that no single approach or discipline would be sufficient to address the

Fig. 11 The TIPPING+ approach. Exploring tipping points dynamics and processes in coal and carbon intensive regions from different social science perspectives



large complexities of the research on social-ecological tipping points. Instead, multiple and different perspectives, methodologies and social science concepts would be needed; and this was especially relevant when trying to go beyond explaining socio-technological transitions from a unifying master s-curve framework so a more nuanced understanding of full-systems transformations could be developed; one that would, for instance, allow for alternative and more ecologically-coupled notions of time and would not assume single end-point or equilibria, given that social justice systems are never in equilibrium and are always changing, sometimes in dramatic ways and even in opposite directions.

The various cases included in this volume, without providing an exhaustive systematic treatment, show such diversity of approaches, methodologies and understandings of tipping points from various social and interdisciplinary perspectives. In this way, Marco Grasso and Daniel Delatin Rodrigues (2024) focusing on city of Civitavecchia in Italy provide a framework for the analysis of practices of destabilisation and disruption carried out by 'agents of transformation (ATs)' and argue that no single AT but many are needed for tipping a system toward a deliberate socio-energy trajectory. Also in Italy, Elena Apostoli Cappello uses an ethnographic approach to trace the dynamics in the construction and changes in the systems of meaning, and applying the notion of cultural 'energyscapes' examines how local communities can—or cannot, or are not willing to—participate in large EU decarbonisation policies. Francesc Cots and colleagues (2024) also explore the role of symbolic icons and identities in the processes of rapid decarbonisation of former mining regions, noting that after a tipping event, diversification may not only occur within the economy but also at the level of cultural identities yielding the possibility for the emergence of transformative 'project identities'. Ismael et al. (2024) examine the relationships between narrative changes and network dynamics in Indonesia and identify two main tipping narratives involving different kinds of actors and network configurations, hence opening a space for mutual learning between both. Jan Frankowski et al. (2024) explore, using a macro-economic framework, to which extent implementing carbon taxes can be considered a tipping intervention in accelerating decarbonisation in two areas of Poland and Greece, and reveal that to be qualified as such they need to be combined with other interventions and coordinated under a broader transformations policy narrative. Anna Sveinsdóttir and Brigt Dale (2024) present how a series of tipping events resulted in the rapid reframing of the dominant narrative of the future of the Lofoten islands region in Norway, from being mainly formulated around petroleum extraction to becoming a reference of 'green islands'. While, also in Norway, Veland et al. (2024), using a qualitative perspective, look at the processes and implications that are leading the closing down of the only coal power plant and the last remaining Norwegian-operated coal mine in Norway on Svalbard, together with the larger geopolitical implications of that. Also in the Arctic, Hansen and Tàbara (2024) elaborate the idea of tipping narrative confrontations, provided that whilst Greenland contains vast of fossil fuels deposits and keeping them in the ground is arguably one of the most efficient and fastest strategies to limit global GHGs as to avoid a climate catastrophe, Greenland materials are also needed to develop and provide alternative resources for the global green energy transition—underlying the need to harmonise natural resource with Earth System Justice ethical principles, and in ways that consider the rights, needs, worldviews and institutional traditions of local communities. Last but not least, Lukash and Namoniuk (2024) explore the possible low-carbon energy scenarios that could emerge from the systemic shock generated by the Ukrainian war. They note that such structural convulsion did not only show some of the vulnerabilities of high-intensive, centralised and dependent energy systems but also the need to accelerate the building of more resilient low-carbon infrastructures in the face of potential global change and interdependencies, the effects of which go also beyond Ukraine.

All these cases also underline the importance of considering the role of justice as a key driver for the emergence of positive tipping points in structural low-carbon sustainability transformations as well as a main outcome of them. Early gains in justice at the regional level can create the necessary transformative conditions for achieving positive tipping points at larger scales, and may also help to trigger chains of positive changes in other regions. Addressing inequalities and providing early mutual gains derived from tackling climate crisis are likely to help regional agents to support energy and climate policies, and function as demonstrators for other regions, showing that just transformations are not only possible but desirable. On the one hand, this means considering and extending generally accepted dimensions of *justice* in energy transformations that include *distributive justice* and that relates to the equitable distribution of resources, benefits or costs of transformations; *recognition justice*, that regards the fair representation and inclusion of gender, ethnicity, youth or other disadvantaged groups; and *procedural justice*, aimed at guaranteeing that people can influence actual decision. Making processes by setting inclusive ground rules of participation, including access to relevant information and the selection of criteria used in the organisation of such engagement processes. But in addition to these, also *capability approaches* that emphasise the need to foster explicit *means and enabling conditions*, such as political or community power of agents to influence decarbonisation decisions, in a way that can be relevant to climate mitigation, adaptation or more broadly, by fostering tipping processes towards systems' transformations. Whilst on the other hand, there are other perspectives and dimensions of *injustice* that need to be considered, provided that the relationships between justice and injustice are not symmetrical. For example, *intersectional injustice* occurs when multiple social characteristics or conditions overlap and affect negatively certain groups, revealing the need to apply equity policy interventions beyond those applied to the general population. Likewise, *epistemic injustice* happens when the knowledge or expertise claims of certain groups are disregarded, ignored or misrepresented, as with indigenous knowledge or non-expert people. All in all, a holistic approach to justice—and attention to injustice—in regional decarbonisation processes is needed, that go beyond compensation for the loss of existing power or economic positions of certain sectors, and that addresses much broader systems' transformations in terms of redistributions of rights, harms/benefits and responsibilities. Hence, a very difficult challenge is how to place these multiple justice criteria and dimensions that occur at the level of on European regional decarbonisation processes and move towards *transformative justice* within in the broader context of global environmental challenges and risks. These comprise the need to avoid trespassing Planetary Boundaries—thus contributing to and ensuring a safe and just corridor for humanity—and that entail adopting transformations-oriented understandings of justice that also consider intergenerational, intragenerational, as well as inter-species dimensions of justice (Gupta et al., 2021; Gupta, Liverman et al., 2023).

4 Final Remarks

Looking back, as a research journey, the TIPPING+ project did not search for a destination. Instead, it looked for a point of departure, for an opportunity space in which different disciplines, researchers and interests could develop their ideas and start their own new research ventures. Entering in such a complex field in a moment when researchers were being hit at the very first month of work by over 2 years of the Covid pandemic, and then followed by the Ukrainian war, did not help... The project was confronted with many uncertainties that had to be addressed in ways that had not been tested before—including the online organisation of the International Transformations '21 Conference. The lack of face-to-face interaction also impeded at many instances the possibility to address and reconcile the existence of different expectations and perspectives among researchers and to carry out the required personal interactions with stakeholders. Under these conditions, in practice, this meant that TIPPING+ could not attempt to find a 'definite answer' to the role of tipping points in accelerating regional decarbonisation processes; nor to arrive to a definition of social-ecological tipping points that could be used accross all contexts, methodologies, modelling exercises or disciplines. In contrast, it simply constituted an opportunity space to initiate many different debates—whilst providing some seminal examples of empirical research on possible future developments in an extremely difficult field of social interdisciplinary research.

This notwithstanding, an important overarching message that came out from the TIPPING+ project is that the challenges of just energy transitions in CCIRs are not just about energy transitioning; but about understanding how to deal with full-systems societal transformations that include multiple socioeconomic and cultural dimensions as well as profound changes in governance mechanisms, individual capacities, economic arrangements and even collective and cultural visions about the kind of just societies we want to live in, e.g., more socially, open and resilience-oriented or not. The corollary and derivative policy questions from this position therefore were: how far regional/national/EU policy makers do wish to go towards enacting full systems transformations (transformative tipping points)? Or else, do they want to limit themselves to implement sectorial, partial approaches to energy transitions (sectoral tipping points; with all the risks and potential inequalities and rebound negative effects that the latter may entail)?

As for future research, tipping points, as a heuristic conceptual device whose purpose is to help explain, articulate and operationalise policy narratives about the acceleration of deliberate systemic change, also need to be explained. And in such complicated interaction between concepts and realities, it is important to acknowledge that positive tipping points in CCIRs will have to look at the formation of validated narratives and careful assessment of the diverse, distributed and place-based decarbonisation strategies which could eventually be creative and engaging. In such endeavour, justice in its multiple notions and dimensions will have to consider how regional decarbonisation can also reduce poverty, enhance equity, and create sustainable forms of wealth and social welfare, and also explore how local processes of positive structural change can be linked to global processes in a way that also consider broader issues such as Earth System tipping points and distributional issues (Gupta, Prodani et al., 2023; Lenton et al., 2022). Tipping points research requires addressing multiple domains and scale interlinkages at the same time, so no one-size-fits-all solutions or single pathways of solutions are to be expected; but only multiple adaptive, possibly regenerative and flexible ones that may emerge from situated social learning processes in a way that fulfil local visions and values, and are able to create the necessary transformative conditions and capacities for rapid systemic change (see Olson & Moore, 2024). Moreover, such a research challenge also entails the acknowledgement that inter and transdisciplinary sciences have also their limits, and that the transformations-oriented knowledge derived from them first needs to be built on the rigorous application of methods and concepts generated by well-established disciplines as well. Indeed, in the future, many different disciplines may come up with new definitions and methodologies to understand tipping points that contrast with the ones created or used in TIPPING+; or utilise the positive tipping points concept to explain or to deliberately transform reality in many other different ways. In fact, we can only hope this to be case, so we can further understand how to accelerate positive deliverable transformations toward a sustainable world.

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Tipping Points Emerge in the Interaction Between Narrative and Reality

Sander van der Leeuw

Abstract The paper considers narratives as dynamic memory banks and shifts understanding from emphasizing the *origins* of the present to the *emergence* of the present. In the construction of reality, imagined futures articulate with knowledge obtained in the past.

In another inversion, rather than explain change and consider stability as the norm, it focuses on change as the norm and investigates the creation of stability to explain, for example, why our societies are so slow in acting on climate change.

The creation of meaning is the result of an interaction between thinking and experience, like the interaction between a map and the territory it represents. It reduces the complexity of the territory to the simplicity of the map, shaping simultaneously the cognitive map and the territory it represents. Such cognitive structures evolve into dense networks of cognitive dimensions.

Tipping points emerge as a particular cognitive structure is no longer enabling a society to deal with its changing environment because it does not fully trace the logical and functional nature of the relationship between the two. To facilitate that, we need to understanding noise as signals for which no interpretative conceptual and cognitive structure has yet been identified.

Keywords Interaction mind-environment · Narratives · Tipping points

1 Introduction

All of us human beings live in the present, and thus between the past and the future. In ancient Rome, the god Janus symbolized that. He had two faces, of which an older, often bearded, one looks backward to the past, and a younger, often clean shaven, one looks forward towards the future. Etruscan in origin, Janus was the god of beginnings, ends and passage from one thing to another. He was invoked at the

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beginning of all actions or engagements and thus linked past and future in a society that profoundly anchored itself, and its actions, in history (https://en.wikipedia.org/wiki/Janus, consulted 1/19/2023) (Fig. 1).

In our current society, we are generally more used to looking at the present, or to limit our perception to the short-term past and/or future, rather than see our actions as part of a deep-time historical continuum. The academic discipline of history emerged, in our societies, over the nineteenth century, as part of a shift from generally considering the present as a continuation of the past, to a perspective where change could be introduced to create a (different) future (Girard, 1990). Considering history thus became the discipline of a particular community focusing on the interaction between continuity and change. Over the last two centuries, as explaining change became more important than studying continuity, in the modern a-historical perspective the present, the recent past and the future increasingly dominate in narratives.

This paper attempts to broaden out our perspective on narratives and tipping points by proposing somewhat different ways to look at those issues. It raises a number of issues that I think are worth considering. But it does not present coherent solutions to them. In that sense, the paper is programmatic, a work in progress, outlining some directions where our thinking might go rather than presenting a firm and coherent approach.

I will elaborate a perspective on the emergence, use and change of narratives that takes the past-future duality of human temporal perception as point of departure. It considers the emergence of tipping points to be part of the changing perception by society of the dynamic interactions between the social and natural environments. In the process of attempting to understand, and deal with, the world that surrounds us as humans, we *exploit* what we have learned in the past about the environment with which we interact, to *explore* how to deal with the situations we are faced with.

The paper is divided into four parts. The first outlines my approach to human cognition and decision-making, which is rooted in my understanding of the creation of categories in human cognition. It sketches the role of narratives as dynamic memory banks. It shifts our perspective from "ex post" to "ex ante", from an emphasis on *origins* of the present to an emphasis on the *emergence* of the present and emphasizes the role of imagined futures articulating with knowledge obtained from past

Fig. 1 The Roman god Janus. He is the god of transitions and looks both towards the past and towards the future

interactions in the construction of reality. It ends with a section on the role of collaborations in creating collective meaning, institutions, and technologies.

The *second* part begins with another inversion of our perspective. Rather than explain change, and consider stability as the norm, I think we also need to *focus on assuming change as the norm and investigating the creation of stability* if we are to fully understand the dynamic. Making that change might help us to explain why current societies have been so slow in acting on climate change and related issues: they were under the *illusion of control*. In building and maintaining control, a crucial factor is the construction and spreading of meaning, as here exemplified by the introduction of the concept of a united Europe.

The *third* part concerns the process of creating meaning. Little work has been done on that within our narratives community. I adopt Gendlin's (1997) approach that meaning is the result of a *responsive interplay* between thinking and experience. In practice, that can be translated as the interaction between a map and the territory it represents. That interaction creates, simultaneously, both the cognitive map and the territory it represents, reducing the complexity of observed phenomena in our minds and using those ideas to simplify the phenomena observed.

In the *fourth* part, I outline the emergence of tipping points as a process of invalidation of a particular cognitive structure that was created to enable society to deal with its environment. Such structures evolve into dense networks of cognitive dimensions, as can be observed for technology in the way the USPTO shapes emergent technological knowledge into a cognitive space. Then, moving towards Kuhn's outline of scientific change (1962), I argue that he does not fully trace the logical and functional nature of the relationships between the old paradigm and the phenomena that cannot be fitted into it. To facilitate that, I conclude by arguing that we need a new approach to the understanding of noise—as signals for which no interpretative conceptual and cognitive structure has yet been identified. Right now, the 100,000 Euro question is whether Machine Learning could provide that approach.

2 Part One: Cognition

2.1 Narratives as Dynamic Memory Banks

In the cognitive dynamic, societally accepted narratives function as memory banks of what the society has learned, and thus partly shape the way in which the society looks at its present circumstances and imagines its future. In much of the discussion about the structure and role of narratives, they are considered as existing stories that impact decisions. The exploitation of cognitive categories and structures that result from acquired past experience is therefore the primary focus of the research, and the dynamics of exploration of the future are paid less attention. Here, I want to re-equilibrate that bias, adopting Beckert's (2016) argument that our decision-making and our behavior are affected by the role imaginary futures play in our thinking.

How does the interaction between exploitation of acquired understanding and exploration of the unknown future impact on decisions?

2.2 *The Role of Imagined Futures*

Since around 1750, according to the economist Beckert, the opening up of the western perspective on the future set in motion a (uniquely Western) cognitive feed-forward loop that creates in our minds imagined futures and then develops fictional expectations that motivate people towards realizing them. In his words: "… expectations of the unforeseeable future inhabit the mind not as foreknowledge but as contingent imaginaries (2016, 9) […] they create a world of their own into which actors can (and do) project themselves" (2016, 10). These fictional expectations are anchored in narratives that are continually adapted. The exchange between imagined futures and present conditions shapes the narratives involved, which in turn drive our imagined futures and our decision-making. Hence, "*fictionality, far from being a lamentable but inconsequential moment of the future's fundamental uncertainty, is a constitutive element of capitalist dynamics*", including economic crises (2016, 12). Beckert illustrates that in detail for the four main pillars of economics: money, credit, investment, and innovation. But the implications of the role of narratives in shaping our imagined futures stretch far beyond capitalism or the economy, into the fundamentals of our worldview. Some of these implications are the following:

First, narratives express the cultural, institutional, social, and environmental embeddedness of our human decision-making. Decisions reflect the value systems of the people concerned; they are shaped in the interaction networks among these people, and they determine to a considerable extent the path-dependent evolution of societies. The UN's Sustainable Development Goals (UN, 2015), for example, are in essence based on a Western imagined future of continued "progress" that, as part of globalization, has been projected onto other cultures. In other parts of the world, one finds underneath that global projection very different imagined futures. As Henrich argues (2020), the particular intellectual and social history of Euro-American culture has created a worldview that differs uniquely from the worldviews of most other cultures.

Second, because our future is constructed in a confrontation between the experienced past and such imagined futures, those visions of the future are only maintained for as long as there is confidence in that future. In the absence of such confidence, a degradation in the clarity of a society's perceptions and certainties, a crisis, or even a tipping point is experienced. The anticipatory loop can then, very rapidly, be turned in a negative direction characterized by self-fulfilling negative dynamics driving towards uncertainty, as in the case of recent financial crises. But it is not confined to such sharp crises—it can also slowly undermine the totality of our vision of the future and result in hesitations, contradictory actions, and general loss of self-confidence.

Third, we need to consider the relationship between our imagined futures and the "real world out there" in detail. It is impossible to predict the outcome of future confrontations between imagined futures and the material and social "real" world, especially over the longer term. That is due to the unintended consequences of such interactions, which cause changes in the second order (change-of-change) dynamics of the context in which shorter-term decisions are made. That interaction is clearly an open-ended one that is not fully controllable, as it is subject to ontological uncertainty (Lane et al., 2009). Loss of confidence in the future can very rapidly transform peace into war, progress into the opposite, and trust into distrust. As Gurri (2014) argues, the introduction of electronic social networks has rapidly accelerated the second-order communication dynamics, with major political consequences.

2.3 Categorization as the Core Cognitive Process

In an earlier paper (van der Leeuw, 2019), I have argued that the core dynamic underpinning perception and decision-making is categorization, in which first open, exploratory (groups) and subsequently closed, entities (classes) are created that are exploited to grapple with the unknown. In technical terms, based on theoretical and experimental work of Tversky and Gati (1978), the evolution of pattern recognition is here seen as a shift from extrinsically circumscribed, polythetic open categories to intrinsically defined, monothetic, closed categories. That perspective is chosen because the distinction between open and closed categories has been widely discussed in the cognitive sciences (e.g., Cohen & Lefebvre, 2018), but also in cultural anthropology, sociology (e.g., El Guindi, 1972, 1973; Selby & El Guindi, 1976) and other disciplines (e.g., Davis-Floyd, 2018).

The open categories introduce a hypothetical intellectual construct that identifies certain dimensions of the patterns as potentially relevant to the society's knowledge system but does not exclude all those dimensions and all the patterning that may ultimately not be considered relevant, so that there is a degree of fuzziness in the description of the categories. In a second step, defining closed categories fully selects the relevant patterns and excludes the irrelevant ones. That selection is based on the existing knowledge system which has emerged over time in a path-dependent evolution of its own. Open categories maintain the possibility that several alternative hypotheses could describe them, which is not the case for the closed categories. Therefore, the former do not allow the cognitive system to dependably manipulate the material world, whereas closed categories do.

Adopting this dynamic perspective on category formation and cognition, it follows that the emphasis on the codification of an existing worldview in the emergence of a narrative does, in my opinion, unduly emphasize the importance of closed categories in that process. And it does not pay enough attention to the dynamic interaction between imagined futures and present, ongoing, experience that all human beings practice in creating their narratives. We need to investigate two questions: first "What is the role of imagined futures in the generation of a narrative?", and then "What is the nature of the confrontation between imagined futures and everyday reality?" or "How does the confrontation between imagined futures and everyday reality change those imagined futures?"

To begin answering these questions, we must first attempt to distinguish, in narratives, between the contribution of closed and open categories respectively. In a paper with van der Leeuw & Folke (2021) I have pointed at a way to do so, notably by systematically monitoring the difference between the expected and the observed entropy as one follows the course of a narrative. Where that difference is slight, the narrative usually refers to a known past, formulated by the narrator in terms of closed categories, but where the difference is larger, the narrator seems to refer to personal experience, so that the categories used are predominantly open, and there is room for different conceptions of the future.

2.4 Early Acquisition of a Cognitive Structure

Cognitive structuration evolves through time in a dynamic process that begins with the earliest experiences of a child as it learns to identify categories, patterns, and dynamics in its interaction with the outside world. That interaction dis-embeds certain dimensions of potential perception from among the infinite multitude that constitute the unknown unknown that the child is confronted with: mother and father, light and dark, pleasant and unpleasant, different smells and shapes. These early cognized dimensions lay the groundwork for the structure of the worldview of the child; dimensions that are subsequently identified elaborate the ever-growing number of dimensions of that perceptual skeleton (van der Leeuw, 2016). The process is fed by the double niche-creating dynamic of resonance between the internal niche of the mind and the external niche of the environment (Iriki & Taoka, 2012; Laubichler & Renn, 2015; Odling-Smee et al., 2003), summarized in van der Leeuw and Murase (2021).

In the present context, it is important to emphasize that many of the dimensions of the cognitive framework that is thus dis-embedded are not consciously retained in the world view of the (adult) individual; they do however play an important role in that individual's decision making. The same goes for collective decision-making in groups. Many of these dimensions are what the anthropologist would describe as constituting the 'culture' of the community of decision-makers. 'Culture' in that context summarizes a large, and in part inextricable, number of such unconscious or semi-conscious cognitive dimensions that have become standard operating procedure in the interpretation of observed phenomena (cf. van der Leeuw & Dirks, in press b). In this paper, we will call these dimensions the "metadata" that individuals bring to bear on any perception or decision-making.

Any individual or group is part of, and employs, a multi-level decision-shaping hierarchy of cognitive dimensions that structures his, her or the group's worldview. The organization of that structure will generate unknown biases in the decision-making process which will play an important role in interactions among individuals in collaborative contexts (Dirks & van der Leeuw, in press). In practice, in the interaction between the internal and the external cognitive niche creation processes, this organization determines the values and the priorities of individuals' cognitive decision making. Those values are in part shared by the group, but within the group the priorities accorded to individual values usually vary.

2.5 Collaborations

Recent brain research is beginning to open up ways to improve our understanding of the impact of group interaction on shaping group members' thinking. In a very interesting paper entitled "*How consensus-building conversation changes our minds and aligns our brains*", Sievers et al. (in press) have studied how conversations between individuals have impacted on their respective ways of thinking, and on the role of these individuals in a collaboration. They conclude on the basis of a very stringent experimental protocol that conversations result in developing shared areas of brain activity among the participants in the conversation. Their work thus confirms the long-standing ideas about the importance of social interactions in shaping basins of attraction in group cognition.

This draws our attention to a new research domain that has until now been underappreciated: the cognitive dynamics of collaboration. In May 2022, a timely and interesting symposium on this topic was organized by Lupp, Verschure and Roepstorff at the Ernst Strüngmann Foundation in Frankfurt.[1] My takeaway from that symposium concerns first of all the ubiquity of collaboration as the basis for negotiating cultural values, institutions, and priorities. Next, there are now a number of perspectives on the emergence and decay of collaborations that bring us closer to understanding the intricacies of collaboration and how they shape their outcomes. But no less important is the fact that these raise new questions that have insufficiently been dealt with in the transdisciplinary approach used here. Among these, I want to emphasize three:

- How do collaborations emerge?
- How do the results of collaborations perdure?
- How might collaborations end?

Based on our discussions there, my colleague Gary Dirks and I propose the following tentative, "nutshell" perspective on how collaborations emerge, and how individual perceptions among the participants can be transformed into a collective solution to a challenge, including a societal institution or a technological innovation (Dirks and van der Leeuw, in press).

[1] The workshop was held under Chatham House rules, so that I cannot cite any individual contribution. The collective results are to be published in an edited volume (Lupp, Roepstorff, Verschure, eds.) by MIT Press in 2023 or 2024.

Resonance between individuals' ways of conceiving the world around them forms the basis for all productive collaborations. Without such resonance in the form of partially shared ideas, including underappreciated or even unrecognized metadata baggage, participants are unlikely to begin collaboration. If there is no initial resonance at all (for example in certain business collaborations), resonance needs to be created by imposing shared values and goals, and that makes the collaboration much more difficult.

In the collaborative process, discussions between participants will discover cognitive dimensions that offer the best chance of bringing the group together. Other dimensions suggested by each of the participants are accorded secondary importance. In that selection process, the group engineers a shift from individuals' open, exploratory, categories emphasizing potential shared dimensions, to closed categories defined in terms of shared dimensions, which also emphasize the differences between the group's ideas and everyone else's. These are deemed effective as a framework to work on the issues the group is attempting to deal with. That framework is then adapted and elaborated by the participants in the form of one or more rules, laws, institutions [2] or technological solutions. Once thus "invented", such rules of behavior spread among the wider community involved as adequate solutions to perceived challenges, in a process which is generally called "innovation" in the relevant literature (Stengers & Schlanger, 1991).

The transition from groups to classes, which excludes many of the individual cognitive dimensions of group members, formalizes ideas that are the result of the collaboration, ensuring a transition from the *comprehension* of socio-environmental dynamics that is necessary to formulate an effective solution to the challenges the group attempts to deal with, to a situation in which mere *competency* is sufficient in dealing with the solution implemented (without the need for comprehension). This generates what might be called "tools for thought and action" such as institutions, laws, technologies, implicit or explicit algorithms, or aspects of the external environment that are intended to perdure beyond the period of active collaboration.

Once that transition has taken effect, these closed categories become a major barrier to changing societies' attitudes. After language, closed ontological categories are the most important structuring elements in our thoughts. There is a connection between the two. Language creates the platform for thinking about the categories and has often integrated many of the "metadata" individuals have acquired in becoming part of a societal community. Language thus contributes a cultural history that is not necessarily conscious.

As the group's "tools for thought and action" are impacting on its environment, the latter is changed by the unanticipated consequences of the "solution(s)" the group has implemented. This is the inherent result of the fact that the collaborators' collective solution *eo ipso* adopts a very limited set of dimensions but is then confronted with the almost infinite dimensionality of the realm of phenomena in which

[2] "institutions" is here used in the anthropological sense of "*any and all collective ways to organize behavior, from shared ideas to informal customs and habits, to technology, and to formal institutions*".

it is instantiated ("the wider world"). As a result of that confrontation, both the solution and its wider context are changed in ways beyond the control or the perception of the collaborating individuals. I have discussed this elsewhere, calling attention to the fact that "Solutions create problems" (van der Leeuw, 2012).

As these changes emerge, they are dealt with by the individuals of the group, each in their own way or in the context of other collaborations. As a result, *the original collaboration usually falls apart because individual members of the group refocus on the changed situation, and in the process mobilize other cognitive dimensions than those they have shared in the collaboration*. That in turn will ultimately undermine the ideas the group collectively put forward and will thus signal the end of the collaboration. The ideas that were not shared become the seeds for institutional—and ultimately societal—change. Thus, transient stability institutionalizes instability.

3 Part Two: Change and Stability

3.1 How to Create Stability?

The relationship between stability and instability highlights the way in which our Western scientific approach biases our work. In general, that approach is based on the Aristotelian world view—and notably the assumption that stability is the "normal" state of things, and that change is the exception that needs to be studied. The above argument in favor of a direct causal relationship between stability and instability opens the door to another approach, based on the Heraclitan perspective, in which *change is considered permanent* and *stability* is the exception and needs to be investigated. This suggests an interesting and highly relevant question: "How do humans create a (temporarily) apparent stability in a dynamic process?" My initial answer should be clear: "through collaboration". But that is not enough. If we are to understand tipping points, we need to investigate the creation of apparent stability and its relation to time in much greater detail. For one, the appearance of stability is directly related to the temporal scale of observation chosen. Apparent stability disappears when the temporal scale of observation is changed to a more encompassing one. That relativity is often ignored in many studies of societal dynamics.

In the study of transitions, taking this point of view is a necessary complement to the more generally proposed question "What are the dynamics of change?" It assigns our understanding of the socio-environmental dynamic to the societal domain. That seems highly relevant as humans are, in the Anthropocene, the main actors of the combined socio-environmental dynamics. "Tipping points" are then understood as the moment that human attempts at creating the illusion of stability (and the illusion of control, see van der Leeuw & Dirks, in press b) are no longer sufficient, rather than as moments in which the supra-linear forces of change overcome a particular dynamic structure. Although this does not at first sight change our understanding of any structural transitions in socio-environmental dynamics in any major way, the change in emphasis re-directs an important part of the research effort towards questions such as the following:

- In the process of collaboration, which values/priorities are shared? How is that determined?
- Does that selection change during the collaboration? If so, how?
- Are the selection and its changes related to closed/open categorization?
- What decides which of the participants' perspectives comes to dominate?
- How do changes in the context (as a result of collaboration) affect that collaboration?
- What values decide individuals' thinking?
- How are the values in the collaboration prioritized/ordered?

These require a major, transdisciplinary effort to answer, which greatly exceeds the context of the present programmatic paper aimed at motivating a community such as the TIPPING + one to deepen out these questions.

3.2 The Illusion of Control

The dynamics that lead up to a tipping point in social-environmental systems have been studied brilliantly from a combined natural and life science perspective by Scheffer and his team (e.g., Scheffer, 2009), applying a Complex Systems approach to improve understanding of the emergence of change. Numerous others have approximately taken up this approach, mainly in the context of the Resilience Alliance (e.g., Carpenter et al., 2019; Folke et al., 2010; Homer-Dixon et al., 2015). Here I am arguing for a different perspective. To do so, I will be building on the first part of this chapter and on two earlier papers (van der Leeuw, 2020; van der Leeuw & Folke, 2021).

The core of my argument is that, *as categorization in a group or culture shifts from open, exploratory categories ("understanding") to closed ones ("knowledge"), the relationship between observations and interpretations changes because, increasingly, the acquired knowledge comes to dominate the observations on the phenomena. As a result, observable differences and questions are pushed to the background in favor of a set of fixed interpretative ideas*. The representation of the subject increasingly comes to be divorced from its immediate context. That growing disconnect leads to what many have called unintended consequences, not because the dynamics change (which they do) but because *the interpretation no longer tracks the changes*. It is thus that *solutions create problems* (van der Leeuw, 2012).

In the runup to a tipping point, the group or society concerned holds on to its interpretation of what is happening in the outside world, although that increasingly becomes ineffective, if not illusionary. Hence, I emphasize the "*illusion of control*" as the state of the group or society just before a tipping point (van der Leeuw & Dirks, in press b).

A good example is the tipping point ("*Zeitenwende*") pronounced by Chancellor Scholz upon the invasion of Ukraine by Russia. Sauerbrei (https://www.nytimes.com/2022/12/24/opinion/germany-scholz-zeitenwende.html, New York Times, 25/12/2022, consulted 25/12/2022) argues that this tipping point follows a phase of "*Überraschungsresistenz*," (resistance against upsets or surprises), in which Germany, notwithstanding many warning signals such as the Russian war in Syria and its invasion of Crimean peninsula, built an economy heavily dependent on Russian gas and neglected its military. Japan is going through the same process in implementing, with an eye on the threat to a war with China, a constitutional change that for the first time, after 70 years, allows its armed forces to serve other functions than defensive ones. Why were these societies holding on to an outdated narrative?

Such illusions of control are often structured around specific narratives (as in the German and Japanese cases the idea that these countries could survive as pacifist islands in a warring world, that Russia would forever be a trustworthy provider of cheap energy, and that China could be shaped into a peaceful global economic partner). To understand such developments from our perspective, we want to gain an improved understanding of why and how such narratives emerge, and why and how they become resistant to change even though the environment the society interacts with clearly does change! In the process, In the process, people increasingly believe what is anchored in their closed categories and accommodate their narratives and justifications accordingly (Douglas & Wildavsky, 1982).

4 Part Three: Creation and Role of Meaning

4.1 Birth and Growth of the European Union

I want to begin this argument by going back to the immediate post-WWII period and the beginnings of the movement towards European unification, which initially led to the European coal and steel community (ECSC), founded in 1951 in Paris under the inspired leadership of a small group of people let by Robert Schumann and Jean Monnet. Their collaboration was inspired by the idea and narrative that further Franco-German wars needed to be avoided, and that this was best done by creating economic dependencies between the two protagonists. That idea was Beckert's "imagined future" of Europe. In applying it, the first emphasis was on dependencies grounded in the heavy industries that were the core of their economies.

A few years later, after other politicians joined the movement, the collaboration was expanded to the (equally fundamental, but emerging) domain of nuclear energy by establishing Euratom. In 1957, the next step was the founding of the European Economic Community by the treaty of Rome, involving the six countries that were members of the ECSC and Euratom (Germany, France, Italy, and the Benelux countries). This treaty involved a much wider economic domain. From there, suffice it to say that the initiative grew in impact (including a huge harmonization of economic and industrial rule-setting, leading up to the Euro), in size, and by increased transfer of sovereignty into the European Union of 28 (now 27) countries (Treaties of Maastricht (1993) and Lisbon (2007).

Underpinning this whole development was a path-dependent dynamic that slowly but surely transformed an imagined future of a few people into a reality, implementing the European narrative in many domains of the everyday life of the citizens of the participating countries: values, laws, institutions, policies, technologies, etc. It created its own cognitive space. This could not have happened if there had not been (1) important resonances between the different countries values and priorities, reflecting centuries of interactions between the peoples concerned and (2) a context (the cold war) that was a threat to Western Europe. The convergence was enabled by resonances between the ruling elites in different countries, who had generally lived through the consequences of WWII. These initially backgrounded the differences between countries that began the movement, and later those between the Western European and the Eastern European conceptions of society. In more recent years, these differences are being foregrounded, and that is creating tensions.

In order to understand those tensions, we must investigate how such resonances reflect wide, underlying structural similarities in thinking among the populations concerned, asking "What are the structural similarities and differences?" and then "How have these on the one hand enabled the emergence of a shared meaning, and subsequently generated the observed tensions?"

4.2 The Construction of Meaning

The path-dependent dynamic underpinning the concept and the implementation of the European Union was built around an idea, and that idea came to dominate the politics and economics of Western, and later also Eastern, Europe, enabling the creation of a relatively stable institutional structure. For that to happen, those ideas would have to confer meaning to the people involved. It seems therefore that the question "What creates and confers meaning among people?" is a central one when considering how human beings create (temporary) stability in societal dynamics.

If we assume, as many in the narratives research community seem to do, that narratives are a direct reflection of the structure and references of thinking among the community that share them, that focuses our attention on the relationship between the developmental trajectory of narratives and the creation of shared meaning as a foundational element in the conceptual stability that is being constructed. Many questions arise concerning that relationship. The one that here concerns me most is the relationship between experience and language. Language involves the conceptualization, and thus also the categorization and expression, of individual or collective experiences. Not being a specialist in this domain,

I rely in what follows heavily on the work of Eugene Gendlin (1997), who strikes a position between on the one hand the empiricist-rationalist position that maintained Descartes' mind-body distinction and on the other the (post-)structuralist position (Levin, 1997). In the former, representations of the real world were created in the mind by an association of sense data and distinct ideas. In the latter, the conceptual network of a language is held to determine the forms and categories through which one experiences the world, so that there are no objective meanings, and attaching a meaning to a word is always arbitrary. Gendlin's position is that there is something he calls 'felt meaning', which is not an inner representation of the outside world, but the result of a *responsive interplay* between thinking and experience, between the realm of phenomena and that of ideas. In the terms used here, his felt meaning has a higher sensed dimensionality than its linguistic expression, and the communicable linguistic expression thus involves a reduction of the meaning's dimensionality. In that sense it is not unlike the concept of 'Gestalt' in psychology and in cognitive science, or the approach of Ingold to 'embodied knowledge' (2000), emphasizing that we don't know what we know until it is confronted with relevant aspects of the outside world.

4.3 The Map Is Not the Territory

One could thus summarize the interaction between the realms of phenomena and ideas as expressed in the title of this section: the territory is described on the map by a reduced set of dimensions. One can thus have different maps (different dimensional reductions) of the same territory. A narrative can be described as a map of a realm of observations, and different narratives can be applied to one and the same realm of observations. If that is accepted, then the fundamental question concerns the choice of map (the perspective from which one wants to study the territory).

I have argued in Sect. 2.4 and elsewhere (2016) how that choice is determined to an important extent during the very earliest acquisition of a cognitive structure by the individual(s) concerned, because throughout life, an individual's perceptions will be shaped in a path-dependent process rooted in early experiences, which during the person's lifetime expands and details her perception. This early shaping of individuals' cognitive structure, before they are trained in a scientific discipline, is for example responsible for what many scientists consider "scientific illiteracy"—which has assumed major proportions in the USA (cf. van der Leeuw, 2015).

This early acquisition of information processing structure results in a considerable number of implicit and unconscious cognitive dimensions ("metadata"), which have an impact on perception and decision making that is generally underestimated or completely ignored. Many of these dimensions are "cultural" (shared by a community), including aspects of the individual's epistemology in shaping and treating "data". But not all are due to shared cultural information processing. Some are individual or are shared by subgroups of a population. Only when they are shared can one speak of narratives in the societal sense of a repository of values and dimensions of perception. As mentioned, to truly understand these dimensions a detailed multi-scalar analysis of the relevant perception structure is needed. Such an analysis can begin with close reading of the narratives individuals refer to.

The emphasis in the *process of acquiring meaning* is therefore on the interactions between the internal (individual or collective) information processing structure as reflected in a society's language and narratives and the outside world of phenomena. Another way to come to grips with that process is to look at what, within an individual's or group's cognitive structure, is called "noise". Generally, noise is considered in Western science as constituting statistically insignificant signals "around" the categories that fit a particular interpretation (Kahneman et al., 2016). They are thus ignored. I would argue that another interpretation of noise is relevant in this context: noise concerns those signals for which information processing has not (yet) found a coherent interpretative framework in the society concerned. Noise is thus "significance that remains to be found", not unlike "felt meaning". Extending the arguments of Tett (2021), one could therefore also begin by identifying cognitive dimensions and interpretative structures for what is considered noise.

5 Part Four: Tipping Points in Cognitive Space

5.1 Energy Narratives from Comprehension to Competency

Subtly but surely the status of the narrative changes over time as it becomes more and more solidly established and includes more and more people. In Sect. 2.5, I have summarized that process as a move from *comprehension* to *competency* (van der Leeuw & Dirks, in press a), from fully understanding a system and exploring unanswered questions to responding to that system without understanding it fully, no longer exploring its cognitive space. I have related that to the ongoing shift from open to closed cognitive categories. Here, I want to illustrate that by taking the dynamics of the current energy debate as example, conceiving it as a dynamic interaction between two narratives, the fossil energy narrative and the renewable energy narrative.

If we go back some 50 years, to the 1970s, the fossil energy narrative is well-established and has spread its cognized space to encompass most of Euro-American societies' world view. Yet, even at the time, there was among the fossil fuel community a spark of awareness of some of its future challenges.[3] That seems to have led to early defensive reactions focused on spreading doubt about scientific results that were negative for the industry (such as we know much better from the tobacco industry (Oreskes & Conway, 2010).

While fossil energy use was spreading, the community's narrative spread all over the economic and political communities, to the point that Euro-American societies waged wars to control the fossil energy sources in the Near and Middle East, and elsewhere. Secret negotiations about the threats to the industry brought the

[3] Recently, it was discovered that Exxon, in a confidential internal report in the 1970's, pointed to some of the potential challenges to its 'oil for all' worldview.

community closer together and closed more and more of the categories that anchored the fossil energy narrative. Thus, the community increasingly isolated itself from interacting with other parts of society, becoming a more or less closed silo, holding on to the past values, categories, and worldview on which it was based, without adapting these to the changed context. Control became its aim, to ensure continuity of its existence.

In the beginning of this century, as alternative, renewable sources of energy became technically and financially available, a bottom-up movement emerged that strove to fundamentally change the energy narrative, moving from fossil to renewable energy. In its early days, that community was essentially exploring novel possibilities, technologies, and ideas. It had a worldview formulated in open categories. But over the last 20 years, as the alternative solutions which that community proposed became more widespread and solidly anchored in particular technologies, its categories also tended to close, creating an increasingly siloed community. Natural disasters, phenomena clearly ascribable to climate change, and the huge publicity that was given to the potential threats for our (mainly Euro-American) lifestyle, spread this narrative in different parts of our societies, particularly among the young. *Fridays for Future* became a worldwide movement, and in the last few years, we saw a shift in the alternative energy community to disruptive societal actions, such as those of *Extinction Rebellion.*

That shift was a clear sign of frustration that very little was changing. Why? In my opinion because the alternative energy narrative was subject to the same silo-ing that the fossil energy community had undergone earlier. Categories closed, the community's vision increasingly depended on accepted (by now 'old') ideas and cut itself off from discussions with non-members. Here, too, the shift from comprehension to competency reduced the possibility of change, adaptation and—importantly—negotiation.

This example conveys an important lesson about the dynamics that lead up to tipping points: the fact that the narrative that leads up to such points has 'fossilized'—has shifted from comprehension to competency, from an open exploratory narrative trying to understand what is going on to a closed narrative that exploits certain assumed 'truths' ('knowledge') about the phenomena concerned. Such a cognitive shift seems to be inherent as any narrative grows older, spreads among more people who integrate an abbreviated version of it, and thus becomes institutionalized. It inevitably leads to a "tipping point".

5.2 Tipping Points

Now let's get to the final aim of this paper: a reconsideration of the concept of "tipping points". In the general discussion about such events, the assumption is that an exogenous or an endogenous nonlinearity, or a combination of these, relatively rapidly tilts a system's dynamic into a different basin of attraction. That discussion therefore focuses on what causes change. Here, our interest is primarily in what created the stability that dominated the system before the change, and how that stabilizing dynamic came to a point that it relinquished control.

The acquisition of meaning occurs in a collaboration between individuals negotiating a focus for their collective effort, backgrounding most cognitive dimensions of participants, while foregrounding a selection that they can all agree to. That process, which we have summarized in Sect. 2.5, and exemplified in Sect. 4.3, ends with the reduction of the dimensionality of the initial, exploratory categories into intrinsic definitions of clearly closed categories that are integrated in the overall information processing apparatus. It permits the community involved to develop ways to handle particular aspects of the environment, devising “solutions” to the problems that were the subject of the collaboration. Such solutions are based on *societally agreed* conventions, which we often formulate as ‘knowledge’.

But at that point, the interaction between the information processing structure and the environment does not stop. The solutions implemented create their own unintended consequences, which then come to preoccupy the collective concerned. Further collaboration can negotiate new solutions, which add to the information processing apparatus. Mostly, these involve the creation of additional categories and conceptual feedback loops creating further understanding of the dynamics involved.

The process of creating a cognitive structure by filling cognitive space with disembedded dimensions can be followed by monitoring the growth of the US Patent and Trademark Office’s patent database (or its European or other equivalent). Because an approved patent mentions the other patents on which it is based, this permits us to construct technological genealogies and show the growth of the dense network of branches that structure the cognitive space that can grow out of the invention of a single solution (Strumsky et al., 2011a, 2011b; Strumsky & Lobo, 2015; Youn et al., 2015). Most of these new conceptual entities are either *embellishments* on existing solutions or *combinations* of existing solutions to new functionalities. Truly completely new inventions, called “*originations*”, are far and few between. Overall, this process captures how a particular cognitive logic, initiated by an originating invention can create a cognitive space by filling it, resulting in a path-dependent evolution of both the internal, mental, niche creation and the creation of the external niche that developed in tandem with it (Iriki & Taoka, 2012).

It is important to remain aware that this example concerning technology is just one way to create a cognitive space by filling it. An infinite number of others could do the same thing in the same or different domains. This is the case, for example, for societal values, legal systems, institutions, or scientific paradigms. Moreover, it is conceivable that different genealogies, emphasizing different aspects of the same cognitive domain, structure a cognitive space differentially.

Kuhn’s famous “*Structure of scientific revolutions*” (1962) focuses on how one scientific cognitive structure is transformed into another, novel one. He takes the paradigm shift from Ptolemaic to Copernican as example. His main argument is that during the period of use of a paradigm, ultimately, phenomena will be observed that cannot be fitted into that paradigm. As these accumulate, a “tipping point” is reached at which the existing paradigm is deemed insufficient, another one is invented and over time replaces it.

Because Kuhn is studying historical phenomena, what he does not fully trace is the logical and functional nature of the relationship between the old paradigm and the phenomena that cannot be fitted into it. Can one specify that further than simply referring to "unintended consequences" of applying a particular paradigm to the realm of phenomena? "What is the interaction between a cognitive structure that is limited to the discrepancy between the relatively few dimensions of human perception, and the (almost?) infinite number of dimensions of any 'real world' phenomena?

5.3 Reinterpreting Noise

Is there a relationship between cognized dimensions and un-cognized ones in a cognitive space? In particular, does the role of noise adjacent to cognized signals, such as Tett (2021) seems to argue that we need to investigate, move us closer to understanding dynamics? As I adopt the perspective that noise constitutes signals for which no theoretical explanatory framework has been created, it clearly is not "statistical uncertainty" as Kahneman et al. (2016) argue. But that asks the question "How can we explore relationships between different non-interpreted signals in order to create interpretative intellectual frameworks?" I have no clearcut answer to this question but am wondering whether Machine Learning (ML) might bring us closer.

Computers are now able to make and implement their own decisions, and to beat human champions at games such as Chess and Go. They acquire this capability by being confronted with very large numbers of data and searching independently for correlations in them—similar images, similar language, or any other kind of positive or negative similarity. Interpreting these configurations allows them to develop categorizations that are regularly beyond human perception because humans could never digest such huge volumes of data. Japanese astronomers, for example, have developed a new artificial intelligence (AI) technique that transforms into information signals that were until now considered noise (https://scitechdaily.com/astronomers-use-artificial-intelligence-to-reveal-the-actual-shape-of-the-universe/, consulted July 14, 2021). They do this without the step that is fundamental in science—the development of categories that make sense to the observers.

This approach opens up questions about the nature of human knowing. The scientist responsible for this experiment (Qin, 2020) asks: "Don't scientists want to develop physics theories that explain the world, instead of simply amassing data?", "Aren't theories fundamental to physics and necessary to explain and understand all phenomena?", "What about doing the same for large numbers of signals on narratives?", "Would that enable the identification of relationships between some of those signals that have not yet been brought into an understanding of ongoing dynamics and are regularly qualified as noise?" From a social science point of view, one would have to add: "How is one to situate knowledge?", which opens up yet another major domain once it is understood that such situation needs to be done collectively.

6 Conclusion

This paper aims to open up a number of interesting discussions around narratives and tipping points by shifting the emphasis towards a complex systems perspective, emphasizing emergence in our thinking rather than origins, and looking at what creates stability rather than change in interactions between individuals and groups. Collaboration is seen as eliciting shared cognitive dimensions from among the many individual dimensions that are always present, and formulating them in terms of shared, closed categories that establish a cognitive structure that a community can use to manage its relationships with it's environment. Such structures are codified in terms of narratives, and these are used to articulate the community with its unknown future. That also shifts the emphasis on tipping points, from moments at which endogenous and/or exogenous dynamics create a sudden change in the community's environment to moments at which the cognitive structure of the community is no longer capable to deal with the changes occurring in its environment. Moments when solutions create problems (van der Leeuw, 2012). If, as I do, one accepts Luhman's (1989) idea that rather than communicate with the external world, humans communicate *among themselves* about the external world, but that their activities trigger changes in that external world, this creates a field of tension between societies' perspective on the external world and the dynamics driving change in that world. That 'cognitive-reality' dissonance regularly brings a society to a (tipping) point where it has to revise its perspective on the outside world and its dynamics (van der Leeuw, 2020, Ch. 16). In a sense, one could call the social construction of a new worldview after such a breakdown a 'positive' tipping point which involves societal collaboration (see Dirks & van der Leeuw, in press).

A deep reassessment of our current Western scientific epistemologies and the perspective on the ontologies and narratives that they have shaped will be necessary. Questions to be asked include "What are factors that shape and limit scientific perception"?, "Are these to be found in humans' cognitive capabilities?", "What is the value of the scientific theories that, until now, rule our life?", "What are the structural biases of Western science?", and thus also "What are the biases introduced by the current scientific approaches?" and "What are the phenomena that science has ignored because of these structural biases?". Those questions relate scientific knowledge directly to the information processing system that the society has, through its worldview or mindscape, and its institutional, political, and economic structure. In the case of our present challenges, one will have to ask, for example, "Is our democratic structure able to deal with the environmental change issues?"

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Tipping Points. Deep Roots and Contemporary Challenges in Psychology

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Abstract As an object of study, tipping points raise several questions for psychology. Unless one wants to use this term as a generic metaphor to indicate sudden change, any attempt to better define this concept has to take into account some fundamental psychological features including acceptance, promotion or resistance to change, the relationship between quantitative and qualitative transformations, the dynamics between individual, social and societal levels, and the relationship between psychological and environmental changes. All these facets refer to classical approaches and theorisations developed in the early 1900s as well as to more recent systemic models, including societal and cultural psychology approaches and proposals for a socio-ecological psychology. In this chapter, we will identify points of contact with classics such as Insights and Dynamics of field forces, Cognitive dissonance, Grievance, Bounded rationality, Coping, and Socio-dynamical approaches to social representations. Moreover, looking at the recent literature, we will highlight advances in our understanding of tipping points provided by cognitive, socioecological and systemic models. Common to all these views is the attempt to describe and explain the processes that favour or hinder qualitative transformation, both in terms of its perception and its enactment. In this chapter, we will provide an overview of the different approaches mentioned, which should be read more as an agenda for future research rather than an exhaustive review of state of the art.

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1 Background

Change has always been a central theme in psychology, whether understood as a linear development, a stadial process, or a radical and sudden transformation.

Early examples of a radical and qualitative transformation in individuals' psychological states can be found in crowds and masses psychology. These early theorisations—nowadays largely revised—assumed that a change in the social context could trigger a qualitative shift in individuals. The contagion in the crowd, its stream, its inclinations were considered to be able to transform the 'normal' and 'rational' functioning of the human being either in a regressive or in an imitative key: "an individual immerged for some length of time in a crowd in action *soon finds himself in a special state* [emphasis added], which much resembles the state of fascination in which the hypnotised individual finds himself in the hands of the hypnotiser." (Le Bon, 1947, p.11). Can't we consider this qualitative state change as the result of a tipping point?

In the next paragraphs we will first offer some insights into the contribution psychology has provided to understanding processes of sudden and qualitative transformations. Moving from the individual to the societal levels of analysis, we suggest that concepts derived from research on trauma, gestalt psychology, cognitive approaches to resistance to change, and social representations, that for space reasons we can only introduce here, are at the basis of proposals that directly address tipping points. In the second part of the chapter we will describe current models that explicitly refer to tipping points, conceptualised at the individual level as the sudden emergence of patterns of meanings, and at the societal level in terms of systemic and socio-ecological psychology. We will accompany the chapter with a few examples of how these mechanisms relate to energy transition issues, and relevant to the research presented in the second part of the book.

1.1 Traumatic Changes

A foundational reflection in psychology—which we can just briefly recall here—comes from studies on trauma and self-defence.

Trauma is an event or series of events that cause an extremely stressful experience, which can leave a person with long-term psychological disorders. Traumatic events can be physical, such as a car accident (or a grenade such in the early studies on post-traumatic stress disorder, PTSD), or emotional, such as abuse or a significant loss. Studies on trauma focus on how people react and recover from these events and how professionals can offer support and treatment to those affected.

Environmental events, including natural disasters such as hurricanes, tornadoes, floods, earthquakes, and fires, can also cause trauma. Direct or mediated traumatic experiences include the destruction of one's own home and community, losing possessions and loved ones, and being forced to evacuate or live without necessities for an extended period. This can lead to long-term psychological disorders such PTSD and depression. Other examples of environmental trauma may include exposure to pollution, experiencing an oil spill, or dealing with the aftermath of a nuclear accident.

A number of self-defensive processes are enacted to cope with traumatic and potentially dangerous conditions. Concerning environmental events, self-defence encompasses a range of actions individuals and communities can take to prepare for, respond to, and recover from environmental hazards to protect themselves, their property, and their communities from harm. For example, in the case of a natural disaster such as a hurricane, self-defence may involve preparing for the event by stocking up on emergency supplies, creating an evacuation plan, and securing one's home and property. During the event, self-defence may involve taking shelter and staying safe during the storm. After the event, self-defence may include cleaning up and repairing one's home and seeking help and support from government agencies, non-profits, and community organisations to recover and rebuild. Self-defence may also involve taking legal action to hold corporations or governments accountable for environmental damage caused by their activities. In the case of an oil spill, self-defence may involve pressuring the responsible party for a clean-up and compensation and taking preventive measures to avoid future spills. In summary, in relation to environmental events, psychosocial studies on trauma and self-defence aim to understand how negative experiences can affect people's lives and how they can be overcome through enacting behaviours, acquiring skills and implementing techniques for managing stress and dangerous situations.

The concept of self-defence is strictly connected with coping processes. Coping studies, however, go beyond behavioural responses and include psychological mechanisms which foster (e.g. self-efficacy) or hinder (e.g. denial and inaction) behavioural coping and effective mitigation and adaptation responses. As for other crises, the dramatic effects of environmental change affect individual and social well-being, disrupt social relations, and contribute to feelings of anxiety and loss of confidence in the future. The capacity and efficacy of psychological and behavioural coping responses come to the forefront. With a focus on coping strategies, the psychology of emergency deals with sudden and radical environmental changes (e.g. earthquakes, floods), trying to prevent disruption and restore a sense of continuity, power, and meaning.

Psychological, social, and cultural resources are necessary to support and promote individual and community well-being not only in the immediate aftermath of destructive events but also before and in the medium terms after the shock. Emergency psychology stresses that the systemic dimension is also relevant for coping and empowerment. The actors to be taken into consideration are not only those who directly suffer from traumatic change but also their micro, meso and macro systems (i.e., family, friends, neighbours), including also those who are external to the context but are asked to intervene and are thus exposed to high levels of stress (Taylor & Frazer, 1982).

1.2 Restructuring the Phenomenological Field

From a different standpoint, the Gestalt school is a second classic approach that deals with qualitative change. Gestalt doesn't look only at traumatic contextual changes, but connects individual and contextual forces, perceptions and actions in a broader and systematic way. Gestalt treats concepts such as figure-ground perception or insight learning as processes of a general restructuring of the phenomenological field. In Köhler's experiments, a re-organization of the perceptual field happens in primates, making it possible to qualitatively transform the quality of objects (e.g. from boxes into steps, from two sticks into a long pole) and to reach the bananas hanging high above the cage. In the observation of children, it's the change in structure and direction of external and internal barriers that foster or obstacle the mobilisation of individual forces. For example, just by declaring 'it's playtime', children change their perception of context, which qualitatively changes the sofa into a castle or a space shuttle. Seen from the perspective of Lewin's dynamic theory, these are radical changes in the field that foreshadow a qualitative and not just quantitative transformation of its perceptual properties and the behavioural opportunities it offers (Lewin, 1935).

1.3 Cognitive and Affective Resistance to Change

Nowadays, 40 years of social cognition led to the development of robust bodies of knowledge concerning the nature of mental representations (e.g., schema, scripts, typologies of memory) and their role in guiding information processing and behaviour. Social cognition models often assume that human beings consciously and unconsciously avoid or resist to change. In this perspective, biases, heuristics, and specific needs (e.g. need for closure) are often invoked as basic mechanisms of individual cognition. Their main function is to save cognitive resources, leading humans to prefer stability and simplicity (of thoughts, attitudes, and behaviours) over complexity and change. As a counterproof, cognitive dissonance—that is, the awareness of holding two opposite beliefs or of having behaved inconsistently with one's beliefs—is often considered one of the main drivers for seeking new information or restructuring one's own beliefs, attitudes or behaviours so to reach internal consistency again.

Within this perspective, in environmental psychology, several processes have been identified that act as veritable barriers to perceiving and enacting change (see Du Nann Winter & Koger, 2004). A radical transformation, to be effective, should thus be able to overcome these dragons: *Limited cognition* (e.g., Ancient brain, Ignorance, Environmental numbness, Uncertainty, Judgmental discounting, Optimism bias, Lack of perceived behavioural control/ self-efficacy); *Ideologies* (e.g., Worldviews; Suprahuman powers; Technosalvation; System justification); *Comparisons with others* (e.g., Social comparison and norms; Perceived inequity); *Investments in money, time, previous behaviours* (e.g., Sunk costs, Behavioural momentum, Conflicting values, goals, and aspirations); *Discredence* (e.g., Mistrust, Perceived program inadequacy, Reactance, Denial; *Perceived risks* (e.g., Functional, Physical, Financial, Social, Psychological, Temporal risks); *Limited behaviour* (e.g., Tokenism, Rebound effect) (Gifford, 2011; Gifford et al., 2011).

Adding to these, emotions, motivations and drivers have been highlighted as regulators of cognition. The renewed attention towards deep motives and emotional drivers proved useful in understanding some counter-intuitive aspects related to individual and collective responses to crises.

For example, self-serving bias in causal attributions or systematic errors, such as the "just world hypothesis", would not only save cognitive resources but respond to deeper psychological motivations. The just world hypothesis postulates that we all tend to believe that "good people" have nothing to fear while bad events occur to "bad people". This process not only serves to maintain a sense of stability but also to project outside of the self the responsibility of negative outcomes resulting from our own behaviours, and to feel in control through an irrational phantasy that nothing negative can happen to those who behave correctly, especially to ourselves.

As Joffé suggests, these tendencies are coherent with the psycho-dynamic interpretation of the projection of the 'bad' outside the self and Douglas' social anthropological theory of the response to danger. In summary, the illusion of stability, of being able to control change, of being sheltered from transformations that we perceive as traumatic would be the result of individual foundations of the self, which are embedded in the western society cultural milieu: "From infancy to later life there is a rearrangement in people's representations of themselves and others in accordance with the struggle for a sense of control. The subjective management of anxiety is a relational process in which the self continuously strives for protection. The taking on of certain and not other representations, of the self and others, in relation to threatening phenomena, relates to a self-protective motivation." (Joffé, 1996, p. 208).

1.4 Placing Change in the Social Representations and Cultural Context

Contributions such as Joffé's are relevant because they bring us closer to a systemic psychology reading of the change, in which individual—even unconscious—dynamics are read within the cultural contexts. Her reference to *social representations* points to the continuous and culturally situated meaning-making process, which defines who we are (the so-called personhood and identities) and our relationships with others, human and non-human. In this perspective, symbols, metaphors, and images that circulate and compete in the public arena come to the forefront as rhetoric tools and communicative mechanisms through which change as an object is managed, familiarised, and endowed with meaning. Pivotal is the use of language which contributes to define the connotation of events (e.g. is it a risk or an opportunity?), the representations of self and others engaged with the issues at stake, and the pragmatic orientation which the individual and collective actors expect.

This latter way of addressing change is at the core of cultural, discursive, narrative, and socio-constructivist approaches to change in psychology (Contarello, 2022). Stability and transformation, in these perspectives, are emerging properties of communicative exchanges through which individuals and communities attribute meaning to novelties, manage them and make them more or less threatening.

The theory of social representations, in particular, has been largely used to examine how environmental issues are subject to negotiation, anchoring processes, selection of information, decontextualisation, simplification and neutralisation, and processes of cognitive polyphasia (i.e. the simultaneus use of different type of knowledge to make sense of specific social objects) (Castro, 2015; Provencher, 2011; Rouquette et al., 2005). In this regard, different representations are connected with group belongings, adherence to ideologies and cultural worldview. The transition discourse becomes not only a way to know the world but also and above all, a way to impose hegemonic ideological vision or to contrast and reverse them (Amari et al., 2016; Brondi et al., 2014, 2016; Norton et al., 2022; Sarrica et al., 2018). Even attention becomes a tool for social regulation: "not only does society affect what we habitually inattend, but it also tells us what we ought to actively disattend" (Zerubavel, 2015, p. 60).

Denial mechanisms should be intended not only as individual cognitive processes, but as social organized strategies. An example are the tendencies to accept pro environmental discourses, until they call for deeper and radical changes of the capitalistic system such as the one connected with de-growth or even of personhood, such as the one called by the Gink movement (green inclination no kids). These mechanisms play a decisive role in the orientation in the face of crises, including the environmental ones (Lima & Castro, 2005; Witt et al., 2013).

A further theoretical approach in line with the theory of social representations is that of cultural psychology.

According to cultural psychology, the individual and the context are inextricably linked and cannot be understood separately. The individual behaviours and cognitions are shaped by the cultural context in which they live, including the beliefs, values, norms, and practices of the culture. At the same time, individuals also shape their cultural context through their own behaviour and cognition. This mutual shaping of the individual and the context is known as the "person-context" relationship.

One key principle of cultural psychology is that culture is not just a set of external factors but is also internalised by individuals through their experiences and interactions with the culture. This internalisation of culture is known as enculturation, and it shapes the individuals cognitive and behavioural processes, including their perception, memory, reasoning, and emotions. For example, research has shown that the way people perceive and experience emotions are shaped by the culture in which they live.

Another principle of cultural psychology is that culture is not a monolithic entity but consists of multiple and diverse cultural practices, beliefs and values. This means that individuals within a culture may have different experiences, beliefs and behaviours depending on their specific subculture, social class, gender, race, religion, etc. It is essential to be aware of these nuances when studying the person-context nexus.

When looking at transformation from a cultural psychology perspective, the three-level model of the social context proposed by Mantovani (1996) is a useful framework. The model consists of three levels of analysis: the micro-level, the meso-level, and the macro-level. Each level represents a different aspect of the social context and how it influences the individual.

The micro-level of analysis focuses on how an individual behaviours and cognitions are shaped by personal characteristics, such as personality, abilities, and past experiences. This level of analysis also includes the individuals immediate social context, such as their family, friends, and immediate social interactions.

The meso-level of analysis focuses on how groups shape individuals' behaviours and cognitions. This level of analysis includes the norms, values, and beliefs that are shared in a given group and their influence on group members.

The macro-level of analysis focuses on how individuals are shaped by the larger societal context, including laws, policies, and institutions that shape the culture of the society. This level of analysis also includes the broader historical events and cultural traditions that have shaped society.

According to Mantovani, the three levels of analysis are interrelated and interact with each other. A change in the norms and values would shape an individual behaviours and cognitions at the meso-level and activate loops of reciprocal influence also with the broader cultural and historical context at the macro-level.

1.5 A Tentative Summary of Psychological Factors to Be Considered

As it is possible to notice already from this extreme synthesis of the main constructs through which gestalt, social, environmental, constructivist and cultural psychology read qualitative change, a common assumption is that it has a subversive nature. Rather than unfolding incrementally, as the results of small adjustments to pre-existing patterns and/or representations, qualitative change occurs when established cognitive and discursive structures are no longer able to respond to the fundamental functions of understanding and managing reality. Traumatic situations, a profound transformation of the perceptual field, elements that are too dissonant to be managed through polyphasic processes, require a radical transformation of our relationship with our surroundings in both symbolic and behavioural terms. These situations are outside that sphere of reality that is everyday life, and test our resilience, reaction and adaptation capacities (Axia, 2006; De Piccoli, 2007). However, each disruptive change is followed by an attempt to recover the stability and predictability of a system of reference within which individual and groups behaviour and goals are conceivable. That is, to recover that "known, controllable, non-problematic dimension of existence [in which] we feel at home, that is, in a relationship with the environment that sustains and favours adaptation, also understood as psychosocial well-being" (Emiliani, 2008, p. 9). It is precisely in this tension between extraneousness and everydayness that qualitative transformations can be examined.

It is clear that these radical transformations require resources ad different levels. Cognitive psychology teaches us that human beings act cognitively as resource economisers, bending their perception of reality to their prior knowledge (much more than we like to imagine). In parallel, at the societal level, social representations and cultural models are all the more effective the more invisible and 'normal' they become. It therefore takes cognitive and cultural resources, skills and power to be engaged in order to make oneself again at home in a radically changed world. In this regard, the difficulties in processing trauma, the choice of non-adaptive forms of coping, signal precisely the difficulty (sometimes the obstacle) to mobilising the necessary resources. As a results individuals and groups often engage in processes aimed at avoidance, resistance, adaptation to and mitigation of changes. As summarized in many recent reviews (Caillaud, 2016; Gifford et al., 2011; Smith & Joffe, 2013; Swim et al., 2011), individuals easily engage in symbolic coping responses that fulfil motivational needs (e.g., sense of control, positive identity) without, however, having a significant impact on the materiality of environmental degradation (Uren et al., 2019). Psycho-social variables such as values, beliefs, and norms are as fundamental as individual factors such as perceived control and non-conscious habits to activate behavioural coping responses (Kaiser et al., 2005; Klöckner, 2013; Stern et al., 1999).

A preliminary summary of how we might look at different types of social-ecological tipping events and connected tipping-points, therefore, includes processes of attention and perception, behavioural and symbolic coping mechanisms, pragmatic and ideological facets of communication, resources that individuals and communities have and believe they can put in place.

In sum, we suggest that what Swim et al. refer to as climate change can be easily extended to other typologies of crises, including the radical crisis activated by social-ecological tipping events:

> Adapting to, and coping with, climate change is dynamic; it involves many intrapsychic processes that influence reactions to (and preparations for) adverse impacts […]. Some relevant psychological processes include sense-making; causal and responsibility attributions […]; appraisals of impacts, resources, and possible coping responses; affective responses; and motivational processes related to needs for security, stability, coherence, and control. These processes are influenced by media representations of climate change and by formal and informal social discourse that involves social construction, representation, amplification, and attenuation of climate change risk and its impacts. […] Individual and

> cultural variation influence all aspects of the process, providing context, worldviews, values, concerns, resilience, and vulnerability (Swim et al., 2011, p. 244)

For our purposes, certainly, the extensive body of research that has dealt with the ecological crisis provides numerous cues that can be transferred to our understanding of the social-ecological tipping point connected with decarbonisation processes. However, there is still a dearth of research that directly connects these dots with the social-ecological framework and with tipping points in particular.

2 Current Insights on Tipping Points

2.1 Tipping Points as a Transformation in Perception, from Noise to Signal

A first relevant programme of research is trying to define tipping points by looking at a qualitative transformation in perception and at the variation due to time and valence of stimuli.

The line of research developed by Ed O'Brien and his team is rooted in studies on perception of streaks, change perception, and impression updating. It aims to identify the basic psychological processes underlying tipping points (O'Brien, 2020). Taking a human information processing stance, the tipping point can be defined as "the point at which people begin to perceive noise as signal" (O'Brien & Klein, 2017, p. 161). In this extremely synthetic and effective definition, we can identify both the qualitative transformation and the active role that individual and situational forces play in shaping their perception. The line of research activated from these premises is mainly based on an experimental behavioural paradigm and provides relevant and promising findings and a better understanding of individual processes. However, in order to apply tipping point conceptualisation to more complex and societal phenomena, it is necessary to refer to other approaches and levels of analysis. We will therefore limit here to mentioning two results that seem to us most relevant.

A first basic process, which could also be relevant to understand social and societal dynamics, and which is coherent with well-established paradigms such as the prospect theory, is the asymmetry of valence. In the experiment conducted by O'Brien and Klein (2017), a few failures (e.g. poor grades, poor sport performances) led participant to diagnose a loss in individual capacities yet the same amount of positive results was considered not enough informative. According to this process, "People reach their tipping point more quickly when they are evaluating evidence for possible decline than when they are evaluating evidence for possible improvement" (O'Brien, 2020, p. 56). In other terms, a few negative pieces of evidence are considered much more informative and lead more easily to conclude about having reached a tipping point. Perceiving a positive tipping point might thus prove to be much more difficult. Going beyond results, these evidences seem to suggest that, for example, an institution that wants to support the idea that a given policy has led to a positive tipping point has to consider deploying many more resources to convince citizens than those deployed by detractors.

A second basic process in the perception of tipping points is the asymmetry across time: “People predict slower tipping points than they express, regardless of valence” (O’Brien, 2020, p. 59). This means that when we imagine a tipping point, we anticipate needing much more than what’s actually necessary. For example, to change an idea, less evidence and information are required than what we think. It seems an optimistic view for those aimed at changing the community: it’s more difficult to think about change than to do it.

2.2 Dynamical System Psychology

Moving from cognitive processes to social transformations, as a second point of reference, are the contemporary developments in dynamical system psychology. This literature is more directly connected with studies on processes and dynamics of change, and in particular with the systemic approaches pioneered by von Bertalanffy.

The General System Theory provides a holistic approach to all sorts of social, and natural systems. It stresses the importance of considering not just the elements of the system, but their interrelationships, the relationships outside the boundaries and among sub-systems (e.g. internal processes, feedback, communication processes), in order to understand the overall functioning of each system. In this perspective, tipping points can be conceived as a peculiar trajectory of change through time.

It is important to stress that systems change in response to internal and/or external factors. Moreover, they display a dynamic existence, alternating periods of balance and change coherently with the general process of *adaptation*: “over time, systems may attempt to preserve their present status; but they may also need to change in response to transformations in their environment or alteration of a component within the system itself” (Cooper, 2012, p. 10). In such dynamic, tipping points can be defined as ‘non-gradient models of change’, i.e., an abrupt or dichotomous change in the status of the system.

These concepts have been recently absorbed into the dynamical system approaches in social psychology, which provides useful constructs to interpret and model critical junctures, loops, and transitions from one basin of attraction to another (Vallacher & Nowak, 1997; Wiese et al., 2010). Within this framework, system stability and change are considered as emergent properties guided by principles of self-organisation. In this sense, an organised system is not only stable but also resistant to change, thanks to its capability to attract the behaviour of existing and new elements into regular dynamics. Change depicted by tipping points should thus occur as a non-linear transition dynamic when mutual influences among the elements are transformed and when the coherence and stability of the higher-order state are weakened (Wiese et al., 2010).

For example, dynamical system approaches in social psychology are starting to be used to interpret and model critical junctures, loops, and transitions from one basin of attraction to another (Wiese et al., 2010). An example is provided by research at the crossroad between political and social psychology, which is interested in locating psychosocial processes within historical and political trajectories. Interesting in this sense is the proposal to examine nations as dynamical systems, defined by three parameters:

1. State symbologies, that is, the systems of symbolic meaning which are actively promoted by the state itself, including narratives, rituals and other symbolic strategies aimed at preserving and promoting the legitimacy of a given political and social structure
2. An identity space that is the ensemble of groups and social identities that co-exist, cooperate and clash within a society. Their own symbols may, and narratives may converge or be aimed to replace or become a viable alternative to the state symbologies and technologies
3. Technology of the state, that is, the material facets of states, including the apparatus, the institutions and the technological means used by the state to maintain and reproduce itself (Leone and Sarrica, 2017; Liu et al. 2014)

2.3 Socioecological Psychology

Finally, putting individual and systemic processes in context, the emerging field of socioecological psychology seems particularly relevant to understanding complex phenomena such as decarbonisation. Socioecological psychology (Oishi, 2014) shares with environmental and community psychology a common interest in everyday environments, and with cultural psychology the assumption that environment and mind mutually constitute each other. However, recovering a historical and materialist tradition, socioecological psychology underlines more than the other approaches the importance of "objective, concrete, macro conditions (e.g., green space, sex ratio, and income inequality) as well as cultural contexts" (Oishi, 2014, p.583).

For example, socioecological psychology can be used to study how social norms and values, as well as economic and political systems, influence the adoption of renewable energy technologies and the development of policies that support energy transition. Additionally, socioecological psychology would require considering the role of material environmental factors on energy transition. For example, access to green spaces, such as parks and forests, can influence people's attitudes and behaviours related to energy, or living in polluted spaces could activate denial mechanisms when behavioural responses are considered ineffective or non-viable.

3 Conclusion: An Area to Be Explored

Despite the centrality of the models of change in psychology, and the growing interest in the perception of tipping points, dynamical psychological model and socio-ecological approaches and, if we look in particular at psychological approaches to energy transition (Krupnik et al., 2022), and more specifically ad those interested in decarbonisation processes, the use of the term tipping-point is not common.

In the literature we examined in a previous review, which was not strictly psychological but included studies in social sciences dealing with decarbonisation processes (Rizzoli et al., 2021), the concept is explicitly addressed only in Otto et al. (2020), who consider tipping points as the transition in the perception of the environment: from fuzzy noise into well distinct stimuli to which humans react. Tipping points are otherwise used as an interpretative key to draw overall conclusions (Schmitz, 2017), or are broadly assimilated to dynamic in decision making (Cuppen et al., 2015), to threshold (Strauch, 2020; Weng et al., 2018), to the key events, decisions and actions associated with speed and scale of transition (Wiseman, 2018), non-linear transformations (Messner, 2015).

Drawing on the psycho-social understanding of tipping points sketched in this chapter it thus emerges the lack of a proper understanding psychosocial processes underlying tipping points.

In this sense, a first direction would be to rediscover the theoretical and methodological foundations through which psychology has dealt with processes of qualitative transformation. For example, although insights from gestalt have been included in contemporary systemic models, bringing out the (also historical) foundations of studies on perception would allow the tipping points to be defined in more detail, operationalising them at both the individual and societal levels.

Furthermore, research should understand the psychological connotation of tipping points. This complexity is determined by the different perspectives that are adopted in the evaluation of change. Within the same individuals change and inconsistencies can be observed from the outside, but managed and denied from the subject him/herself. Construct such as, polyphasia, cognitive dissonance, removal, stand for our capacity to deal with inconsistency without necessarily recognising them. Parallel, at the community level, visions external to the communities involved in the change, or internal to them, each carrying different interests, chase one another.

The classic distinction between emic and etic perspectives can help us in this regard. Following an etic perspective, the identification of "positive" or "negative" tipping points would depend on the dimensions decided from the outside, as a transformation in knowledge, in the group dynamics, in the materiality or in the enacted behaviours. Taking a pro-environmental perspective, for example, as the one that we share, the increase in significant as well as of relevant behaviours would be evidence of positive tipping points, since they would signal an increase in mitigation behaviours and in environmental awareness respectively. In the second case, from an emic perspective, the connotation of tipping points can only be identified "from the inside". Closely related to social representations and cultural models, an emic approach would focus on changes in interpretations, narratives, representations, and practices that define the relationship linking self-other-reality. An emic approach would rather identify a positive tipping point as a transformation in consciousness (at the individual or social levels) or in self-perception, even without an evidence of actual behaviours.

Finally, and perhaps this is the most innovative line, it will be crucial to link psychological processes and material components in the study of systemic transformations. Indeed, the proposal for a socio-ecological psychology, as well as the systemic approaches briefly summarised here, aim to address the difficult relationship between political, historical, ecological dimensions and psychological and cultural dimensions. This is a even more fundamental challenge, at a time when the radical changes brought about by the climate crisis are becoming evident. How, for example, will communities that have been connected to Alpine glaciers for centuries cope with their disappearance? how will the transformation of marine species affect the psychological well being of fishing communities?

In the cases reported in the second part of the book, environmental transformations intersect with other material aspects to which psychology has often given too little attention: changes in policies, economic transformations, power imbalances. Although from different perspectives, the relationship between qualitative changes in these material spheres and in the symbolic spheres connected to them appears in all chapters. Memory, identity, agency, justice, are just some of the aspects that are radically changing in the CCIR regions involved in decarbonisation processes.

Understanding how to leverage these mechanisms to foster a just transition, is a frontier and a challenge, which psychology cannot escape and to which, indeed, it can provide deep-rooted models and innovative proposals.

The field is all to be explored.

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Transformations, Agency and Positive Tipping Points: A Resilience-Based Approach

Per Olsson and Michele-Lee Moore

Abstract This chapter focuses on a social-ecological systems (SES) resilience-based approach to critically examine the relationship between tipping points and transformative change. Resilience science provides a framework for understanding the dynamics and interdependencies of complex systems and their ability to persist, adapt, or transform in response to change and uncertainty. Transformation refers to a deliberate and fundamental restructuring of a system or a set of relationships that hold a system in a particular state. We argue that the integration of a resilience-based approach to transformations can enhance the understanding of the link between tipping points and transformations, as well as the agency and capacities required to navigate them. In particular, we focus on how transformations research emphasizes the need to: better understand tipping points as one of many aspects of deeper transformation processes, include consideration of the distributed nature of agency and relationships, and how uncertainties will emerge in relation to shocks and disturbances which will surround tipping points. To achieve this, we drawing on the inter- and transdisciplinary scholarship related to transformations to sustainability including leverage points, social-ecological tipping points, disaster resilience, and case studies. We conclude that social tipping alone is insufficient; instead, there is a need for capacities to navigate the entire tipping process, or the full range of tipping dynamics, toward desired outcomes.

Keywords Transformations · Agency · Transformative capacities · Positive tipping points · Complex systems · Tipping dynamics · Resilience-based approach

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1 Introduction

The concept of tipping points, particularly positive tipping points, holds promise in the effort to comprehend and facilitate the rapid, large-scale, systemic transformations necessary to address significant global challenges, such as biodiversity loss and climate change (Sachs et al., 2019; Steffen et al., 2018). We refer to tipping points here as representations of critical junctures where a system undergoes a rapid and often irreversible shift in behavior or state in response to certain triggers or conditions (see for e.g. Milkoreit et al., 2018). Positive tipping points specifically pertain to collective actions, behaviors, or social movements that lead to substantial and positive societal change (Lenton, 2020; Lenton et al., 2022; Marten, 2009; Milkoreit, 2022; Milkoreit et al., 2018; Tabara et al., 2018).

It has been argued that understanding and harnessing positive tipping points can enable and catalyze transformative change at a broader scale (Tàbara et al., 2021). The idea is that through identifying leverage points and interventions that can trigger cascading effects, we can unlock the potential for widespread adoption of sustainable practices, policies, and behaviors (Otto, Donges, et al., 2020; Sharpe & Lenton, 2021). The hope underpinning the existing arguments is that tipping points hold the potential to accelerate key transitions to more sustainable and resilient futures by overcoming inertia, generating positive feedback loops, and creating a momentum for change.

However, as the sub-field of scholarship focused on positive tipping points continues to evolve, there are valid concerns and critiques regarding the use of the concept, especially in considerations of achieving transformative change in complex systems. A major concern is the recognition that not all tipping points necessarily lead to transformative outcomes with some leading only to temporary or localized shifts without fundamentally altering the underlying system dynamics (Milkoreit, 2022). Additionally, the eventual outcomes of tipping points, and whether they truly lead to sustainability and justice or are considered “positive”, will be influenced by various factors that all shape transformative change processes. For instance, with a too narrow focus on technological innovations or a specific problem such as carbon emissions, “positive” change can have unintended and unexpected negative consequences in other parts of the system, including biodiversity and justice (Olsson et al., 2020). Moreover, whether underlying structural barriers are addressed, whether and what types of agency are mobilized, how inclusive decision-making processes are part of the “tipping”, and how well agents navigate complex social, economic, cultural, and ecological dynamics across scales all matter to the directionality of transformations processes (Geels & Ayoub, 2023).

More specifically, some of the existing research on positive tipping points has neglected the critical and specific roles of agency that have been well studied in other transformations scholarship; that is, whose agency and which capacities will be necessary once a system has reached a tipping point and starts to rapidly form new, self-reinforcing feedback loops. In resilience and transformation research terms, this is the threshold when a social-ecological system is reconfigured and begins to move towards new attractors and stability basins, also referred to as the transition phase (Olsson et al., 2006). It is in the interplay between transformative agency and the broader system dynamics and feedbacks that will shape whether a tipping point is a negative or positive one. Moreover, we build on previous scholarship that has showed that conceptualizing social tipping as a single threshold alone is insufficient; instead, there is a need to consider a full range of tipping dynamics, including the capacities to navigate the entire tipping process (Geels & Ayoub, 2023; Herrfahrdt-Pähle et al., 2020; Milkoreit et al., 2018; Stadelmann-Steffen et al., 2021).

Therefore, recognizing both the promise and perils of this concept, we focus this chapter on a social-ecological systems (SES) resilience-based approach to critically examine the relationship between tipping points and transformative change. Resilience science provides a framework for understanding the dynamics and interdependencies of complex systems and their ability to persist, adapt, or transform in response to change and uncertainty. Transformation refers to a deliberate and fundamental restructuring of a system or a set of relationships that hold a system in a particular state. We argue that the integration of a resilience-based approach to transformations can enhance the understanding of the link between tipping points and transformations, as well as the agency and capacities required to navigate them. In particular, we focus on how transformations research emphasizes the need to: better understand tipping points as one of many aspects of deeper transformation processes, include consideration of the distributed nature of agency and relationships, and how uncertainties will emerge in relation to shocks and disturbances which will surround tipping points. To achieve this, we draw on the inter- and transdisciplinary scholarship related to transformations to sustainability including leverage points, social-ecological tipping points, disaster resilience, and case studies.

2 A Resilience-Based Approach to Transformations and Tipping Points

The resilience-based approach defines transformations as a distinct form of change, differentiating it from other types of change such as adaptation (Folke et al., 2010; Walker et al., 2004). Adaptation is understood as adjusting responses to changing external drivers and internal processes in order to remain in the current pathway of development, while transformation involves creating new pathways of development when ecological, economic or social conditions make the continuation of the existing system untenable (Folke et al., 2010).

The feedback loops or relationships involved in a transformation are those that make up a “system” (Tàbara, 2023) and its particular state (Hebinck et al., 2022). From this perspective, transformation will involve altering key relationships and feedbacks that influence the distribution and flow of authority, power, and resources, and involve changes in the practices and processes that reflect and reproduce these structures, as well as shifts in the underlying norms, values, and beliefs that support these structures and processes (Moore et al., 2014, 2023). Furthermore, transformations involve the reconfiguration and reconnection of these elements in a way that is deeply connected to ecological systems across multiple scales (Moore et al., 2023). In essence, transformative change entails restructuring, reconnecting, and reshaping the meaning of relationships between individuals, as well as between humans and the ecosystems in which they are intricately embedded (Abson et al., 2017).

According to SES resilience theory, tipping points are critical points where a small change can have large and irreversible effects on the structure and function of a SES (Scheffer et al., 2001). Resilience scholars have focused on identifying and anticipating tipping points (Biggs et al., 2009), and to design strategies to avoid those that would create further unsustainability or injustice (Biggs et al., 2018) and how to navigate them (Olsson et al., 2006). This research also recognizes that some tipping points may be desirable or inevitable, and that they can create opportunities for transformation (Herrfahrdt-Pähle et al., 2020) if the system has been prepared for change.

Early theoretical frameworks of SES resilience describe complex adaptive systems as having landscapes with multiple basins of attraction and stable states, and multiple development trajectories (Scheffer & Carpenter, 2003), often pictured as a cup and ball model (Fig. 1). In the context of transformations, the notion of moving from one basin or state to another is central (Gunderson et al., 2022; Scheffer &

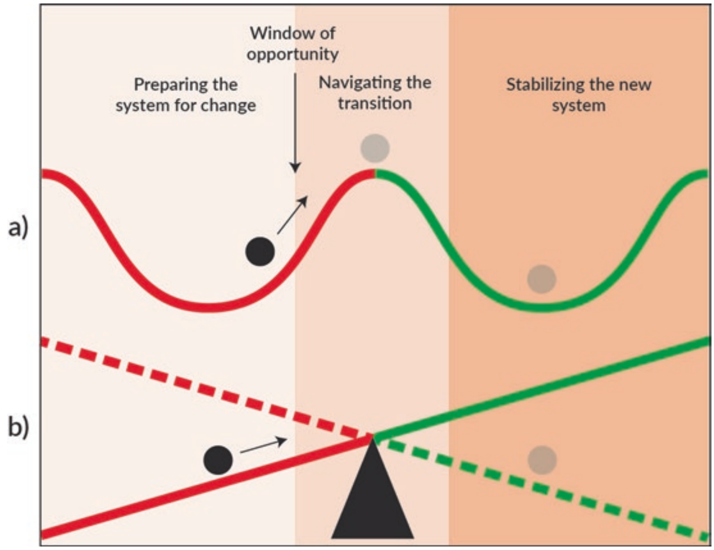

Fig. 1 Shows an early resilience-based transformations model, with a system that shifts from one basin of attraction to another, over a threshold (**a**) or tipping point (**b**) (Olsson et al., 2010). It also shows the three phases of transformation defined by the agency involved (1) preparing the system for change, (2) navigating the transition, and (3) stabilizing the new system (Image by: J. Gustafsson)

Carpenter, 2003). Each basin represents a distinct configuration of the system, held in place by specific sets of self-reinforcing feedback loops or relationships (human-human and human-non human) and organized around particular attractors.

Drawing on the concept of multiple basins of attraction, early frameworks in resilience-based transformations describe transformations as regime shifts between stable states, involving the crossing of thresholds or tipping points (Folke et al., 2005; Olsson et al., 2004, 2006, 2010) (Fig. 1). From this perspective, any transformation process will involve the dissolution of negative attractors and at least some of the feedback relationships associated with the dominant state, as well as the generation of new attractors, relationships, and feedback loops in alternative basins. Put more simply, transformations involve both "unmaking" and "making" of specific sets of relationships that make up a system (Feola et al., 2021; Moore et al., 2023).

Attractors can be metaphorically described as patterns that "attract" the behavior and self-organization of the system (van der Leeuw & Folke, 2021). In social-ecological systems, attractors can encompass physical conditions such as temperature, soil, or water, as well as hopeful and newly articulated visions, narratives, and imagined futures that are embedded in specific sets of values that can attract behaviors and institutions to organize around them (van der Leeuw & Folke, 2021). Attractors can vary in strength and are represented by the depth of each basin. A deep basin signifies a strong attractor that is resistant to transformation even when the system experiences disturbances, while a relatively shallow basin can be more easily tipped when disrupted (Holling, 1973; Scheffer & Carpenter, 2003).

At the threshold or tipping point between two basins, the metaphorical "ball" could roll in various directions across a landscape of multiple possible basins of attraction (Herrfahrdt-Pähle et al., 2020; Hill & Kolmes, 2023; Tabara et al., 2018) (Fig. 2). This means that trajectories of transformation might lead towards positive attractors, such as peace, sustainability, and justice (Donges & Barfuss, 2017;

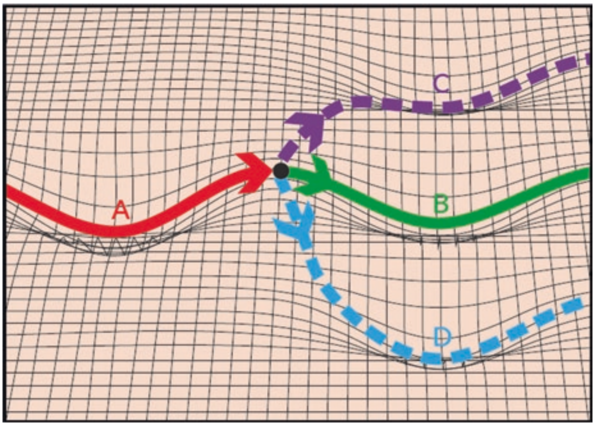

Fig. 2 Illustrating multiple system trajectories represented by multiple basins of attraction that the "ball" can roll into in the transition phase, due to many competing, latent attractors (C (purple) and D (blue)), not shown in the two-dimensional Fig. 1 (from Olsson & Moore, 2024) (Image by: J. Gustafsson)

Elmqvist et al., 2019; Westley et al., 2011). However, the ball could also revert to the previous basin or even gravitate towards different versions of negative and sometimes latent attractors (Malka, 2021). The outcome of the transformation process depends on the complex interplay of various factors and the contestation of competing attractors within the system.

Studies using SES transformations frameworks have examined the interplay between tipping dynamics and shocks and crises and how these disruptions have the potential to create pivotal moments, or opportunity contexts when significant transformations become possible (Moore et al., 2023; Olsson et al., 2004). As an example, Hebinck et al. (2022) examine the interplay of factors shaping the coal and carbon-intensive energy regimes that are the focus of many transformation efforts. Additionally, Herrfahrdt-Pähle et al. (2020) examine the role of political crises and the range of cognitive, structural and agency factors that interact across multiple scales and multiple phases of a transformation. SES transformations frameworks treat tipping dynamics as mainly occurring in one specific phase in the transformation process: the transition phase (Fig. 1a), although these will be shaped by what happens during the preparation and institutionalization phases. The transition phase can be characterized as a period of uncertainty and surprise, representing a state of limbo between systems and basins of attraction (Olsson & Moore, 2024). During this phase, characterized by the crossing of thresholds and tipping points, the dissolution of old feedbacks and the formation of new feedback loops are occurring rapidly, and the dynamics of the system are in flux. Within this phase, as previously stated, there is the potential for both positive outcomes and negative consequences, including periods of intense conflict and violence (Hartwell, 2007; Stedman, 1997).

Recognizing the transition phase represents a period of complexity and heightened uncertainty (Moore et al., 2023), and diverse agency including the full range of "strategic moves and countermoves, interactions learning, reflexivity, and cognitive changes" (Geels & Ayoub, 2023, p. 2) that will interplay and co-evolve with ecological change, scholars have argued for the need to move away from treating tipping points as singular thresholds or control parameters (Geels & Ayoub, 2023; Milkoreit et al., 2018; Stadelmann-Steffen et al., 2021). We adopt this approach here and argue that understanding the possibilities for positive tipping dynamics for peaceful and just transformations towards sustainable and equitable futures requires a deliberate focus on the role of agency in navigating the uncertainties and complexities inherent in the transition phase of transformative change.

3 The Role of Agency and the Capacities for Navigating Tipping Dynamics

Having summarized the relationship between SES perspectives on transformations and tipping dynamics, this section dives deeper into the role of agency in relation to transformative tipping dynamics. By exploring how agency interacts with and influences the threshold and tipping dynamics within a system, we can better understand its potential to navigate transformative change and offer insights into how to foster positive outcomes and build capacities that can help guide systems towards a more sustainable and equitable future. We focus on three issues that a resilience-based approach to transformations highlights with respect to agency and tipping dynamics: (1) that agency is distributed and no single actor or agent can control a complex system or tipping point, (2) transformation is a nonlinear process that involves more than diffusion of specific technologies, behaviours or practices, and (3) tipping dynamics will lead to emergence, but will also be subject to crisis, disruption, and surprise as these are key features of any complex system change process and agents will need to navigate these as well as the changes associated with tipping.

3.1 Distributed Agency and the Illusion of Control of Tipping Points

In the resilience-based transformations approach, a rich accounting of transformative agency has been established. Early efforts to connect positive tipping points, transformation, and agency were influenced by scholarship on resilience conducted by Berkes et al. (2003), Berkes and Folke (1998), Gunderson et al. (1995), Gunderson and Holling (2002), Ostrom (1990), and Westley (1995, 2002). These endeavors encompassed both theoretical and empirical work, incorporating case studies such as Kristianstads Vattenrike (Hahn et al., 2006; Olsson et al., 2004), Chile coastal fisheries (Gelcich et al., 2010), and the Australian Great Barrier Reef (Olsson et al., 2008). These studies shed light on the dynamics of transformative change, capturing both slow and fast dynamics of such change, and how complex adaptive systems can rapidly and abruptly change development trajectories at specific point in time, and under certain conditions. They drew upon concepts such as critical transitions and regime shifts (Scheffer et al., 2001), bifurcation points (Ludwig et al., 1997), bifurcation policy (Olsson & Folke, 2001), window of opportunity (Kingdon, 1995), critical junctures (Baumgartner & Jones, 1991), and punctuated equilibrium (Repetto, 2006). Notably, the early work highlighted the role of agency and the necessity of specific capacities for transformative change, including "tipping-point leadership" (Folke et al., 2005; Olsson et al., 2006).

Together with more recent contributions (e.g. Benessaiah & Eakin, 2021; Bennett et al., 2016; Drimie et al., 2018; Nilsson & Paddock, 2014; Pereira et al., 2020), this scholarship shows that the mobilization of transformative agency will relate to the capacity of actors to navigate the direction and outcome of change processes in complex systems. Agency is crucial for navigating tipping dynamics and transformation between different basins of attraction, as it determines how actors perceive, respond to, and shape the system in the context of uncertainty and surprise (Folke et al., 2005; Olsson et al., 2004, 2006; Westley et al., 2011, 2013). Transformative agency can be enhanced or constrained by various factors, such as power relations, institutions, values, and knowledge (Benessaiah & Eakin, 2021).

Perhaps most importantly to tipping dynamics however, is that agency has been shown to be collective and distributed across space and time, and involves coordination and collaboration among different actors across different phases of a transformation process (Moore et al., 2018; Olsson et al., 2006; Rosen & Olsson, 2013; Westley et al., 2013). The notion of distributed agency however, has not yet been well considered in relationship to tipping dynamics (Otto, Wiedermann, et al., 2020).

Given that an SES resilience-based approach to transformations treats existing system states as related to broad sets of relationships and dynamics, it is worth remembering that some of those are path dependent and can contribute to traps (Carpenter & Brock, 2008; Haider et al., 2018), while other dynamics and relationships may be emergent and not something that an individual or group have set out to deliberately create. Too often, problematic dynamics, system states, or traps are treated as something held in place only by powerful "others". Inevitably, that leads to scholarship focusing on the roles of different actors, and the likelihood that those actors may have influence on a tipping point or transformation. For instance, scholars have analyzed civil society and their role in grassroots change (Frantzeskaki et al., 2018), shadow networks and their work to influence decision-makers (Olsson et al., 2006; Sendzimir et al., 2008), and keystone actors that hold positions of wealth and power that would need to be redirected for the trajectory of the system to be moving towards sustainability and justice (Österblom et al., 2017).

Although understanding the different roles that different sets of actors play, and when, is essential for understanding transformation processes, the risk is that some scholarship can tend towards discussing transformations and tipping dynamics in deterministic terms. The notion that either wealthy corporate elites or civil society are somehow able and more likely to control a complex phenomenon such as transformation or a tipping point ignores what is understood about the lack of control associated with complex systems. Transformation will involve some deliberate exertion of agency, but it will be combined with emergent, nonlinear dynamics that cannot be predicted nor "managed" before or after they emerge (see for e.g. Mintzberg & Westley, 1992) and will require constant re-calibration and navigating. As Westley et al. (2006) recognize, we are all the system; the system is not just something done to us as agents, nor is it held in place simply by one set of actors or one specific structure. At best perhaps, agents can develop reflexivity sufficiently enough to begin to be able to "see" the dynamics as they emerge around them (Moore et al., 2018).

3.2 Transformations as Complex, Nonlinear Processes

The idea of agency as distributed across space and time scales also raises issues for how tipping points scholarship can model social tipping dynamics. Existing analyses are explicit in recognizing complex transformative change processes will be nonlinear (Lenton, 2021; Otto, Donges, et al., 2020). However, social tipping point modelling has tended to rely on contagion and diffusion theories for the rapid scaling out of technologies (e.g. zero emissions technologies) to hypothesize whether it is possible to make a difference large enough to contribute to mitigate further changes to the climate (Otto, Donges, et al., 2020). While these are useful for understanding the potential impacts of technology adoption by a specific number of people, these models tend to treat transformation as relatively linear, and further neglect that transformation processes will involve far more than adopting a few technologies, and the much more nuanced insights transformations research has already established about agency in nonlinear processes (Smith et al., 2020).

As stated, we follow Geels and Ayoub (2023) in treating tipping more as a range of dynamics rather than a singular point, and we place these sets of dynamics as one aspect occurring within the transition phase of a transformation process (Herrfahrdt-Pähle et al., 2020). Although research has shown that the capacities of this phase depend on the capacities of the preparation phase (including readiness and leveraging) and stabilization phase (including consolidation and routinization) (Herrfahrdt-Pähle et al., 2020; Olsson et al., 2004, 2006),—that is, the capacities of the different phases will affect one another—we focus here specifically on the agency and capacities of the transition phase that are crucial for navigating positive tipping dynamics.

If the transition phase typically involves a rapid shift in at least some of the systems' behaviors, rules and regulations, and values, leading to profound changes in relationships and rapid formation of new self-reinforcing feedback loops, then the overall tipping dynamics can be understood as representing that critical time where shifts in feedback loops may accelerate both the making and unmaking processes of transformations. In transformative change, the unmaking process is particularly crucial as it may facilitate tipping and moving through the transition phase (Olsson et al., 2014). The resilience-based approach for example, recognizes the pivotal role of agency in reducing the resilience of undesired systems that perpetuate injustices and unsustainability (Elmqvist et al., 2019; Olsson et al., 2014; Walker et al., 2002), ultimately aiming to dissolve self-reinforcing feedback loops that maintain such systems in a particular basin of attraction. Without adequate attention to the unmaking aspects of transformations, which will happen in the preparation phase and throughout a transformation process, significant portions of the status quo system may persist, posing risks of cooptation for initiatives or interventions aimed at enabling transformative change and limiting the depth of change that may be possible.

One capacity required in the "unmaking dimension" is rapid hospicing, which involves honoring, grieving, and addressing the losses and legacies of the dominant system (de Machado Olivier, 2021). Another capacity relevant for both dimensions is systems reflexivity, which entails recognizing and adapting to the constraints and opportunities shaped by existing institutions and structures during the transition phase (Moore et al., 2018).

Apart from the dissolution aspects of transformative change, capacities will also be needed for establishing alternative attractors (van der Leeuw & Folke, 2021). For example, capacities for envisioning and self-organizing are essential in the "making dimension" to support the emergence of new states and attractors (Hölscher & Frantzeskaki, 2020; Moore et al., 2018). Similarly, imagination is likely to play a critical role in the making of alternative attractors and ultimately, alternative futures (Galafassi et al., 2018; Moore & Milkoreit, 2020, Pereira et al., 2018). Recognizing the interconnectedness of social-ecological systems, strengthening the connection to the biosphere also becomes a crucial capacity. It can be a part of healing approaches, revitalizing identities, cultures, languages, biocultural practices and more that have been damaged through conflict or marginalization by the previous dominant system (Westoby et al., 2022).

3.3 Navigating Crisis, Shocks, and Disturbances Surrounding Tipping Dynamics

As mentioned earlier, the transition phase, and the tipping dynamics, of any transformative change can be the most turbulent and challenging. Understanding the role of agency and the capacities necessary for navigating for example the conflict and violence associated with this phase is crucial. In Olsson and Moore (2024), we use peacebuilding as an example of a transformative process that offers a refined conceptualization of the transition phase. This conceptualization incorporates positive tipping dynamics and provides insights that can guide further exploration of specific agency and transformative capacities, determining which aspects of agency and capacities are important and why. These capacities encompass methods to secure inclusivity and representation and the ability to navigate "backlash" dynamics that often arise in transformative change efforts, including conflicts and violence.

An illustrative example of the kinds of dynamics that can emerge surrounding tipping involves any number of social movements that have arisen but are not yet directly linked to a transformation. Acts of resistance, such as protests or campaigns by social movements are often critical in effectively weakening the attraction to the dominant governing regime's basin. However, while such acts are important, they can focus more capacity on weakening the existing attractor, which can be limiting if it is not also linked up to other efforts that are strengthening capacities to envision and build attraction towards alternative states or navigate the liminal space between them. In these instances, although a social tipping "point" can theoretically be reached regarding the rejection of the existing system state, the broader tipping dynamics have not yet lead to transformative change. This example also highlights the need for capacities to deal with latent attractors or generate new attractors during the transition phase and the tipping dynamics. It is important to recognize that various efforts by different groups may represent different and sometimes competing support for different attractors which may affect the trajectory during and after the transition phase.

Literature on conflict resolution can also be useful to combine with the resilience-based transformations approach to better understand the dynamics that can emerge during the transitions phase in which tipping dynamics occur (de Coning, 2020). Scholars have described instances of violence that erupted in response to transformative change, such as the types of violent opposition that can erupt during national transitions from conflict and dictatorships to peace and democracy (see for e.g. Edles, 1998). The evidence indicates that there can be a potential for backlash to occur when societies begin to tip in a particular direction or when they even show a potential to do so as the preparation of the system for change becomes obvious to those that comprise the system (Olsson and Moore 2024). Again, having capacities to navigate such dynamics are as crucial as building a social tipping if transformative change is sought after.

Resilience scholars have also studied another key aspect of tipping dynamics—the role of crisis in transformations. Crisis can include economic, ecological, or socio-political shocks, natural disasters, and pandemics (Benessaiah & Eakin, 2021; Brundiers, 2020; Herrfahrdt-Pähle et al., 2020; Moore et al., 2023; Olsson et al., 2004). Crises and polycrises (several interacting crises) can serve to create different opportunity contexts for transformation, and sometimes can weaken the unwanted attractor and make the basin more shallow and more susceptible for "tipping". However, crisis can emerge at any time in the transition phase—as well as during any other phase of a transformation process—which will inevitably add to the complexity of the tipping dynamics. As crises can lead to a wide range of outcomes, it is crucial that capacities for navigating positive tipping dynamics will need to also include abilities to continually respond to additional, unanticipated crises or disturbances that may arise during the transition phase.

In the precarious transition phase of any transformation process, which determines whether a system moves towards sustainability and justice, it has been argued that the development of a temporary, shallow basin of attraction can be crucial for navigating positive tipping dynamics (see Fig. 3) and allow for new attractors to be collectively defined and new relationships and feedback loops to form. Key capacities would involve creating the conditions necessary to allow for this and to deal with the uncertainties, volatility, and resistance that can emerge in any transition phase. It is essential to recognize that the transition phase, and the tipping dynamics itself, represents a state, albeit a more temporary one compared to the other phases.

In addition, from a resilience-based transformations perspective, ensuring this temporary state can provide space to foster new attractors requires having the capacities to grapple with two other aspects of transformative change. The first is having the capacities to consider and even anticipate cross-scale dynamics, or teleconnections—those hidden relationships that can exist across problems and vulnerabilities at different spatial and temporal scales (Adger et al., 2009; Liu et al., 2015). Such a capacity would be needed to ensure that any future attractors are not serving to reinforce issues that existed in the previous dominant state, nor creating new unsustainable or inequitable dynamics that might not have otherwise been anticipated.

Second, capacities will be needed to bring forward aspects of the previous dominant system that are needed for any future. As just one example, certain forms of knowledge and ways of knowing, such as Indigenous ways of knowing and knowledge, provides essential elements for continuity, recognizing specifically that continuity does not mean static (Apgar et al., 2015; Bartlett et al., 2012; Prosper et al., 2011; Tobias & Richmond, 2014). Likewise, Lansing (2009) documented the roles

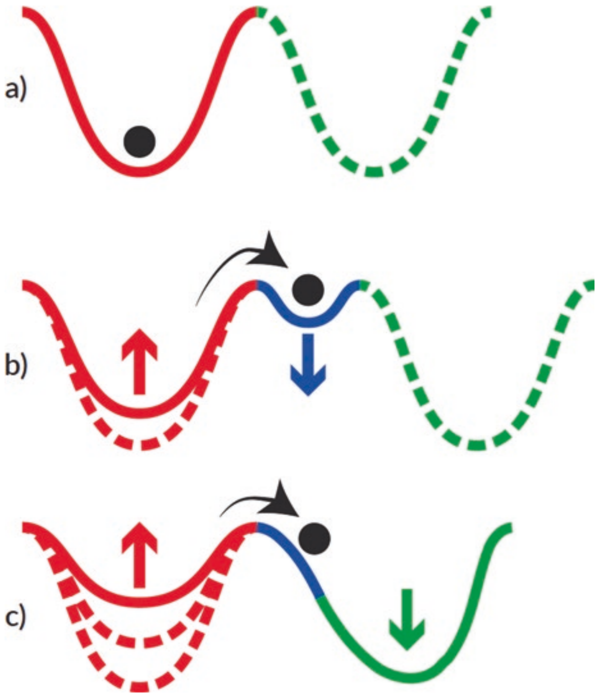

Fig. 3 (**a**) The red basin of attraction or "cup" is the current system state, with negative attractors, that needs to be transformed. The dotted green line is the future basin of attraction and the imagined, transformed state of the system, with new, positive attractors. (**b**) Since the transition phase can be difficult to navigate (due to high level of uncertainty and surprise and latent, competing, and negative attractors), agency and transformative capacities can help create a temporary, shallow basin of attraction (in blue). Thus, it can provide a liminal space when moving from one state to another. (**c**) This can create enough time and space to allow for new attractors to be collectively defined, the navigation of tipping dynamics, and new relationships and feedback loops to form (from Olsson & Moore, 2024) (Image by: J. Gustafsson)

of spiritual leaders who maintain the stories, practices, and rituals for ways of knowing and connecting with nature in the relationship between Balinese water temples and rice irrigation. Thus, Indigenous and local, place-based or context-specific knowledge, institutional memory, social-ecological memory (Andersson and Barthel, 2016), and more all shape the dynamics that may follow tipping and can provide context and experience for reorganization after periods of instability and change (Olsson et al., 2022).

Such a perspective places less emphasis on finding the perfect "seed" or set of initiatives to grow to a large scale, which has been the focus of current social tipping point modelling, and moves away from early understandings of innovation that rely on linear, diffusion theory. Instead, the focus is more on creating the potential for different building blocks and combinations within a system that help break path dependence and reorganize around a new attractor during this temporary transition state.

4 Conclusion

Recent scholarship has described how early scholarship used the concept of social tipping points too loosely and more as a metaphor, raising major questions about the complex social dynamics that were glossed over by positive orientations to tipping points (Milkoreit, 2022; Otto, Donges, et al., 2020; Smith et al., 2020). We respond to that growing awareness by drawing on insights from resilience-based approaches to transformations, suggesting the findings in this sub-field of resilience scholarship could help better understand the capacities needed to navigate the momentum that tipping dynamics involve.

We begin by describing transformations as a multi-dimensional and multi-phased process (see Olsson et al., 2014), arguing this understanding of transformations raises questions about what happens beyond tipping points, and even, what happens while tipping dynamics are underway. As Milkoreit (2022) describes, a significant increase in the number of articles related to social tipping points has emerged in relationship to climate change solutions. While the risks that climate tunnel vision creates have been acknowledged elsewhere, these same risks appear applicable to social tipping point research. Climate solutions should not be disconnected from other issues such as biodiversity, and should not be considered in isolation from the broader dynamics of social-ecological transformations. As part of the resilience-based approach to transformations, we also urge scholars working to understand social tipping dynamics to better account for both phasing out of existing dominant feedbacks and relationships and the generation of new, alternative attractors as critical to the phase in which tipping occurs. A tipping point that can contribute to a new, stabilized state will depend on how fast or slow the unmaking dynamics may play out, and how much momentum for the new attractor has been established—if neither of these has occurred, it is unlikely that any tipping dynamics would lead to transformation.

The making and unmaking processes will rely in large part, on agency. Based on existing conceptual and empirical scholarship, we suggest that understanding the role of social tipping dynamics within broader transformation processes requires consideration of three key aspects of agency. One, social tipping dynamics research needs to move away from emphasizing the role of individual agents and their adoption of specific technologies, behaviours, or practices, since no single actor controls a complex system. We suggest future research needs to better grapple with the distributed nature of agency in complex change across multiple scales. Two, in moving away from the idea of scaling out a specific technology, behaviour, or practice, we suggest stronger consideration be given to what transformations has already established about the capacities needed for both the making and the unmaking of different basins of attraction, or different system states. Three, given the uncertainties and risks of backlash and resistance during the transition phase, we urge a stronger consideration of the dynamics of surprise, uncertainty, disruption, and crisis in relationship to tipping dynamics. Surprise, uncertainty, disruption, and crisis have all been central to resilience-based transformations research, but are often neglected in current social tipping point analyses despite the fact that agency and strategies will be needed for stabilizing the tipping point and guiding the trajectory towards certain attractors over others.

Finally, while we point to specific capacities needed to navigate the tipping dynamics and the broader transition phase we consider them to be part of, we note that much more research is required to both further empirically gather evidence for and against specific capacities, and to give consideration of questions that currently remain unanswered. While we state that transformations can be shaped but not controlled by a single actor group, substantive theorization about accountability and responsibility of different actors during tipping is still urgently needed.

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Principles for a Case Study Approach to Social Tipping Points

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Abstract Recent interdisciplinary study has led to significant conceptual advances and a broad empirical evidence base for ecological and climate tipping points. However, the literature has yet to present convincing empirical case studies of social tipping, as the data-driven identification of social tipping points remains a challenge. Arguing that the barriers to such empirical research are largely methodological in nature, we develop methodological guidance to identify social tipping processes in social-ecological system case studies, based on four key elements—multiple stable states, self-reinforcing feedback dynamics, abruptness, and limited reversibility. We apply our approach to food system changes linked to the Flint Water Crisis between 2010 and 2020. We identify seven principles that can simultaneously serve as a seven-step process for social tipping point analysis in any social-ecological system. We highlight two major challenges: the limited availability of high quality, longitudinal social data, and the possibility that value-driven social processes tend to curb abruptness and non-linear change. Utilizing the seven prin-

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ciples to study historical, ongoing, or anticipated cases of social tipping processes could facilitate a deeper understanding of the conditions and limitations of non-linear social change and, therefore, inform efforts to facilitate change towards more sustainable futures.

Keywords Social tipping points · Case study · Qualitative methods · Food systems

1 Introduction

Over the last decade, the use of the term tipping point has dramatically increased across the natural and social sciences, including the social-ecological systems (SES) literature (Lauerburg et al., 2020; Milkoreit, 2023; Milkoreit et al., 2018). Concerns about undesirable non-linear change have been driving tipping point research in the natural sciences, especially in ecology and climate science, where scholars increasingly focus on challenging questions of predicting and avoiding ecological regime shifts and Earth system tipping points (Martin et al., 2020; Swingedouw et al., 2020). The parallel discussions in the social sciences have been following a different logic, exploring the effects of natural tipping dynamics on social systems or feedbacks between them (Howard & Livermore, 2021). First, there is a concern with the social impacts of Earth system and ecologic tipping processes, e.g., economic shocks (Kopp et al., 2016) or migrations. Second, there has been growing interest in generating non-linear change to counter and prevent potential Earth system tipping points, e.g., behavior changes that contribute to decarbonization, and, more generally, to create more sustainable relations between humanity and the biosphere (Egerer et al., 2021; Kull et al., 2018; Tàbara et al., 2018). The concept of anticipatory, deliberate, and desirable social tipping processes has led to calls to identify social tipping points (STPs) that could support necessary, rapid social system changes, e.g., in the process of decarbonization (Farmer et al., 2019; Lenton, 2020; Otto et al., 2020; Sharpe & Lenton, 2021).

While significant conceptual-theoretical progress has been made in the scholarship on social tipping, complex interactions within socio-ecological systems have so far prevented a systematic understanding of social tipping dynamics, and therefore empirical evidence of such dynamics remains scarce. Our aim is to advance the study of social tipping by developing methodological guidance for empirical, case-study based research to identify historical instances of STPs in social-ecological systems, especially their mechanisms of change. After a brief review of current methodological approaches and methods-related discussions in the literature, we use the Flint Water Crisis as an exemplary case study for a STP analysis to develop a set of principles that can guide social tipping case study research in a wide variety of systems.

2 Defining Social Tipping Points Through Common Criteria

Social tipping points in a sustainability context—those occurring as a consequence or in anticipation of Earth system or ecological tipping points—need to be studied through a social-ecological systems lens (Tàbara et al., 2021), thus social tipping refers to small initial changes in social system dynamics that trigger a nonlinear change driven by feedback mechanisms and lead to a qualitatively different state of the social-ecological system which is hard to reverse (Milkoreit et al., 2018; Winkelmann et al., 2022). This definition foregrounds four aspects of a tipping dynamic that inform our methodological approach and require empirical evidence: multiple stable states, abruptness, feedback dynamics as drivers of change, and limited reversibility. These four components have been characterized differently across different branches of literature (van Ginkel et al., 2020). Here, we present broad definitions applicable in social-ecological systems scholarship (Milkoreit, 2023).

- **Multiple stable states**: The stability of a social-ecological system can be defined by the capacity to remain in a limited and bounded state space with certain structures and functions when the system is subjected to a perturbation due to balancing (sometimes referred to as negative) feedback dynamics (Walker et al., 2004). However, multiple stable states have been demonstrated for many ecological systems, e.g., lake eutrophication (Scheffer et al., 1993), ice sheet collapse (Calov & Ganopolski, 2005), or desertification in drylands (Rietkerk & van de Koppel, 1997). A tipping process involves the system restructuring its core components and their relationships, moving from one stable state to another and altering the system's identity.

- Social systems can also exhibit multiple stable states in the sense that they can be configured in different ways. Key examples include societies before and after a political revolution or economic sectors before and after the emergence of a new technology (e.g., electricity generation before and after the spread of solar power technologies). Social systems are more likely to exhibit more than two possible stable states due to their complexity (Winkelmann et al., 2022).
- **Positive feedback dynamics as a driver of change**: As outlined above, feedback dynamics play an important role in creating both stability and change in social-ecological systems. Negative feedback dynamics maintain the current state while strong self-reinforcing (positive) feedbacks drive the establishment of alternative stable states (van Nes et al., 2016). A self-reinforcing feedback loop leads a system to respond to an incoming signal (e.g., disturbance) in a way that amplifies the signal (Meadows, 2008). With each iteration of the feedback loop, the social-ecological system moves further away from its original ability to perform its core functions, eventually moving to a stable state with different functions.
- Positive and negative feedback also exists in social systems. A number of positive feedback mechanisms that could play a role in tipping processes include social contagion, information cascades, and economics of scale (Lenton et al.,

2022; Sharpe & Lenton, 2021). Geels and Ayoub (2023) identified a set of 'interacting feedback loops' that cross political, economic, and technological domains, while Strauch (2020) looked at positive feedback dynamics across multiple scales within the multiple-level perspective theory of socio-technical transitions.
- **Abruptness**: Abruptness or non-linearity relates to the speed of change, more specifically to an exponential rate of change during the tipping process as compared to the general 'background' speed of the system in question (Bestelmeyer et al., 2011). To measure abruptness requires longitudinal data from which both rates can be quantified or at least approximated. Then abruptness may be assessed in different ways: for instance, Boulton and Lenton (2019) proposed to detect abrupt shifts in time series by analyzing significant changes in the gradient of the series.
- Abruptness in social systems is challenging to characterize empirically, but similar to natural systems, fast and slow change processes can be differentiated. Theories like punctuated equilibrium in institutional change grapple with these temporal qualities of the change process (Gould & Eldredge, 1993).
- **Limited reversibility**: While irreversibility is not a strict requirement (Winkelmann et al., 2022), change generated by a tipping dynamic tends to be hysteretic, i.e., returning to the initial stable state is difficult. Hysteresis implies that the changes persist even if factors that contributed to them are removed or returned to their pre-tipping conditions (Dakos et al., 2019).
- In social systems, hysteresis can be observed, e.g., when policies that foster the expansion of a new industry (e.g., feed-in tariffs in the German electricity market) are removed, the subsidized industry continues to grow without this driver because it has passed a critical threshold of maturity after which it is competitive enough to sustain itself.

An extensive body of research has identified these characteristics of tipping processes in the ecological components of social-ecological systems, but while empirical work on social tipping has been expanding rapidly, it remains scarce and is often directed at identifying and fostering future tipping processes (Lenton et al., 2022; Tàbara et al., 2021) rather than studying historical instances of social tipping.

3 Methodological Approaches to the Study of Social Tipping

The expanding scholarship on social tipping is driven by a diverse set of methodological approaches. Prominent among these are sophisticated dynamic modeling studies, including agent-based models (Kaaronen & Strelkovskii, 2020), that are usually based on theoretical-conceptual assumptions, but have no foundation in empirical observations of social-ecological system behavior (Mathias et al., 2020; Wiedermann et al., 2020). A growing body of work explores tipping in beliefs, i.e., the spread of social norms, and corresponding behaviors, with primarily lab-based experiments (Andreoni et al., 2021; Berger, 2021; Centola et al., 2018). The key objective of this work is to predict how many “committed individuals” (Andrighetto & Vriens, 2022) are needed to reach a threshold in norm adoption or behavior change within a community. While these approaches often do not identify feedback dynamics, measure abruptness, or engage with the question of hysteresis, Andrighetto and Vriens argue that insights from this type of experimental work could be fruitfully combined with computational modeling to create empirically calibrated agent-based models that could provide insights into social tipping mechanisms and dynamics. Other methodological approaches to the study of social tipping include network models, regression analysis and other statistical tools.

In the small but growing literature on empirical approaches to studying tipping dynamics, several useful methodological approaches and research challenges are becoming apparent. Multiple studies recognized the need for deliberate system bounding and description in the early stages of a case study analysis and tend to rely on participatory approaches for system modeling or mapping exercises (Lenton et al., 2022; Murphy et al., 2021; Riekhof et al., 2022). Researchers make important choices at this stage (e.g., regarding units, scales, processes to include and exclude), and scholars emphasize the corresponding need for reflexivity and transparency (Tàbara et al., 2021). Efforts to study social tipping empirically tends to rely heavily on the distinction of different system scales, including temporal scales, and cross-scale interactions. A central challenge consists of the identification of different system states, which cannot be easily derived from the different states of individual units (system components). Hence, system state descriptions have to include relationships between units and dynamics. Further, this early work recognizes the challenge to identify key driving variable(s) in complex systems and the need to identify positive feedback dynamics as drivers of change (Lenton et al., 2022).

While these advance methodological thinking for ongoing/anticipatory case studies, they largely ignore the need for and challenges of historical case studies—efforts to identify whether, how, in which systems and under what circumstances social systems have tipped in the past. This requires a different research strategy, which is our focus here.

What is lacking are convincing historical case studies of social tipping that can demonstrate whether, how (mechanisms) and under what conditions social tipping dynamics have occurred in the past. A case study approach can create in-depth understanding of a social-ecological system (Feagin et al., 1991), although it may not result in generalizable findings that apply to other contexts. We use a case study to develop methodological advances for the operationalization of tipping points in social contexts.

4 Our Methodological Approach

Considering the four characteristics outlined above as a minimum, non-exhaustive set of criteria for establishing a tipping point, we applied them in a historical case analysis of the Flint water crisis. The Flint Water Crisis resulted from a switch from

Detroit City water to the Flint River on April 25, 2014 (Clark, 2018). Enacted by a non-elected Emergency Manager, water was no longer properly treated which resulted in the systematic poisoning of residents as they were exposed to high concentrations of lead and bacteria (Hanna-Attisha et al., 2016). As a result, both Flint community members and external media often discuss the Water Crisis as a tipping point across a range of social and ecological variables, many of which have implications for food security in Flint e.g., in contaminant concentrations (Smith, 2019), public health (Hanna-Attisha, 2017), trust in government (Hughes, 2021), and economic development (Hanna-Attisha, 2017).

Previous analyses based on primary and secondary data from Flint over an extended time period have demonstrated that the Water Crisis caused a reorganization of the food system (Hodbod & Wentworth, 2021). Here, we use a similar interdisciplinary and longitudinal dataset to support a choice of tipping point candidates and independent variables that would influence them. Observed changes in these are then explored through a tipping point framework.

The case's complexity allowed us to identify multiple tipping point candidates. Below, we describe our analytic process and insights for one of these in detail: the food system. Given our purpose here, the analytic findings are less important than the process of generating them. Tracing and reflecting on our methodological and analytic experience, we describe likely typical patterns and challenges of a case study approach to STP research. Integrating insights from this experience and the expanding literature on the methodological challenges of studying STPs, we develop principles that can facilitate and support future case study work.

5 Operationalizing Social Tipping Points

5.1 Case Study Selection

Case study analyses begin with the identification of one or more suitable case studies. Typically, this will be a historical case study, i.e., the change process has concluded or is in its final stages. The existing scholarship on positive tipping rarely uses a historical approach; more work of this kind has been attempted by scholars of social innovation and social-ecological transformations (Olsson et al., 2008; Spielmann et al., 2016; Westley et al., 2017). Instead, current scholarship on social tipping focuses on systems where stakeholders seek to foster tipping processes. Rather than seeking insights from past tipping processes, this work is transdisciplinary, future- and solution-oriented (Feola, 2015).

If researchers take a more conventional historical approach, several challenges already arise at this early stage of case selection: detecting a social phenomenon with at least superficially perceived abrupt change and ensuring that data is available or can be collected for potential variables of interest. Longitudinal data will be needed to describe the social system pretipping and post-tipping and with a high-enough resolution to allow for the analysis of the speed of the change process.

We selected the Flint Water Crisis as a case study context. Based on existing data and prior research (Flint Leverage Points Project (FLPP; Gray, 2020)), we had reasonable grounds to believe that several rapid changes had occurred in a distinct time period in the Flint community. We had to make decisions regarding the specific social-ecological system to focus on (e.g., food system, water supply, local economy, health care, politics, …) and the temporal bounding of our study (i.e., number of years before and after the Water Crisis). We had to consider that different 'candidates' of tipping processes existed in different social domains, each with different temporal characteristics. For example, rapid changes in the Flint economy occurred long before the Water Crisis in relation to the closure of General Motors facilities and the exit of the automotive industry from the region. Focusing on the city's food system, we hypothesized that the Water Crisis had contributed to the reorganization of Flint's food system into a more equitable and food-secure state, and that this change had followed a tipping pattern.

5.2 Bounding the System

Next, we sought to identify the spatial, institutional, and temporal boundaries of the system of interest (Resilience Alliance, 2010). While the boundaries of ecological systems and their exogenous drivers can often be defined with reasonable clarity (e.g., lakes, ice sheets), bounding social systems is generally more difficult due to their higher complexity, connectivity across scales, multiple system interdependencies, and unclear causality patterns (Arias-Arévalo et al., 2017). Additionally, social-ecological systems include human agency, which can affect whether system's tip or not as well as affecting levels of hysteresis (Winkelmann et al., 2022). Nevertheless, (likely iterative) bounding efforts provide needed constraints for the analysis. Riekhof et al. (2022) introduce the concept of windows of tipping point analysis in which they bound the system of analysis at multiple scales to allow analysts to zoom in and out in order to define the elements of analysis, the temporal scale of relevance, the rate of change, the relationship between system components and the multiple possible states, among other items. This is analogous to the bounding we use in the Flint case as well as the pre-tipping and post-tipping descriptions identified below.

We bound Flint's city-scale food system, demarcating related systems and processes, and deliberately excluding some from the analysis. For example, we determined some water-system related variables were relevant for the food system (e.g., availability and quality of potable water), while others (e.g., water management, infrastructure) were not (Hodbod & Wentworth, 2021; Wentworth et al., 2022). However, given the nested nature of food systems, Flint is dependent on regional and international food production, trade, and transport. We used county boundaries to distinguish food produced within and outside the system given better data availability at that scale, while recognizing that the city of Flint only represents 24% of the Genesee County population (Wentworth et al., 2022). This choice influenced institutional boundaries, which consequently included institutions at the county, city, and neighborhood scale. We selected temporal boundaries based on data availability from the FLPP (1950–2020), focusing initially only on the most recent decade (2010–2020) to study the effects of the Water Crisis.

5.3 Pre-tipping and Post-tipping System Descriptions

It is valuable to create qualitative and/or visual descriptions of the presumed pre-tipping and post-tipping system states early in the analysis, and to update these after each step of the process. These description or maps should include the identification of key system components and their relationships (similar to steps 1 and 3 suggested in Riekhof et al., 2022), stabilizing feedback effects, and resulting functions, to provide insight regarding the existence of multiple stable states. A comparison of the system states before and after the change process is central for assessing whether the system has undergone structural reorganization, i.e., whether the identity of the system has changed.

System descriptions are highly dependent on the level of observability. Often, social scientists use indicators as proxies for complex variables characterizing the social state they want to track. For instance, the Gini index is used to quantify inequalities in a population. However, the resulting dynamics of the social system can be impacted by this observability, which may be biased by the observer. Therefore, it is crucial to consider and understand the limitations of observability when describing social system dynamics.

Identifying and describing distinct stable states involves temporal descriptions and corresponding observability issues (see step 2 suggested in Riekhof et al., 2022). During which time period (for how long) did the initial stable state exist? When did the change process start and when was the current or new stable state established? How do these time horizons relate to the study and observation period? The concept of stability depends on the observation timescale given that we cannot "prove" system stability in the absence of mathematical models. Therefore, it is important to consider multiple stable states according to the timescale of interest. Further, the question of irreversibility is a matter of time. As Riekhof et al. (2022, p. 3) observe, "If a period is chosen sufficiently long, most states become reversible, but only considering a long-enough time period may reveal different states in the first place."

System descriptions should contain how actors and their interactions form a social structure—shared culture, values, norms and beliefs with a shared goal, objective, or function (Parsons, 1991). In many cases researchers might find it easier to create a post-tipping system description first, since this might be the current system state. Here, we present our post-change system description and provide some comments regarding its differences to the pre-change state. We also developed a conceptual model to aid our understanding of important system components and processes.

Food systems consist of a set of activities broadly summarized as production, processing, distribution and consumption, pursuing three broad outcomes—food security, environmental security, and social welfare (Ericksen, 2008). We started a post-tipping description with key actors and their relationships, using the results of stakeholder mapping by FLPP which identified four groups in Flint's food system—consumers, commercial actors, supplemental actors (i.e., non-profits), and governance actors representing the city, county, and state, as shown in Fig. 1.

Figure 1 shows consumers tended to have extremely centralized networks, with multiple connections with commercial and supplemental food system actors. The latter two actor groups had more complex relationships with each other and the governance actors. The primary interaction modes included the exchange of food (for cash in the commercial sector or through public or non-profit supported free food programs) and information (i.e., between city government offices and non-profits). After reviewing the stakeholder mapping data and associated qualitative data from the conversations with community members while mapping, we decided that flows of food through commercial actors (i.e., supermarkets) were less

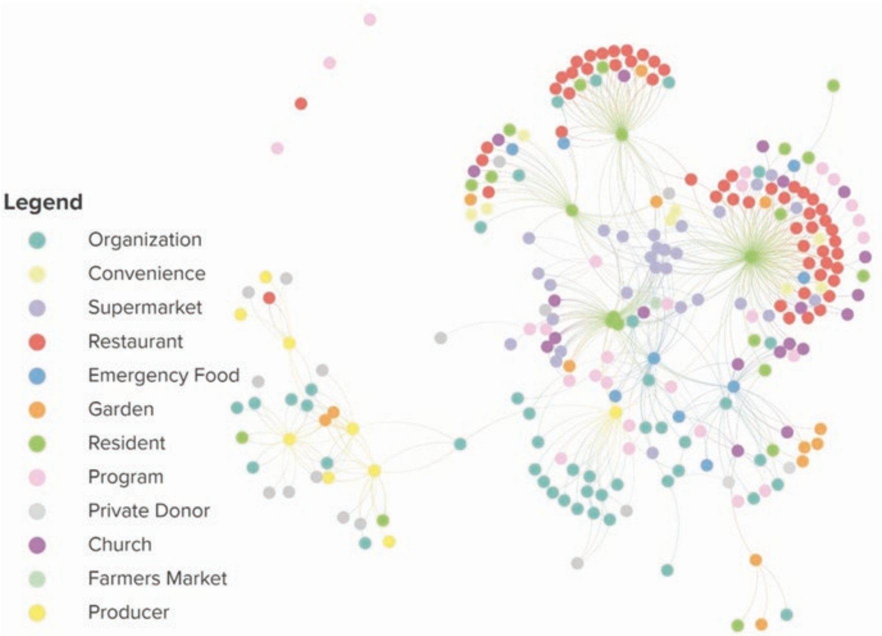

Fig. 1 Combined stakeholder map, created in Kumu.io from ten mapping workshops in Flint showing social interdependencies within the food system. The main cluster shows consumer groups (green) are linked with both commercial and supplemental actors, but that they are poorly linked with the local food production system (bottom left top cluster). Relationships with governance actors are indirect, through the programs they fund

indicative of food security than flows through supplemental actors (i.e., the Food Bank of Eastern Michigan), so we moved forwards with a focus on the supplemental and emergency food distribution.

Actors identified 16 core values and goals for the Flint food system, including food security but also social welfare (i.e., economic opportunity, comfort, safety) (Belisle-Toler et al., 2021). The current (post-tipping) food system was not perceived to support all these values, especially the overarching goal of food security. However, neither did the pre-tipping system, which was perceived to have a different social structure, with more competition over fewer financial resources in the supplemental system. To create a full pre-tipping system description, we examined key variables using longitudinal data.

5.4 Key Variables

Informed by the current system description, we selected key variables that could be subject to or indicators of rapid change. Ecological tipping point (regime shift) analysis often rely on measurements of a single variable that causes non-linear changes in the system once it reaches a threshold, such as levels of phosphorous in a lake eutrophication process (Carpenter et al., 1999), fish population (Cooper et al., 2020), or human population growth and land clearance (Brandt & Merico, 2013). Although at times the behavior of complex systems approaching a tipping point can be dominated by one single control variable (Lenton et al., 2022), in real world scenarios multiple, interacting, variables may be contributing to the tipping process by accelerating or hindering it (Winkelmann et al., 2022). Hence it becomes fundamental to identify the key control variables and their interaction, and, at the same time, confining the analysis to a manageable number (3–5, as per suggestions for other social-ecological systems analyses (Gunderson & Holling, 2002)). Balancing the complexity/simplicity is thus a key task if we are to assess a tipping process without being overwhelmed by information. Further, studies looking at single variables and tipping points are often based on system dynamics or agent-based models, however, assessing STPs requires multiple methodological approaches combining both quantitative and qualitative data (for qualitative longitudinal data, see Calman et al., 2013). To derive key variables of a system of interest it is then necessary to develop a system map, often with co-participation of stakeholders and experts of multiple disciplines (Lenton et al., 2022; Popa et al., 2015; Singletary & Sterle, 2020).

In the Flint case study, we moved in multiple iterations from a long list to a short list of food system variables that would explain the impact of the Water Crisis on food system outcomes, considering the availability of longitudinal data given it was often the limiting factor. We found that our conceptual model—part of our system description—was particularly helpful in identifying relevant variables.

We settled on food security rates and their key independent variables—poverty rates, resident's autonomy, trust between key actors, inflow of food-program funds, and pounds of food and water distributed through assistance programs as key

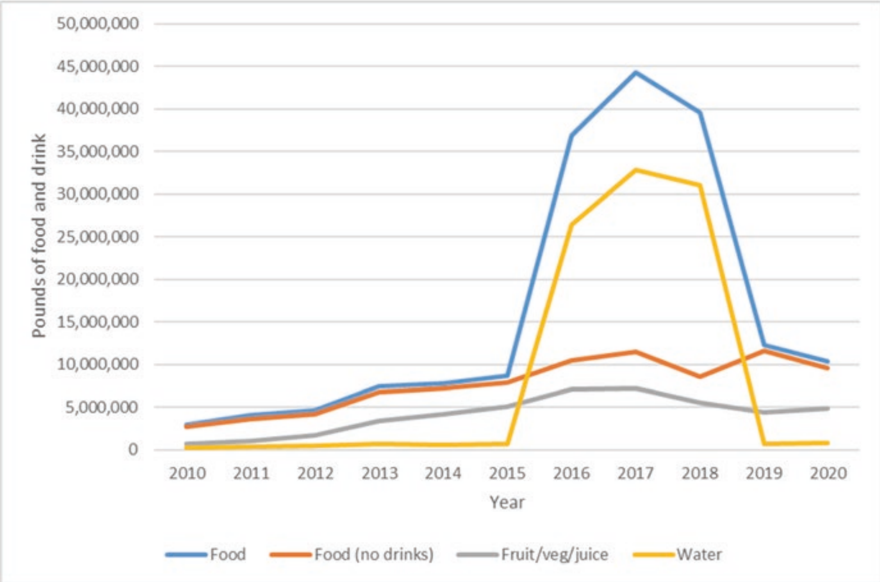

Fig. 2 Distribution of food from the Food Bank of Eastern Michigan in 2010–2020 increased rapidly in 2015, with the bulk of the increase in the distribution of water, but some increase proportionally in fresh fruit and vegetables and their by-products

variables. Some of these (i.e., pounds of food and water distributed) could be analyzed for shifts in trend. For example, Fig. 2 shows that in 2016–2018 the provision of supplemental and emergency food by the Food Bank of Eastern Michigan in Flint jumped drastically (326%). Bottled water accounts for most of this rapid increase as consumption of mains (tap) water was first under a 'boil water advisory' and then not trusted, although food provision did continue to increase. However, this change was temporary and distribution levels returned to pre-crisis levels in 2019.

5.5 Tipping Dynamics

Synthesizing the longitudinal food system dataset allowed us to add more context to the pre-tipping and post-tipping system descriptions, in particular regarding the extent of functions such as distribution of food and food security. Expanding our conceptual model, we integrated the independent variables to demonstrate the core relationships between these components (Fig. 3).

We created a table with the four tipping criteria and used the system descriptions and datasets (2010–2020) for the independent variables to assess whether all criteria were met during the study period.

We first explored the presence of multiple stable states. Our analysis revealed that the Water Crisis had triggered a reorganization of the actor relationships and

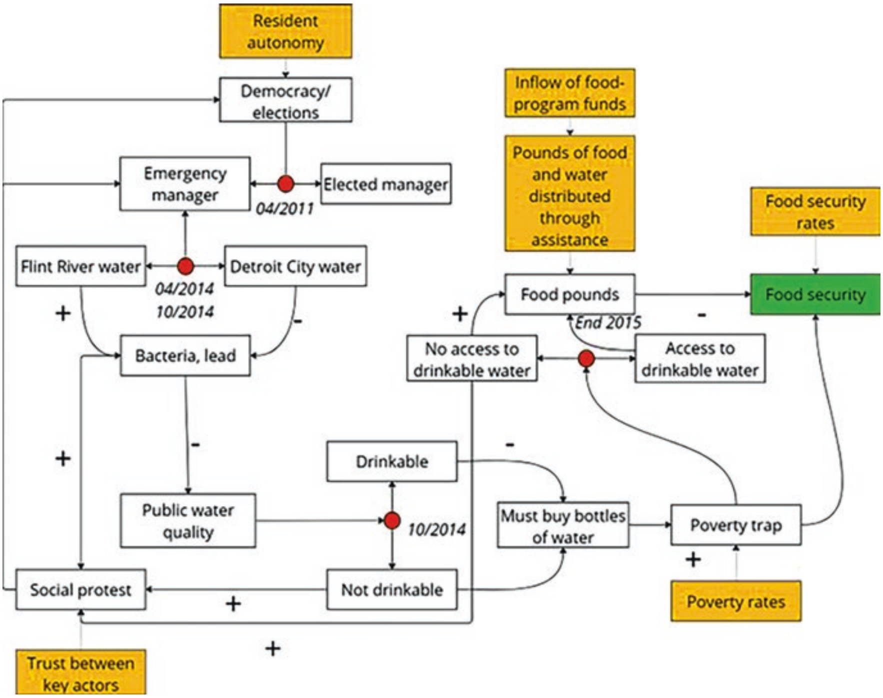

Fig. 3 Our conceptual model of potential tipping points that would influence the Flint food system, with independent variables in yellow and the dependent variable in green. Red points correspond to key-events that potentially tipped the dynamics of the system

institutional components of the food system, altering the flows of funds, food, and information in the city. Increased levels of funding coming into Flint after 2015, mostly from philanthropic organizations and to a lesser extent the government (Hodbod & Wentworth, 2021), supported and triggered collaboration between non-profits where there previously had been competition, which increased distribution of food and bottled water and information about lead-mitigating foods. Nevertheless, food security rates did not change significantly during this period (Feeding America, 2023), indicating that other structural elements related to food access remained stable, likely poverty given per capita personal income rates were declining during this period, both shown in Fig. 4. Given these mixed results the lack of restructuring of the system identity while maintaining food security, we concluded that the food system as a whole had not transitioned between two stable states.

Regarding abruptness, our dataset (including primary data from stakeholder interviews and timelining) demonstrated rapid change in certain food system indicators during the initial years of the Water Crisis (2015–2017), for example, residents' autonomy decreased rapidly, the provision of food and water increased drastically (as shown in Fig. 2), funding from external actors flooded in, and collaboration between internal actors intensified. Note that the rate of change in a

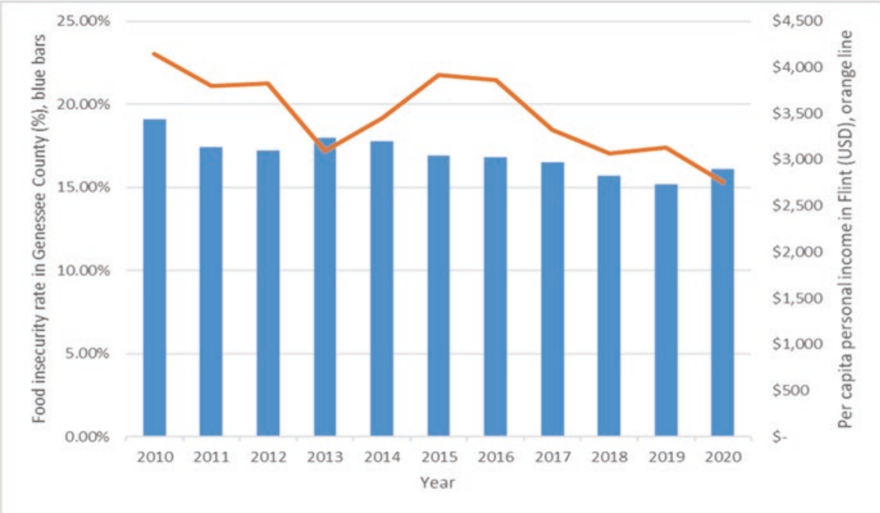

Fig. 4 Food security rates did not change significantly during the focal temporal scale (Feeding America, 2023)

social system is relative to past observations. When a change occurs that has not been previously observed, it may be described as rapid in comparison to historical dynamics. However, other system components did not demonstrate abrupt change (i.e., food security and income Fig. 4), and some of the abrupt changes were only temporary, indicating that the food system as a whole had not experienced significant and lasting identity change.

Identifying reinforcing feedback dynamics proved to be the most challenging and ultimately unsuccessful part of our analytic effort. Lenton et al. (2022) describes the difference between identifying system features (what tips) and control variables (what causes the tip or how it tips). Using our system description and conceptual model, we explored multiple effects of the Water Crisis on the food system, finding only examples of event chains at this scale, but not closed feedback loops. In our case, we were identifying control variables but not system features that tipped. For example, the lead contamination of Flint's drinking water in 2014 quickly increased awareness among citizens of the importance of fresh fruits and vegetables as lead-mitigating foods. However, the data did not demonstrate increasing uptake of related programs over time, or changes in diet or health outcomes because of this. When we ended our search for feedback dynamics, it remained unclear whether they did not exist (possibly explaining why the system did not move to a new state) or we had failed to identify them.

Given these results—no changes in system identity and absence of reinforcing feedback dynamics—we concluded that the Water Crisis did not create a STP for the Flint food system. While there may have been some changes in structure of and available resources in the food system, these changes cannot be characterized as a social tipping process. This rendered the question of reversibility (and hysteresis) irrelevant.

6 Principles and Process for Social Tipping Point Analysis

The above analysis allowed us to operationalize our definition of STP and create general principles for STP analysis that could offer a structure for future STP case studies, as shown in Table 1.

First, case studies should be selected carefully for their relevance, i.e., because they are potential instances of STPs (**principle 1**), rather than some other desirable characteristic (e.g., decarbonization potential). The observed social change should have clear social-ecological implications, and selection should acutely focus on data availability, especially time-series data that enables the study of abruptness. Multiple sources of data should be used, and a balance of qualitative (e.g., interviews, perception) and quantitative (e.g., assessment of economic indicators) data might be most insightful.

An awareness of data availability and data quality grounded in knowledge of the case study context is required to bound and describe the system (**principle 2**). The focal temporal and spatial scales should align with the characteristics of the social

Table 1 Emerging principles of STP analysis

Principles	How to operationalize?
1. Select case studies with a focus on data availability	Working with a clear definition of STPs, ensure you have the capacity to collect qualitative and/or quantitative time series data for the cases you believe are instances of social tipping
2. Bound and characterize the social-ecological system	Identify the focal spatio-temporal scale of the system of interest, as well as higher and lower scales that have important interacting dynamics. Create detailed system descriptions of the presumed pre-tipping and post-tipping (stable) states early in the process; keep updating these descriptions later
3. Identify and assess variables of interest	Identify 3–5 variables (indicators of structure and function) that can be used to explore the speed and nature of change. Assess them in an appropriate qualitative and/or quantitative manner
4. Measure abruptness	Using time-series data with a frequency appropriate for your system (i.e., tied to its 'background' speed), assess change in the rate of change to establish non-linearity in at least one of the variables of interest compared to 'background' change
5. Synthesize datasets to identify multiple stable states	Assess the existence of multiple stable states by synthesizing data to understand whether structure and function have changed significantly (structural reorganization)
6. Identify reinforcing feedback loops	Explore system dynamics to understand what is driving the non-linear change
7. Assess reversibility	Evaluate the conditions or required efforts to reverse the observed change and determine whether system is hysteretic

system, especially its governance systems. A system description can support the identification and measurement of 3–5 variables (**principle 3**) that characterize the system. The number of variables is a pragmatic choice but should be data driven, resulting in a robust dataset for fewer variables or considering more variables with partial datasets.

Data collection is followed by four analytic steps. First, variables for which time series data is available are analyzed for non-linear change over the study period to identify evidence of abruptness (**principle 4**). Abruptness is embedded in many definitions of tipping points (Kopp et al., 2016; Lenton et al., 2008) but is rarely assessed when discussing social tipping, possibly because time series analysis of social data can exhibit limitations and have a strong qualitative dimension. When, under what conditions, by whom, and why is a certain change considered abrupt? The answer depends on the social properties of interests and is at least to some extent a normative question involving those affected. If no abrupt pattern of change can be found, it is possible to return to principle 2 and adjust the temporal bounds of the case study. This is not just limited to quantitative analyses—qualitative data can be analyzed for significant changes between the beginning and the end of the study period.

Second, bringing together the quantitative and qualitative analyses of individual variables, a synthetic view across multiple interacting variables is required to determine whether the system has undergone a reorganization (and at what scale) leading to a change in structure and function (**principle 5**). With this understanding of the nature and extent of the system's change, third is to explore reinforcing feedbacks driving the observed changes and/or balancing feedback loops that explain the lack of change (**principle 6**). Is the process being described a loop that can close (feedback) or not (a chain of effects, or cascade)? At this point it is possible to determine whether the change is non-linear, thus a tipping point. We leave assessing limited reversibility (**principle 7**), i.e., the efforts required to reverse the social change and return to the previous set of functions, until last because it only becomes relevant if the analysis so far confirms a non-linear state change. This final step is particularly challenging if reversing the system's new stable state has not occurred, especially because intentional efforts to reverse state changes are not common beyond policy-based STPs. There are also significant questions regarding how to measure reversibility (or system identity) in social systems.

Principles 1, 4, 6, and 7 are specific to tipping point analyses; they determine whether the social dynamics observed in the case study represent a tipping process or some other form of change. Principles 2 and 5 are key for demonstrating that a significant change in the system's character—identity change, regime shift—has occurred. However, these principles could also be applied to transformation and transition analyses.

At this point, it should be possible to conclude whether the observed change in the case study is an STP. At a minimum, given the requirement of meeting the four criteria, it can be determined when there is *not* an STP.

7 Challenges

Two main challenges are tied to our definition and the need to provide evidence for the four STP criteria. First, data availability is the main barrier to the empirical study of social tipping processes, particularly sufficient longitudinal data frequency to observe abruptness. Data requirements are demanding, including quantitative and qualitative data regarding social and ecological variables. Currently, the feasibility of social tipping case studies is severely limited compared to ecological or even Earth system tipping points, given that high-quality quantitative data for statistical analyses is less common in social systems.

Second, not all social tipping criteria are clear-cut; they may be hard to identify or differ across groups. As Tàbara et al. (2021) convincingly argue, social system characteristics are open to interpretation and depend on specific stakeholder groups' goals, core values and beliefs, and resulting perceptions. Given that values and norms are embedded in social systems, desirability is a feature of stable states for stakeholders and becomes embedded in power dynamics and system structures. As a result, adaptive capacity, governance techniques, and foresight are utilized in social systems to prevent and mitigate abrupt change by strengthening stabilizing feedback dynamics and mitigating change (Angeler et al., 2020; Pahl-Wostl, 2009). The observation that complex-adaptive social systems might not lend themselves to non-linear, abrupt change raises fundamental questions regarding the prevalence of tipping dynamics in social systems.

These issues imply that a solid understanding of the social complexity of social-ecological systems is a prerequisite for the specification of data and knowledge needs that can enable the discovery STPs. Researchers should consider that non-linear change in coupled social-ecological systems might occur only under specific and rare circumstances, possibly because value-driven social processes tend to curb abruptness. However, the current challenges in building an evidence base for social tipping might simply be a result of data constraints and the corresponding analytic limitations that could be addressed by further case studies or methodological advances.

8 Conclusion and Outlook

Social tipping points are of great interest to the sustainability science community, but empirical research on social tipping dynamics has so far remained scarce. Here we developed methodological guidance for a case study approach to STP analyses that is closely tied to a common but specific definition of tipping. Our guidance takes the form of principles derived from our experience studying the food system of the city of Flint following the Flint Water Crisis. We identify seven principles that can simultaneously serve as a seven-step process for STP analysis.

Our discussion highlighted the significant challenges that remain regarding the empirical study of STPs, especially data availability. Looking ahead, we recommend an anticipatory approach to empirical social tipping research in addition to the exploration of historical cases. Our principles can help identify potential case studies and key variables that have a high chance of facilitating an analysis of ongoing and future change as a tipping point. Such a strategic approach could, for example, focus on social systems with a high CO_2 reduction potential, and start data collection—both quantitative and qualitative—ahead of expected changes. Data collection could be designed to enable time series analyses following experimental intervention, enabling observations of change dynamics in real time, but also process tracing and system mapping. For example, Otto et al. (2020) have identified removing fossil fuel subsidies, building carbon-neutral cities, and strengthening climate education as potential 'social tipping interventions'. An anticipatory and longitudinal approach would outline whether and how these interventions become STP but would also support broader analyses to understand the conditions and limitations of tipping points, critical for our understanding of how to create change to more sustainable futures. However, such an anticipatory approach to research is challenging, especially regarding the selection of variables and scales of analyses and will require relationships in the social-ecological systems of interest as well as support from funding institutions. The Long-Term Ecological Research (LTER) program of the National Science Foundation provides a good example for a funding model.

Despite these challenges, there is much to be gained from the study and knowledge of social tipping processes in the context of sustainability science. Whether or not these studies identify STPs, their conditions and histories, they always contribute to the existing knowledge base about social change, especially system structures, functions, and identity over time, as well as the barriers and conduits to different types of change.

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Post-war Development Energy Scenarios for Ukraine

Olha Lukash and Vasyl Namoniuk

Abstract The systemic shock provoked by the Russian invasion created a radical discontinuity in the national development policies of Ukraine. This research examines the state of energy policy and the consequences of the ongoing war on plausible decarbonisation scenarios. Ukraine's commitment to decarbonization was firmly established before 2022, and the National Energy Strategy 2050 already aimed at a substantial 65% reduction in emissions of the economy in comparison to 1990. The war however, precipitated the need to adjust these targets and policy instrument to the current realities. For that, we conducted quantitative research to identify the most GHG intensive regions and sectors and related these to their Gross Regional Product and population. We found out that Zaporizhzhia, Dnipropetrovsk and Ivano-Frankivsk turn out be the most critical regions that require special consideration—so for the later region, we also identify particular decarbonization pathways. Our research shows that the Ukrainian war not only unveiled the inherent vulnerabilities of heavily centralised, carbon-dependent systems, but also can lead to the acceleration of non-linear structural low-carbon energy transformations more resilient to global change and systemic interdependences.

Keywords Decarbonization · Energy decarbonisation · Renewables infrastructure · Ukraine · Systemic shocks and discontinuities · Reconstruction

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Abbreviations

BuTPS	Burshtyn Thermal Power Station
CHP	Cohesion heating plants
CLD	Causal loop diagram
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GRP	Gross regional product
GVA	Gross value added
IBS	The Institute for Structural Research
IPS	Integrated power system
KSE	Kyiv School of Economics
NPP	Nuclear power plant
TPP	Thermal power plant
TPS	Thermal power station
UN	United Nations
USD	United States dollar
USSR	Union of Soviet Socialist Republics

1 Introduction

Ruined Kakhovka Hydroelectric Station (Dnipro River, Kherson Region, Ukraine). Photo by MAXAR

Decarbonization of economies through structural and technological changes has become a global priority to tackle climate change and its impacts. The 2015 Paris Agreement saw nearly all of the 197 countries that are party to the agreement commit to developing national plans and strategies to transition towards low-carbon economies and cut greenhouse gas emissions (The Paris Agreement, n.d.). Decarbonization is expected to bring major social, economic and environmental benefits—spurring growth in renewable energy and high-tech industries, improving public health through reduced pollution, and increasing access to green products and services markets (Climate change…, 2022).

Ukraine had made decarbonization a key priority before the 2022 Russian invasion. The country's economy remains heavily reliant on fossil fuels, with the energy sector accounting for nearly 70% of Ukraine's greenhouse gas emissions (Kudyrko et al., 2022). Ukraine adopted an Energy Strategy to 2035 in 2017 aimed at transitioning towards carbon neutrality through modernizing infrastructure, phasing out coal, expanding renewables like solar and wind, and increasing energy efficiency. The strategy set targets to reduce the energy intensity of Ukraine's GDP by 50% and greenhouse gas emissions by 65% by 2030 compared to 2005 levels (Ministry of Energy and Coal Industry of Ukraine, 2017).

The systemic shock from Russia's 2022 invasion of Ukraine created a radical discontinuity, disrupting structural conditions underlying the nation's decarbonization ambitions. Ukraine's commitment to sustainable transition was firmly established pre-war, with policies targeting substantial emissions cuts. However, this progress now faces severe reversal amidst humanitarian crises, infrastructure destruction, and economic collapse.

Rebuilding after such an immense systemic disruption provides potential tipping points to fundamentally transform Ukraine's legacy fossil fuel dependence. Strategic integration of climate considerations during recovery can steer structural changes towards resilience and sustainability.

This chapter examines Ukraine's pre-invasion decarbonization goals and progress. We assess the shock's disruptive impacts across the energy system and economy. Finally, we explore leveraging prospective tipping points during reconstruction to balance immediate needs with catalyzing green transformation aligned with global climate objectives.

Opportunities exist amidst the challenges to develop a new energy system that addresses urgent humanitarian and infrastructure priorities while accelerating Ukraine's stalled decarbonization. Realizing this will require seizing potential windows for non-linear change during the rebuilding process. Our study intends to provide recommendations on navigating trade-offs and actualizing tipping points to emerge from crisis with enhanced sustainability and self-reliance.

A growing body of research examines how systemic shocks can catalyze sustainability tipping points when harnessed strategically. Lenton et al. (2022) synthesize theory and examples to provide guidelines on creating conditions to enable positive tipping points across socio-technical-ecological systems. Multiple potential interventions and actors can contribute to triggering them.

Literature on social tipping dynamics elucidates how small perturbations unlock rapid change by overcoming incumbent interests (Otto et al., 2020). This highlights the need for socio-political perspectives when considering nonlinear transformations.

According to Herrfahrdt-Pähle et al. (2020), socio-political shocks may constitute windows of opportunity for transforming natural resource governance regimes, and Ukraine should take advantage of this opportunity regardless of the depth of the negative impact of other factors. The authors also argue that successful transformation depends on a number of interacting factors across levels, such as the state of preparedness of the social-ecological systems, the enabling environment as well as the degree of change at the landscape level, the prevalence of visionary leadership, and the capacity to navigate each phase of the transformation. And it's a crucial factor for post-war Ukrainian situation.

Besides, some researchers (Tàbara et al., 2021) underline that embracing transformative change towards green transformations may entail adopting more diversified, self-defined complex forms of collective sense-making processes based on project identities. Such tipping points overlap well with the peculiarities of Ukrainian regional development.

Work on transformative climate science indicates conventional assessment methods have limitations in spurring systemic shifts. Instead, solutions-oriented processes that link adaptation, mitigation and development are required (Tàbara et al., 2019). This demands new interfaces supporting societal engagement and ownership.

The green economy discourse envisions transformations towards sustainability underpinned by policy, finance, technology, and governance innovations (Dogaru, 2021). However, equitable distributional aspects remain paramount.

Synthesizing these perspectives indicates Ukraine's rebuilding necessitates strategic governance to leverage disruptions in catalyzing sustainability tipping points across multiple dimensions. Despite the challenges, this moment offers unprecedented opportunities not previously feasible within the entrenched system.

2 The Energy Sector of Ukraine on the Eve of the War

2.1 Generating Capacities of the IPS of Ukraine

Ukraine's economy is characterised by its high energy intensity,[1] ranking among the highest globally. This legacy of inefficient infrastructure poses challenges but also opportunities to catalyze sustainability tipping points during reconstruction. The reference point for Ukraine's high energy intensity is IEA international comparison

[1] Energy intensity refers to the amount of energy consumed per unit of economic output, calculated as units of energy per unit of GDP. A high level of energy intensity indicates an economy is using energy inefficiently.

data (Ukraine energy profile, 2020). In 2019, Ukraine's energy intensity was 0.15 toe/thousand 2010 USD, over twice as high as Poland (0.07) or Germany (0.05). This means Ukraine consumed over twice as much energy for each unit of economic output compared to these European nations. This high energy intensity is attributable to factors such as Ukraine's industrial structure. Although some countries like Canada also exhibit high energy intensity, Ukraine's exceptionally low energy efficiency significantly contributes to its energy profile. Many industrial processes depend on outdated technologies, and energy efficiency in buildings is generally suboptimal. Equipment, including heating boilers, is antiquated and poorly maintained, restricting opportunities to enhance energy efficiency. Consequently, firms and individuals face substantial obstacles in making profitable energy-efficiency investments. The absence of affordable financing options and limited incentives due to historically regulated household energy prices exacerbate the situation, along with logistical and organisational issues for apartment building residents.

As of February 2022, Ukraine had extensive energy infrastructure and production capacity, positioning it among European leaders. However, the reliance on Russian gas imports vulnerable Ukraine's energy security. Accelerating renewables and efficiency represents a resilience tipping point. Specifically, Ukraine ranked in the top ten European nations in terms of installed electricity generation capacity, with a total of 55 gigawatts (GW) (Eurostat, 2022). The country was also one of Europe's largest natural gas producers, extracting over 20 billion cubic meters annually (Ukrainian energy …, 2022). Additionally, Ukraine possessed Europe's largest underground gas storage capacity, with around 31 billion cubic meters of storage spread across several facilities (Ukrainian energy …, 2022). This extensive infrastructure and Ukraine's role as a major producer and transit country for Russian gas gave it a strategically important position in Europe's energy system.

Ukraine's sophisticated and reliable gas, oil, petroleum product transportation, and electricity transmission systems connect the country with neighbouring EU nations and Moldova. Notably, around 70% of Ukraine's electricity was from low-carbon nuclear, hydro and renewables (Fig. 1). This is a strong foundation to build upon. Setting ambitious targets to expand renewables could act as a decarbonization tipping point.

As of December 31, 2021, the total installed capacity of power plants in the IPS of Ukraine, excluding the Crimean power system and the temporarily uncontrolled territory of the Donetsk and Luhansk regions, amounted to 56.247 GW. Thermal power plants (TPP), Cohesion heating plants (CHPs), and block stations accounted for 49.7% of the installed capacity, followed by nuclear power plants at 24.6%, hydroelectric power plants and pumped storage power plants at 11.2%, and renewable energy sources, such as wind farms, solar power plants, and bioenergy plants, at 14.5%.

Thus, phasing out coal reliance, while socially challenging, presents a major emissions reduction opportunity. Structural transitions to provide new economic opportunities in affected regions could make coal phase-out viable as a prospective tipping point.

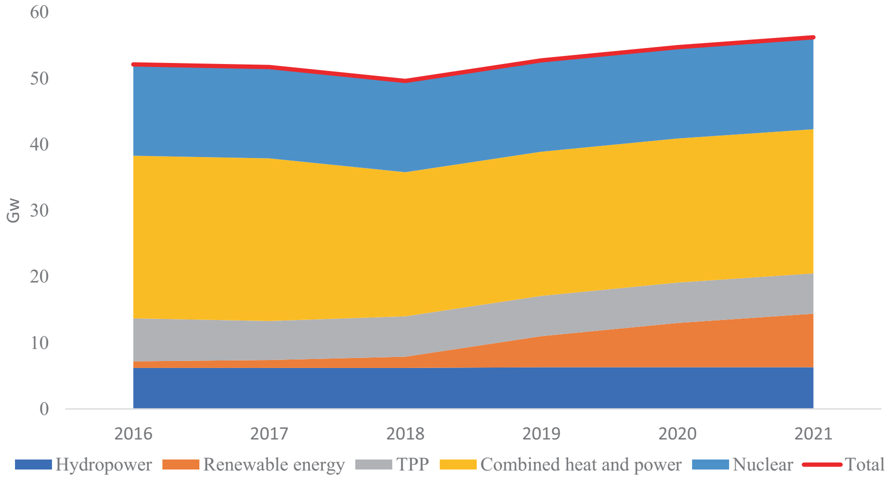

Fig. 1 Energy mix of Ukraine (Omelchenko, 2022)

2.2 Russia-Ukraine War

The Russian invasion severely disrupted Ukraine's legacy fossil fuel-dependent energy system. This jarring systemic shock provides opportunity to rebuild in a more sustainable manner, rather than reproducing outdated technologies and practices. Energy infrastructure facilities hold economic, humanitarian, and geopolitical significance, making them frequent targets of Russian aggression. Despite this, Ukraine's power grid has demonstrated remarkable resilience, with power engineers maintaining the stable operation of the industry during the hostilities. However, hostilities have destroyed 4% of the generating capacity, and an additional 35% of capacity is now situated in occupied territories.

The Russian invasion inflicted substantial damage to Ukraine's energy infrastructure, disrupting the nation's climate plans and exposing the vulnerabilities of its heavily fossil fuel-dependent power and industrial sectors. Ukraine's pre-war emissions landscape was characterized by a reliance on fossil fuels in power generation and heavy industry. Progress made toward decarbonization objectives was undermined by the war, as industrial activity declined due to the conflict, while emissions surged due to fires and ecosystem degradation. In the wake of the devastation, there emerges a critical juncture for Ukraine's energy future. Reconstruction offers a unique opportunity to rebuild in a more sustainable and resilient manner, emphasizing the importance of reaching tipping points in energy policy. However, this endeavour necessitates a delicate balance between addressing immediate energy security concerns and realizing long-term climate objectives. Proposed strategies to restart stalled sustainability momentum represent prospective tipping points. Expanding renewables, enhancing efficiency, integrating with EU grids and regulations, and securing external climate financing could drive transformation. Realizing

Ukraine's interconnectedness with European energy systems spotlights shared decarbonization tipping points. Collaboration and shared standards can multiply progress regionally.

Europe's largest nuclear power plant, the Zaporizhzhia NPP, operates within the Ukrainian power system and faces constant pressure from Russian occupiers. The plant has a production capacity of 6000 MW, equivalent to 43% of the total capacity of all Ukrainian nuclear power plants. Gas production has decreased by 10–12% since the full-scale invasion.

The KSE assessment (Report on the direct damage to the infrastructure from the destruction caused by Russia's military aggression against Ukraine a year after the start of the full-scale invasion, 2023) estimates the damages to Ukraine's energy sector at a minimum of $9.5 billion, including $8.1 billion in the energy sector and $1.4 billion in utility infrastructure (including district heating, water supply and drainage, and household waste management facilities).

According to the World Bank's Rapid Damage and Needs Assessment (2023), the damage to Ukraine's energy sector is estimated at $10.6 billion, including $6.5 billion in the power sector alone. The total needs for recovery and reconstruction of the energy sector are estimated at $47 billion.

It is worth noting that the actual damages and losses are likely to be higher, as complete information on Ukrainian facilities in the temporarily occupied territories is unavailable, and there is no publicly accessible information on the detailed damages inflicted on the country's energy infrastructure facilities.

The war has significantly affected energy demand, resulting in a substantial decrease of approximately 30–35% compared to the previous year's consumption. Additionally, the relocation of consumers to the western regions has led to a considerable shift in the consumption profile.

Presently, the annual electricity consumption by the population stands at around 32–33 billion kWh, marking a significant drop from the pre-invasion level of 38.6 billion kWh. Likewise, industrial consumption has experienced a considerable decline, dropping from fifty billion to approximately thirty-six billion kilowatt-hours.

Before the full-scale war, there were a lot of discussions about decarbonisation as a necessity in Ukraine. For example, the energy sector was the largest greenhouse gas emission before the war. It took two-thirds of these emissions in the whole volume. But after more than 1 year of severe war in Ukraine, the emissions volume from economic activity has significantly decreased. The main reasons for this are the outflow of the population, the destruction of industry, the closure of many enterprises, and so on. The occupation of Mariupol and the destruction of large metallurgical and other enterprises located in the Donetsk and Luhansk regions also significantly affected the change in the balance of greenhouse gas emissions in Ukraine. But at the same time, the number of emissions related to war is constantly increasing. Many burned oil depots, destroyed forests, fires, constant shelling, and bombing resulted in enormous environmental damage and emissions, the extent of which was even difficult to imagine until now. So, we face such negative balancing when emissions are increasing and decreasing parallel, and they both are the result of the war. According to Ministry of Environment data, Russia has already caused damage to the Ukrainian environment of 1373 billion hryvnias. Some ecosystems have been completely lost due to Russian aggression (Fig. 2).

During the war, many enterprises and infrastructure of cities and regions of Ukraine were destroyed or significantly damaged. And these destructions do not stop. Already now, it is necessary to start developing possible strategies for their renewal. But under these conditions, there may be several possible solutions. And it's important to look at all of them and analyse them from a carbon intensity perspective. In the process of reconstruction and restoration, the construction of roads, bridges, infrastructure, factories, and housing will take place. And this will also lead to a significant amount of greenhouse gas emissions. But there may be several options: to rebuild them, try to save everything that survived or create everything from zero. It is also clear that soon, Ukraine will try to maintain what it has—the infrastructure that remains in the energy sector, the remains of coal or gas-fired thermal power plants because there is nothing else yet. And it is also clear that essential investments are needed for any option of renovation, which could hardly be attractive in modern conditions of uncertainty.

The ongoing war on the territory of Ukraine has caused great damage to the economy and ecology of Ukraine. There is also a risk that Ukraine will not fulfil the already set climate goals, because the war is a contribution to climate change, and the recovery of the country will inevitably be accompanied by significant emissions of greenhouse gases. The lack of proper energy-efficient consumption, for example, or the failure to use the existing potential for the development and accumulation of renewable energy sources makes it impossible to compensate for the necessary "green effect" regarding the implementation of the Green Deal directives. It is important to have a plan for the reconstruction of the country now, long-term and

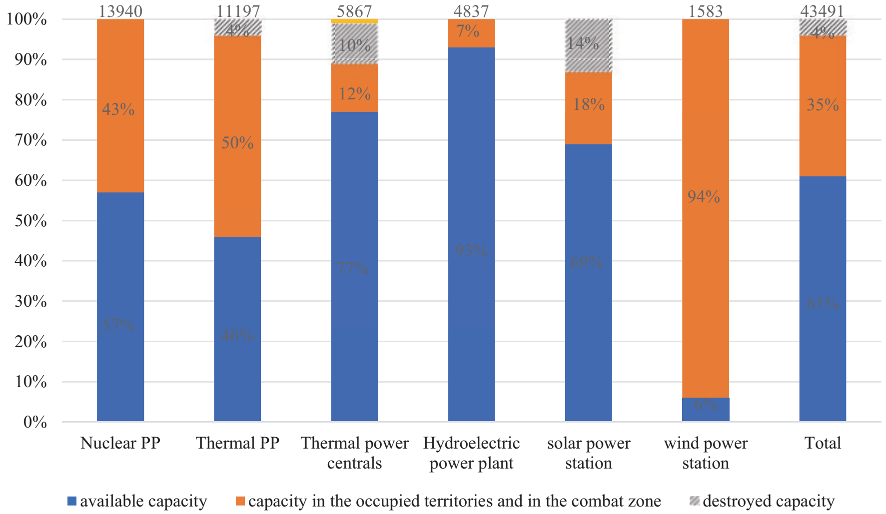

Fig. 2 Distribution of power generation facilities (Omelchenko, 2022)

high-quality solutions are needed that will ensure a balance between benefits for the economy, the environment, and society.

It is also worth focusing on the development of safer and more decentralized renewable energy. Nuclear and coal power is dangerous for the environment even in peacetime. The oil and gas sectors are also extremely vulnerable to several crisis phenomena (geopolitical, climatic, etc.) and are not a permanent solution for the recovery of Ukraine. Therefore, the reconstruction of the energy sector should focus on renewable energy sources that cause much less damage to the environment and people. Such a transition should be accompanied by an increase in energy efficiency and a fair transformation of regions dependent on traditional energy (How…, n.d.).

This infrastructure damage and disruption of the coal industry has led to significant declines in greenhouse gas emissions from the energy sector. With lower industrial output and coal use, Ukraine's CO_2 emissions dropped sharply in 2022 compared to pre-war levels. However, military activities have also caused substantial emissions through fires, combustion of fuels, damage to carbon-absorbing forests and lands, etc. Studies estimate the Russian invasion released over 67 million tons of CO_2 equivalent as of June 2022 (Bohdan, 2023).

Rebuilding damaged infrastructure once the war ends will necessitate increased emissions in the short term. But Ukraine also has opportunities to rebuild more sustainably and get back on track towards its decarbonization objectives. Seizing these tipping point opportunities requires assessing both the retrogression and possibilities created by war impacts. This analysis examines that tension.

2.3 Current Environmental and Energy Issues and Decarbonization in Ukraine

Ukraine's development trajectory over the past century has been intricately tied to environmental factors as part of the wider European region. Industrialization and economic growth have come at the expense of resource depletion, pollution, and rising carbon emissions. Addressing these environmental impacts while achieving sustainable growth will require economy-wide decarbonization. This transition brings immense challenges but also opportunities to modernize Ukraine's energy systems, attract investment, reduce imported fuel dependence, and increase integration with the European Union.

Major environmental challenges in Ukraine stem from several key factors:

- Unsustainable resource consumption practices including industrial deforestation, uncontrolled mining, and overexploitation of soils and fisheries. These practices supported heavy industrialization but with ecological consequences.
- Widespread industrial pollution across sectors like coal power, steelmaking, chemicals, and manufacturing. Lax pollution standards have led to severe air, water and soil contamination.

- Impacts of military conflict, especially the 2022 Russian invasion, which caused substantial ecosystem damage, industrial infrastructure destruction, landfill ruptures, and chemical/oil contamination.
- Insufficient waste management and regulatory oversight including uncontained municipal waste dumping and limited enforcement of environmental rules.
- Growing transportation emissions as private car ownership has risen without accompanying efficiency standards or electrification policies.
- Dependence on fossil fuel exports at the cost of domestic environmental health, as seen around sites like the Donbas coal mines.
- Overall lack of mainstreaming of environmental considerations into economic planning and behaviour, although awareness has expanded since independence.

Ukraine has taken steps to improve environmental policies since the 1990s, including developing standards aligned with the EU, promoting renewables, and reforming governance systems. However, the deeply entrenched legacy effects of unsustainable Soviet industrialization continue to pose major decarbonization challenges.

The energy sector is crucial for the decarbonisation of the Ukrainian economy. It accounts for two-thirds of greenhouse gas (GHG) emissions in Ukraine. Consequently, addressing this sector is vital for achieving meaningful progress in mitigating climate change and promoting green development in Ukraine after the war.

The energy sector contributes the most to GHG emissions in Ukraine. In 2021, this sector constituted approximately 64% of the emissions, excluding the Land Use, Land Use Change, and Forestry (LULUCF) sector. Around 76% of emissions in this sector are attributed to fuel combustion, which includes energy industries, manufacturing industries and construction, transport, other sectors, and other categories. Additionally, 24% of emissions are due to fugitive emissions from fuels.

The share of GHG emissions from fugitive emissions in the energy sector gradually increased from 1990 to 2000, reflecting the ageing infrastructure and industrial capital of the country. Since 2001, this proportion has steadily declined, reaching 24.0% in 2021 due to energy efficiency measures and the replacement of energy sources implemented in Ukraine.

The COVID-19 pandemic and subsequent measures against the disease decreased GHG emissions in the energy sector in 2020, particularly affecting energy industries, transport, and other sectors. The economic decline following the collapse of the USSR in 1991 resulted in a reduction in production, energy consumption, and, consequently, lower CO_2 emissions.

To foster sustainability, efficiency, and security, the reconstruction and modernisation of the Ukrainian energy system must adhere to EU standards. Adopting EU standards will provide a framework for creating a modernised and sustainable energy system in Ukraine, ensuring compatibility with European energy markets and enabling the country to benefit from regional energy trade.

There is a need for a green transformation of the Ukrainian electricity sector to align with international climate goals and European energy policies. By seizing the opportunity to rebuild and modernise its energy infrastructure, Ukraine can embark on a more sustainable and resilient energy system, better integrated with European markets and contributing to a greener future.

Ukraine's 2017 Energy Strategy established important tipping points for decarbonization across eight key pillars. The strategy's targets and policies aimed to transition Ukraine's energy system towards greater sustainability through 2050. However, Russia's invasion has severely impeded progress towards these envisioned tipping points. This comprehensive strategy delineates key policies and targets for transitioning towards greater energy sustainability through 2050. The plan aims to balance energy security and affordability with environmental goals while increasing self-sufficiency and aligning Ukraine's energy system with European markets.

The strategy identifies eight key pillars for energy sector transformation (Ukraine Energy Strategy, 2050):

- Modernizing energy infrastructure including thermal power plants, hydropower stations, nuclear generators, transmission grids, district heating systems and storage capabilities
- Expanding use of renewable energy sources such as solar, wind, small hydropower and bioenergy
- Substantially increasing energy efficiency and conservation across all sectors of the economy
- Reducing coal-fired power generation share by increasing nuclear, natural gas and renewables
- Boosting domestic oil and natural gas production from both conventional and unconventional sources
- Integrating Ukraine's energy markets with the European Union to increase trade and transparency
- Developing and expanding nuclear power generation as a zero-carbon baseload electricity supply
- Supporting alternative energy technologies including hydrogen, electrification, smart grids and distributed generation

Under this strategy, Ukraine set a target to reduce greenhouse gas emissions by 65% compared to 1990 levels by 2030. Multiple analyses indicate this goal is achievable through concerted efforts across the above decarbonization pathways. Key policies and measures to achieve this target include (Ukraine Energy Strategy, 2050):

- Increasing the renewable energy share in gross power generation to 25% by 2035 through large-scale deployment of solar, wind, small hydro and bioenergy
- Refurbishing and expanding hydroelectric power stations
- Continuing nuclear capacity additions and lifetime extensions to retain a 55% nuclear share in power generation through 2050
- Implementing demand-side energy efficiency improvements in buildings, district heating and industry
- Modernizing electricity transmission infrastructure and adopting smart grid technologies

- Electrifying rail-based transport networks
- Substituting natural gas for coal in thermal power plants
- Improving efficiency and reducing losses in gas production and distribution systems
- Developing onshore and offshore conventional and unconventional natural gas resources
- Implementing carbon capture on industrial facilities and gradually phasing out obsolete methane-intensive mines
- Expanding biofuel blending mandates to help decarbonize transport
- Impact of the 2022 Russian Invasion

While prudent when formulated, the realities imposed by the war now require re-evaluating timelines and approaches for reaching these tipping points. As Ukraine rebuilds, it must update strategies to seize new potential tipping points that can drive momentum towards a decarbonized and European-integrated energy system despite the ongoing conflict.

However, rebuilding after the war also provides an opportunity to construct back better. Ukraine can pursue more sustainable and resilient reconstruction strategies that restore self-sufficiency and prosperity while meeting climate goals. This will require substantial international support. Key principles for green reconstruction include:

- Prioritizing renewable energy systems and decentralized power generation to enhance self-reliance and minimize reliance on imported fossil fuels
- Building flexibility into new energy, transportation, water and waste management systems to improve climate adaptation and disaster resilience
- Leveraging reconstruction financing to implement clean technologies, electrification, smart grids, and efficiency upgrades
- Tightening environmental regulations on rebuilt infrastructure and restricting unsustainable resource extraction
- Mainstreaming sustainability and low-carbon development into national, regional and local planning
- Capacitating Ukrainian workers and institutions on green technologies and climate-aligned practices
- Collaborating with EU partners to align rebuilt infrastructure and governance frameworks with European sustainability standards
- Integrating climate resilience and risk reduction into new public service provision including healthcare facilities and affordable housing

Achieving deep decarbonization in Ukraine entails overcoming substantial environmental legacy challenges while also navigating the new obstacles imposed by conflict. But with prudent policies, external assistance, and integration of climate aims into recovery efforts, a transition to resilient and sustainable development is attainable. Ukraine established strong climate strategies pre-war, demonstrating rising ambition. Once humanitarian needs are met, Ukraine must leverage reconstruction to reach tipping points for a sustainable transition. The stalled green agenda underscored energy-climate-security connections. Strategically seizing this realization as a tipping point could catalyze climate action amid rebuilding. With diligent policies, recovery can set course for a decarbonized, resilient future.

2.4 Methods

This analysis utilizes a quantitative emissions data assessment to identify potential decarbonization tipping points by region and sector. Carbon dioxide emissions data from stationary sources was compiled from Ukraine's State Statistics Service for 2017–2021 (Tables 1 and 2). This established national totals and breakdowns by economic activity. Additionally, industry development metrics were collected on Gross Regional Product and sectoral contributions for the top five emitting regions (Tables 3 and 4). Leveraging this dataset, a benchmarking analysis was conducted. Emissions were recalculated on a per capita and per GDP basis for the priority regions (Tables 5 and 6).

This multi-dimensional perspective aimed to reveal areas of disproportionate impact beyond absolute totals. The goal was elucidating where targeted interventions could induce sustainability tipping points. This quantification of priority sectors and regions provides an analytical foundation. It enables developing tailored policies and strategies to restart stalled decarbonization momentum through reconstruction tipping points.

The integrated data assessment offers robust evidence-based identification of decarbonization priorities. This can inform strategic rebuilding aligned with climate objectives.

Table 1 Carbon dioxide emissions from stational pollution sources by regions (top five regions), thsd. t

Region	2017	2018	2019	2020	2021
Donetsk	22,879.8	25,143.4	23,528.1	22,258.3	22,699.5
Dnipropetrovsk	26,072.6	23,620.7	23,496.6	20,474.8	22,321.8
Zaporizhzhya	14,047.4	14,614.1	13,663.3	12,979.6	12,935.8
Ivano-Frankivsk	11,965.1	13,763.2	12,898.9	10,207.1	12,067.1
Kharkiv	5765.5	7281.4	7595.8	7789.6	6173.3
Ukraine	**124,217.9**	**126,378.3**	**121,282.9**	**109,079.4**	**111,854.2**

Based on Carbon… (2023)

Table 2 Quantity of carbon dioxide emissions in Ukraine from stational pollution sources by types of economic activity, thsd. t

Type of economic activity	2017	2018	2019	2020	2021
A—Agriculture, forestry and fisheries	1099.8	1174.0	1162.2	1187.5	1461.7
B—Mining and quarrying	3365.2	3892.2	3105.0	2119.7	2448.9
C—Manufacturing	49,085.4	47,877.4	48,782.3	46,868.1	51,132.4
D—Electricity, gas, steam and air conditioning supply	63,865.2	68,464.0	63,274.0	56,262.1	51,997.5
F—Construction	52.8	57.0	38.0	48.9	67.3
G—Wholesale and retail trade	110.5	88.4	76.4	68.6	159.0
H—Transportation and storage	4393.3	3749.2	3703.9	1588.6	1687.2
Selected activity (A+B+C+D+F+G+H)	*121,972.2*	*125,302.2*	*120,141.8*	*108,143.6*	*108,954.1*
Ukraine (total)	**124,217.9**	**126,378.3**	**121,282.9**	**109,079.4**	**111,854.2**

Based on Air… (2023)

Table 3 Gross regional product (for selected five regions), mln. USD

Region	2017	2018	2019	2020	2021
Donetsk	6239	7065	7928	7653	10,383
Dnipropetrovsk	11,788	13,579	15,102	14,791	21,343
Zaporizhzhya	4895	5406	6003	6205	8389
Ivano-Frankivsk	2399	2884	3354	3353	4386
Kharkiv	7040	8576	9580	9563	11,720
Ukraine (GDP)	**112,091**	**130,891**	**153,883**	**156,618**	**199,766**

Based on Gross… (2022)

2.5 Basic Conditions for Analysis

For our research, we focused on basic data about carbon dioxide emissions (Tables 1 and 2) and industry development level (Tables 3 and 4) for the period 2017–2021 (Lukash & Nikulina, 2023).

The abovementioned data reflects the current state of issue carbon dioxide emissions and industry development level for five chosen regions chosen by the highest level of carbon dioxide emissions from stational pollution sources. Further, we will use these official data for in-depth analysis.

3 Results and Discussions

3.1 Pre-war Situation

In the first stage of decarbonization analyses, we suggest an overview of the current situation with carbon dioxide emissions (for 2017–2021) from stational pollution sources as one of the most significant problems for Ukraine. Firstly, this analysis

Table 4 The share of GVA by types of economic activity in the total amount of regional GVA in 2021 (for selected 5 regions), %

Region	A	B	C	D	F	G	H
Donetsk	8	28	15	3	3	10	5
Dnipropetrovsk	8	22	24	4	2	8	3
Zaporizhzhya	13	5	26	10	1	11	4
Ivano-Frankivsk	13	6	15	6	4	9	8
Kharkiv	11	8	12	3	3	15	5
Ukraine	**13**	**8**	**12**	**4**	**3**	**16**	**6**

A, agriculture, forestry and fisheries; B, mining and quarrying; C, manufacturing; D, electricity, gas, steam and air conditioning supply; F, construction; G, wholesale and retail trade; H, transportation and storage
Based on Regional… (2023)

Table 5 Carbon dioxide emissions from stational pollution sources by regions (top five regions), per capita (t/person)

Region	2017	2018	2019	2020	2021
Donetsk	5.4	6.0	5.7	5.4	5.6
Dnipropetrovsk	8.1	7.3	7.4	6.5	7.2
Zaporizhzhya	8.1	8.5	8.1	7.7	7.8
Ivano-Frankivsk	*8.7*	*10.0*	*9.4*	*7.5*	*8.9*
Kharkiv	2.1	2.7	2.8	2.9	2.4
Ukraine	**2.9**	**3.0**	**2.9**	**2.6**	**2.7**

can help us find weaknesses and the most problematic Ukrainian regions in the sense of high carbon dioxide emissions in relative measurement (per capita and GRP). Secondly, based on this analysis, we can develop a target policy for decarbonization. In the first stage, based on official statistical information, we choose the top five Ukrainian regions by carbon dioxide emissions (Table 1) (Carbon…, 2023). These regions (Donetsk, Dnipropetrovsk, Zaporizhzhya. Ivano-Frankivsk, and Kharkiv regions) in total cover 68.1% of carbon dioxide emissions in Ukraine in 2021. But the main task for us is not only to find the most significant carbon dioxide pollution sources but to identify regions where such emissions cause the highest social and economic issues.

For this purpose, we recalculated carbon dioxide emissions on two variants: per capita for selected regions (Table 5) and compared with Gross Reginal Product (GRP) (Table 6). Both calculations based on (Gross …, 2022; Population…, 2022) clarified the regional situation in more detail and significantly changed the ranking of the top five most problematical regions.

This multi-dimensional analysis elucidated priority decarbonization zones based on holistic environmental, social (Table 4), and economic (Table 5) considerations. The aggregated results definitively spotlight Ivano-Frankivsk Oblast as the highest leverage region for interventions that can catalyze sustainability tipping points.

Indexed analysis of emissions trajectories over the examined period indicates substantive intensity reductions. On a per capita and per unit GDP basis, all focus

Table 6 Carbon dioxide emissions from stational pollution sources by regions (top five regions), t / 1 mln USD GRP

Region	2017	2018	2019	2020	2021	2021/2017
Donetsk	3667.3	3559.1	2967.9	2908.4	2186.1	**–40.4%**
Dnipropetrovsk	2211.7	1739.5	1555.8	1384.3	1045.9	**–52.7%**
Zaporizhzhya	2869.8	2703.4	2276.0	2091.9	1542.0	**–46.3%**
Ivano-Frankivsk	*4987.2*	*4772.7*	*3846.1*	*3043.9*	*2751.2*	***–44.8%***
Kharkiv	819.0	849.0	792.9	814.5	526.7	**–35.7%**
Ukraine	**1108.2**	**965.5**	**788.1**	**696.5**	**559.9**	**–49.5%**

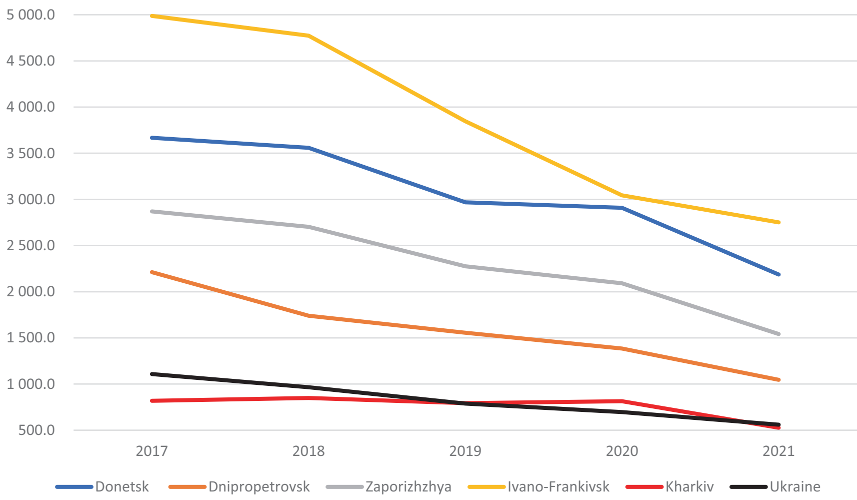

Fig. 3 Carbon dioxide emissions from stational pollution sources by regions (top five regions), t/1 mln USD GRP (Lukash & Nikulina, 2023)

oblasts exhibited downward emissions trends, signifying economy-wide decoupling of pollutive externalities from growth. Almost a 50% decrease for all Ukrainian regions and an even higher reduction for some of them (Dnipropetrovsk region) during the last 5 years, see Fig. 3. This momentum provides a strategic platform to launch targeted policies that can induce tipping points across both legacy and emerging industries.

A pivotal research inquiry is delineating high-impact decarbonization pathways for the Ivano-Frankivsk region. This region constitutes a priority area based on disproportionate emissions contributions relative to economic and demographic factors. The predominant source of Ivano-Frankivsk's elevated emissions profile is the lignite-fired Burshtyn Power Plant. This facility not only ranks among the most carbon-intensive generators in Western Ukraine, but exerts outsized environmental externalities nationally.

Targeted interventions centered on Burshtyn could catalyze a regional tipping point with national ramifications. Retiring a share of its capacity in favor of renewable energy installations, while providing transition assistance for affected workers, could spur momentum. Moreover, complementary strategies like distributed solar and wind, efficiency upgrades, and electrified transport can compound sustainability benefits. If underpinned by appropriate finance and policy frameworks, Ivano-Frankivsk could pioneer decentralized low-carbon development, creating demonstration effects to accelerate national progress.

BuTPS generation is very important for the entire region. The installed electrical capacity is 2400 MW (this is the second-largest TPS in Ukraine). BuTPS is the basis of the Burshtyn Energy Island (part of the energy system of Ukraine, on which BuTPS electrical networks are located, together with the adjacent power grid and its electricity consumers within Transcarpathian and partially Ivano-Frankivsk and Lviv regions). Unlike the rest of Ukraine's power grids, the Burshtyn Energy Island was connected to the power grids of EU countries and allowed to export Ukrainian electricity abroad since July 1, 2002. On February 26, 2022, it was connected to the Ukrainian energy system. On March 16, 2022, Ukraine joined ENTSO-E and the Burshtyn Energy Island ceased to exist.

The main technological fuel of BuTPS is coal, and the auxiliary fuel is natural gas and fuel oil. For the BuTPS, the problem of storage and processing of solid waste—fuel slag and ash—which remains after burning coal in the furnaces of the BuTPS is extremely relevant.

As of the beginning of 2022, the BuTPS was producing about 1000 MW. The share of BuTPS in the industry of the local region exceeds 20% (by revenue in 2021). About 2500 employees work at the enterprise. The station covers domestic consumption (where approximately three million people live) and transfers up to 645 MW of energy for export.

Reduction of emissions is possible due to the replacement of BuTPS capacities, but this is a rather difficult issue. There are several main reasons for this:

1. The relatively low current cost of generation, which makes the export of BuTPS electricity very attractive
2. A sufficiently large number of workers who will not be able to find alternative jobs in such a small region
3. The difficulty of introducing alternative generation into the outdated energy supply system, which will require significant investment and time

3.2 *Ukrainian Energy Strategy: Actual Challenges and Issues During Wartime and After*

Modernization and decentralization represent prospective tipping points to transform Ukraine's energy system beyond merely rebuilding the legacy fossil fuel dependence. The scale of reconstruction also enables non-linear expansions of renewables, efficiency improvements, and interconnections with the EU grid that can catalyze decarbonization. These goals are planned to be achieved through the development of modern and safe nuclear generation, renewable energy sources, and the modernization and automation of transmission and distribution systems. According to the developed strategy, by 2050, the energy sector should be as close as possible to climate neutrality, which means the availability of clean energy, overcoming energy poverty, development of an innovative and decentralized energy system, the full functioning of national energy markets and their integration into international ones (Energy…, 2023).

Ukraine's energy system suffered significant damage and destruction because of military operations. And now it needs restoration. But this reconstruction will not be done only through repairs; it will include modernization. Increased deployment of distributed energy resources and smart grids constitutes a pivotal tipping point for flexibility and resilience. Transitioning towards decentralized renewable energy can dramatically improve Ukraine's self-sufficiency. It is planned to introduce energy storage facilities that accumulate it. One of the essential elements of decentralisation should be encouraging Ukrainians to install solar panels and individual energy storage installations. The use of microgrids and smart grid technology is also expected. This should provide better control of the load on the power system and respond more effectively to modern challenges. The third direction of the Strategy is the continuation of the integration of the Ukrainian energy system with the European one. Of course, the Ukrainian energy system is already a part of the European one, but certain actions still need to be completed before full integration. These actions include the implementation of EU directives, the development of market mechanisms that would ensure a transparent and fair approach, as well as the increase of physical opportunities for the export and import of electricity with EU countries. Ukraine has enormous potential in this area, and the Ukrainian government believes that energy will be one of the drivers for the future recovery and growth of the Ukrainian economy. Among the important directions of the strategy is the development of "green" energy. For this purpose, the government is developing effective tools to stimulate and support green generation: auctions, certificates of origin and other tools to increase the share of green generation in Ukraine. The war continues and a separate important task is operational preparation for the autumn-winter period. The government is preparing for various scenarios: damaged ones are being repaired, new ones are being built, energy resources are being accumulated, and assistance from international partners is being mobilized for all these purposes (Cabinet…, 2023). Strategic leveraging of prospective tipping points is imperative amidst reconstruction, given heightened energy security needs. International climate financing will prove critical in catalyzing investments that can achieve sustainability tipping points domestically.

The new Ukrainian Energy Strategy envisages Ukraine achieving carbon neutrality in the energy sector by 2050 and considers:

– The consequences of the full-scale war of the Russian Federation against Ukraine, strengthening the role of energy security and strengthening the stability of the energy system
– The results of joining the UES of Ukraine to the European network of electricity transmission system operators (ENTSO-E) and deepening the integration of Ukraine's energy system into the European one
– The availability of the latest technologies (in particular, the production and use of hydrogen for energy purposes, small modular nuclear reactors, and energy storage facilities), technical changes in the energy sector, world trends and innovative solutions, requirements for environmental safety by EU regulations and accepted obligations of Ukraine
– Ukraine's international obligations regarding energy efficiency, use of RES, and reduction of greenhouse gas emissions
– decentralization of electricity generation throughout the country to improve the stability and reliability of energy supply (Ukraine…, 2023)

3.3 Possibilities and Consequences of Phasing Out Coal in Ukraine

For several decades, the coal sector has been an integral part of the Ukrainian electricity system. But the fact that it needs to be modernized for many reasons becomes obvious. Among these reasons are outdated infrastructure, significant emissions of carbon dioxide, and military actions on the territory of Ukraine, which create security for the entire energy system. Several conducted studies indicate the technical and economic possibility of gradually abandoning the use of coal, which should create an ecological and economic effect, reducing the need for subsidies to support the coal industry.

Based on the results of a study conducted in the period from October 2020 to April 2021 by the Aurora Energy Research company, a transition scenario was simulated, which provided for the linear closure of all 17 GW of coal-fired power in Ukraine in the period 2021–2030. According to this scenario, with the closure of coal-fired power plants, we get a tripling of the parallel installed power generation capacity from renewable sources, which reaches 35 GW of wind, solar, hydro- and bioenergy power by 2030. However, other capacities, particularly nuclear generation, remain unchanged in this scenario. Therefore, the results of this study confirmed that it is possible to guarantee the security of the electricity supply under the condition of gradual abandonment of the use of coal. In addition, researchers' hourly simulation of electricity production showed that renewable energy sources could occupy an increasingly large share of electricity production.

In the developed transition scenario, electricity production from coal decreases from 28% in 2020 to its gradual abandonment in 2030, and renewable energy sources occupy an increasingly large share of the structure of the electricity industry. In 2030, they can provide more than half of electricity generation. Electricity production from wind farms accounts for the largest share of electricity generation from all renewable energy sources, and under this scenario, in 2030, it should make up 25% of all generation. Photovoltaic electricity generation almost triples its share, from 4 to 11% in 2030. By 2030, nearly 14 TWh of electricity will be produced with the help of biomass, which is 8% of the entire generation. The transition scenario calls for significantly more gas-fired capacity to provide the necessary flexibility, with existing combined-cycle gas turbines replacing coal-fired generation during semi-peak load and adding new open-cycle gas turbine units to the system. Thus, the results of this study prove that the main challenge for the Ukrainian electricity system is flexibility and not a lack of renewable capacity (The consequences…, 2022).

In 2019, Ukraine entered the top 10 countries in the world regarding renewable energy development rates due to the increase in total renewable energy capacity of 61.6% in 1 year (IRENA, 2020). In 2020—in the TOP-5 European countries in terms of solar energy development rates due to the increase in total solar energy capacity of 266.0% in 2 years (IRENA, 2021). In 2021, the share of electricity generated from RES reached 8.1%, of which 56% came from solar radiation, 33% came from wind energy, almost 8% came from burning biomass and biogas, and 3% came from small hydropower. It is worth noting that in 2021, an active pace of development was observed in the segment of domestic SPPs, which in 2021 was 36.4% of the new RES capacities put into operation in 2020. Most renewable energy facilities currently installed in the country are concentrated in Ukraine's southern and south-eastern regions, where active hostilities have been ongoing for more than a year. According to various experts' estimates, 30–40% of RES power plants in these regions have already suffered in one way or another.

Russia's full-scale war against Ukraine brought an unprecedented social and humanitarian catastrophe, which affected all spheres of activity, including the economy, energy, and ecology. It is currently quite difficult to fully assess the consequences of this war crime, just as it is difficult to predict the further development of events and their consequences. But, considering the experience of the post-war recovery of European countries, for the economic recovery of Ukraine, it is worth choosing a course of carbon neutrality in energy to achieve annual GDP growth of 4% by overcoming import dependence through the availability of the best technologies, diversification, decentralisation and digitalisation. Thus, it is recommended to continue the process of diversification of sources of supply of energy resources, in particular nuclear fuel for nuclear power plants, at the expense of expanding own resource base of uranium, mastering the production of zirconium alloys and creating capacities for its fabrication in cooperation with global manufacturers. The further development of the alternative energy sector and the evolution of the power system is only possible with the reconstruction of substations and digitalisation. Therefore, it is suggested to move first to the operation of modular and unified structures of substations, as well as to equip the switching equipment with electric drives with the function of remote control and monitoring of their technical condition. Given the emphasis on decentralising the national energy system, it is essential to implement a distributed energy resource management system that includes a virtual model, active networks and microgrids. To complete the process of decentralisation of the energy system, it is necessary to develop and implement local programs for the modernisation of thermal energy infrastructure to optimise local energy systems by considering the potential of local types of fuel, supply logistics, regional and national energy infrastructure (A new…, 2022).

Analysing the Energy Strategy of Ukraine 2050, it should be noted that not all representatives of the authorities optimistically perceive the reality of implementing this strategy. Critics of this strategy have the most doubts about the announced plans for developing RES. They insist that the strategy should also include a conservative scenario of a protracted war. Experts, who do not share the optimistic views of the supporters of the Strategy, believe that at the first stage, the primary attention should be paid to gas generation, which is a relatively simple solution so that it can be quickly implemented. Gas generation and nuclear generation should become the basis for the development of Ukraine's energy system because it can balance unstable renewable energy sources in the future.

Even before the war, the shortage of balancing capacities reached 2 GW, which led to the emergence of the infamous "green-coal" paradox, in which, to balance the "clean" and "green" generation, "Ukrenergo" was forced to turn off the sides of the NPP and balance the system with "dirty" coal blocks TPP (The energy…, 2023).

The green-coal paradox is the need to significantly increase electricity production at coal-fired thermal power plants, which have harmful emissions, with many "clean" wind and solar power plants in Ukraine's energy system. At the same time, it is also necessary to reduce the base load of nuclear power plants, which, unlike coal-fired thermal power plants, do not emit harmful emissions into the atmosphere. This situation is caused by a significant shortage of power for manoeuvring in the energy system of Ukraine. In other words, there is a paradoxical component in Ukraine's energy system—an increase in the number of wind turbines, and SPPs leads to an increase in carbon and other harmful emissions (Paradox…, 2018).

Of course, solar and wind energy must be developed. However, the development of wind turbines in the coming years is a big question since the most attractive regions for this are either in the occupation zone or very close to the front line, making implementing such projects problematic. Regarding SES, the situation is a little better, but it is challenging to discuss implementing large new projects in the current unstable situation. Only the domestic SPPs segment continues to develop actively, where the main driving force is the consumer's desire to provide himself with the most stable energy supply.

The common and indisputable opinion of supporters and critics of the Strategy is the need to decentralise the energy system. The energy transmission system must become more decentralised to reduce dependence on the central power transmission systems under constant enemy attacks (The energy…, 2023).

4 Conclusions

The 2022 Russian invasion of Ukraine created a radical discontinuity in prevailing energy policies and starkly exposed the weaknesses and inherent vulnerabilities of Ukraine's heavily centralized, carbon-intensive energy systems. However, amidst the challenges and destruction wrought by the war, there emerges a unique window of opportunity to reshape Ukraine's energy landscape along a green and sustainable path.

The war's impact on Ukraine's energy infrastructure, while devastating, underscores the urgency of adopting a new approach. These changes, precipitated by the conflict, align with the global imperative to address vulnerabilities related to climate change and improve the quality of life.

Before the invasion, Ukraine had made significant progress in decarbonization, but the path forward was marred by the legacy of Soviet-era industry and centralized energy systems. The destruction of critical infrastructure, including coal and gas plants, created a paradox of reduced emissions in the short term but with the need for increased emissions during reconstruction.

To navigate this predicament successfully, Ukraine must strike a delicate balance between immediate energy security needs and long-term sustainability goals. This necessitates a strategic approach, combining prudent policies and external support.

Rebuilding damaged infrastructure represents a tipping point opportunity to modernize towards sustainability, if climate considerations are integrated into planning. Prioritizing decentralized renewables, aligning grids with the EU, and tightening regulations could serve as positive tipping points driving a resilient, low-carbon energy future.

While coal may remain important in the short term for specific applications, a managed transition to alternative energy sources, including solar, wind, biomass, and nuclear, is imperative for achieving affordable, low-carbon electricity. Enhancing grid flexibility will be essential to accommodate a higher share of variable renewables.

Strategic partnerships and targeted assistance will play a pivotal role in advancing Ukraine's energy security and climate ambitions. The mobilization of substantial financial resources and technology transfer will be key. Integrating climate resilience and energy efficiency considerations into the reconstruction process is essential for sustainable recovery.

This analysis underscores the importance of adopting a prudent strategy to advance Ukraine's energy security and climate aspirations during the recovery period. While significant challenges persist, a commitment to sustainable energy can bolster resilience and prosperity in Ukraine, ensuring that the post-war era represents a turning point toward a greener and more self-sufficient energy landscape.

Significant differences in the socio-economic development of the territory of Ukraine and peculiarities of regional, cultural and ethical perceptions of the importance of changes inevitably leave an imprint on the strategy of further action on the way to decarbonization. On the other hand, such tipping points can contribute to faster practical implementation of sustainable policies for some regions (Ivano-Frankivsk, as shown in our research) and become an essential driving force and example for others. The war is an incredible and unpredictable stress and test for all branches of politics. Still, it is necessary to use the opportunity for fundamental changes whose time has long come.

In conclusion, Ukraine faces major challenges balancing immediate needs and long-term vision. Yet strategic policies and investments during reconstruction could serve as tipping points for transformational change. Despite difficulties, leveraging this opportunity can catalyze Ukraine's stalled sustainability ambitions. With prudent planning, the recovery period can pave the way for a decarbonized, European-aligned economy in Ukraine.

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Exploring Transition in Coal- and Carbon-Intensive Regions Through an Interdisciplinary Lens

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Abstract This chapter introduces an interdisciplinary perspective to investigate the transition process and to identify empirical evidence of social-ecological tipping points (SETPs) in the case studies on coal and carbon intensive regions (CCIRs) analyzed in the project TIPPING+. The interdisciplinary lens considers different modes of thought, frameworks, and multiple perspectives and interests from diverse stakeholders, a systems' understanding, and different culture considerations across the CCIRs. Within this interdisciplinary process, we applied various lenses to study the potential for SETPs by combining insights from human geography, social psychology, regional socio-technical systems, and political economy perspectives on the phases of low carbon transitions and on the justice component of the transitions. Subsequently, this chapter gives an overview of how the eight CCIRs case studies in this book have applied various interdisciplinary lenses to investigate the regional transition and the emergence of SETPs.

Keywords Energy transition · Social-ecological tipping points · Coal and carbon intensive regions · Interdisciplinarity · Socio-technical transition · Socio-ecological transition

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1 Introduction

National and international climate mitigation policies and strategies often do not consider the nuanced needs and real constraints and opportunities present at the regional level, resulting in misalignments between (inter)national climate policy goals and local conditions and priorities. The challenges are more acute in coal and carbon-intensive regions (CCIRs) that are economically dependent on fossil fuels but must also meet national and EU climate change targets.

National climate policies often lack credibility at the regional and local level as longer-term climate goals do not resonate with the immediate socio-economic needs nor actual possibilities for transformation observed in the actual local context (Amundsen et al., 2018; Frantál et al., 2022). Moreover, national policies do not account for individuals' preferences and how they respond to fast socio-structural changes occurring at local level, or they are based on assumptions which can lead to a limited understanding of the behavior and abilities to adapt or innovate at a local level (Sarrica et al., 2018). In regional socio-ecological systems, different community values, social identities and cultural practices unfold and may—or may not—be integrated as part of broader climate mitigation actions. Another issue is that, while coal and fossil fuels are well defined technological sectors, CCIRs are not clearly defined and are rarely systematically analyzed as a 'complex system' (Allen et al., 2017). There is a lack of systemic understanding of systems' dynamics regarding CCIRs. Looking at a region as a complex system involves considering multiple geographical, social, cultural, and political dimensions that are integral starting points of its analysis. Failing to systematically consider these multiple dimensions and perspectives can lead to the ineffective implementation of mitigation actions and climate policies at all governance levels (Tàbara et al., 2019; Geels et al., 2017).

In the case studies of this book, we conducted theoretical and empirical in-depth investigation in CCIRs transitioning to low-carbon futures to understand how Social-Ecological Tipping Points (SETPs) emerge. Tipping points are well understood in the natural sciences. They have been documented in ecosystems (Lovejoy & Nobre, 2018; Möllmann et al., 2021) and physical systems (Eisenman & Wettlaufer, 2009). In social systems, meanwhile, tipping points are less well understood. In TIPPING+ we used interdisciplinary social science to understand the fundamental changes in sociodemographic, geographical, psychological, cultural,

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political, and economic patterns of interaction in the socio-ecological system. To examine societal tipping points, we have examined statistical changes in these patterns, as well as the narratives that have described, catalyzed, and opposed a post-coal transition. Lieu et al. (2020) have described these narratives as on-stream, off-stream, and transformation stream. Through workshops and interviews with local community actors across the numerous case studies in Tipping+, we engaged in conversations to identify potential triggers for positive tipping points (following Tàbara et al., 2019). Our purpose has been to find patterns and narratives that have led or are leading to the emergence of SETPs, both positive and negative. For instance, the decision of 'leaving fossil fuels in the ground' could be understood as a positive outcome of a tipping intervention from a climate policy and sectorial perspective as it could trigger alternative energy innovations and technologies if they are mature enough and there is an enabling environment. However, the practical consequences of such a decision at the regional and local levels in terms of employment, cultural identity, and social-ecological restructuring need a careful examination before being qualified as 'positive' (Dale et al., 2018; Dale & Kristoffersen, 2018). Such an interdisciplinary process enabled us to have a multi-faceted and nuanced view of the transitions in CCIRs.

In this chapter, we first introduce the interdisciplinary foundations of the project to investigate the transition process in the CCIR regions under study. Subsequently, we give an overview of how the eight regional case studies on which we focus in this book have used an interdisciplinary lens to investigate the regional transition and the emergence of SETPs.

2 Exploring Transitions Through an Interdisciplinary Lens

In our analysis of assessing potential SETPs, we explore different understandings of transition, transformation, or system changes. We first provide a broad overview of SETP based on socio-technical systems theories (STS) and socio-ecological systems theories (SES). We then introduce concepts from human geography, social psychology, regional socio-technical, and economic perspectives to have a broader understanding of *low-carbon transitions* and *social justice.*

The study of transitions, transition phases, transformations as well as the very notion of tipping points (TPs) are grounded in complex systems theory, which in turn builds on general systems theory (Ashby, 1957; Holland et al., 1963; von Bertalanffy, 1968). These concepts are adopted by many disciplinary theoretical perspectives such as economics, socio-technical system theories, socio-ecological systems theories, resilience perspective originating from SES (Folke, 2006) and others.

The STS theories study systemic change or transitions as a progressive shift of regimes that are spread across economic and political structures, norms and values, and patterns of behavior. These regimes influence the development of technological sectors (Geels & Schot, 2007; Wesselink et al., 2020). Rotmans et al. (2001)

advanced the thinking behind socio-technical transition, distinguishing between predevelopment, acceleration, take-off, and stabilization phases of socio-technical change. In a similar way, Gunderson and Holling (2002) advanced the thinking that an SES can shift into fundamentally different configurations after a release phase opens for reorganization and exploitation of new structures, followed by a new phase of conserving structures.

The SES theories try to explain how a system changes by considering the environment, society, and economies as fundamental parts of the system. In SES theories, transformation happens when a tipping point is reached (Wesselink et al., 2020). Building on SES, resilience scholars see the transition as a subset of a larger transformation (Herrfahrdt-Pähle et al., 2020).

Expressing elements of both SES and STS-style theories of change, the Adaptive cycle approach conceptualizes interlinked societal/technical and ecological systems change into four cyclical phases (Gunderson & Holling, 2002). As a system moves through the phases of the adaptive cycle, a system may remain resilient to processes of change at greater or smaller scales or shift into a fundamentally different configuration. A tipping point will happen following a release phase that provides potential for reorganization and exploitation of new structures, followed by a new phase of conserving structures.

Both SES and STS theories have identified general patterns of how transitions unfold over time, including types of change (incremental and abrupt), their nonlinearity (thresholds and tipping points in disruptive innovations and events), and multiple phases of transitions (Loorbach et al., 2017). The transition phases of STS, SES, and adaptive cycle perspectives have corresponding concepts and phases (Table 1).

The socio-technical perspective emphasizes the deployment and diffusion of technological innovations as the focus of change and implies a management and engineering perspective focusing on human-technology coupled systems (i.e., technology-society relationship). The STS perspective is grounded in innovation research, science and technology studies and evolutionary economics (Loorbach et al., 2017; Barile & Saviano, 2018). It has a narrower focus and has been accused to have a selective bias toward technological innovations and the transition of socio-technical systems providing goods and services to society (i.e., food, water, energy, waste).

The socio-ecological perspective, on the contrary, emphasizes the interactions between natural capital and ecosystem services and implies adopting a perspective

Table 1 Synopsis of transition phases in socio-technical, socio-ecological, and adaptive cycle approaches

Socio-technical transition phases	Socio-ecological transition phases	Adaptive cycle phases
Predevelopment	Pre-transformation	Release
Acceleration	Preparation	Reorganization
Take off	Navigation	Exploitation
Stabilization	Institutionalization	Conservation

centered on human-nature coupled systems (i.e., the environment-society relationship, Ostrom, 2009). The SES perspective is grounded in sustainability science and environmental studies focusing on environmental assessment, environmental policy, and sustainability governance and addresses sustainability transformations with a whole system perspective. Here, transformation refers to the creation of fundamentally new systems of human-environmental interactions and feedback (Walker et al., 2004), thus involving the change of multiple elements of socio-ecological systems such as beliefs, behaviors, and institutions at multiple levels (Moore et al., 2014). From this perspective, SETPs refer to a family of frameworks and concepts that describe the process of socio-ecological transformations (Totten, 2012; Westley et al., 2013; Moore et al., 2014; Tàbara et al., 2018). According to these frameworks, a socio-ecological system such as a CCIR may go through a series of events whose effects accumulate and, at some point or points in time, the SETPs, cause changes in key elements of the system (Moore et al., 2014; Tàbara et al., 2018). Such changes alter the feedback mechanisms stabilizing the system and bringing cascading effects that 'move' or attract the system toward a new trajectory and different state creating new feedback loops (see also Olsson & Moore, 2023). Put it simply, from a SES perspective, this involves the 'unmaking' and 'making' of given sets of relationships making up a system (Feola et al., 2021). While for an STS perspective it involves the destabilization-reconfiguration of a socio-technical system that is characterized by break-down and build-up dynamics or processes of 'exnovation'/phase-out and innovation/phase-in (cf. Hebinck et al., 2022).

Among SES approaches, the adaptive cycle has a cyclical understanding of change, where the transformative (tipping point) potential of each cycle is not given, but dependent on the presence of key drivers of change at greater or smaller scales. The adaptive cycle was conceptualized by Gunderson and Holling (2002) based on observations of marine ecosystems and expanded to also consider human societal and technical dimensions such as political regimes. Their observation was that all systems will exhibit a similar pattern of change: a conservation stage in which structures are maintained (a late-succession forest; the end of an elective cycle), giving way to a release phase (fire; elections) that allows for a reorganization (plant pioneers; reelection or new government) and exploitation (plant succession, policy implementation), before a new period of conservation of structures (c.f. resalliance.org for examples and literature). The equivalent of a tipping point may or may not be induced between the reorganization and exploitation phases, pushing the system out of its previous state and into a new one (Olsson et al. 2014). For instance, a forest ecosystem becoming open grassland or desert; a democratic system of governance becoming a dictatorship; a former coal region becoming a node in a larger network of renewable energy infrastructures. Pelling and Dill (2010) describe disasters as potential tipping points that change the trajectory of a social system. Inherently, disasters are events that overwhelm capacity to respond at a given scale, requiring mobilization of resources at greater scales to either stabilize or transform a vulnerable SES. For the purpose of deliberate, positive tipping points, the ability to engineer a disturbance that catalyzes reorganization and a transform into a desired SES state depends on the capacities and potential present in the dynamics of systems at scales above and below. Gunderson and Holling (2002) captured such cross-scale aspects in the notion of a *panarchy*, conceptualized as nested dynamic systems across temporal and spatial scales.

2.1 Human Geography Perspective

Human geography builds on space, place, and scale as three foundational concepts. For CCIRs, these three allow consideration of how transformative change in an STS or SES is experienced and located in space and place, as well as how such change is scaled from personal to global levels and across time. Space is at once a material and conceptual term that is experienced by an individual or a culture and includes physical and cultural phenomena (Massey, 2005). The sense of space in many ways precludes the sense of place, setting the conditions for how a given place is experienced. For instance, a given place within a CCIR may be experienced as a site of opportunity and growth to a person whose sense of space is vested in new economic activities, while the same place may be experienced as a site of loss and ruination for a person whose sense of space is rooted in a coal mining identity.

Scale dimensions in CCIRs are an important consideration for just transition. In the pursuit of low-carbon societies, it is often the resilience of large-scale SES systems and states such as regional and national governance and ways of life that it sought, while local or individual levels are required to transform (Amundsen et al., 2018). There may be a sense of injustice among those whose lives are required to transform if their quality of life is expected to decrease to support the resilience of life of others. The experience of such tipping points may not be unlike that of a disaster (Pelling & Dill, 2010). Further, the scale dimensions in CCIRs are important in terms of how lessons on transitions can be scaled. It may be, for instance, that lessons from transitions in coal region STS/SES founded on black anthracite coal cannot be scaled up to include regions dependent on lignite since the two have fundamentally different forms of extraction and economic profitability (cf. Veland et al., 2023). Finally, the unit of geographical scale called a CCIR may not be the best unit of analysis or policy for the transformation of that same region. While coal may have unified the region historically, the features of the transformed region may align with a new or different formal, functional, or administrative region.

In the case of the CCIR represented in the four stages (Fig. 1), the region may go through periods of exploitation, conservation, release, and reorganization (Gunderson & Holling, 2002) and retain the same characteristics. For instance, the drop in coal prices can represent dynamics in a nested SES that ushers then release of a conservation-phase coal economy. This might in turn cause a reorganization of policies, actors, and financing instruments that could tip the system into a fundamentally new post-coal domain of attraction; or the CCIR may return to exploitation of coal because the triggers of transformation were insufficient to reach a tipping point.

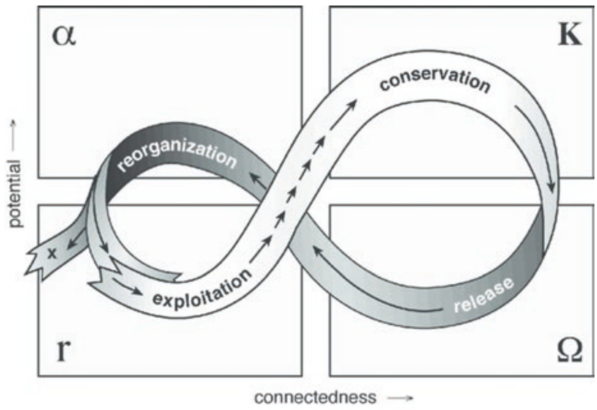

Fig. 1 The adaptive cycle (Gunderson & Holling, 2002, figure 2-1, p.34)

It is important to consider that transition phases may be conceptualized differently when approached as entangled socio-natural systems or as separated social and natural systems. The STS may have shifted fundamentally into a new way of narrating the political, technological, and economic space, and the population characteristics may have shifted to match new political and economic priorities, but the natural/ecological system, or the physical energy system infrastructure may not yet have shifted to match. The societal tipping point is in this way closely tied to the physical system limitations and opportunities.

In conceptualizing CCIRs, the most applied human geography concept of a region is the formal region (Gillespie, 2014). This concept tends to acknowledge only dominant characteristics of a region, for example, one culture, language, customs, identity, etc. (Kitchin & Thrift, 2009). In terms of governance, these formal regions are typically enclosed by administrative boundaries that are centered in urban cores. This understanding of a region does not include a justice perspective and may leave out minority groups, and work as an unconscious bias that impedes the participation of underrepresented groups. To better account for justice dimensions, a transformation may involve shifting from an existing formal coal region to one or more functional regions, their extents aligned with a diversity of economic, environmental, cultural, historical, linguistic, etc. features that are harnessed to induce positive change (or stability). Perhaps over time new administrative or functional regions would emerge.

Regarding the justice dimension in transitions in CCIRs from a STS perspective, two key themes can be identified (McCauley & Heffron, 2018). First, the just transitions idea, that communities affected negatively by the cessation of coal and other carbon-intensive industries should be somehow compensated for their losses or have access to assistance to find alternative means of economic activity. Second, the issue of justice might concern justice to future generations and to those negatively affected by coal and carbon-intensive industries today. That is, those who may have done nothing to cause climate change but are or will be suffering most from its effects. The need to cease carbon- and coal-intensive industries is in part driven by the injustices to such populations.

2.2 Social Psychology Perspective

As discussed above, both SES and STS theories have identified general patterns of how transitions unfold over time. Both theories include—in an explicit way—references to psychological and psychosocial processes that foster or hinder change.

Social psychology has primarily engaged with STS, integrating its theories and variables (e.g., identity, values, beliefs) into socio-technical frameworks to better understand technology uptake, acceptance, and diffusion at various levels (Bögel & Upham, 2018). However, less attention has been given to how these factors contribute to regime stability or dynamics of destabilization and decline (Biddau et al., 2022b). By privileging a sectorial perspective, the discipline is not only failing to acknowledge the systemic dimension of such type of change, but also how psychosocial factors can intervene in the different phases and influence the timing and pace of transitions. This bias is particularly relevant as transitions in CCIRs involves vulnerable communities navigating a complex pathway of destabilization and reconfiguration that extends beyond a socio-technical change and encompasses struggles between the 'old' and the 'new' (Johnstone & Hielscher, 2017). The onset and success of systems' transformations depend on how actors respond to regime destabilization, and psychologically cope and adapt to the newly emerging regime (Herrfahrdt-Pähle et al., 2020).

For all these reasons, the point of intersection with psychological approaches to transition being that transformation involves the change of multiple elements of systems including beliefs, behaviors, and institutions at multiple levels (Moore et al., 2014).

In this regard, through a close comparison, it is possible to schematize some basic phases of transformations as defined by resilience scholars such as Olsson et al. (2014) and Moore et al. (2014), which relate as much to individual as to societal psychological processes of stability or transformation, and to relate different psychosocial mechanisms to the phases suggested in the literature: (1) *triggers/pre-transformation*, (2) *preparing for change*, (3) *navigating the transformation*, and (4) *institutionalizing and building the resilience of the new trajectory*.

1. The *pre-transformation* phase includes *perturbations, pressures, or crises*, which emerge internally or as exogenous forces, and which serve as an opportunity for destabilizing the dominant state. At the individual level, perturbation may be referred to as a moment in which the changes in the environment are still perceived as noise (i.e., they are not perceived as meaningful signals) (O'Brien & Klein, 2017). At the community level, problem awareness such as environmental concern or risk perception influence the preparedness for change and the identification of windows of opportunity essential for initiating transformations

(Nelson et al., 2007). At the societal level perturbations emerge in the level of agency that the different discourses acquire, and in the overall attempt made by off-stream narratives (Lieu et al., 2020) to gain space, especially on local media. Stakeholders, including social movements, can deliberately try to challenge hegemonic representations or to preserve them through, for example, the introduction of new norms or the enactment of communicative campaigns aiming at introducing new beliefs or at propagating polemic representations. Alternatively, they may react to such perturbations by conveying hegemonic discourses reproducing the dominance of certain institutions, technologies, and practices (Simoens et al., 2022).

2. The *preparation* phase, which includes all the individual and collective processes aimed at making sense of the situation and may eventually lead to envisioning alternative visions and gaining momentum around new ideas and innovations. Relevant in this phase, are all the individual processes involved in recognizing patterns of signals (e.g., schematization, naming, framing), as well as the individual and collective processes of resistance to change and of symbolic coping (e.g., social memory and place meanings), which may lead to avoidance and to suppressing the need for further elaborations of alternatives (e.g., use of heuristics, denial) and undermine the community capacity to respond to new problems and opportunities (Wilson, 2014).
3. The *navigation* phase is characterized by the selection, learning, and adoption subprocesses. In the Social Representations theory, this phase is characterized by the actual elaboration of new representation and eventually in the polyphasic presence of multiple and incoherent representations and practices. The discrepancy between perceived and observed change is a crucial element here, especially to move from a transformation in behaviors towards an actual process of learning and elaboration of significant behaviors, new social norms, meanings, and identities.
4. Finally, the *institutionalization of the new trajectory* phase is characterized by routinization, strengthening cross-scale relationships, and stabilization. At the individual level this would be noticed by the emergence of new habits. From the social representation approach, it would be identified as the establishment of new hegemonic representations. But it is probably the dynamical system approaches which could be more extensively adopted to identify this phase and especially the stabilization level, which at the societal level implies to reach a new basin of attraction and to actively maintain it. This phase covers three dimensions: (1) The institutionalization of so called "state symbologies" (i.e. the systems of symbolic meaning which are aimed at and promoting the legitimacy of a political and social structure); (2) the active management of the identity space (i.e. the ensemble of groups and identities that coexist within a society), and; (3) the implementation of "state technologies" (i.e. the material, institutional and technological means used by the state) (Leone & Sarrica, 2017; Liu et al., 2014).

Aspects of justice in transitions in CCIRs can be operationalized by using the concept of regional place identity (Paasi, 2003; Gillespie, 2014). Justice can be included in a situated analysis within case studies to investigate the preconditions for decisive breakthroughs on the transition front, and if and which breakthroughs are taking place in practice. A just transition in practice should involve local communities and expand their agency. This can be contrasted with exclusionary and exploitative dynamics typical of extractive production systems (energy and otherwise), which are often replicated in energy transition processes (Sovacool et al., 2019). Applying a social psychology approach thus sees local-level agency and ownership, the ability of communities to participate in decision-making processes taking place at regional, national and community scales, and benefit from change as pivotal elements of a just energy transition.

2.3 Regional Socio-Technical Perspective

In the socio-technical perspective, regional transitions are considered as historically contingent processes going through different phases. Several authors have depicted these phases and described them in rather stylized patterns. There are usually three to four stages presented: (1) *initiation or emergence*, marked by experimentation and niche-innovation, (2) *early adoption and pioneering*, (3) *expansion and diffusion*, where technologies become mainstream (reconfiguration in Geels & Schot, 2007) and (4) *consolidation and stabilization*, comprising standardization processes (Chlebna & Mattes, 2020; Geels et al., 2008; Rotmans et al., 2001).

Transitions are not linear processes and may halt or progress without change being obviously visible. For example, the transition to zero-carbon energy may be progressing even if emissions are presently not decreasing, because progress is made for emerging technologies or because incumbent regime actors are being weakened. As another example, in a coal region, the closure or phase-out of the coal industry may not necessarily be aligned with and accompanied by the uptake of readily available alternative energy technologies. Instead, the predominant process may revolve around coping and managing the industry decline over an extended period and be accompanied by economic diversification, local capacity building and education measures.

In the last decade much attention has been given to phase-out, stressing its significance in creating room and momentum for innovation uptake and diffusion as well as for accelerating transitions (Rogge & Johnstone, 2017; Turnheim & Geels, 2012; Trencher et al., 2023). Recent scholarship suggests an X-curve framework that consider simultaneously the break-down or exnovation and phase-out dynamics along with build-up dynamics and innovation diffusion and phase-in (Hebinck et al., 2022) (Fig. 2).

Based on the four phases identified by the socio-technical perspective, the case study teams within the TIPPING+ project defined more specific phases to further refine the transition dynamics in a CCIR, which might differ from one CCIR to another. As an example, the case study on energy transition in Duisburg and Essen, in Germany, identified the six following phases:

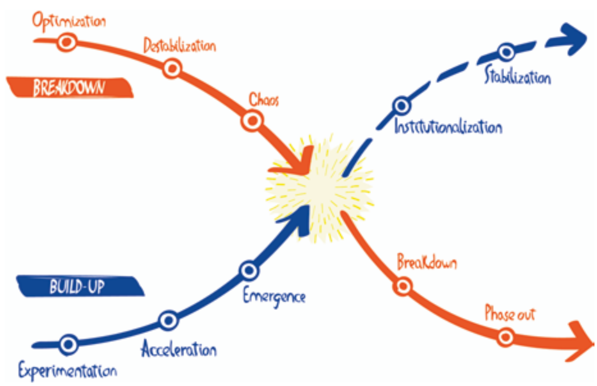

Fig. 2 The X-curve (Silvestri et al., 2022, p.5). The X refers to the specific moment when these two descending and ascending pathways interact and align

1. *Shock* triggered by the coal price crisis (tipping event);
2. *Avoiding collapse* of the system in place (e.g., interventions to stop further mine closures on basis of national energy security and social policy—coal laws);
3. *Grasping for salvation* through interventions (e.g., an introduction of coal subsidies);
4. *Denial* of looming end (e.g., the coal sector receives continuous support and only sees incremental reduction of subsidies);
5. *Loss of public legitimacy* (e.g., ultimate breakup of "coal coalition" and loss of election(s));
6. *Acceptance* (e.g., of the end of coal mining), *visioning of and pursuing new opportunities* (*possible tipping interventions).*

Regional transitions such as a coal phase-out studied in some of the case studies in TIPPING+ are embedded in multiple dynamics at local, regional, and national level. Hence, these phases may have been manifested at different times and varying intensities at different levels, and they take a long time. Our empirical case studies show that the transformation processes are still ongoing, and regions have not entered a stabilization phase yet. In addition, our empirical work suggests that it is important to terminate the old paradigm (e.g., with a "final date" and an official symbolic act) to be able to mobilize the capacities and focus on the new (e.g., visioning of new future for the region).

Regarding the aspects of justice in transitions in CCIRs, one of the main criticisms of the socio-technical perspective is that it does not address socio-ecological or distribution systems (e.g. inequality, poverty, work conditions) and issues of power, justice and plurality (Røpke, 2016; Munro, 2019). However, more recent research is bridging the socio-technical perspective and the justice aspects of regional energy transitions and distributional consequences of sustainability transitions (Jenkins et al., 2018; Sareen & Haarstad, 2018) also linking it to 'just transitions'. Such research engages with the main two frameworks for thinking on energy justice and defining it as a concept: *the three central tenets of the energy justice* introduced by McCauley et al. (2013)—distribution, procedural and recognition justice—and applied throughout the energy system and *the eight core principles* developed by Sovacool et al. (2016): availability, affordability, due process, transparency and accountability, sustainability, intragenerational equity, intergenerational equity and responsibility.

2.4 Economics Perspective

The main processes of change in the economic realm are the structural and technological change. At the macro-economic level, structural change is measured through statistical aggregates (GDP, Investment, R&D investment, unemployment, population, GHG emissions). The process of structural change can be captured by econometric analysis that characterize the evolution of the relationship between these aggregates across regions or across time.

At the micro-economic level, structural and technological change can be captured by the evolution of production networks (i.e., input-output or buyer/seller relationships). Changes in technological paradigms induce changes in the structure of the network (Acemoglu & Azar, 2020; Gualdi & Mandel, 2019).

At the regional level, aggregate econometric results abstract away from substantial heterogeneities found at the local level and the resulting grouping of regions can be unintuitive and imperfect. The empirical work on regional cases allowed us to complement this aggregate perspective and to identify micro-level dynamics and processes that substantiate structural change at the macro level and define the following transitions phases:

1. *Awareness raising*;
2. *Emergence:* marked by experimentation, innovation in the laboratory, and demonstration in the field, to produce technologies and system architectures (Geels, 2005);
3. *Early adoption* (pre-tipping point): technologies go from the laboratory to limited commercial application;
4. *Diffusion* (at the tipping point): technologies become mainstream;
5. *Stabilization* (past the tipping point): new technologies, systems, and behaviors are both standardized and insulated from rebound effects and backsliding (Andersen & Gulbrandsen, 2020).

In the socio-economic realm, justice is strongly associated with inequality or more broadly with the distributional consequences of policies. In this context, justice can be understood firstly as a trigger, then a process and finally, an outcome. Perceived regional or social inequalities in the outcome of transition policies can have very strong impacts on social acceptance and thus be a strong barrier for implementation (e.g., the Yellow Vest movement in France). Just transition policies aim to overcome these barriers. The just transition perspective is embedded in the wider energy and environmental justice discourse emphasizing the conditions and challenges for a fair and equitable transformation (Heffron & McCauley, 2017; LaBelle, 2017; McCauley & Heffron, 2018; Schlosberg, 2007). Simplified, 'just transition' terminology is used to synthesize environmental, labor, and social justice frames drawing on different perspectives highlighting socio-economic implications of the sustainability transformation process.

One dimension of just transition is gender, since transitions tend to affect women differently than men (Lugonzo & Chege, 2021). While research focusing on gender, social equity and intersectionality started only recently (Johnson et al., 2020; Allwood, 2020; Lahiri-Dutt, 2023), little is known about the gender impacts of CCIRs transitions. In an extensive review of literature on coal phase-outs, Walk et al. (2021) found that past coal phase-outs meant both opportunities (e.g., increased labor market participation) and challenges for women (e.g., difficulties to gain access to union structures). However, their review show that the impact of sustainability transitions on women's lives remains largely under-researched.

The design of just transition policies can be informed by data on income/wealth distribution and by models assessing the distributional consequences of policies. This shall lead to more comprehensive policy packages addressing the asymmetry of risks and opportunities across economic sectors. These shall aim at accompanying economic and geographical mobility made necessary by structural change (e.g., fostering the shift to a service economy and the concurrent increase in labor demand). Notably, addressing distributional consequences of transitions is one of the key objectives of the Just Transition Fund in the European Union.

In the discourse, justice appears in various contexts (energy justice, just transition, just energy transition, coal transition, sustainable transition). Still, the discussion about it at the policy and local level is not as vigorous as in academic studies. Moreover, the term justice probably loses its explanatory power because of the discretionary interpretation of the 'justice' and 'just transition' phrases by very different stakeholders (green NGOs, administration, trade unions). Interestingly, trade unions use the category of justice in terms of cosmopolitan justice (insecure and low-paid jobs in the Global South compared to well-paid jobs in Europe) (McCauley et al., 2019). Environmental movements use the category of restorative justice (to compensate for damages) and intergenerational and procedural justice (to engage all interested sides) (McCauley & Heffron, 2018; Page, 1999).

2.5 Summary of Transition Phases from Different Disciplinary Perspectives

After reviewing the timing and phases of transitions in CCIRs based on STS and SES theories and understanding how these phases and the justice component have been conceptualized and framed in human geography, social psychology, regional social-technical, and economic perspectives (see Table 2), we attempted to bring

Table 2 Summary of transition phases from different disciplinary perspectives

Perspectives	Transition stages	Justice components
1. Inter-disciplinary	1. Release 2. Exploitation 3. Reorganization 4. Conservation (Gunderson & Holling, 2002)	– Justice issues occur between the local, regional-, and national levels. For example, the need of changes at the local level for the stability of the national level. – Intergenerational justice, especially to those negatively affected by coal and carbon intensive industries today (Page, 1999).
2. Social psychology perspective on transitions	1. Pre-transformation 2. Preparation 3. Navigation 4. Institutionalization (Biddau et al., 2022a, 2023)	– Local-level empowerment, ownership and agency, engagement of communities in decision-making processes taking place at local regional and national scales and community's benefits from change.
3. Regional perspective on socio-technical transition	1. Initiation/emergence 2. Early adoption and pioneering 3. Expansion and diffusion 4. Consolidation and stabilization	– The three central tenets of the energy justice: distribution, procedural, and recognition justice (McCauley et al., 2013) – The eight core principles of justice: availability, affordability, due process, transparency and accountability, sustainability, intragenerational equity, intergenerational equity and responsibility (Sovacool et al., 2016).
4. Economic perspective on transitions	1.Awareness raising 2. Emergence 3. Early adoption 4. Diffusion 5. Stabilization (Mandel et al. 2022)	– Justice strongly associated with inequality and the distributional consequences of policies. – Just Transition of the workforce and the creation of decent work and quality jobs (McCauley & Heffron, 2018). – Just transition is gendered with strong focus on men in CCIRs, but transitions affect women differently than men.

together these different disciplinary perspectives to detect changes that eventually lead to SETPs.

It is important to note that the disciplinary conceptualizations of transition phases presented here encompass various facets of low-carbon transitions. While human geography and social psychology perspectives offer a broader view of transitions, the regional socio-technical and economic perspectives respectively address the phases of destabilization and decline (i.e., the phase-out) and innovation uptake and stabilization, representing the complementary processes of any transition.

Bringing in different disciplinary perspectives on understanding transitions and exploring how they consider justice can help us detect dynamics and changes that could lead to SETPs. In the following section we briefly introduce the chapters in this book section focusing on regional case studies. Each case study uses different perspectives or combines several of them and investigates potential tipping points.

Overall, the chapters underscore that the success and pace of low-carbon transitions in CCIRs are contingent on a variety of factors contributing to system stability. These encompass socio-political, socio-economic, and socio-cultural legacies, as well as structural features ingrained in the local biophysical and infrastructural environment. Factors like economic and energy dependencies on fossil fuels, as well as the readiness of available alternatives to replace coal and carbon-intensive economies, can bolster the cultural legitimacy and dominance of the fossil fuel regime. This, in turn, constrains opportunities for alternative visions and pathways to gain space and momentum. Conversely, when the deliberate or accidental break-down of these legacies aligns with the emergence of alternatives, regions can gradually shift towards a different trajectory and configuration with the appropriate interventions.

This indicates that to gain a comprehensive understanding of the state of transition, its direction and speed, as well as actionable insights for identifying SETPs and tipping interventions, the analysis of transition dynamics must transcend isolated elements or facets and integrate both build-up and breakdown dynamics.

The theoretical and empirical perspectives presented here align with recent scholarship (Hebinck et al. 2022; Biddau et al., 2023) and suggest that deliberate destabilization and decline of existing practices and structures in CCIRs cannot occur without due consideration towards the build-up of alternatives. This includes among others developing new community identities, alternative socio-economic sectors, and viable energy futures that address justice concerns and meet community needs along the destabilization-reconfiguration pathway.

While justice elements may not be explicitly stated in each CCIR case study, justice is more broadly considered through social inclusion or exclusion and/or by exploring how different actors are positively or negatively impacted by the politics, policies, technologies, and social changes in the break-down and build-up dynamics of transition process.

3 Case Studies of Transition and Tipping Dynamics in Coal and Carbon Intensive Regions

This book compiles eight chapters that combined SES theory with other social sciences. An intersection with Human Geography is present in Dale and Sveinsdóttir (2023) and Hansen et al. (2023). A combination with Social Psychology is shown in Cots et al. (2023), Ismail et al. (2023), Apostoli Cappello (2023) and Hansen et al. (2023). Whereas a stronger Political Economy focus is given in Veland et al. (2023) and Dale and Sveinsdóttir (2023), Frankowski et al. (2023) present an Economic focus. Additionally, a Justice lens is present in Ismail et al. (2023) and Apostoli Cappello (2023) and a Regional STS approach in most chapters.

In Delatin Rodrigues and Grasso (2023) explore the social tipping processes in the transformation of the socio-energy system in the city of Civitavecchia, Italy which led to the exit from fossils fuels. The authors use the categories of destabilization and disruption as analytical tools to identify agents of transformation that can trigger social tipping processes in the Civitavecchia's 'fossil machine', conceptual category inspired by Gramsci (1929). They show how understanding the change in the case of Civitavecchia required following the micro-socioecological aspects of destabilizing the 'naturality' of fossil energy and the practices that disrupted its reproduction and expansion. An interesting finding is how the conditions of acceptability had been constructed by what started as minority groups which gradually acquired social consistency and legitimacy to decisively oppose fossil energy. The chapter ultimately shows that the category of social tipping processes constitutes a useful framework to understanding and explaining the processes of socio-ecological change and rupture that have occurred. By emphasizing the processual dimension, it allows to identify practices that can have positive effects and understand how these effects are generated and propagated from and within a particular social-ecological environment.

In Dale and Sveinsdóttir (2023) explore the 20-year history of oil and gas extraction debate in the Lofoten archipelago in Norway to understand how a predominantly petroleum-focused economy already tipped over to alternative, low-carbon energy. By identifying important events and interventions that shaped the trajectory of the debate, the authors aim to understand how alternative visions of an oil free Lofoten emerged, took shape, and became a collectively held and performed vision of a desirable future. They argue that the success is rooted in place-based and community-driven engagement, and that a shared, communal vision of the past played an important role in creating a new, shared vision of the future. Examining the Lofoten case yields useful insights into conditions and interventions that can both unsettle the status quo of fossil fuel energy systems as well as foster lasting a transformation towards less-carbon intensive emissions trajectories.

In Cots et al. (2023) explore the role of identities and perceptions of the future in a post-coal mining region in the case of Andorra. The chapter investigates the demolition of the cooling towers of the coal power in Andorra as a definitive sign of the socio-economic transformation towards sustainable development pathways. The authors analyze the role of identities and perceptions as either enablers or barriers towards a tipping point and show how the tipping events such as the demolition of the plant are the result of decades of socio-economic, political, and cultural and ecological forces interacting which collectively move away from authoritarian identity built around coal mining. They also show how multiple socio-economic, political, cultural, and ecological forces converge and interact in incremental modes to push the original system towards a different configuration. The authors conclude that while it is reasonable to believe that the conditions for positive tipping points can be enabled through deliberate actions and policies, there is a need that normative justice safeguards, precautionary policy criteria and institutional arrangements to be already put in place in an anticipatory way so to realize positive outcomes and avoid negative ones.

In Ismail et al. (2023) explore the narrative-network dynamics in tipping processes towards low-carbon energy futures in the case of Indonesia. The chapter investigates the significance of the relationships between narratives and social networks adopting proactive measures and perspectives which contribute to the emergence of enabling conditions for tipping points leading toward sustainability. The authors utilize several established empirical studies and analysis techniques to empirically show that the deliberate acceleration of socio-ecological systems towards tipping points that favor sustainability require the transformation of narratives propagated by agents occupying significant political and economic authority while also highlighting the importance of social network dynamics to create new, transformation-oriented narratives.

In Apostoli Cappello (2023) explores the energy transformation in Carloforte, in the island of San Pietro, Italy. By conducting an ethnographic analysis of this region—considered an exemplary case for sustainable transition—the author aims to better understand the sociocultural and community preconditions that could contribute to determining the engagement of local communities in rapid policy-driven energy transition processes, and to explore alternative routes for such developments considering the justice dimensions and the transformation processes already under way. A particular emphasis is put on understanding the agency that communities hold in rapid energy transitions. The empirical evidence gathered ethnographically shows a complex picture, suggesting the possibility of the region being on the cusp of a yet unexpressed tipping point. However, the lack of coupling of technological change with cultural transformation impedes reaching a tipping point. The author shows how the narrative construction of collective identities and an almost mythical reconstruction of the past, serving as the main local ideology, contributes to the continuation of the status quo. Moreover, she shows that any attempt at transformation driven by policy needs to be aligned with the visions and horizons of the local communities, which would not adhere to the timescales, worldviews and technologies narratives arriving from outside the communities.

In Veland et al. (2023) explore the tipping dynamics which took place in the phaseout of coal in Svalbard, Norway. By combining different disciplinary perspectives, this chapter examines the processes that led to the decision to end coal mining and how these changes affect the local economy, society, and demographic trends as well as their geopolitical implications. The authors analyze how the decision to cease coal mining, which was not only Svalbard's main industrial activity, but also crystalized in the region's identity, has been driven by economic factors such as low demand and low prices as well as by ageing infrastructure. They analyze the narratives concerning demographic and socio-economic developments in Svalbard and identify the politico-economic, demographic, and socio-cultural tipping points in this context. The chapter contributes to the understanding of transitions towards low-carbon societies, by highlighting the combined importance of societal and earth system components and identifying key enablers and barriers for positive tipping points towards more sustainable social-ecological systems.

In Hansen et al. (2023) show how relatively small decisions such as those taken by small communities and constituencies in Greenland can have major positive effects in preventing catastrophic tipping points at the global level. The Inuit Ataqatigiit-led government decision to halt all the vast oil reserves exploration in Greenland, however, is not exempt of contradictions. Many ethical and pragmatic paradoxes emerge when the transformations required towards low-carbon energy development in the EU and elsewhere are also dependent on the extraction of alternative materials and minerals affecting the very local communities that prevented a global carbon-intensive development pathway in the first place. To overcome such paradoxes, the authors argue that it is of paramount importance to develop robust institutional mechanisms able to integrate and reconcile local worldviews and principles of justice in natural resource use -such as those that understand land cannot be privately owned across generations- with Earth system justice aimed at avoiding transgressing planetary boundaries in a fair way.

In Frankowski et al. (2023) explore the potential role of carbon taxation as a tipping intervention towards accelerated decarbonization and comparatively assess the macroeconomic effects of carbon taxation implementation in two high carbon regions undergoing coal phase-out, Upper Silesia, in Poland and Megalopolis, in Greece. To assess the macroeconomic effects of implementing a carbon tax, the authors use the MEMO model, which combines input-output with general equilibrium modelling. While the two regions considered have significant differences in their coal phase-out horizons and economies, the authors show that a carbon tax could indeed be a tipping event provided that funding and appropriate compensatory mechanisms are placed to address critical socio-economic regional needs. However, they also show that the debate about economic interventions in coal regions should be broader than providing information about existing compensation schemes, such as the Just Transition Fund or the Social Climate Fund. Buy-in from the local communities to long-term regional policy vision and nationwide policies at the intersection of social and environmental is needed in order to be able to implement ambitious climate goals and targets, which could eventually lead to a positive tipping point in the region's development trajectory.

4 Conclusions

This chapter contributes to the systemic understanding of systems' dynamics regarding CCIRs. We have introduced an interdisciplinary lens to investigate the transition process and provide empirical evidence of SETPs in eight CCIR regions. Looking at regions as complex systems and considering multiple geographical, social, cultural, and political dimensions that are integral starting points of analysis can alleviate the ineffective implementation of mitigation actions and climate policies at the regional level.

By providing concrete examples of cases and innovative methods aimed at identifying and characterizing tipping points at the regional level using an interdisciplinary social science approach, we have shown how to potentially identify tipping points, and particularly, with regard to policy action, as those moments in which due to previous cumulative and targeted interventions, a relatively small additional action or event is able to generate structural deliberate change and create different qualitative configuration aligned with sustainability.

The empirical evidence in the case studies reveals that there was no systematic evidence of SETPs in the CCIRs studied, a result which supports existing studies that claim that there is currently no documented empirical evidence of SETPs

(Milkoreit et al., 2018). However, our case studies' data lead to interesting findings, particularly regarding justice as an important part of the processes of change. We also find that incremental and/or radical changes can happen at smaller scales in social systems which then can impact socio-ecological systems over different periods of times where multiple triggering factors and actors can influence and reinforce these socio-ecological changes. The cumulative effects of changes at smaller scales of social and/or ecological changes potentially lead to transformations at a regional or wider scale.

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Social Tipping Processes in the Transformation of Civitavecchia's Socio-energy System

Daniel Delatin Rodrigues and Marco Grasso

Abstract The chapter introduces the notion of 'social tipping processes', an interdisciplinary framework for the analysis of complex transformation processes which helps to identify the sequence of, broadly understood, socio-political events that can trigger positive or negative dynamics of transformations of current social-ecological systems. Social tipping processes are first framed and delineated, then this category is applied to a spatially and temporally delimited empirical case, the long-standing Italian energy city of Civitavecchia—near Rome—to investigate the transformation to renewables of the local socio-energy systems as a dynamic and relational process. The chapter concludes by outlining the main paths forward for a sustainable future, as advocated by the social tipping processes perspective put into action in the case under scrutiny.

Keywords Agents of transformation · Destabilisation · Disruption · Fossil machine · Social tipping processes · Socio-energy systems · Transformation

1 Introduction

Since the post-war 'Great Acceleration', the consumption of natural resources, land use changes (with a vertiginous growth in deforestation rates), greenhouse gas emissions, and the world's population have produced disastrous consequences for our planet (McNeill & Engelke, 2016). These changes are directly associated with the expansion of urban infrastructure, the construction of dams, the increase in transport of people and goods, telecommunications, the use of fertilizers for agriculture, and mostly by the consolidation of socio-productive models and lifestyles intensively dependent on the use of fossil fuels (Steffen et al., 2015). The planet's temperature has skyrocketed (Bova et al., 2021; Kaufman et al., 2020), causing a

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sharp increase in the frequency and intensity of extreme weather events. The crossing of safe boundaries (climate change being one of them, the others linked to ocean acidification, stratospheric ozone depletion, freshwater use, biodiversity loss, interference with global nitrogen and phosphorus cycles, land use change, atmospheric aerosol rates) signals a path toward existential conditions hitherto unknown (Rockstrom et al., 2009). The repercussions are devastating, both concerning the conditions of ecological and climatic stability required by the multiplicity of Earth's living forms, and with respect to the ability of current sociocultural and political systems to respond to these events in ways that ensure the continuity of such systems.

Unfortunately, current attempts to transform global socioeconomic systems are inadequate to address the impending ecological and climatic crises (IPCC, 2021; IISD, 2022). This situation illustrates a political and analytical chasm between the seriousness of the events and the responses given so far in terms of effective commitment to changing the current non-sustainable socio-economic model.

To avoid, or at least mitigate, the effects of the global ecological crisis, humanity should pursue a socio-economic future different from today's dependence on fossil fuels and the current radical extractivist approach (Chagnon et al., 2022; UNEP, 2022). The enormity of this task requires considering the processes of sustainable transformations of societies from within the existing socio-technical, political, ecological, and climatic entanglements. This implies admitting that no general model can guide these transformations. The compounding climate and ecological crises indicate that human activities and ecological systems are in continuous coevolution through complex and interdependent feedback dynamics (Mathias et al., 2020), and this marks a breaking point in different disciplinary domains that until recently sought to understand social and climate and ecological dimensions in an isolated and autonomous manner (Orr et al., 2015). Moreover, the nonlinear processes that characterize both social and ecological dynamics reduce the possibility of identifying management strategies that maintain or restore the sustainability of social-ecological systems and that can guide a way out of this catastrophic path.

Caution is required, however. And it is with caution and a sense of exploration that this chapter develops the notion of 'social tipping processes' and applies it to a spatially and temporally delimited empirical case. This category derives from the notion of tipping points, i.e. a small perturbation can be enough to irreversibly push a system into a qualitatively different mode of operation due to strongly self-amplifying feedback (Lenton et al., 2008).

Social tipping processes, as an interdisciplinary framework for the analysis of complex transformation processes, help to identify the sequence of, broadly understood, socio-political events that can trigger positive or negative dynamics of transformations of current social-ecological systems. Destabilization and disruption will be considered here as mechanisms that can trigger these processes. Today, it is uncontroversially accepted that to avoid dangerous biophysical tipping points, it is necessary to trigger substantial changes (Otto et al., 2020; Hinkel et al., 2020; Lenton et al., 2019) or activate "sensitive intervention points" (Farmer et al., 2019) that could move the current socio-economic system in a new direction.

The category of social tipping processes will be used in the case study of Civitavecchia—the long-standing 'fossil energy' city close to Rome—where different agents concurred to obstruct and eventually to terminate the planned fossil-to-fossil conversion of a coal plant to natural gas in favour of a renewable future. In our analysis, social tipping processes are triggered by multiple heterogenous agents and practices in different scales and temporalities.

The notion of process, however, requires the identification of the agents and practices of destabilisation and rupture, as well as the events that marked changes in the trajectory towards the transformation of socio-energy systems (SEnS), defined here as "the technical, political, social, and economic arrangements and assemblages of people, institutions, organisations, technologies, and machineries in which the forms of production, distribution, and consumption of energy, their supply chains, and their lifecycles are organised" (Grasso & Delatin Rodrigues, 2022, 2). This chapter first frames social tipping processes, then introduces the categories of destabilisation and disruption as elementary mechanisms through which social tipping processes can be triggered, and finally presents the case of the transformation of Civitavecchia's SEnS through the categories given above. In this chapter we present a dynamic and relational process of effective transformation of fossil socio-energy systems.

2 Social Tipping Processes

Sustainability transformations involve, among other objectives, a structural evolution towards a low-carbon world with yet unknown socioeconomic, cultural, and political implications. Thus, they require a profound change in attitudes, behaviours, values, norms, incentives, and policies (Tàbara et al., 2019; Fazey et al., 2020), where the roles, actions, and interactions of multiple actors are critical to overcome resistance and force and/or guide the incumbent regime to move toward a low-carbon future (Geels et al., 2017; Skjærseth et al., 2021).

Practices of destabilization and disruption, analysed in the following section, aim to create moral values that denaturalise the use of fossil fuels from sustainability transformations that can be triggered. These practices should be understood as mechanisms to promote social tipping processes to fill a gap between climatic and ecological change and socio-political processes. Considering these interactive processes, each one with its specificity, as units of analysis has been recurrent in the history of the social and natural sciences (Stengers, 2010, 2011). However, as noted by Milkoreit et al., (2018: 2), "It remains unknown whether tipping points in natural systems, such as a lake or the climate, display the same underlying mechanisms as tipping points in social systems, such as in financial markets or political institutions." It becomes then necessary to recognise that the methodological and analytical procedures used for scientific research in the two systems are different and belong to different ontologies: the prospect of their unification should be considered with caution and involves much more transdisciplinary effort.

The cross-cutting promise of the category of social tipping processes invites researchers to pay particular attention to the unit of analysis. It is an invitation to improve the empirical tools available to allow—even partially—to follow this socio-ecological entanglement as a process and to understand how to promote transformative actions. A further issue is that of temporality, which in the social sciences explicitly calls for the historicity proper to a trajectory considered in its specificity.

To be useful, the category of social tipping processes requires detailed descriptions of the types of trajectories undertaken over time; it also implies making explicit the socio-ecological environment in which destabilisation and disruption practices will take place. Only in this way will it be possible to establish the conditions to generate effective transformations. By looking at the social tipping processes over a bounded period, we can identify how and in what ways initial disturbances in a given social-ecological system can create conditions for the bifurcation of the initial trajectory. Therefore, the question that arises is investigating how these conditions can be generated.

It is important to note that if social tipping processes suggest a symmetrical analysis of social and ecological systems, this implies extending the relational attribute of the existing against a static and overly functional notion of the individual or social institutions with precise boundaries and identities (Orr et al., 2015). If the ecological system is in constant process, the same should be considered of the social one—implying changing identities, values, and political systems: agents are co-produced through interactions, implying not just values but evaluation judgement and power relations (Flyvbjerg, 2001). How researchers will define the edges of entities is crucial to the outcomes that may emerge (Tàbara et al., 2022). The consideration, for instance, of the political and social stability of fossil fuel dependence as a relational effect allows to better explore practices of destabilisation and disruption from the point of view of the effects they generate and the agents that produce them.

To move toward a sustainable future, it is necessary to first destabilise and disrupt the—running at full speed, seemingly out of control—fossil machine (FM): this is a conceptual category inspired by its focus on the coalescence of vested interests to what the Italian Marxist philosopher Antonio Gramsci (1929) defined a 'transnational historical bloc'. The category of machine used here should not be understood only in its technical dimension. This is the most important lesson brought either by the philosophy of technology (Simondon, 1958; Deleuze & Guattari, 1987; Anders, 2007) or by the field of science and technology studies (Latour, 1996; Appel et al., 2015; Appel et al., 2018; Watts, 2019): it operates at the intersection between the biophysical, climatic, and ecological dimensions and the socio-technical and political dimensions. As noted by philosopher Felix Guattari:

> *Les machines ne sont pas des totalités refermées sur elles-mêmes. Elles entretiennent des rapports détermines avec une extériorité spatio-temporelle, ainsi qu'avec des univers de signes et des champs de virtualité. (*Guattari, 2018*: 500).*
>
> *Il articule l'outil, la machine à son environnement social, humain, corporel, à la gestuelle machiniste et aux rapports culturels qui les supportent* (Guattari, 2018: 253).

It is therefore possible to consider the FM dynamically as a continuous process of assemblage (*agencement*) of the social environment to ensure its functional continuity over time and, in turn, to elucidate the variety of actions necessary to block or stop the extraction, circulation and combustion of fossil fuels and their products. The notion of the machine, moreover, points to a particular property of the social environment to which it is linked: that of widespread 'extractivism' as a means of sustaining relentless economic growth, which includes conditions for the machine's reproducibility and expansion. In the definition adopted here, the FM is usually set up, coordinated, and led by fossil-fuel companies and is composed of governments and policymakers at various levels, formal institutions, industry representatives, unions, other industries dependent on fossil fuels, the agricultural system, the financial system, managerial elites, the military, epistemic communities, PR companies, think tanks, pundits, advocacy groups, private foundations, religious institutions and communities. The ubiquity of the FM requires adequate knowledge about how and where to erode its power, which guarantees its resistance to change and the reproduction of its modes. The destabilisation and disruption of a FM are carried out by 'agents of transformation' (ATs), entities—individuals or groups, potentially every subject—that contribute to overcoming the FM's power and win its resistance against the limitation and/or termination of the current carbon-intensive model and to compelling or inducing it to adopt more sustainable behaviours. ATs are, therefore, 'political entrepreneurs' (Tilly, 2008) who seek to change politics through practices of destabilisation and disruption. ATs' actions, initiatives, behaviours, and provisions destabilise and disrupt the ambits and ramifications relevant to the FM to favour the achievement of a just and rapid decarbonisation of SEnS in the public interest.

The adopted approach argues that there are countless ways to generate this transformation: they will depend on ATs' capacity to enact practices that interfere with and/or block the FM. This chapter focuses on the case of Civitavecchia, the longstanding 'fossil energy' city close to Rome, Italy, where a planned coal-to-gas conversion of a fossil energy plant was recently abandoned. In particular, the chapter investigates the interactions between different ATs (individuals, groups, institutions), an FM, the local environment and global climate transformations from the category of social tipping processes. Civitavecchia is a point in the worldwide infrastructure of energy production and a source of carbon emissions that contribute to global climate change, but it is also a territory that hosts a FM whose singular historical trajectory, social composition, interests, and conflicts can usefully be considered through the perspective of social tipping processes.

3 Destabilisation and Disruption

The categories of destabilisation and disruption are useful analytical tools to identify ATs that can trigger social tipping processes. It is first necessary to clarify what the practices—actions, initiatives, behaviours, and provisions—of sustainability-oriented destabilisation and disruption are and, therefore, the difference between the two families of practices. To this end, a specification of ATs is necessary. They cannot be sorted out in terms of identity, but ATs should rather be categorized in terms of activity. Regarding the FM, a particular AT can be simultaneously involved in destabilisation in a context and/or point in time and engaged in disruption in another context and/or point in time. For instance, an environmental NGOs working on climate change may try to destabilise the oil industry through awareness-raising initiatives, but as a shareholder of an oil company, the same NGO, at the same or at a different point in time, can attempt to disrupt it through resolutions and other initiatives aimed at slowing down the company's FM. At the same time, identifying an AT, such as a social movement, cannot be considered in itself: an AT must be relationally situated among other ATs and practices. As we shall see in the case study, the effect on FM depends on the correlation of different ATs and practices in a given social environment. In this sense, considered as a rupture process, this perspective offers empirical description and analytical insight to investigate the points a FM addresses and its ramifications.

In light of these specifications, ATs, by and large, employ practices of destabilisation to break the consensus about the naturalized use of fossil fuels and to promote dissent against the fossil-centric model. Destabilisation engages the part of the social environment – including the communities not directly involved by the FM – and have the goal to foster and maintain social/moral norms and principles and good practices that, for instance, favour the acknowledgement of the harmfulness of fossil fuels, emphasise the harmful behaviour of the FM, discourage high-carbon lifestyles, support the rectification of the harm done, and, more generally, try to shape behaviours in favour of a less harmful low-carbon world also through the opposition to strategies and practices of climate denial, delay, disablement, and obstruction (Grasso 2022). In short, practices of destabilisation shape and steer individual and collective agents in different contexts and at different levels towards progressively less carbon-intensive behaviours. At the same time, ATs carry out in multiple contexts—not necessarily only proximate to the site of production of fossil fuels—disruption practices through existing institutional, political, and economic arrangements that directly target the FM to slow down/halt the reproduction of the fossil model and its overall functioning, fruition, and continuity. These practices consist, for instance, of lawsuits, legal and administrative provisions, divestment initiatives, shareholders resolutions, alternative options, alternative projects and plans. By subtracting modalities and space to the FM and its fossil reproduction, disruption can trigger social tipping process and open new opportunities to enact sustainable futures.

Destabilisation and disruption target the FM's discursive, institutional, and material power (Avelino & Rotmans, 2009) and its protective carbon lock-ins (Seto et al., 2016). ATs who operate destabilisation are called 'primary' and use practices that mostly erode the discursive power of the FM; practices of disruption are carried out by 'operational' ATs, by and large, target the institutional and material power of the FM: the latter practices are more feasible when destabilisation has raised the awareness of the urgency to phase out fossil fuels. Practices of destabilisation and disruption occur along transformation axes, internally homogeneous societal ambits recurrent in the, so to speak, energy and social sciences literature (e.g. Köhler et al., 2019; Kivimaa et al., 2021; Grasso & Delatin Rodrigues, 2022). They are context-dependent but can generally be grouped according to the set of issues predominantly addressed: socioeconomic-technological, institutional-political, and educational-informational; those relevant to the Civitavecchia case study are reported in Table 1.

Besides the relationality between ATs and practices of destabilisation and disruption, the current perspective is inclusive: it covers all spheres penetrated by the FM—recurrent in the literature on transition and transformation (Köhler et al., 2019; Kivimaa et al., 2021) but also in that of social tipping points and processes (Stadelmann-Steffen et al., 2021). The generation of positive transformations towards sustainability cannot be done without promoting goals that redefine the social environment and without the material redefinition of the links that associate them.

4 Methods: The Case of Civitavecchia

The power plants in Civitavecchia were installed in the immediate post-war period. Work began in the summer of 1951 in Fiumaretta, where the first fossil–coal and then naphtha—plant remained in operation from 1953 to 1990.

Altogether, the power plants in Civitavecchia were part of a narrative about progress after the city was reduced to rubble in the second world war. By generating jobs and professional qualifications for young people, the National Electricity Board

Table 1 Destabilisation and disruption axes and examples of practices of destabilisation and disruption of the Civitavecchia's FM

Set of issues	Axis	Practice
Socioeconomic-technological	Social cohesion	Communitarian meetings, assemblies, and demonstrations
	Economy	Strikes
	Science and technology	Alternative low carbon projects
Institutional-political	Governance	Community/policy-makers joint initiatives
	Law	Legal appeals against the fossil industry
	Policy	Regulations and laws against fossil fuels
Educational-informational	Culture	Protest and dissent artworks
	Education and awareness	Civic science program in epidemiology
	Media and communication	Formation of counternarratives

Source: authors

(*Ente Nazionale per l'Energia Elettrica*—ENEL) could present itself as a promoter of local development. In 2019 the Italian Ministry of Economic Development published the national integrated energy climate plan (PNIEC—*Piano Nazionale Integrato per l'Energia e il Clima*). It stated that by 2025 all Italian coal-fired power stations should stop operating. Our research focuses on this crucial moment that triggered an intensely local and extra-local mobilization (Viale, 2021)—investigating it as a social tipping process makes it possible to identify important events and to correlate ATs, practices of destabilisation and disruption, and outcomes.

Between April and June 2022, a total of 8 non-structured interviews were carried out with the primary and operational ATs of Civitavecchia reported in Table 2, along with the axes of destabilisation and disruption they predominantly worked on and examples of types of the practices they carried out. In September 2022, two structured interviews were conducted with the two previously interviewed ATs with the deepest and most comprehensive knowledge of the issues at stake and the role of all the other ATs involved.

The first contestations against fossil energy production started in earnest in the 1980s. The first destabilisation practices demanded the right to health, a clean environment, and professional (non-fossil) alternatives for local workers. The long-running controversy divided the local community between "those who defended the environment and those who defended jobs". In the words of a member of the '*No al fossile*' group:

> "Until 2003, the year of the authorisation [to shift the energy production from oil to carbon], there was a strong tension in Civitavecchia that literally split parties, unions, associations, and even families. The mobilisation was very strong; the municipal council of Civitavecchia was occupied for several days. We also occupied the tracks and interrupted the Rome-Genoa-Ventimiglia railway line. The level of conflict was high, but we couldn't couple the struggle on environmental and public health with that for good employment. The historical context was different, and the immature technologies we had prevented the proposition of an alternative." (De Girolamo & Pezzopane, 2022).

This juxtaposition—between environment/health and economy/employment—was used to justify pro-fossil choices and ensured the support of part of citizens, unions, and political groups to fossil continuity at the expense of health and environmental concerns. The narrative of a conflict between environment and employment limited the horizon of action of the ATs preventing them from opening up to other problems and alliances. As an AT of the '*Forum Ambientalista*' group states: "ENEL has polluted not only the environment but also people's consciousness".

In 2019 ENEL presented its plan for converting to gas the existing coal plants 3 and installing new fossil plants in Civitavecchia. According to a '*No al fossile*' AT: "The switch from coal to gas would not guarantee the polluted territories employment, environmental protection, or public health".

During this period, with the decision to abandon coal and the proposal to switch to gas, ATs decided to engage directly in generating a socio-technical alternative to fossil production. "We started reading books on chemistry and physics and learning how an energy plant actually worked", one AT said. Instead of relegating this work to experts and professionals, the activists established alliances with them to keep

Table 2 Ts interviewed, axes of destabilisation and disruption, and types of destabilisation/disruption

ATs	Axes of destabilisation/disruption	Types of destabilisation/disruption
Città Futura (environmental group)	Social cohesion, Science and Technology, Culture, Education and awareness, Media and communication	Meetings; research; cultural events; educational events; information though social media and various other channels
Comitato Sole (environmental group)	Social cohesion, Science and Technology, Culture, Education and awareness, Media and communication	Meetings; research; cultural events; educational events; information though social media and various other channels
Confederazione Nazionale dell'Artigianato (the Civitavecchia chapter of the National Confederation of Crafts and Small and Medium-sized Enterprises)	Economy, Governance, Law, Policy	Lobby; participation in institutional and political processes;
Forum Ambientalista (environmental group)	Social cohesion, Science and Technology, Culture, Education and awareness, Media and communication	Meetings; cultural events; educational events; information though social media and various other channels; demonstrations; citizen science
Fridays for Future (social movement)	Social cohesion, Science and Technology, Culture, Education and awareness, Media and communication	Meetings; cultural events; educational events; information though social media and various other channels; demonstrations;
No al Fossile (social movement)	Social cohesion, Science and Technology, Culture, Education and awareness, Media and communication	Meetings; cultural events; educational events; information though social media and various other channels; demonstrations; protests
Technical committees (professionals, firms, and agencies to support the offshore wind farm and 'Porto Bene Comune' projects)	Social cohesion, Science and technology	Technical support to developing non fossil alternatives
Unione Sindacale di Base (labour union)	Social cohesion, Economy, Governance, Law, Policy	Participation in institutional and political processes; strikes; "state of agitation"

Source: authors

technical and social issues together. The alternative to fossil fuels was a set of projects based on renewable energy. Direct engagement in this process allowed the generation of other socio-technical imaginaries that included other agents, not just environmental groups. According to a USB unionist, this shift from protest to project allowed “the deactivation of ENEL’s narrative” based on the contraposition between environment and work.

The first alternative project proposed—the ‘*Porto Bene Comune’*—focused on the energy conversion of the port of Civitavecchia and was submitted to the Italian Ministry of Economic Development (*Ministero dello Sviluppo Economico*—MISE) within the EU-ERC Horizon 2020 call for proposals. Although it appears as a place of energy consumption rather than production, it was through the port that ATs began to elaborate socio-technical alternatives. The port was a laboratory that allowed them to take a step forward from protest to constructive proposals. The port project envisaged using green hydrogen to make this infrastructure the first zero-emission port in the Mediterranean. This project was considered fundamental since, according to an AT of the ‘*No al Fossile*’ committee, it synthesised the local energy transition process.

The second alternative project was an offshore wind farm with a total capacity of 270 MW and an annual production potential of approximately 935 GWh. Its construction would have an employment impact in Civitavecchia of between 300 and 1000 units; the Italian Ministry for the Ecological Transition (currently named Ministry of the Environment and Energy Security) has started in June 2022 the environmental impact assessment (*Valutazione di Impatto Ambientale*—VIA) of this project. Altogether it is an inclusive and overarching project which pays particular attention to employment.

5 Results: Destabilisation, Disruption and Social Tipping Processes in Civitavecchia

The rejection of the fossil continuity, the construction of alliances, and the emergence of new collective subjects should be considered in a timeline where different ATs perform destabilisation and disruption synchronously and diachronically: it is from the material and immaterial ‘disturbance’ of a given social environment that possible alternative trajectories begin to emerge. However, as we will see, to generate social tipping processes, destabilisation and disruption practices must create socio-ecological conditions that can anchor hese trajectories in new stable conditions. These practices are not limited to the local dimension; international, national, or regional decisions can favour or obstruct the FM and transform SEnS. The approval of the national PNIEC, for example, setting a time limit to quit coal, created a possible bifurcation between fossil continuity and its abandonment: “The date is 31 December 2025, but the same document proposed a transition to gas or renewables. This quickly led the city to imagine itself differently.” (De Girolamo & Pezzopane, 2022).

The importance of this event is fundamental but not enough to trigger generalisable transformation processes—as the experience of Civitavecchia shows. Citizens’ committees, environmental movements, and professional organisations (such as doctors and lawyers) became the most prominent ATs that opposed fossil fuel longevity. The environmental health concern is the concern that crossed the power plant's history, being redefined with each new piece of information and articulation. The formation of dissident, citizen-driven expertise made the consequences of continuous exposure to fossil fuel-generated pollution explicit. Studies carried out by popular epidemiology groups and citizens—a form of civic monitoring, understood here as a practice of destabilisation—showed the dramatic incidence of some forms of cancer directly linked to the activity of coal-fired power plants.

This favoured the dissemination of devices that allowed environmental control by citizens; these data became ingredients used in scientific journals, journalistic reports and/or in preparing manifestos and documents critical of the plant. These practices of making the environmental and health damage explicit have allowed the erosion of the consensus regarding the benefit of the coal-fired power station, as well as the legitimacy of its continuation—generating lawsuits for the adoption of pollutant control measures..

In short, they became ingredients that communicated directly with the experience of the subjects involved in a dramatic way in the local reality: several interviewees declared that no family in Civitavecchia had not suffered health issues or developed a disease due to the environmental degradation created by local combustion plants.

A second aspect to highlight is that of the media and communication axis. Once again, it seems necessary to precisely define what is communicated and how communication occurs. The messages, just like the practices producing them, change over time (Tilly, 2008), are enriched, receive new ingredients from the encounters and frictions generated in local and extra-local interaction (Tsing, 2005), and lose or gain relevance depending on the existing socio-technical conditions. The existence of technical solutions to produce renewable energy, for example, gave significance and credibility to the proposal: the social conditions of opposition to the local FM and social re-composition promoted by ATs could be anchored and articulated in the available technological solutions.

From the heterogeneity of subjects and practices and the socio-technical existence of an alternative, ATs structured a narrative that emphasised what they defined 'fossil slavery as the result of a series of decisions over time, which conditioned and limited the horizon of the political imagination of a life outside fossil fuel.

Discussions about the possibility of a switch to renewables in Civitavecchia gained momentum in 2019. However, with the Covid-19 health emergency, ATs had to develop alternatives to discuss the options publicly. In that period, face-to-face meetings were forbidden. The alignment of the local radio and television company TRC allowed ATs free access to the network's programming; several meetings and debates were held from more traditional information and entertainment devices—such as radio and television—widely used by the city's older population.

Processes under the 'Policy' axis—like those of communication—are complex, composed of varied dynamics and formulated from local and extra-local problematic aspects over a long period. During the coal conversion 2003, several ATs reported that this event caused irreversible political ruptures in existing groups and organisations. Instead of a division between right and left, political forces were split between a ‘coal party’ and an ‘anti-coal party’, a name that was irrevocably modified when in 2019, the switch from coal to gas was decided. At this point, the alignment was redefined as the ‘ENEL party’, encompassing actors, organisations, parties, and institutions aligned to the company’s industrial plan.

The votes against the conversion to gas of coal-fired power plants that took place in municipal and regional chambers set a limit to the FM’s action (first Civitavecchia City Council resolution 130 of 24 October 2019 and the Lazio region’s 2021 provision banning fossil production in the city), although positively received by local groups, was considered by some ATs as ‘not enough’. Political forces organised and active in state institutions did not seem seriously committed to the sustainable transformation of the local energy production infrastructure and to building alternative socio-energetic pathways. This aspect invites us to be cautious about how policymakers are described and evaluated in these processes.

In the case of direct or indirect workers of the fossil industry, disruption practices happened along the axes ‘Economy’ and ‘Governance’ and were configured as a declaration of ‘state of unrest’ (*stato di agitazione*) or through strikes in the plants or in the supply chain linked to it. The installation of the power plant provided the local workforce with a horizon for training and professional occupation. The fundamental change occurred only when the consequences—in terms of occupation—of converting coal-fired power plants to gas became known simultaneously as the availability of alternative technologies and a strong social commitment to the transformation existed.

In relation to the ‘Law’ axis, while in 2003, groups that opposed the conversion of oil to coal filed an unsuccessful appeal in the courts to stop them, in 2019, ATs planned to resort to legal action if ENEL had continued with its initial coal to gas conversion project; the decision to abandon the project made it unnecessary.

ATs acted along the ‘Social cohesion’ axis from the available conflictual repertoires (Tilly, 2008), whether authorised or unauthorised, mostly through street demonstrations, occupations of public buildings, occupation and blocking of railways and highways, and hunger strikes. These destabilisation practices concurred with reconstructing the social context torn apart by decades of fossil continuity. Attacks and confrontations with public authorities and ENEL’s leaders were also recurrent—such as throwing vegetables at ENEL’s executives visiting the city. Along the ‘culture’ axis, ATs have endeavoured to create content—songs, banners, shows—affecting the public perception of the harmful aspects of fossil fuels and the territorial dependence on the energy monoculture that could destabilise the FM. Along the ‘Governance’ axis, the consensus that the future of the city’s SEnS should be outside fossil fuels made it possible to initiate meetings between different parties to discuss models of governance of the new alternative projects. Political parties of different matrices, initially “functional in the maintenance of FM”, argued an AT of ‘*Città Futura*’, began to push territorial demands and perspectives at the institutional level. They constituted permanent negotiation spaces, effectively creating a political representation at the institutional level of the diffuse destabilisation and disruption practices. Table 3 reports and categorizes some of the more remarkable among such practices within the axes outlined.

6 Discussion: Looking into Civitavecchia's Case: Lessons and Ways Forward for Sustainability Transformations

A first lesson we can draw from the Civitavecchia case is that transformations need multiple ATs working at different levels at different times, albeit on such a non-linear process. ATs repositioning, disruptive events—such as the pandemic and the Russian military aggression on Ukraine—can modify the pace, practices, and socio-political alignments. We find it difficult to provide other generalisations since the framework given by social tipping processes is context-dependent.

Table 3 Destabilisation and disruption practices in Civitavecchia

Axis	Destabilisation	Disruption
Social cohesion	Meetings, demonstrations, and protests at the local, regional, and national level	Job creation through alternative projects
Economy	Reports and initiatives to clarify the economic potential of renewable alternatives	Lobby by the business community against, and exit from, fossil fuels Strikes
Science and technology	Environmental and health monitoring Citizen science campaigns	Advancement of technical solutions for the alternative projects
Governance	Bottom-up initiatives and alliances that bonded the local community to political representatives at various levels, in particular the regional one	Permanent table for a low carbon future Strikes
Law	Pollution reporting to legal institutions Environmental rules and regulations (bottom-up proposals)	Lawsuits (projected, not implemented)
Policy	Occupations of city councils	Regulations and laws at the municipal and regional level
Culture	Tour of the power plants Songs Banners Online graphic	n.a.
Education and awareness	Awareness campaigns (e.g., on the possibility of overcoming of the job/health dichotomy) Self-education programs Popular epidemiology, physics, chemistry	n.a.
Media and communication	Narratives shaping Careful use of social media (Facebook, WhatsApp, Instagram)	Subtraction of narrative spaces for the reproduction of fossils

More broadly, with this framework, it is possible to dynamically define a set of conditions and constraints that favour or block social tipping processes; through this set, it is possible to identify the ATs and means used to disseminate new norms and values—here called destabilisation—as well as the practices necessary to initiate new trajectories—defined as disruption.

As the case of Civitavecchia clarifies, the different conditions imply specificities of axes, ATs, and practices of destabilisation and disruption, which, however, change over time. To analyse social tipping processes, it is, therefore, necessary to consider how dissemination occurs and what consequences it may generate. The instruments, targets, narratives, and counter-narratives must be made explicit to reveal how transformation processes can be framed and promoted and to evaluate how effective they can be in triggering these processes—that is, what methodological instruments should be used to evaluate these effects.

While disruption on one axis may require a long period of destabilisation (as usually happens on the political axis), in other axes—because of the modification of the social environment and the alignment to the related axes—it can occur at a faster pace, as seen often on the economy axis. The analysis must therefore find the points of fracture, and for this, it is necessary to clearly establish the unit of analysis and which transformation will be the object of investigation: in our case, Civitavecchia's FM has allowed a controlled study whose limits should stimulate the development of new analytical instruments and research strategies.

This case study shows that the notion of FM should not be considered only from a technical point of view—as a mere energy infrastructure. It is maintained through the material and immaterial assemblage of resources, people, political, legal and cultural institutions, and media systems. The alternative of renewable energy production signals a procedural opening to other forms of assemblages—which, in the case of Civitavecchia, means in very concrete terms the establishment of other forms of work, professional figures, political relations, environmental conditions, and social acceptance.

The empirical analysis confirms that ATs are both primary and operational and that the same AT can play roles in the same transformation axis, not necessarily at different times. Unlike the dominant perspective that places great emphasis on policymakers, the case of Civitavecchia shows that without agents 'from below' and without the transformation of the social environment carried out by them, the transformation would hardly have occurred. At the same time, political allies in the Lazio region government allowed these actors to accelerate the process—an aspect that all the interviewees recognized.

The potential for disabling power articulations to address sustainability transformation in the case of Civitavecchia shows that the more FM's forms of power are targeted, the greater the chances of success. To capture these processes, it is necessary to broaden the gaze and follow agents and practices along every axis—specifying the target and the means used—functional to the legitimate continuity of FM. While destabilisation can be successfully accomplished by a single AT, disruption largely requires multiple ATs; since the latter aims to obstruct and occupy the various spaces of fossil reproduction, it must be deployed in several different ways, at different levels, and over extended periods. This aspect shows us that processes of social tipping process can be triggered by combining destabilising practices simultaneously with disruptive ones that effectively subtract spaces for the reproduction and expansion of FM. This shows that despite being necessary, destabilisation practices are not sufficient to take the current socio-economic system in another direction; for this, it is necessary that other agents—defined here as operatives—effectively prevent the continuation of FM through actions across the whole set of interests.

Consistent with the demand for a systemic perspective as voiced by the more recent transition literature (e.g., Davidson, 2019; Kivimaa et al., 2021; Van Oers et al., 2021), a focus on the Civitavecchia's FM highlights how disablement blurs the usual distinction between sectoral and systemic levels and shows that a process apparently targeted only to decarbonise the local energy system can involve an entire community/socio-economic ambit and can thus be part of a systemic effort towards a sustainable future. However, this does not exclude that systemic community success in one place may generate negative consequences in other places—where the social environment favours installing fossil energy plants.

This evidence suggests three broad ways forward. First, the social tipping processes can be followed by identifying ATs, those who hold new values and whose practices can potentially transform the current socio-ecological system through an evolutive process of learning which becomes a social self-propelling process of transformation. Second, social bias processes occur through concomitant practices, the successful combination of agents to destabilize and disrupt the FM, and the existence of solid and viable renewable alternatives. This point is important because it emphasizes the need to move, so to speak, from 'protests to projects', that is, to move from a social dimension to a more explicit socio-technical dimension (Jasanoff, 2015). Third, notions of FM and destabilizing and disruption practices are powerful metaphors to support transformative narratives. By emphasizing the socio-political and climatic-ecological entanglement, these notions allow us to individualize specific objectives for the social tipping processes, and also to recognize the relational and processual dimension of ATs, practices of destabilisation and disruption, and of the FM itself. ATs and practices are modified both about the effects produced in the FM through its practices and due to the modification of the social environment where this machine is sustained; on the other hand, the FM resists the attempts of deactivation through forms of power—discursive, legal and material—that can block or delay sustainable transformation processes and thus preserve a social environment conducive to its continuity.

7 Conclusion

The Civitavecchia case study shows that the category of social tipping processes constitutes a useful framework for understanding and explaining the processes of change and rupture—of transformation, in fact—that have occurred. First, by emphasizing the processual dimension, it allows to identify practices that can have positive effects. In this case, it constrains to pay attention to how they are generated and propagated from and within a particular social-ecological environment.

The framework should communicate the particularities of the scale of the research object and not just impose itself on it. This means that when analysing these processes, at the macro or micro scales, it is necessary to clearly define which transformative processes this framing helps to shed light on. As shown in this chapter, the case of Civitavecchia required following the micro-socioecological aspects of destabilizing the 'naturality' of fossil energy and the practices that disrupted its reproduction and expansion. The agents declared that energy production plant had broken the relational fabric of the community. The re-composition of this fabric took on the character of a clear opposition to the continuation of 'fossil slavery'. What started as minority groups acquired the social consistency and legitimacy to decisively oppose fossil fuel energy. In this sense, social transformation processes allow us to follow this evolution, offering useful tools to make the complexity of this process intelligible. The exit from fossils was possible because conditions of acceptability had been constructed, and the anti-fossil relational fabric had been consistently generated to sustain the transformation to a different trajectory.

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Realizing Alternative Energy Futures: From the Promise of a Petroleum Future to Imagining Lofoten as the Green Islands

Anna G. Sveinsdóttir and Brigt Dale

Abstract This chapter examines the 20-year-long oil dispute in Lofoten and the decision to deviate from oil and gas development in the region. Our objectives are three-fold: (1) to better understand how carbon-intensive development pathways can rapidly shift towards decarbonization, (2) to yield insights into how alternative narratives about the future materialize in historically pro-carbon contexts such as Norway, and (3) examining to which extent we can identify and assess potential social tipping events that impacted the decision to deviate from oil and gas development in Lofoten. Drawing on a qualitative framework, we address our objectives by identifying and assessing important events between 2000–2020 that impacted the decision to halt plans for oil and gas development and by examining how alternative visions of an oil free Lofoten emerged and took shape over the last two decades. We argue that the fact that the Lofoten regions remains closed to petroleum development is unusual given the significance of petroleum production to the Norwegian economy and the dominant logic of the Norwegian resource regime. Examining the Lofoten case thus yields insights into conditions and interventions that can both unsettle fossil fuel energy systems and foster lasting transformation towards less-carbon intensive emissions trajectories.

Keywords Energy transformation · Oil · Tipping points · Energy futures · Norway · Lofoten

1 Introduction

The seas outside of the Lofoten region in northern Norway are rich in petroleum deposits that hold potential for energy development. However, the region is also the hub of some of the richest and most valuable fisheries in the North Atlantic Ocean and a world class tourism destination. Efforts to allow exploratory extraction in the

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region began in the 1980s but came to a standstill during a twenty-year long debate over whether to allow petroleum production outside of Lofoten. This chapter leverages the debate about offshore oil and gas exploration outside of the Lofoten archipelago in northern Norway to examine how—over the course of the first 20-years of the twenty-first century—a seemingly locked-in trajectory towards a petroleum-dependent future tipped over to an alternative, low-carbon pathway. Our objectives are three-fold: (1) to better understand how carbon-intensive development pathways can rapidly shift towards trajectories that foster decarbonization, (2) to yield insights into how alternative narratives about the future materialize in historically pro-carbon contexts such as Norway, and (3) examining to which extent we can identify and assess potential social tipping events—understood as nonlinear processes of transformative change in social systems[1]—that impacted the decision to deviate from oil and gas development in the Lofoten region. Drawing on a qualitative framework and semi-structured interviews, we address our objectives by (1) identifying and assessing important events between 2000–2020 that impacted the decision to halt plans for oil and gas development and (2) examining how alternative visions of an oil free Lofoten emerged and took shape over the last two decades.

By the turn of the twenty-first century, the Arctic was seen as the next big frontier for the oil and gas industry (Korsnes et al., 2023). However, plans to expand extraction northward and begin exploration off the coast of the Lofoten, Vesterålen and Senja regions (abbr. LoVeSe) had become increasingly divisive and polarizing. While those in favor of oil argued that petroleum activities would bring vitally needed economic prosperity to a region experiencing rapid out-migration, rural decline and economic challenges, opponents voiced concerns about the potential environmental risks associated with drilling activities and threats to traditional marine-based livelihoods. Opponents were particularly concerned about risks to the North Atlantic cod, which spawns in the Lofoten area during the winter months and has been vital to the region for centuries (Kristoffersen & Dale, 2014).

Through the dispute, a coalition of fishermen, environmental activists, and residents emerged and evolved into a broad-based social movement, The People's Action for an Oil Free Lofoten, Vesterålen and Senja, which fought against petroleum activities in the region for over ten years. In addition to grassroots-driven civil society engagement, politically elected municipal decision-makers, most of whom were staunchly pro-oil in the early days of the debate, eventually "switched sides" and opposed the plans for oil and gas extraction in the region. A watershed moment then took place in 2019, when the Norwegian Labour Party, a long-time supporter of the oil and gas industry, announced that it was withdrawing support for drilling off the coast of the LoVeSe region. The move was seen by many as the de facto end to substantial political support for further exploration in the regions and as a major blow to Norway's oil and gas industry, which viewed access to the region as a holy grail.

[1] Milkoreit (2022).

In June 2022, the People's Action declared victory in its campaign for a permanently oil-free Lofoten Vesterålen and Senja and unanimously voted to disband the organization. The fact that oil and gas development was halted is highly unusual given the significance of oil and gas production to the Norwegian economy and the dominant order of the Norwegian resource regime, which is characterized by deeply entrenched pro-carbon interests (Mildenberger, 2020). Indeed, despite these conditions, the Lofoten conflict disrupted a highly change resistant, pro-carbon pattern in Norwegian energy politics. Today, a new regional development plan centered on green growth and decarbonization has replaced oil and gas aspirations in the region.

In what follows, we trace the 20-year history of the Lofoten oil debate and identify important events, interventions and conditions that shaped the trajectory of the debate and the eventual decision to deviate from oil and gas development in the region. We then explore how alternative visions of an oil free Lofoten emerged and took shape over the last two decades, focusing on how an "oil free" Lofoten became a collectively held and performed vision of a desirable future. We conclude the chapter by reflecting on insights from our empirical case study vis-à-vis scholarship on socio-ecological tipping points. In doing so, our goal is to contribute to ongoing discussions about whether concepts such as tipping points and tipping interventions can be used to successfully accelerate sustainable transformations at the systemic scale.

2 Norwegian Oil and the Arctic Resource Frontier

The oil and gas sector has been a pillar of the Norwegian economy since the 1960s. Since then, Norway's economy, politics, and society have become inextricably intertwined with the production and exportation of oil and gas (Dale & Farquharson, 2021). Oil and gas revenues play a central role in Norway's economic prosperity, accounting for almost half of the country's export revenues in 2021,[2] and are a cornerstone of the Norwegian welfare state. The "Norwegian model" of petroleum governance has often been held up as a success story with regards to the democratic control of petroleum resources and the relatively equitable distribution of petroleum-related benefits to the general population, most notably apparent in the nation's Sovereign Wealth fund, which is amongst the largest in the world at $1500 billion USD (May 2023)[3] (Bang & Lahn, 2020, p. 1000).

Against this backdrop, Norway has also positioned itself as a pioneer in progressive climate policy action and aims at net carbon neutrality by 2050—a move that has required what critics refer to as a disassociation of petroleum and

[2] The country's export revenues from the petroleum industry were estimated to be over NOK 800 billion (EUR 80 billion) in 2021 and are expected to double in 2022 (International Energy Agency, 2022).

[3] See https://www.nbim.no/en/the-fund/Market-Value/ for continued update. Accessed May 19th, 2023.

climate politics (e.g., Bang & Lahn, 2020). Being an energy-rich country, Norway is in a unique position with respect to the renewable energy transition. The country's abundance of affordable hydropower has enabled the development of energy-intensive industries and a high level of electrification of homes and businesses with limited greenhouse gas (GHG) emissions. However, at the same time, Norway is—and aims to remain—a major global oil and gas producer, a stance which is currently fortified by an increasingly volatile energy security situation in Europe (IEA, 2022). Norway thus finds itself in a contradictory situation where the future of oil is both contested and promoted, and which exemplifies several paradoxes in relation to the renewable energy transition (Korsnes et al., 2023).

2.1 A New Oil Adventure in the North?

One of the most polarized debates in Norwegian oil policy centered around the oil industry's expansion northward and into the Arctic (Dale & Farquharson, 2021). The debate dates to the late 1970s but came to a standstill mostly due to an abundance of mature, more easily accessible fields further south on the Norwegian Continental Shelf. However, from the mid-1990s onwards, a higher extraction rate, not least driven by the intent to build up a sovereign pension fund based on oil and gas revenues, was prioritized in Norwegian oil politics (Bang & Lahn, 2020; Andersen, 2017). As a result, pressure once again mounted to expand oil and gas exploration northward, and by the turn of the twenty-first century, Arctic oil was seen as the next big frontier for the oil and gas industry (Korsnes et al., 2023).

There were several main drivers for expanding oil exploration into the north within the Norwegian context. First, concerns regarding the declining production of the mature oil fields in the North Sea was seen as threat to Norway's economy and the future of the welfare state (At the time, more than 200,000 Norwegian jobs were directly or indirectly tied to the petroleum industry) (Dale et al., 2019). The industry sought to meet the output decline of mature fields through two mechanisms: (1) an international expansion of Norwegian oil companies (with Statoil, now Equinor, at the forefront) and (2) by accessing unexploited fields in the north (Dale et al., 2019). Second, technological advances in hydrocarbon recovery coupled with declining sea ice cover made oil and gas activity in the north a more reliable and cost-effective enterprise for industry (Gautier et al., 2009). Oil and gas fields in places like the Arctic, that were previously inaccessible thus became viable investment options. Third, expanding Norwegian oil and gas northward was also framed within the context of Russian presence in the Arctic, and the future potential for large-scale development by both the Russian and Norwegian oil and gas sector in the area (Moe et al., 2011). In 2011, Norway and Russia resolved their 40-year long delimitation dispute in the Barents Sea and the Arctic Ocean, ending a moratorium on all forms of exploration in the disputed areas in the process. There was thus a sense of urgency to solidify the presence of the Norwegian oil and gas sector in the Arctic before the Russians. Finally, oil in the north was promoted as a "solution" to regional development needs and it was argued that it was finally northern Norway's turn to experience the petroleum adventure firsthand. Most powerfully, perhaps, was the view of petroleum production as a regional development pathway that would reverse population decline in northern Norway through the creation of jobs (Dale, 2012).

2.2 Opposition and Emerging Counter-Narratives to Oil and Gas

Plans to expand oil and gas activities northward included opening areas in the seas outside of the Lofoten, Vesterålen and Senja regions (LoVeSe). However, over the years, these plans became increasingly divisive and polarizing. While those in favor of oil argued that oil and gas would bring vitally needed economic prosperity to a region experiencing rapid out-migration, rural decline and economic challenges, opponents voiced concerns about the potential environmental risks associated with drilling activities. Opponents were particularly concerned about risks to the North Atlantic cod, which spawns in the Lofoten area during the winter months and has been an integral component of the region's livelihood and cultural heritage for centuries (Dale & Kristoffersen, 2018).

Through the dispute, coalition of fishermen, environmental activists, and residents emerged and later evolved into a broad-based social movement, The People's Action for an Oil Free Lofoten, Vesterålen and Senja, which fought against petroleum activities in the region for over a decade. In addition to grassroots-driven civil society engagement, politically elected municipal decision-makers, most of whom were staunchly pro-oil in the early days of the debate, eventually "switched sides" and opposed the plans for oil and gas extraction in the region. In 2001, the Norwegian parliament postponed the decision to open the areas and has since then continued—albeit begrudgingly—to extend a de facto ban on drilling in the region one election cycle at a time. A watershed moment then took place in 2019, when the Norwegian Labour Party, a long-time supporter of the oil and gas industry, announced that it was withdrawing support for drilling off the coast of the LoVeSe region. The move marked the end of political support for further exploration in the Arctic waters and was seen as a major blow to Norway's oil and gas industry, which has for a long time viewed access to the region as a holy grail. In June 2022, the People's Action declared victory in its campaign for a permanently oil-free Lofoten Vesterålen and Senja and unanimously voted to disband the organization. Today, a new regional development plan centered on green growth and decarbonization has replaced oil and gas aspirations in the region.

The Lofoten dispute in many ways mirrors other grand challenges in the Arctic and the sub-arctic in that they often involve dimensions of national and international energy security and revenues, the livelihoods and prospects of a thriving, year-round tourism industry and protecting cultural heritage, traditional coastal fisheries, and sustainable local livelihoods (Arbo & Thủy, 2016). As Kaltenborn (2017, p. 3) points out, these are all elements in the larger picture of dramatic on-going changes in northern coastal regions, where political, societal, and natural drivers of change across different scales act in tandem to produce complex socio-political landscapes that are often difficult to navigate from the perspectives and positions of divergent stakeholders.

In what follows, we briefly describe the Lofoten region, where alternative trajectories to futures beyond oil were present throughout the entire period, and where these alternatives materialized in specific ways.

3 The Lofoten Islands: Coastal Fisheries, Cultural Heritage, and Nature-based Tourism

The Lofoten archipelago is located just above the Arctic circle in northern Norway. The region (see Fig. 1), which is characterized by its rugged coastlines, steep mountains, and bountiful fishing waters, covers 1227 km^2 and has a population of 23,643 inhabitants in six municipalities (Flakstad, Moskenes, Røst, Vestvågøy, Værøy and Vågan). Lofoten is sparsely populated and most of the population lives in and around the two administrative centers of Svolvær and Leknes, in addition to small villages spread throughout the region. Most settlements in Lofoten were originally based on fisheries, and many still rely on income generated from marine resources, whether it be as costal fishermen and trawler crew, as seafarers in the shipping industry or in the offshore petroleum industry elsewhere in Norway.

For centuries, fisheries have laid the foundation for life in coastal communities in northern Norway and fisheries are deeply embedded in the cultural heritage and political economy of the Lofoten region (Dale & Farquharson, 2021; Karlsson & Dale, 2019). Every winter, the Atlantic Cod migrates from the Barents Sea and the Arctic Ocean to the coastal areas of Lofoten and Vesterålen to spawn. For 1000 years, this migrating cod stock has been harvested during a winter fishing season known as the *Lofotfiske*. Today, much of the Norwegian Arctic cod is caught by large, industrialized vessels in the southern Barents Sea and off the coast of northern Norway. However, the *Lofotfiske* remains vital for small-scale coastal fisheries that promote value creation in marine-based livelihoods in the north (Hultman et al., 2018; Misund & Olsen, 2013). Nevertheless, despite Lofoten being home to some of the richest and most valuable fisheries in the North Atlantic Ocean, in recent decades, the region has faced many of the same challenges that are typical for other peripheral and rural regions: a declining and aging population due to low birth rates and young adult outmigration, a lack of infrastructure investment enabling business to compete with more centrally positioned competitors, a chronic scarcity of risk capital and relatively scarce municipal finances meant to ensure that basic needs and services are provided for inhabitants.

Even so, in recent years urban areas in Lofoten, such as Svolvær and Leknes have experienced a resurgence and increase in population. Tourism has played an

Fig. 1 The Lofoten region and it's six municipalities (Røst, Værøy, Moskenes, Flakstad, Vestvågøy and Vågan). Map by Julien Lebel, Nordland Research Institute

important role in this trend and, today, Lofoten is a world-renowned tourism destination (Antonsen et al., 2022). The main attractions are the region's striking natural beauty, its unique landscape, and its coastal cultural heritage rooted in traditional fisheries. As a result, the local tourism industry, which is dominated by nature- and marine-based tourism, relies on a broad set of interconnected ecosystem-based products and services, as well as a coastal cultural heritage, which are seen as at odds with oil and gas activities (Antonsen et al., 2022; Kaltenborn et al., 2017; Karlsson & Dale, 2019). This context is important for understanding how opposition to oil and gas development emerged in the Lofoten region. In what follows we explore how this backdrop shaped alternative narratives about the future in Lofoten. While Lofoten may be a sparsely populated, peripheral region in the north, the conflict about oil became an important symbolic topic about the future of Norwegian petroleum politics and climate action.

4 Research Approach and Conceptual Framework

Our aim is to better understand how carbon-intensive development pathways can shift towards trajectories that foster lasting decarbonization. To do this, we identify and assess potential tipping events that impacted the decision to deviate from oil and gas development in the Lofoten region.

Our analysis draws on a qualitative framework (Maxwell, 2022) and is based on seven semi-structured interviews (using purposive and snowball sampling strategies), ethnographic methods, qualitative process tracing, and textual and document analysis gathered through research undertaken from 2008 to 2022, but which extends further back in time through document analysis and a revisiting of prior fieldwork and data. Our study brings together information gathered from a wide range of political actors, including public officials, environmental organizations, grassroots activists, small-scale coastal fishermen, residents, and industry actors.

One interactive workshop was also held at the Lofoten Conference (*Lofotkonferansen*). The Lofoten Conference is an annual gathering that brings together actors from the business sector, the tourism industry, and the municipal sector and which aims to contribute to long-term, comprehensive development in the region. In 2023, the conference centered around the green transition and regional development, and how to make Lofoten an attractive place to live, work and visit in the future. One of the main themes of the conference was understanding what influences narratives about Lofoten both now and in the future. The organizers of the conference were Destination Lofoten, the regional destination management organization (DMO); the Lofoten Council, the regional council for the six municipalities in Lofoten; and the Green Islands initiative. We interviewed current and former mayors from the six municipalities in Lofoten and presented preliminary findings to the regional council prior to the conference. Following this, we were asked to host a workshop at the 2023 Lofoten Conference and give a presentation about alternative visions of the future and carbon dependence in Lofoten. During the workshop, participants discussed why people in Lofoten no longer consider oil development as a viable option for the future. The participants also identified and discussed what lessons could be drawn from the region in terms of advancing the green transition. Participants included public officials from the municipal sector, a PhD candidate, representatives from local businesses, environmental advisors for inter-municipal enterprises, representatives from the real estate sector, and representatives from the tourism industry.

4.1 Analytical Framework

Our analytical framework draws on emerging scholarship on social tipping processes understood as a specific type of social change (e.g., Fesenfeld et al., 2022; Milkoreit, 2022; Tàbara et al., 2022; Winkelmann et al., 2022). According to

Milkoreit et al. (2018), a tipping point can be understood as a critical threshold crossed when a small quantitative change results in fundamental, non-linear qualitative changes in the configuration and dynamics of a given system. This process is triggered by internal feedback mechanisms, which may lead either to a new stabilized state, or to further destabilization. Other scholars have further elaborated on these ideas and introduced the notion to 'socio-ecological tipping points' as an integrative and transdisciplinary concept indicating those critical moments where the combination of events, individual actions, or policy interventions lead at a given moment to structural qualitative effects in coupled social-ecological systems (SES) (Tàbara et al., 2022, p. 566).

Scholars have increasingly explored the idea of positive tipping points that could shift societies on to a more sustainable path, asking how they come about and how they may be enacted for transformative change (Tàbara, 2021; Tàbara et al., 2018). Social tipping processes present a form of social change whereby a small change can shift a sensitive social system into a qualitatively different state due to strongly self-amplifying (mathematically positive) feedback mechanisms. Social tipping processes with respect to technological and energy systems, political mobilization, financial markets and sociocultural norms and behaviors have been suggested as potential key drivers towards climate action" (Winkelmann et al., 2022).

Tipping points emerge from the building blocks of previous conditions for transformative change—some deliberate, others not, and these often derived from the interlinked/intertwined incremental but synergistic effects of multiple tipping events. At one point the system tips to a different development trajectory and that the effects are not/cannot be necessarily or fully guided or anticipated by actors but are also co-managed as the new system conditions emerge, and that such conditions can be conducive to just arrangement and distribute effects (Tàbara, 2021; Tàbara et al., 2018). Social tipping processes are thus recognized as potentially key pathways for generating the necessary shifts towards climate action. (Winkelmann et al., 2022). In our analysis, we particularly emphasize tipping events—a key aspect of understanding of tipping processes—and consider how these events may have triggered specific trajectories in the Lofoten oil dispute, and more broadly in Norwegian petroleum policy, politics, and in the country's historically pro-oil resource regime.

5 Tipping Events in the Lofoten Oil Debate

In this section we present and discuss the events (See Table 1) and processes between 2000–2020 that we find to have impacted the decision to halt plans for oil and gas development in Lofoten. The list is by no means conclusive but is based on an assessment and analysis of previous research (e.g., Dale, 2012; Dale et al., 2019; Dale & Kristoffersen, 2018; Karlsson & Dale, 2019; Kristoffersen & Dale, 2014), as well as workshop results and interviews with key actors involved in decision-making during the period of analysis. Based on our analysis of this information, we

Table 1 Events and processes that impacted the outcome of the Lofoten oil debate (2000–2020)

Year	Description of event(s)
2006	Marine management plan for the Barents Sea and Lofoten
2009	The People's Action established
2010	Norway-Russia Delimitation Treaty
2011	Revised marine management plan for the Barents and Lofoten Seas
2011–2014	"Fact finding" Process
2013	Parliamentary elections and change of government
2014	Oil price decline
2015	The Paris Agreement
2016	Lofoten municipalities say no to oil
2017	Parliamentary elections
2019–	The Labor Party removes support from impact assessment. The Green Islands 2030 initiative emerges
2021	The People's Action declares victory and disbands

identified the following events as particularly important for the gradual replacement of a potential oil future for the Lofoten region with an alternative pathway.

5.1 Marine Management Plan for the Barents Sea and Lofoten

In 2006, the first Integrated Management Plan for the Barents Sea and Lofoten was published by the Ministry of Environment (now the Ministry of Climate and Environment). The purpose of the Norwegian marine management plans is to facilitate value creation while also maintaining natural diversity[4] along the country's vast coastal and ocean areas. The management plan for the Barents Sea and Lofoten introduced a framework for petroleum activities, which included the mention of the areas outside of Lofoten. The plan outlined that petroleum activities outside of Lofoten would be considered during the following parliamentary cycle and in the updated Integrated Management Plan to be published in 2010. The management plan further noted that there was a need to strengthen the knowledge base in these areas and that mapping and research should be carried out. Most significantly, the Norwegian Petroleum Directorate was to carry out geological mapping in the area, which included the sampling of seismic data (Norwegian Ministry of the Environment, 2006). While an impact assessment was NOT to be carried out during the 2006 parliamentary cycle, the geological mapping and the collection of seismic data was seen as putting Lofoten on the petroleum agenda (Kristoffersen & Dale, 2014: 211–212, Interview #1).

[4] https://www.regjeringen.no/en/topics/climate-and-environment/biodiversity/innsiktsartikler-naturmangfold/forvaltningsplaner-for-havomrada/id2076485/

5.2 The People's Action Established

In response to the increasing national interest to put the LoVeSe regions on the petroleum map, two separate people's movements were founded in 2006: one in Lofoten and another in Vesterålen. These two movements joined forces in 2007 with the hiring of a joint manager, and formally merged in 2009. The coalition, The People's Action for an Oil-free Lofoten, Vesterålen and Senja, soon became not only a regional but also a national force, recruiting members and establishing branches in both cities, towns, and rural areas in other parts of the country as well. In 2021, the coalition had over 7000 members,[5] making it one of the most successful protest movements in Norway's history. Their broad-based mobilization of members was the very foundation upon which they sought influence politics and public debate, and they soon allied with both environmental organizations, political opposition parties (and importantly their youth organizations), local businesses opposed to petroleum and the fishery organizations, the latter admittingly being the strange bedfellow in this consortium, as they in the past more often than not had been in conflict with environmentalist sentiments (as for instance concerning fishing quotas and whaling). The success of the movement has been commented on by several of our interviewees, and the coalition is highlighted as a crucial actor in the events that followed their initiation (Interviews #1, #4, #6).

5.3 Norway–Russia Delimitation Treaty

In 2010, Norway and Russia resolved their 40-year long delimitation dispute in the Barents Sea and the Arctic Ocean and established a maritime delimitation line between the two countries in the disputed areas[6] (See Fig. 2).

The treaty brought an end to a moratorium on all forms of exploration in the disputed areas and included detailed provisions regarding potential transboundary hydrocarbon deposits. The Norwegian government wasted no time and already in 2011 included concession areas from the newly opened waters in the 22nd licensing round for the Norwegian Continental Shelf. Then in the 23rd licensing round, where "… a potential new petroleum province"[7] was introduced with 54 blocks in the Barents Sea, 31 of which were in the new area.

The implications of these events for Lofoten's petroleum future are twofold. While the signing of the delimitation treaty accelerated the oil industry's push to the

[5] https://folkeaksjonen.no/content/historien?v=1632486146

[6] https://www.regjeringen.no/en/topics/foreign-affairs/international-law/innsikt_delelinje/treaty/id614006/

[7] Comment by then Director for drilling operations at the Norwegian Petroleum Directorate, Sissel Eriksen. Quote from press release: https://www.npd.no/fakta/utvinningstillatelser/konsesjonsrunder/23.-konsesjonsrunde/23.-konsesjonsrunde-utlysning/

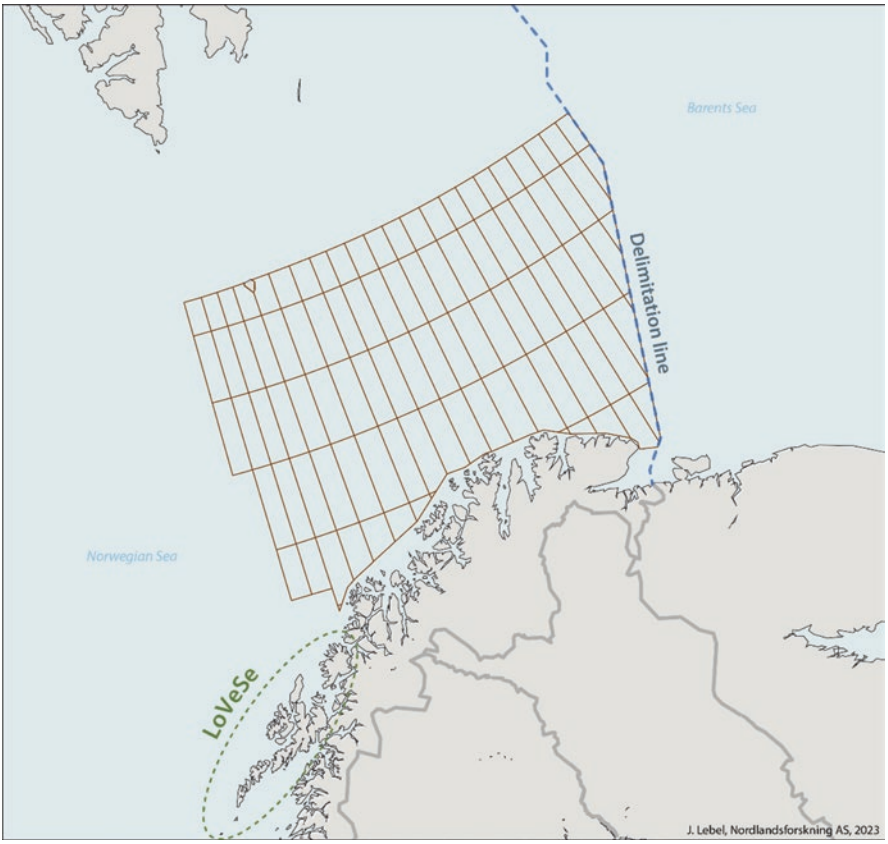

Fig. 2 Norway-Russia Delimitation line. Map by Julien Lebel, Nordland Research Institute

north, it also meant that some pressure was taken off Lofoten when a potential new oil province was now opening to the oil and gas industry and providing companies with areas to explore other than the increasingly controversial LoVeSe areas.

5.4 Revised Management Plan for the Barents Sea and Lofoten

The concern over knowledge needs on the consequences of increased activities on the Norwegian shelf meant that a revision of the management plan was needed. During this process, it became apparent to many that the combined efforts of the scientific community and the increasingly influential industrial actors interested in access to Barents Sea and Lofoten de facto sidelined a lot of other issues and concerns from a broad range of other actors and stakeholders (von Quillfeldt, 2010; Dale, 2016; Andersen, 2017). It was felt that other potential development pathways were not included, and that the consequences of the revision of the management plan could be that rather than to protect against harmful activities, the plan would be used to define *where and how it would be acceptable* to initiate activities such as petroleum exploration. Decision makers in the north—and in parliament—needed another, more inclusive process of knowledge production.

5.5 "Fact Finding" Process

Faced with this criticism, the government initiated a process aiming at filling knowledge gaps and ensuring stakeholder and actor participation. One investigation—on the positive and negative effects of an expansion of the petroleum industry—was lead by the Ministry of oil and energy, whilst five other investigations (on the potential for tourism, marine industries, cultural heritage, minerals, and renewable energy) (Regjeringen, 2013). The results covered the whole of Northern Norway but indicated also strongly that other future possibilities existed also for the Lofoten region, where opposition was the strongest against the reigning oil narrative for the north.

5.6 Parliamentary Elections and Change of Government

Just as these reports were finalized and introduced into the political debate over the future of Norwegian oil, parliamentary elections seemed at first to have provided a push in the direction of opening for more oil and gas in the north. The sitting prime minister Jens Stoltenberg lost his parliamentary support, and a right-wing Cabinet led by Erna Solberg took over. At first, proponents of oil rejoiced; however, the cabinet needed support from two center-leaning parties—Venstre (Liberals) and KrF (Christian democrats)—who both had declared Lofoten as a no- go zone for oil and gas companies. As a consequence, the strategy of postponement introduced by the Stoltenberg cabinet in 2005 and repeated in 2009 was again the result of negotiations for a parliamentary majority. This again meant four more years where 'nothing happened' for the oil industry in Lofoten, and as they had just been provided potentially interesting prospects further north in the Barents Sea, interest from the industry dwindled.

5.7 Oil Price Decline

Another reminder of the growing sense of oil dependency in Norway came with the sudden fall in oil prices in 2014/15. As described elsewhere (ref), geopolitical petroleum powerplay between Russia and Saudi Arabia in particular led to a spike in production globally which again led to a crash in oil prices. The repercussions were seemingly managed over some time, as the Norwegian oil industry indeed has bounced back; however, the event fueled discussions about the dependency of an oil revenue that, eventually, will have to dry out, and how the Norwegian society can ensure a softer transition from a carbon to a green energy-based economy. The event had a negative effect on the overall sentiment about political decisions that could lead to an extension of the oil age, which then influenced attitudes towards opening Lofoten for oil and gas. In other words, the event further spurred initiatives for alternative future pathways.

5.8 The Paris Agreement

Setting new standards for goals and strategies for a post-carbon world, the Paris agreement was yet another event that influenced the sentiments on the Lofoten case. Its influence on Norwegian political discourse was almost immediate, with both critics and sceptics chipping in, as well as all those involved in government and beyond thrilled by the prospects of a truly global movement towards decarbonization. In Norway, the signing of the agreement was yet another incident that moved the debate and development strategies towards greening the economy.

5.9 Lofoten Municipalities Say No to Oil

As a consequence of the general political trends influenced by the both national and international events and decisions here mentioned (but not exclusively these), one municipality after another put the question of oil production on the table, voted over it, and ended up saying no to oil. The last to do so was Vågan municipality in 2016, and with their decision, all municipal assemblies had said no to oil development. The importance of this cannot be exaggerated, as both mayors and other local politicians had been lobbying for development for over a decade. This political *force from bellow* now had shifted from focusing on an oil-dependent future to working on alternative visions, a shift that would prove to be important as a joint strategic plan for the joint Lofoten Regional Council towards a greener future would materialize.

5.10 Parliamentary Elections

As the results from the 2017 parliamentary elections came in, it was clear that The Solberg Cabinet would continue, and once again, the LoVeSe oil issue was up for debate. However, proponents were once again left disappointed, as the necessary support from parties skeptical to petroleum development was needed; thus, the postponement strategy remained.

5.11 The Labor Party Removes Support from Impact Assessment

A mayor turning point in parliament came when the Labor party decided in 2019 to stop working to initiate an impact assessment, formally the first step in an opening process for oil extraction. The decision at the party's annual national convention came as a result of a proposal and the significant lobbying from representatives from the youth party, AUF, who had for many years held what up to now had been the oppositional position in the party on this matter.

5.12 Lofoten the Green Islands 2023

In 2019, a new regional development plan and private–public partnership for a low-emission island society by 2030 was established between the regional council, a regional energy company and the regional DMO. In February 2022 all six municipalities in Lofoten passed the strategic plan for green growth and prosperity in the region. Strategic areas include environmental requirements in public budgeting and procurements; zero-emissions transport zones; renewable and low-emission destination; low emission coastal fishing; low-emission agriculture and aquaculture; and low-emission aviation and electric aircrafts (Interview #7).

5.13 The People's Action Declares Victory and Disbands

As a sign of these new times, the highly effective and influential people's action movement for an oil free Lofoten, Vesterålen and Senja decided to dismantle, and to go out celebrating their victory with a summer festival in Kabelvåg, Lofoten, in August 2023. The decision was made after discussions about how to maintain the necessary momentum in a movement heavily dependent on people's acceptance of working for the organization for free, and as a possible oil future seem at present to be highly unlikely, the annual meeting decided to dissolve the organization.

5.14 Summary

The debate about oil in Lofoten took place within and across multiple scales (local, regional, national, and international), included a broad variety of diverse actors and centred around multi-faceted and cross-cutting concerns about the future of energy sources, the climate crisis, ecosystem degradation, environmental risk, biodiversity loss, economic prosperity, the welfare state, livelihoods, cultural heritage, and notions of the good life. The events we identified all influenced the decision to deviate from oil exploration in the LoVeSe region. However, the extent to which these can be labelled as tipping points is debatable. We do, however, find that there is a pattern of connections—both over time and across scales—that seem to intertwine and interact in ways that makes identification of a single event or decision as a tipping point in and of itself. In the following section we look at how alternative visions of a future beyond oil took shape.

6 Imagining Alternative Visions of the Future: From the Next Oil Adventure to the Green Islands

In this section, we present our analysis of how alternative visions of an oil free Lofoten emerged and took shape through the debate about oil development in the region. Through our analysis, we identify five narratives about the future of Lofoten: (1) the "new" oil adventure in the North; (2) the fisheries and costal cultural heritage narrative; (3) the nature-based tourism narrative; the (4) the climate concern narrative; and (5) finally, as the idea of a future with oil became increasingly unlikely, a new alternative energy future emerged: the new vision of Lofoten as the Green Islands.

In the early 2000s, the mainstream narrative in the Norwegian public discourse was that expanding oil activities northward would result in Norway's next oil adventure (Ruud, 2019). At the regional and local level, this narrative centered around petroleum production becoming the main economic driver in the region and thus a positive and desirable future development pathway. However, this dominant discourse became increasingly challenged by alternative counter-narratives that centered on future development trajectories without petroleum. One of the earliest and strongest counter-narratives to emerge was that of fisheries as a vital cultural heritage and long-standing economic activity in the region and the concern that traditional coastal fisheries and marine-based livelihoods could not coexist with offshore oil and gas development (Dale, 2012). Later, another counter-narrative emerged wherein tourism was increasingly seen as important to the future of the region, and which argued that oil and gas activities conflicted with the goals of regional tourism development (Antonsen et al., 2022). In the early 2010s, a third counter-narrative emerged, in which continued oil expansion became increasingly linked to the climate crisis and its role in future of Norwegian petroleum politics (Bang & Lahn, 2020). Finally—and to a large extent a result of a combination of the above counter-narratives—a new alternative narrative focusing on a future without oil and gas emerged as the new mainstream narrative. Proponents of this counter-narrative argued for a future vision of the Lofoten region where there was an opportunity to choose differently; to focus on the renewable resources in the sea, and therefore say no to oil. Later, the idea of "The Green Islands" set into motion a new regional development trajectory that centers on decarbonization, electrification and circularity.

6.1 Narrative 1: The "New" Oil Adventure in the North

By the late 2000s, the Norwegian oil and gas industry saw itself as at a crossroads. Oil production had dropped by 30 percent since 2000, and forecasts predicted that production could drop by another 50 per cent by 2013, with overall output expected to begin falling within the next decade (KonKraft, 2009:3). The industry argued that to slow the decline in output and maintain the substantial oil revenues so vital to the Norwegian economy, oil companies needed access to "new and attractive exploration acreage." The solution, the industry argued, was to open further areas of the Norwegian Continental Shelf to petroleum activities and expand activities into northernmost parts of the country. The unopened areas along the north-Norwegian coast and north-eastwards to the Russian border were regarded by the petroleum industry as the most promising regions for big discoveries, and which could slow the production decline (KonKraft, 2009:3).

The Arctic and the seas outside of northern Norway were thus increasingly seen as the new frontier for Norwegian oil and gas development, and by the 2000s, there was a dominant narrative that the north ought to be opened to petroleum activities, which would kickstart a "new" Norwegian oil adventure. At the regional level, a new oil adventure in the North was seen as a prosperous pathway for economic development. Those in favor of oil argued that oil and gas would bring vitally needed economic prosperity to a region experiencing rapid out-migration, rural decline, and economic challenges. However, this dominant oil-narrative became increasingly challenged and several counter-narratives, which all centered on future development trajectories without petroleum, began to emerge and take shape over the years.

6.2 Narrative 2: Fisheries, the Cod and Coastal Cultural Heritage

One of the earliest and strongest counternarratives to emerge saw fisheries as a vital cultural heritage and long-standing economic activity in the region. This counternarrative centered around the concern that traditional coastal fisheries and marine-based livelihoods could not coexist with offshore oil and gas development, and that the opening to petroleum activities was a seen as an unacceptable risk to traditional fishing in the area (Interview #6). Opponents were particularly concerned about risks to the North Atlantic cod, which spawns in the Lofoten area during the winter months and has been an integral component of the region's livelihood and cultural heritage for centuries (Kristoffersen & Dale, 2014).

6.3 Narrative 3: Nature-based Tourism

The second counter-narrative to emerge saw tourism—particularly nature-based tourism—as important to the future of the region and argued that oil and gas activities conflicted with the goals of regional tourism development. In recent decades, tourism has played an increasingly important social and economic role in the Lofoten region. The local tourism industry is heavily dominated by nature- and marine-based tourism, and as such, relies on a broad set of interconnected ecosystem-based products and services, as well as a coastal cultural heritage, which are seen as at odds with oil and gas activities (Antonsen et al., 2022; Kaltenborn et al., 2017; Karlsson & Dale, 2019).

6.4 Narrative 4: Climate Concerns and the Anti-fossil Fuel Movement

A third counter-narrative started to emerge in the early 2010s, wherein climate concerns became increasingly seen as urgent, and as time goes by references the Paris Agreement which institutionalizes these concerns. Indeed, notions of carbon risk became ever more present in public debates about new licenses throughout the 2013–2018 period. Environmental NGOs such as Friends of the Earth, Greenpeace, WWF and the Bellona Foundation had mobilized against oil and gas activity in the Arctic for many years, but starting from the 23rd licensing round, opposition was much more explicitly tied to carbon risk. Similar to environmental NGOs in North America and elsewhere (Cheon & Urpelainen, 2018), they built on the Paris Agreement's 2 °C target and the limited global carbon budget it implies to argue that Norwegian oil and gas resources should be left in the ground. Their advocacy shifted from demanding geographical limitations on oil and gas extraction to calling for a 'managed decline' of the industry as a whole—echoing and sometimes collaborating with international NGOs making similar claims (Bang & Lahn, 2020, p. 1002).

6.5 An Alternative Energy Future Emerges (Narrative 5): Long Live the Sea and the Green Islands

Finally—and to a large extent a result of a combination of the above counter-narratives—a new alternative narrative focusing on a future without oil and gas emerges as the new mainstream narrative. In particular, the idea of "The Green Islands" sets into motion a new regional development trajectory that centers on decarbonization, electrification and circularity.

7 Conclusion

In this chapter, we traced the 20-year history of the Lofoten oil debate and identified important events and interventions that shaped the trajectory of the debate and the eventual decision to deviate from oil and gas development in the region. We then explored how alternative visions of an oil free Lofoten emerged and took shape over the last two decades, and how an "oil free" Lofoten became a collectively held and performed vision of a desirable future. Our objective was to better understand how carbon-intensive development pathways can shift towards trajectories that foster decarbonization by identifying and assessing potential tipping events that impacted the decision to deviate from oil and gas development in the Lofoten region. Oil and gas production are vital to the Norwegian economy and petroleum has dominated the Norwegian resource regime since the 1970s. However, despite these conditions, the Lofoten conflict represents a disruption to the otherwise highly change resistant, pro-carbon pattern in Norwegian energy politics. The fact that the Lofoten region remains closed for petroleum development is highly unusual given the significance of petroleum production to the Norwegian economy and the dominant expansive logic of the Norwegian resource regime. Examining the Lofoten case thus yields useful insights into conditions and interventions that can both unsettle the status quo of fossil fuel energy systems as well as foster lasting a transformation towards less-carbon intensive emissions trajectories.

Through our analysis, we traced a shift in strategic planning and policymaking for the Lofoten region, from a dominant mainstream narrative in the early 2000s that centered on opening the seas outside of Lofoten to offshore drilling, towards a new alternative narrative focused on decarbonization, green growth and the good life which emerged in the late 2010s. Analyzing the decision to deviate from oil and gas development in Lofoten is insightful for understanding how alternative, narratives about the future emerge and how they become formalized, particularly when examined in the context of the "hard-coded embeddedness of petroleum in Norwegian society" (Dale & Farquharson, 2021, p. 146). Finally, we argue that the success in Lofoten is rooted in place-based and community-driven engagement, and that a shared, communal vision of the past played an important role in creating a new, shared vision of the future. The Lofoten case generates some interesting questions for future research on tipping points. Spesifically, it would be insightful to study the potential of specific outcomes from the Lofoten oil dispute, such as the "Lofoten the Green Islands 2023" initiative, to foster lasting lock-in of decarbonizing trajectories in the region.

On a more general note, it is worth revisiting the matter of whether specific tipping points towards a greener development trajectory occurs, are identifiable or even useful for academic analysis of societal transformation. Our assessment based on the case here described is that the intent to identify tipping points in and of itself represents a positioning towards societal transformation that reveals case-specific events and decisions that ultimately (may) lead to much needed change, but that as these changes obviously are unique and specific to each case, qualitative bottom-up research on what specifically moves hearts and minds and thus changes targets for development and transformation matters. In this sense, the tipping point framework has unarguably enabled us to both revisit prior work and build new knowledge about the specific change in future trajectory for the Lofoten case; knowledge we believe underlines the importance of place-specific, qualitative methodologies in studying both past and ongoing transformation processes.

Appendix

Interview sources

Interview No.	Role/Organization	Date
#1	Regional council representative	25.02.2022
#2	Former municipal mayor	18.03.2022
#3	Former municipal mayor	22.03.2022
#4	Former municipal mayor/member of parliament	29.03.2022
#5	Municipal mayor	08.04.2022
#6	"The Green Islands 2030" representative	28.04.2022
#7	Regional energy company representative	03.05.2022

Workshop participants

Participant No.	Role/Organization
#1	Municipal sector
#2	Local tourism sector
#3	Inter-municipal enterprise
#4	Real estate sector
#5	Local business organization
#6	University sector
#7	Public official
#8	Municipal sector
#9	Municipal sector

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Exploring the Role of Identities and Perceptions of the Future in a Post-coal Mining Region: The Demolition of Andorra Coal-fired Cooling Towers (Spain) as a Tipping Point

Francesc Cots, J. David Tàbara, Jérémie Fosse, and Gerard Codina

> *"I don't want to talk about coal any more,*
> *I want to talk about the future"*
>
> *Former coal mine worker, Teruel June 2022*

Abstract In May 2022, the last cooling tower of the coal-fired power plant in the Spanish region of Andorra in Teruel province was demolished. After forty years in operation such an event had a huge emotional effect on the local population, since much of the local identity and tradition was built around this industrial emblem. On the one hand, it represented a final symbolic farewell to a way of life around coal, now perceived to have inevitably ceased to exist. On the other hand, it highlighted the need to accelerate the full regional transformation towards a new socio-economic structure whose agents of change, content and new identities were not yet well-defined. Our research explores the role of identities and perceptions of the future as key constraining or enabling factors in tipping former carbon-intensive regions towards clean energy and sustainable development pathways. Understanding how local populations see their uncertainties about the future, and examining other views on relative deprivation and inequality, are central in developing enabling governance arrangements and continuous learning feedback loops required in rapid socio-energy transformations. We found out that embracing transformative change

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towards green transformations may entail adopting more diversified, self-defined complex forms of collective sense-making processes based on *project identities.*

Keywords Tipping point · Resistance identity · Coal phase-out · Systemic transformation · Energy transition

1 Introduction

The regional energy transition processes supported by EU and national policies and funds have created a window of opportunity for the reconfiguration of former coal and carbon-intensive regions (CCIRs) aligned with sustainable development goals. In recent decades, such regions have been affected by an array of negative trends regarding the loss of local jobs, population ageing, migration, lack of services and poor environmental quality conditions. In these socially complex contexts, systemic inertia, aversion to change and immobilism have often been paramount. To overcome this, several factors which have to do with realising the multiple dimensions that affect the deliberate and fast transformation at regional level need to be taken into account. These entail not only technology innovations, but also other more intangible, cultural and perceptual dimensions that affect the willingness and the capacity of different stakeholders to engage actively in transformative governance processes. Harmonised policies need to consider perceptions related to cultural, identity and inequality issues in order to foster the potential of local populations to contribute to systemic change, which may eventually be expressed in more diversified, inclusive and resilient communities.

This chapter explores the role of cultural identity dynamics, and of local perceptions of inequality and uncertainty in low-carbon systems, as well as their transformations and their implications for governance and policy learning. It concentrates on tracking the changes in socio-economic and policy conditions and forces that pushed for an energy transition in the coal-mining area of Teruel in Spain. With this aim, stakeholders' perceptions of energy transition and decarbonisation policies led by the central government through the development and implementation of EU Just Transition Funds were analysed, including those of former coal power plant workers, trade unions, as well as national and local governments, NGOs and academics. Taking into account that the region has been highly dependent on coal for a long period of time and that its inhabitants have constructed an identity around that imaginary, we attempted to answer the following research questions:

- How is the community (symbolically) coping with the energy transition and decarbonisation process boosted by European and national authorities in the region of Andorra (Teruel), also in terms of identity and cultural attributes?

- Is the community resisting or accepting new narratives based on energy transition and the development of alternative sustainable economic activities?

We examine to what extent the inhabitants of the Teruel area originally shaped their cultural attributes, social meanings and collective imaginaries around coal extraction in a way that led to *resistance identities*, but also how the inevitable realisation of the end of the coal era, epitomised by the demolition of the cooling towers, triggered the formation of new *project identities.* The latter are based on decarbonisation and low-carbon strategies and new institutional arrangements but without completely erasing other resistances derived from new perceptions of unwanted changes or uncertain futures.

This chapter is structured as follows. First, we present a succinct conceptual proposal to understand the dynamics of changes of identities and perceptions on impeding or accelerating the conditions for social tipping points to emerge. Then, we present the case of the Teruel coal region in Spain, with a focus on the town of Andorra in which the cooling towers were demolished in 2022. We explore how the evolution of Andorran citizens' identities, imaginaries and perspectives of decarbonisation policies affected the local energy transformation. We also reflect on the extent to which the local community sees decarbonisation policies as driven by outsiders and to what degree they resist, accept or create their own alternative narratives of sustainable development. Finally, the chapter concludes with a reflection on the role of perceptions of identities and relative deprivation in the development of opportunity spaces and conditions for regional system transformations.

2 Regional Identities and Perceptions as Constraining or Enabling Conditions for Positive Tipping Towards Low-Carbon Futures

Following Tàbara et al. (2021), in this section we conceptualise tipping phenomena as triggered by three main temporal and structural dynamics: (i) first, by the occurrence of *cumulative changes in the original cultural, socio-economic and political conditions* within the contexts in which tipping events may occur. These may be derived from either deliberate interventions, cumulative socio-economic, environmental or cultural changes or other exogenous, unintended, or unforeseeable factors; (ii) second, by an *additional force of change or event that accelerates and triggers an abrupt, structural and qualitative change* in a system of reference that precipitates the emergence of alternative development trajectories, and (iii) by the *new system's conditions* derived after the tipping point. We assume that it may never be fully anticipated when or whether tipping points in social-ecological systems will occur. This is because they constitute the outcome of complex non-linear processes prompted by multiple factors. However, it is reasonable to believe that the conditions for positive tipping points can be enabled through deliberate actions and policies, and also that, once tipping points occur, if previous normative safeguards, precautionary policy criteria and institutional arrangements have already been put in place in an anticipatory way—such as those related to justice—, there may be a greater chance of achieving positive outcomes and/or avoiding negative ones.

A contested issue in the analysis of tipping point processes has to do with trying to define what we mean by positive. According to Kopp et al. (2016), beneficial tipping points are those that "increase societal resilience and reduce climate change damages via mitigation or adaptation, whereas harmful social tipping points are more likely to occur where there are low levels of societal resilience, under which societal risks increase because of the failure to effectively adapt or mitigate". Tàbara et al. (2018) defined positive tipping points as emergent properties of systems that would allow the achievement of evolutionary-like transformative solutions to successfully tackle the present socio-climate quandary. However, in a nutshell, when thinking about regional tipping points, we can simply understand that positive tipping points exist whenever there is a substantial and qualitative stepwise advancement in the collective and governance capacities to deal with common challenges and risks—that in turn increase resilience, welfare and quality of life conditions, e.g., as described by the Sustainable Development Goals or other commonly agreed sustainable development criteria or indicators. In contrast, a negative tipping point indicates the moment in which an additional force of change or disruption negatively impacts a given society in an irreversible mode, fundamentally undermining the existing capacities to adequately manage its resources or meet the basic needs of their people. This may happen when such collective and governance capacities to govern substantially decrease or collapse, as in the case of failed states.

Therefore, even though tipping points cannot be fully predicted ex ante, an important task for researchers aiming to understand tipping processes at regional level is to elucidate the various factors that influence structural changes in the original socio-economic, political, cultural and environmental conditions. These also include agents' perceptions of their own capacities and roles in transformative processes. Social imaginaries related to decarbonisation or to the meaning of just transition are therefore essential in the (re)construction of new collective identities and in how events, such as the Russo-Ukrainian War, are being locally communicated and symbolically processed in modes that may also question discourses about the end of coal.

According to Castells (2000), identities, particularly those that have to do with political issues, imply a process of constructing collective meaning by means of which stakeholders give priority to a set of cultural attributes over other sources of meaning. However, identities are never one-dimensional or static, and several of them can be juxtaposed at the same time. Concerning social and political change, Castells differentiates between three types of identities: (i) *legitimising identity,* where there is set of logic and meaning components promoted and propagated by dominant powers, and used to rationalise, reproduce, and expand their existing rules; (ii) *resistance identity*, constructed in response to devaluation and stigmatisation and where social actors build "trenches of resistance" in opposition to the ruling norm. In this case, such a position may lead to communities of resistance, and (iii) *project identity*, whereby a "new identity" redefines the collective position within society and, by doing so, may seek and contribute positively to the transformation of broader social structures.

Therefore, this conceptual heuristic is useful to understand how the original cultural conditions of a CCIR change over time and how they relate to structural changes within socio-economic and political conditions. In Spain, the large-scale and heavy coal infrastructures developed during Franco's dictatorial regime translated into a variety of local symbolic meanings and cultural attributes. In places like the town of Andorra in the province of Teruel, the main economic activities revolved around coal for decades and therefore attitudes towards them were those akin to legitimising identities. Such massive infrastructures not only have clear impacts on the local ways of life—economically, politically and culturally—but also have broader effects on social relations with other regions, due to their systemic and fundamental character (Bridge et al., 2018). Relationships between workers, mines and coal infrastructures may become so interwoven and intense that closure can even be perceived as a betrayal to the community (Grubert & Algee-Hewitt, 2017). In these contexts, it is not unusual for resistance identities to emerge as an outstanding opposition to the new decarbonisation paradigm. However, such phenomena may not entail a perpetuation of existing identities given that, in a fast-changing world, they are necessarily fluid and in constant reconstruction. Processes of accommodation, acceptance and participation in the creation of new identities contributing to sustainability transitions and decarbonisation (i.e., sustainability project identities), are also possible (Sanz-Hernández, 2019).

3 Tipping Towards Uncertainty in the Teruel Coal Mining Region

3.1 Regional and Local Contexts

Since Spain joined the European Union in 1986, coal has been a declining sector, largely due to the lack of market competitiveness of Spanish coal. There have been several transition phases in different mining areas, most of which have failed to create an alternative business fabric to keep the job positions created by coal mining. Currently, the region of Teruel is under the influence of the European Union's Just Transition Fund, aiming to achieve new economic opportunities based on decarbonisation policies and strategies (Mayes et al., 2014; Marshall, 2016). Teruel is a province of Spain in the Autonomous Community of Aragón that covers an area of 14,810 km^2 (INE, 1997) and in 2021 had a population of 134,545 inhabitants (INE, 2023). In this research we focused only on the parts of the region included in the local strategy covered by the Just Transition Plan and in particular on the municipality of Andorra. This research thus concentrates on a total of 31,509 people and seven localities. Population in the area is declining and ageing, with a 13% population loss since 1998 and 20% of people being over 65 years old.

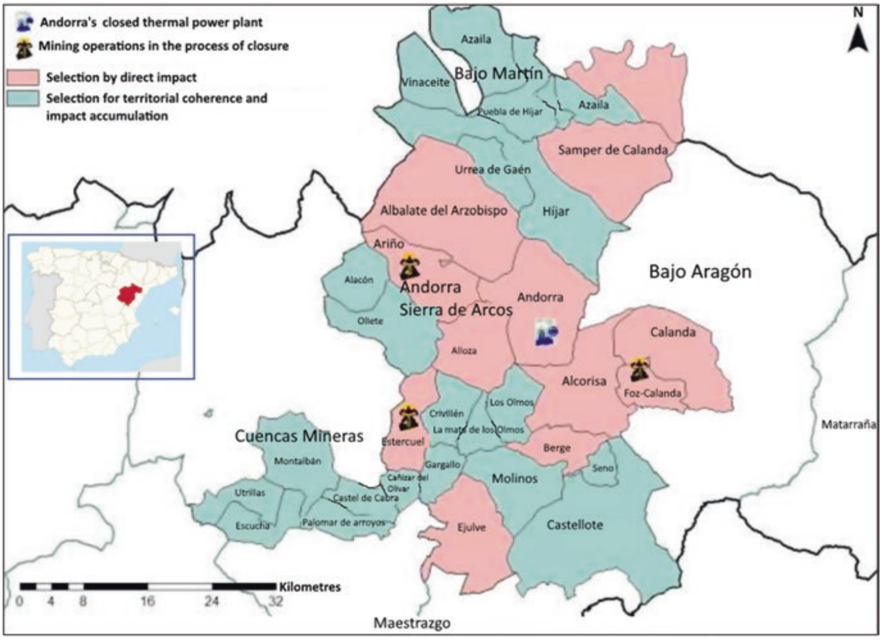

Fig. 1 Area of study and under the effect of the Just transition Agreement for Andorra-Mining Regions (Source: Instituto de Transición Justa, 2020)

Andorra is a traditional coal and carbon-intensive region (CCIR), originally characterised by extractive activities. The production of coal in the province of Teruel fell from 3,531,000 tons per year in 1997 to 2,339,000 tons per year in 2010 (34% reduction). The last coal mine, which closed in 2020, was used to generate electricity in the local coal-powered power plant of 1101.4 MW capacity, following a request by the central government in 2018. A total of 532 workers were affected by the closure, 204 being part of the large power corporation ENDESA workforce and 328 employed by subcontractors (Fig. 1).

3.2 Methods

The following methods have been used to frame the study and collect the data needed for this case study:

(a) *Scientific literature review* on the conceptual framework to explore the intersections of cultural and socio-political factors regarding social-ecological tipping points and identities in CCIRs.
(b) *Content analysis of policy documents*. These were examined to structure initial concepts and obtain a preliminary understanding of (tipping) events and

interventions. In particular, socio-economic data like demographic trends, employment rates, number of workers affected by the closure, distribution of economic sectors, etc., were gathered from the diagnosis of the region developed by the Just Transition Institute of the Ministry of Energy Transition and Demographic Challenge (MITECO), with data updates when needed.

(c) *Content analysis of local newspapers* was used to detect and contrast discursive dynamics and perceptions of different stakeholders concerning how they were affected by the different events and policy interventions. The focus of this analysis was on the perceptions of stakeholders manifested in the media with regard to coal phase-out and decarbonisation processes from the announcement of the closure of the plant in 2018.

(d) *Stakeholder interviews* were used to explore opinions and social imaginaries about coal phase-out in the region. The interview protocol was developed to encourage participants to discuss their perceptions on how the coal phase-out process was being conducted, the impact it had upon their livelihoods, local identities, and the economic pathway alternatives based on large-scale renewables. In total, 11 semi-structured interviews were carried out in two stages (one in 2021 and the other in 2022) with different actors involved in the energy transition process in Teruel (including representatives of the power company ENDESA, Andorra municipality, trade unions, national government, business associations and academia).

(e) *Two workshops* were held, one virtual in June 2021 (due to the pandemic) and another face-to-face in June 2022 (with the participation of two national trade unions, municipal and supra-municipal governments, national government, business and cultural associations, two environmental associations, a rural development association, and representatives from the academia). The content of both workshops was recorded, transcribed and shared among the participating stakeholders for correction and feedback.

The results of this data analysis are reproduced in the next sections. Most common perspectives relating to the value and judgement of events, particularly the ones that have a significant public dimension and social impact, such as the closure of a coal-fired plant for the local population, originate from a narrow set of stakeholders, usually those who are able to significantly influence how value is perceived by the wider community (Armstrong et al., 2011; Zimbalist, 2010). As the appraisal of value cannot occur in a vacuum (Holbrook & Corfman, 1985; Getz, 2018), the analysis was shaped by a set of reference points or temporal events that help to fix the standards by which those events will be judged or valued, including the periods before and after the announcement of the closure of the coal plant, the initiation of large-scale solar and wind projects to substitute the electricity generated by the Thermal Power Plant and the demolition of the cooling towers. As a result, the reactions of different stakeholders (trade unions, local administrations, business associations, the energy company, etc.) which were involved in forming policy directives (Armstrong et al., 2011; Zimbalist, 2010) associated with the decarbonisation process were collected in relation to the above-mentioned temporal events or reference points. The data gathered from the scientific literature review, the content analysis of the policy documents, the first workshop and the first set of interviews were used for a scoping purpose, to better identify the main problems in the area, general perceptions of stakeholders and issues at stake. The data gathered from the content analysis of newspapers, the second set of stakeholder interviews and the second workshop allowed us to go deeper into discourses on identity issues, cultural attributes and social imaginaries, as well as contrasting the perceptions and feelings on the coal phase-out process and its effects, how they were coping with it, their level of frustration, acceptance and hope. This methodological triangulation between the content analysis of newspapers, the second set of stakeholder interviews and the second workshop, and the combination of three data collections to approach the study of the same object, allowed to gather more comprehensive insights, balancing the strengths and weaknesses of each method (Denzin, 2017). The information was processed in order to understand how the community (symbolically) was coping with the energy transition and decarbonisation process promoted by European and national authorities in the town of Andorra (in Teruel province, Aragon), also in terms of identity and cultural attributes (research questions). This data analysis process provided input associated with the level of resistance or acceptance of the new narrative on the regional energy transition by the community and the contrast and differences among stakeholders' perceptions. The analysis focused on how stakeholders perceived the different phases of the decarbonisation process and their level of resistance/acceptance and how they valued the main decarbonisation events, but also their proposals, views and recommendations on how these events should shape and impact governance and policy-making in the region from a normative perspective, which were obviously different depending on how each stakeholder positioned themself in the policy-making spectrum.

3.3 Economic and Political Catalysts Accelerating Structural Change

One of the main catalysts of coal extraction decline was Spain's entry into the European Union in 1986. This led to the adoption of European coal and energy regulations which were stricter with respect to environmental standards, increasing domestic production costs. In parallel with the end of coal subsidies by 2025 (Galindo, 2022), domestic coal was exposed to the EU market and the need to compete with more competitive production facilities. In Spain, there were five coal-mining restructuring plans between 1990 and 2018 that caused a severe decrease in mining workforce and production, with a reduction of 20–25% of the population employed in these sectors over the past 25 years in the coalfields in Asturias, Castile-León and Teruel (Aragón), as well as a complete social and cultural transformation process (Sanz-Hernández, 2020).

Throughout the operational period, the Thermal Power Plant of Andorra operated in a nearly monopolistic environment and the region's inhabitants enjoyed many economic and social benefits (high salaries, energy bill exemptions, early retirement, etc.), which far exceeded the rest of the region and generated strong dependence of the local population on this company. This relationship of dependence was based on an individual and social connection that gave the inhabitants of Andorra and the surrounding areas a sense of attachment and a relative feeling of security and confidence in the future (Sanz-Hernández, 2020). Furthermore, in this context, when the request from ENDESA to the government to close the plant was made public in 2018, both media and interviews with stakeholders reflected that many locals experienced a kind of shock (Saz, 2020). Even if this event had been on the (national) political and economic agenda for many years, workers and local/regional administrations could not believe that it was really happening (Saz, 2020).

However, the election of the progressive government in 2019 marked a change in the approach taken by the Government in relation to the mining regions in Spain. It represented a turning point for the coal regions due not only to the closure of most mines and thermal power plants but also to the design of a just transition plan for these regions. After the election, the Just Transition Institute, an autonomous body of the Ministry for Ecological Transition and the Demographic Challenge, was created with the aim of identifying and adopting measures that guarantee fair and supportive treatment for workers and territories affected by the transition to a greener and low-carbon economy, minimising negative impacts on employment and the depopulation of these territories. This agency is actively involved in the transition processes of coal regions. The new institution therefore marks an important difference that contrasts with the perceived abandonment suffered for years in the area. The institution designed a Just Transition Strategy for the Andorra Mining Region, with the aim of minimising the number of jobs lost by the phase-out of the coal sector. This agency is financed partially by the European Commission's Recovery and Resilience Facility as a post-pandemic recovery package and partially by the annual Spanish government budget. The strategy contemplates the signing of a Just Transition Agreement, negotiated between the Government and the most relevant social actors, which has as priority objectives the maintenance and creation of activity and employment, the settlement of the population in rural territories or in areas with closing facilities, and the promotion of diversification consistent with the socio-economic context. It also takes into account the need to improve employability and working conditions of women and groups with labour market access difficulties, such as the long-term unemployed, youth, people with disabilities or population at risk of exclusion.

In this respect, some positive interactions between top-down and bottom-up policy initiatives seem to have emerged recently from the Just Transition Institute. First, there was the consensus created around the Just Transition Agreement, with an important representation of the most relevant social agents. The priority is local employment, the settlement of the population in rural territories and the promotion of economic diversification. This action was organised around a tender called Nudo Mudéjar, which grants the production rights of the 1200 MW grid capacity that were left free at the connection point after the closure of the plant. This tender incorporated a number of socio-economic criteria, including the creation of green job opportunities and training, the promotion of energy prosumers and energy communities, the generation of municipal income and others. The large company ENDESA was the provisional winner of the tender, with a project that includes the hybridisation of solar and wind renewable projects, energy storage and the development of green hydrogen projects, together with a social plan that foresees the creation of more than 3500 jobs during the construction of the projects, generating 300 direct permanent jobs in the area for the operation of these facilities. This development has a structural transitional capacity, because it will enable the creation of new job positions in research and innovation in a large variety of disciplines. Hence, although it is too early to fully assess to what extent, the introduction of the just transition criteria can help to placate the population, slowing down or reversing the depopulation process in the region, as well as creating job opportunities with a gender perspective and attracting a young and trained population to the region.

3.4 Lost in Transition? The Emergence of New Identities, Risks and Opportunities After Tipping Events

There is a general consensus that, according to local stakeholders' views, the coal industry constituted a key part of the region's identity. The local population had a strong sense of belonging to a mining community and it was hard for everyone to understand and move forward to another economic sector (Quílez, 2020). For a long time, they viewed coal mining and the thermal plant as an integral part of their identity and a key for their survival (Sanz-Hernández, 2013; Della Bosca & Gillespie, 2018). This was also reflected in the media (Rajadel, 2020) and in the opinion of local experts (Sanz-Hernández, 2013). For instance, an Andorran expert and member of the Aragonese Observatory of Art in the Public Sphere stated that: "Andorra's social landscape was decisively determined by seventy years of extractive activity (…) and in addition to being an economic engine, coal, after colonising the entrails of men through their lungs and skin, has ended up becoming part of the Andorran identity, which today is collapsing in the face of new environmental policies" (Artigas, 2019).

In this context, the demolition in May 2022 of the cooling towers of the coal-fired plant, after forty years in operation, had a significant emotional effect on the local population, since much of the local identity and tradition was constructed around such an industrial emblem (Fig. 2). This event not only represented a final farewell to a way of life around coal—now perceived to have inevitably ceased to exist—but also highlighted the need to accelerate an entire region's transformation towards a new economy whose agents of change, content and identity are not yet well defined. Therefore, even if the functionality of the region shaped its identity, at present the sense of belonging corresponds more to the perception of being a former

Fig. 2 Cooling towers of the Andorra thermal power plant being demolished on 13 May 2022. Photo courtesy of Andorra City Council

mining region in “transition” towards a new identity or new set of identities not yet well defined. In this process, many stakeholders pointed out the need for public authorities to accompany and support local communities when dealing with the emotional aspects derived from loss, trauma and grief, but also validating hope and providing evidence of alternative futures due to the high level of uncertainty.

Contradictory feelings and reactions were moreover detected from both qualitative results obtained via interviews and workshops and content analysis of newspapers. On the one hand, the closure of the mines and the plant, and the lack of materialisation of new projects that would support a new “post-coal” regional identity, have created resistance among the population towards the creation of a new project identity, generating feelings of abandonment, nostalgia, resignation, exclusion, etc. In this regard, some representatives from trade unions complained that the phase-out process was too quick in Andorra, and that a minimum coal operational capacity should have been guaranteed for strategic coal reserves (Navarro, 2022), particularly after the start of the Russian-Ukrainian war. On the other hand, growing positive expectations and hope have emerged, particularly thanks to new business models and young entrepreneurs, in relation to engaging in large-scale investments based on renewable energies.

In this regard, Herrfahrdt-Pähle et al. (2020) hypothesised that socio-political shocks may increase opportunities for transformation and argued that research needs to focus on the required capacities to steer such potential tipping point situations towards the desired outcomes (see also Hölscher & Frantzeskaki, 2020). A positive tipping could then also be understood as the moment at which the opportunity space for sustainability transformations actually expands, while a negative one would substantially narrow it. Hence, a regional system’s dynamics would not just follow a linear process of reorienting a single system trajectory towards another of the same system, e.g., following an s-shape1, but rather multiple trajectories and alternative system configurations would potentially unfold, and from this moment the region may be reconfigured towards different plausible forms, many of them being equally valid, equitable and/or sustainable. Figure 3 represents this 'transformative moment' at which a tipping event alters the agents' available degrees of freedom and their patterns of interactions, and in doing so also modifies their opportunity space for transformative futures and their perceived identities. In the new situation, the place-based or single-sector community identity may be replaced by a more fluid set of project-based identities in which individuals also need to decide to whom or to what future project they want to or can belong.

Therefore, after the tipping event, represented in the case of Teruel by the demolition of the cooling towers, the formation of new representations about individual roles and relationships accelerated. In the new situation, it is plausible that a whole new array of identities appeared in a more fragmented but also potentially networked way. There might no longer be a single and place-based identity formed around a single industry with one unifying heavy infrastructure. On the contrary, a more dynamic set of project identities (in the plural) formed by new agents, entrepreneurs and industries, and possibly also more open to social, economic and cultural diversity, may be emerging. However, we should not expect this to be free of potential resistances as opposition comes not only from those agents that formerly held dominant positions and still intend to retain them, but also from those who perceive their roles and positions as uncertain in the future.

The final closure of the thermal plant and the symbolic impact of the demolition of the towers have made the transition an irreversible process and thus question the

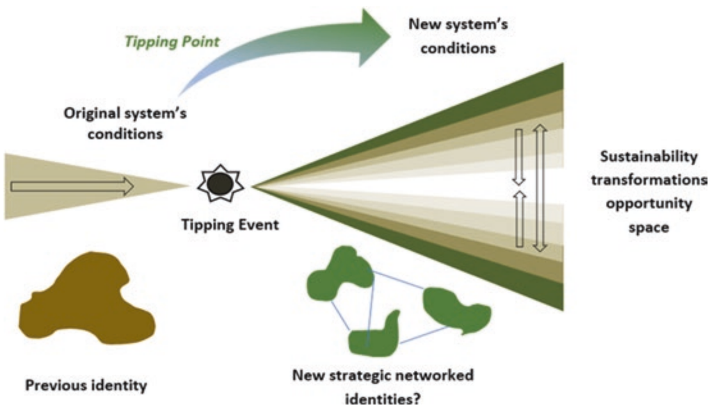

Fig. 3 Tipping points, identity disruptions and sustainability transformations opportunity space. Tipping points, derived from a cultural disruptions in collective meanings may alter the opportunity space for sustainability transformations. e.g., expanding it if positive, or shrinking it if negative. The chances to materialise positive tipping points will also depend on the available degrees of freedom within the system and the transformative capacities of agents to extend it, which also depends of the previous enabling institutional conditions. (Source: J. David Tàbara)

legitimacy of coal identities (Sanz-Hernández, 2020). Although there is still some resistance in place, attachment to the coal landscape is being increasingly questioned. Many of the consulted stakeholders have started to manifest a clear will to move forward and accept the irreversibility of the transition. As expressed by a former coal worker at the Second Workshop held in Andorra in June 2022, "I don't want to talk about coal anymore; I want to talk about the future".

However, the public debate on how to carry out a just transition is ongoing and the promises of new jobs and development related to the Just Transition Agreement and Nudo Mudéjar play a key role. For instance, a platform very critical of the development of large-scale projects called "Plataforma a favor de los paisajes de Teruel "has been created. They protested against wind and solar farm sprawl under the slogan "Renewables yes, but not like this". They claimed that the massive deployment of "oversized" renewable energy projects and connection infrastructure requires too much land, destroys the landscape, leads to irreversible loss of biodiversity and hampers sustainable local development. The alternative, the platform proposes, lies in promoting a model based on distributed energy, self-consumption and energy efficiency without jeopardising the local biodiversity and landscape.

Notably, some consulted academics and environmental organisations were amongst the most critical, highlighting the fact that the prospects of the area to become a new green business hub are compromised, unless a significant mental shift in the local population also occurs. These voices claimed that, as the economic bubble of huge salaries and early retirements has ended, the local population should accept that the future of the region also depends on citizens becoming active agents of change, rather than relying on single large companies coming in from abroad. As noted by one of the consulted NGOs, "from now on we must promote entrepreneurship among young people. What is happening is not a misfortune; it is an opportunity to value the capacities that our people already have".

Our interviews and workshops also revealed some barriers to local entrepreneurship, such as economic risk aversion, a long tradition of being employed by a single big employer and other attitudes not conducive to embracing change, such as "waiting for the job to come from abroad'‘. These factors are compounded with others like the actual lack of a local labour force, youth exodus, bad internet quality and poor offer and opportunities for local re-skilling and training. This is why some stakeholders, because of the considerable future uncertainties, were quite reluctant to start new businesses on their own and pointed out the importance of maintaining a big 'tractor' industry or large project capable of pulling other small businesses with it.

4 Conclusion

As a whole, the preconceived idea of transition in Teruel was based on the possibility to switch towards the generation of renewable energy, focusing on the installation of large-scale solar and wind projects to substitute the electricity generated by the Thermal Power Plant; and that this would create at least as much employment as used to exist during the normal operating time of the thermal plant. The central government has been highly supportive of this transition towards large-scale renewable energy production; however, parts of the local population, civil society organisations and sectors of the academia do not yet perceive that the new projects are able to generate such lasting jobs and fear the impacts on the environment, social cohesion and local landscape.

On the other hand, trade unions, former workers of the thermal plant and business associations perceive the new economic initiatives with a mix of hope for recovering lost jobs and fear that they may mean new unfulfilled promises. In this context, the Russian -Ukrainian w ar together with the fact that some member states had already reactivated coal-fired power plants to mitigate the effects of energy shortages was perceived as a setback in such energy transition process. However, the demolition of the towers and the current process of dismantling the plant had irreversible effects, and to date no public debate has been opened up regarding this situation. Hence it is important to take such transitions processes in their broader contexts, that is as systemic transformations, that include much broader cultural and socio-economic changes across different scales.

Although tipping events at symbolic level, such as the demolition of the cooling towers in the Andorran coal-fired plant, may precipitate substantial qualitative structural change in a given region, the previous conditions that eventually lead to these transformations tend to be engendered over long periods of times, often decades. Multiple socio-economic, political, cultural and ecological forces converge and interact - often in incremental fashion and even unnoticeable by the very agents that experience these forces -, pushing the original systems towards different configurations. It is therefore crucial to build just, anticipatory and transformative institutional capacities at times of great uncertainty and accelerated change, so as to steer the inevitable change from the present social-ecological systems towards deliberate positive processes and outcomes.

With regard to social and interdisciplinary research, there is a lack of empirical work on how to enable positive and systemic transformations in social-ecological systems, particularly at the regional level. The absence of grounded knowledge about when and under what kinds of conditions such deliberate qualitative changes may be induced led us to focus on the role of shifts in identities and perceptions in coal and mining landscapes. Our research revealed that precipitating events, such as the one involving the Andorra coal phase–out, not only led to the abandonment of the old—and authoritarian, centralised, mostly masculine—legitimating identity built around the single heavy coal industry but are also creating new opportunities for the (re)construction of new *project identities*. Once a tipping point is crossed, it may create effects and disruptive developments across multiple dimensions and alternative pathways of development. In this more fluid and potentially dynamic space, the challenge is not only for large operators to contribute to low-carbon energies, but also for citizens to play a more active role in contributing to the emergence of transformative networks and for businesses to potentially contribute more to sustainable futures. In this regard, compensatory policies, such as providing early retirement packages to affected workers and communities, may be positive to reduce resistance to transformative changes, but they are not sufficient to trigger self-reinforcing chains of positive regional feedback changes towards systemic transformations. Hence, a more empowering, endogenous and place-based perspective involving local/community concerns, perceptions and actors is required, whereby all relevant stakeholders can play an active role.

European regulations made it more costly to run coal thermal power plants and this, together with the opening up to global coal markets, triggered the closure of several plants in Spain. Moreover, and although EU policies pushed for the coal phase-out, the position taken by the Spanish Government since 2019 regarding the ecological transition was also very relevant in this respect. The election of a progressive government represented a turning point for the coal regions not only due to the closure of most mines and thermal power plants but also as regards the design of new institutional arrangements, including the just transition agency and plans for these regions. Finally, whilst the demolition of the coal-fired plant towers had quite a dramatic symbolic effect upon the local population of Andorra, it is also true that the actual development of renewable energy projects has succeeded in overriding some of the negative effects on the local population.

In this context, in order to overcome and *move from both old and new resistance identities to sustainable project identities*, local populations may also need to be able to create their own visions about the kind of systemic change they wish to enact; which kinds of feasible economic alternatives they can play an active and creative role; who needs to be empowered and equipped with the required transformative capacities and how; and how local agents can get a sense of ownership of their futures in order to implement their own pathways of solutions towards decarbonisation. For that to occur, further strategic and institutional capacities still need to be built, particularly in the interface of the public, science and policy, to ensure that such transformations are sufficiently engaging and meet both efficiency and equity criteria in all their multiple dimensions.

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Narrative-Network Dynamics in Tipping Processes Towards Low-Carbon Energy Futures: The Case of Indonesia

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Abstract Deliberate actions by social networks and their transformative visions can generate the necessary conditions for the emergence of positive tipping points towards sustainability, such as those that create qualitative, structural changes in sustainable development goals. However, there is a need for more empirical research conducted in non-Western countries to assess these complex processes. In this research, we customised Integrated Sustainability Assessment (ISA) and combined it with participatory narrative analysis, social-ecological network analysis and Q-methodology to capture the transformation processes in social network structures with their guiding visions in two coal- and carbon-intensive regions (CCIRs) of Indonesia: Banten and Bali Province. Our research approach tracked transformation narratives and visions and their associated network dynamics and showed that they could be used as *anticipatory social tipping signals (ASTS)* in deliberate transformation-oriented tipping point processes. Our study revealed two guiding visions actors use to guide their transformative actions to change the energy system. Those transformations emphasise (i) governance coordination and (ii) socio-economic diversification. We argue that making explicit the presence of and promoting dialogue among different visions towards sustainability can promote new

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opportunities for mutual learning and transformative strategy building among diverse social networks.

Keywords Southeast Asia · Coal · Electricity · Networks · Visions · Transformation

1 Introduction

The shift from coal and carbon-intensive regions (CCIRs) is challenging, particularly in poorer but fossil-fuel-rich countries like Indonesia, where coal is abundant. As Indonesia's primary export is coal, reducing its dependence on this fossil fuel poses a challenge to the economy (S. E. Hosseini & Abdul Wahid, 2014; Sewandono & Munandar, 2021). However, addressing climate change necessitates swift and systemic changes globally, particularly in regions most intensive in the use of fossil fuels. For these adjustments to occur, it is necessary to understand the conditions and processes that may accelerate deliberated structural changes aligned with climate and sustainability goals. Without one-fit-all solutions, this requires implementing multiple interventions adapted and emerging from local contexts and endogenous capacities, leading to positive tipping points towards sustainability (Tàbara et al., 2018).

Recent literature has highlighted the role of deliberate agency in the social tipping processes. In this regard, social networks and their visions can be understood as key to building the preconditions for the emergence of tipping points because of their ability to mobilise collective actions, catalyse transformative change and promote adaptive capacities in response to change (Folke et al., 2005, 2010; Milkoreit et al., 2018; Winkelmann et al., 2022). Research has revealed that agents communicate and transmit their visions of the future within their networks to produce new joint activities or interventions for change (Markard et al., 2012; Olsson et al., 2014; Winkelmann et al., 2022). In particular, transformative visions explore alternate, desirable, and attainable futures to be shared across agents to trigger systemic changes (Pereno & Barbero, 2020; Tàbara et al., 2018). However, the ways social networks communicate their visions in complex social-ecological systems remain under-researched (S. A. H. Hosseini, 2009; Sayles et al., 2019).

Narrative analysis has emerged as a valuable tool in analysing complex social-ecological systems such as the energy sector (Moezzi et al., 2017). Through narratives, researchers can capture the complex dynamics of coupled social-ecological systems and explore the interactions between social networks and visions (Hahn et al., 2008). Hence, the transformation of dominant narratives can be seen as a prerequisite in any deliberate attempt to change social-ecological systems. This is particularly true when dominant narratives can no longer explain existing realities, or alternative narrative framings challenge prevalent narratives or present hitherto unexplored prospects (Moore et al., 2014).

Capturing the complex dynamics in switching energy systems towards renewables is particularly challenging in low-income countries. Additionally, tracking links between changes in energy narratives and actual structural practices on the ground has yet to be addressed in developing economies like those in Asia (Apfel et al., 2021). This is challenging for research because of the intricate and asynchronous interactions between narrative shifts and social changes. Also, narratives are developed in advance of actual policy measures or adjustments. In complex social-ecological systems such as energy systems, with high uncertainty and multiple outcomes that may be spurred by a single intervention (Papageorgiou et al., 2020; Shen et al., 2022), transformative narratives are often built upon practical and shared experiences from agents who communicate their aspirations and learnings through alternative visions (Hinkel et al., 2020). Pioneering agents generate transformative capacities through these visions via multiple learning networks and feedback loops (Ofoegbu & Ifejika Speranza, 2021). Therefore, the analysis of narratives provides evocative accounts that allow interpretation of the complex cultural processes that involve changes in collective systems of meaning (Geertz, 1973). Such studies can thus be enriched by examining the diverse agents' interactions in their unique cultural and political contexts and explaining transformation within the networks (Emirbayer & Goodwin, 1994).

Such combined analysis of agents' networks and narratives can be especially useful for understanding the possibilities of systemic shifts in the energy sector (e.g., Hermwille, 2016; Judson et al., 2020; Chailleux, 2020). Given the absence of empirical and integrated analysis in non-Western countries, our research investigates how social-ecological networks and agents' visions can serve as anticipatory social tipping signals, building the conditions for the transformation of systems. Our reference system comprises the agents influencing the Indonesian energy sector's policy-making, technological infrastructures, and market innovations. Against this backdrop, we employed a mixed-method empirical approach to examine the transformative visions of key agents and their interactions in two provinces of Indonesia: Banten and Bali.

We first adapted the Integrated Sustainability Assessment (ISA; Weaver et al., 2006) to identify how the agents envision and strategise the future with the needed capacities to transform the energy system. In addition, our methodology included a narrative analysis using the alternative pathways framework proposed by Lieu et al. (2020) and a more specific Q-methodology for exploring the content of their transformative visions (Charli-Joseph et al., 2018; Silaen et al., 2019; Nieuwenhuis et al., 2022; González-González et al., 2023). Social Network Analysis (SNA), with the region as the ecological boundary, was also employed to track agent structure dynamics (Devisscher et al., 2017; Froehlich et al., 2020). We hypothesised that the use of qualitative and quantitative SNA could constitute a useful tool to assess and anticipate possible social 'thresholds' of transformative change or tipping points and, in this manner, how agents' interactions may help to anticipate potential cascades of positive change or have telecoupling effects on other networks (Franzke et al., 2022; Froehlich et al., 2020). Although SNA is commonly used to map human nodes, it is limited to tracking social-ecological interactions. Given that we recognise the energy sector as part of social-ecological systems, we enriched the qualitative SNA with the concepts of social-ecological networks and nodes (Janssen et al., 2006).

2 Banten and Bali as Coal- and Carbon-Intensive Regions

Indonesia is one of the largest emitters of greenhouse gases. Yet, the country is seemingly moving towards a high-intensity development pathway by relying on fossil fuels (e.g., coal, oil). Such a business-as-usual policy route is particularly visible in the two contrasting provinces of Banten and Bali. Due to their unique energy challenges and renewable energy potential, Banten and Bali provinces make good energy case studies to explore the narrative and agent-network preconditions for structural change (Fig. 1).

Banten Province is known as an economic hub. It is home to about 12.9 million people and thousands of medium and large industries (Rahayuningsih, 2017), such as coal-fired power plants, petrochemicals, and steel production plants. In contrast, Bali Province is recognised as the leading tourist island in Indonesia. As a top tourist destination, the highest energy demand comes from tourist activities (e.g., accommodation, food, transportation). Banten and Bali are connected through an electricity grid in which 50% of the electricity generated in Banten is distributed to the remainder of Java and Bali. Almost half Bali's electricity demand is supplied from Java through a sea cable. The electricity from Banten usually acts as *regional balance*[1] in western Java in addition to securing overall Java-Bali's electricity provision, especially during peak hours.

Indonesia's energy sector is organised by national and local governments and non-governmental, corporate and intergovernmental entities that encourage sustainable development initiatives. At the national level, the government sets national energy policies, regulates power plant operations, and promotes renewable energy sources. The Ministry of Energy and Mineral Resources (MEMR) oversees the country's exploration and extraction of natural resources and developing energy infrastructure. PLN (Perusahaan Listrik Negara)—the state-owned electricity company—is responsible for generating, transmitting, and distributing electricity to the country. As such, the company plays a significant role in implementing national energy policies, together with private generating companies.

At the provincial level, the roles of local government in regulating the energy sector can vary from province to province. However, some common responsibilities of local governments are promoting clean energy sources, ensuring the availability of reliable and affordable energy, and regulating the exploration and extraction of natural resources within their jurisdiction. The responsibilities of MEMR in each

[1] According to RUPTL by PLN (PLN, 2020), regional balance is a situation where the electricity demands of a region are met mostly by the generators in that region and do not depend much on power transfer from other regions through interconnecting transmission lines. Banten is one area that achieves regional balance in western Java in addition to securing the reliability of the JAMALI interconnection grid.

Fig. 1 Location of two regions under study

province are carried out by the local government body, Dinas Energi dan Sumber Daya Mineral (ESDM) or the Agency of Energy and Mineral Resources. For instance, affairs related to the energy sector in Banten are coordinated by the Energy and Mineral Resource Agency (ESDM-Banten) in collaboration with the district down to the local village government. The same pattern applies in Bali (i.e., ESDM-Bali).

3 Approach and Methods: Adapted Integrated Sustainability Assessment

The ISA procedure encompasses the following stages: Scoping, Visioning, Experimenting and Evaluating. As a first step, we adapted the general four-stage participatory integrated sustainability assessment (ISA; Weaver et al., 2006) approach to achieving the research objective. We applied network analysis and Q-methodology to examine agents' interactions and visions in the ISA phases (Fig. 2). The narrative analysis comprises the alternative pathways framework (Lieu et al., 2020) and a Q-methodology analysis to map out different narratives and explore their content differences. We also used the region as the ecological element, according to Cheruvelil et al. (2017), as a spatial unit that captures regional-scale heterogeneity in ecosystem properties and relationships; in this case, the energy system.

Regarding the research process and interactions with stakeholders informing this research, we first participated in ten webinars on the potential and ongoing Indonesia's energy transformations towards clean energy futures. Attending webinars helped to identify key agents constituting the social system the reference before conducting interviews. From May 2020 to September 2021, 20 pertinent national and local agents in the sector participated in semi-structured interviews[2] and acted as informants. We recorded and transcribed the interviews and the results from

[2] The list of interview questions can be downloaded from here https://www.su-re.co/post/semi-structured-interview-questions

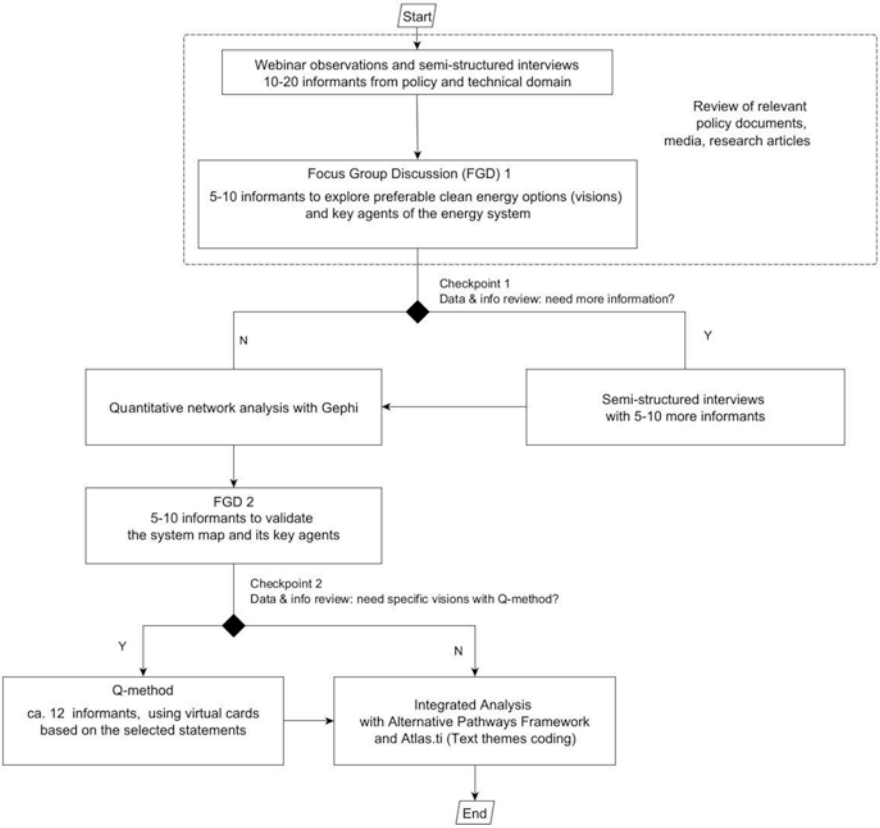

Fig. 2 Research strategy

webinars while keeping the informants' profiles anonymous. Desktop research examined relevant policy documents, media, and research articles. The desk-based review supported participants' data for subsequent phases to reduce bias. The interviewing procedure also followed the stages suggested by Weaver et al. (2006):

(i) *Scoping*: to understand the current situation and energy system and its related challenges in Banten and Bali
(ii) *Visioning*: to explore views of the future guiding the pertinent agents in transforming the current system,
(iii) *Capacity and Network Assessment*: Comprehend the agents' capacities and network dynamics in mobilising the energy sector toward clean energy futures.
(iv) *Strategy-building:* to identify what kind of potential tipping interventions for the emergence of positive social-ecological tipping points (SETPs) towards clean energy in these CCIRs are being mentioned by key agents.

The next step in the first phase was conducting the first focus group discussion (FGD) to validate the transformative visions and the key agents. A checkpoint was suggested at the end of the first phase. Using a snowball approach, the first checkpoint assessed whether the obtained information and networks were sufficient to answer the research questions. The focus at this stage was to identify information on the transformative visions and to map out all key agents and their interactions in the energy system.

A second phase began with the implementation of additional semi-structured interviews to perform SNA within social-ecological networks or SEN. In this phase, 'Checkpoint 1' was used to ensure that valuable information on the agents' networks was not missing. At this stage, additional interviews were not conducted as the agents' interactions included diverse interactions from policymakers, private companies, and communities. Since the identified network was not considered sufficiently complex (<150,000 nodes), we conducted SNA with Gephi (Akhtar, 2014). Gephi is a free and open-source programme for visualising and studying massive network graphs such as social networks (Bastian et al., 2009). Before calculating the network characteristics with the degree of centrality, we listed the agents' capacities according to human-made resources and their regional operation. Subsequently, we deployed the concept of region according to Cheruvelil et al. (2017) to capture regional-scale heterogeneity in energy system dynamics as an ecological boundary. The region component also functions to locate agents' presence according to their authority (Avelino & Rotmans, 2009). Furthermore, we utilised two characteristics of the social networks of interest that Janssen et al. (2006) suggested can be regarded as tipping elements—they can undergo abrupt and irreversible changes in response to small perturbations—for tipping points: level of connectivity and level of centrality. The level of connectivity has two domains: the links' density and the networks' reachability: high density implies high reachability (Janssen et al., 2006). The level of centrality indicates nodes in the network with significantly higher-than-average links. We used Gephi 0.10.1 to examine the agents' networks (without a dynamic approach; Bastian et al., 2009).

'Checkpoint 2' involved assessing specific and shared transformative visions among the agents regarding sustainable futures in the Indonesian energy sector. If semi-structured interviews and FGDs are sufficient to capture the shared visions among the agents qualitatively, Q-methodology can be neglected. Otherwise, Q-methodology is the choice—a statistical method for analysing conflicting discourses around certain topics based on Z-score and eigenvalues. During the Q-methodology exercise, participants virtually sorted statements (see Table 1) on cards into columns ranging from −3 (high disagreement) to +3 (strong agreement): see Fig. 3. Before performing discourse analysis with Q-methodology, we selected several experts and pertinent agents to reduce redundancies and prioritise the relevant statements. Ken-Q—a software tool for conducting Q-methodology analysis online—was used to perform the analysis (Yang & Xu, 2021). A degree of agreement and disagreement for each statement was determined using the Z-score, which allows comparison of the scores of different statements across different visions. The unit of Z-scores is the standard deviation. For example, a statement with a z-score of −2.0 is two standard deviations below the distribution's mean. Finally, eigenvalues determine vision pluralism among agents: a higher eigenvalue indicates that a

Table 1 List of Q-statements[a]

Q statement No.	Description of Q statements
1.	Policy turbulence and technological barriers are the most challenging issues in energy transformation towards clean energy.
2,	Due to their intermittency, the great challenges in solar and wind uptake include storage technology and transmission and distribution infrastructure.
3.	Solar, wind, biogas and biomass are for decentralised and remote electricity systems.
4.	Solar energy can replace the old and inefficient fossil fuel power plants (i.e., oil and coal)
5.	The key agents at the regional level are national and local governments to implement energy transformation.
6.	The citizens can be the agents of change in the collective mode in deciding clean energy adoption (related to social acceptance and communal funding)
7.	The government should be more committed to implementing clean energy transformation with its enabling policy and regulations.
8.	The Government should consider fiscal incentives (e.g., subsidies and tax incentives) for accelerating renewable energy.
9.	Renewable investment from the business and industry sectors is crucial to transforming the coal and carbon-intensive regions combined before policy intervention.
10.	NGOs, village-owned companies and cooperatives are the key agents to ensure the implementation of renewable uptake at the local level.
11.	The role of the young generation is crucial for wide clean energy awareness.
12.	The tipping point towards clean energy also depends on fossil fuel availability.
13.	Clear visioning and targeting in energy transformation accelerate clean energy uptake. Hence, a more ambitious target is needed.
14.	Leadership is an important attribute owned by individual agents or collective agents.
15.	International pressure and support can accelerate Indonesia's energy Transformation towards clean energy.
16.	Overdevelopment in forest areas and the high cost and risk of exploration are the main concerns in geothermal development.
17.	Hydrogen is separate from the energy transformation towards clean energy in 10–20 years due to its high cost.
18.	The Law (Undang-Undang) is the preferable policy intervention to ensure the resilient energy transformation towards clean energy.
19.	The Government Regulation (*Peraturan Pemerintah*) is the minimum requirement to corroborate the position of the hub agent.
20.	Unfavourable and bureaucratic process for renewable operating permit hinders renewable uptake.
21.	Innovation in multiple sectors is crucial to change the regime system. However, policy innovation is essential to enable market growth.
22.	Energy affordability and access are preferable to the concern regarding climate change impacts.

Table 1 (continued)

Q statement No.	Description of Q statements
23.	Capacity building for financiers regarding clean energy uptake is important.
24.	If we only depend on the state budget, it is almost impossible to achieve clean energy. Thus, the private sector and banks are vital for energy transformation.
25.	Migration brings a paradigm shift regarding the importance of energy transformation towards renewable.
26.	Research and reliable data are required to increase the technology and social readiness for renewable energy implementation.
27.	Knowing the importance of clean energy is crucial in determining social acceptance of clean energy uptake.
28.	The pandemic forces the community to be prosumers in generating their energy (i.e., back to nature), for example, by using rooftop solar technology.
29.	The carbon market is one of the triggers for renewable investment.
30.	Engaging the indigenous (local) people with a good philosophy supports the preservation of nature, and they hold an important role in the social movement towards clean energy transformation at the local level.
31.	Under the scenario of energy transformation towards clean energy, coal should be used for downstream activities, e.g., the production of Dimethyl Ether for cooking.

[a]The statements were presented in Indonesian language during the Q-methodology exercise

Fig. 3 Q-sort grid

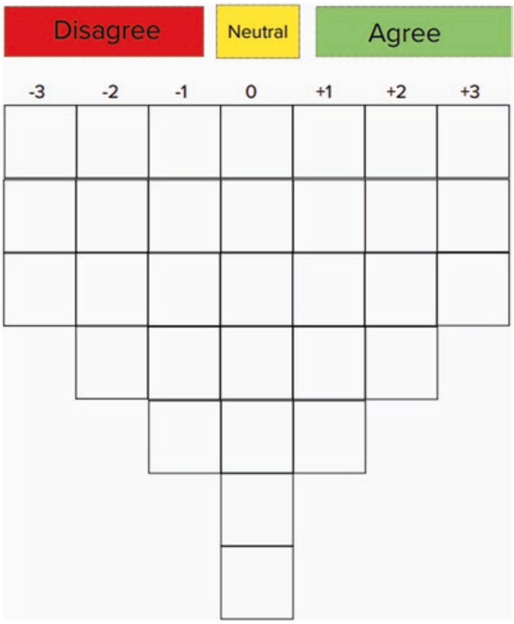

Table 2 List of coding categories to identify transformative visions and the networked agents

Coding Category	Description
Types of human agents	International agencies, government, private companies, state-owned enterprises, civil society, non-governmental organisations (NGOs), financiers, universities/research institutions, policy advisors
Ecological nodes	The natural resources for electricity generation include fossil fuels, land, geothermal, solar, and water (Janssen et al., 2006) and region (Cheruvelil et al., 2017).
Transformative narratives or visions	Narratives that imply "where we want to go" and offer solutions to get there (Hinkel et al., 2020)
Tipping interventions	Farmer et al. (2019) and Otto et al. (2020) refer to deliberate actions that can cause multi-level qualitative changes from the respective agents in an energy transformation context involving social-economic and technological components.

perspective accounts for more data variance and offers a distinct view. A factor or perspective with eigenvalues <1 is usually ignored (McParland et al., 2011).

The Alternative Pathways Framework approach (APF; Lieu et al., 2020) was first used to position agents' general narratives of current and future energy systems collected from semi-structured interviews and FGDs. The Atlas.ti software was used to classify the collected insights to place narratives based on categories: types of human agents, ecological nodes, transformative visions, and tipping interventions (Table 2). Subsequently, the features of future narratives were specified with Q-methodology. APF looks at the mainstream and alternative narratives, where the latter can be characterised as on-stream, off-stream and transformative. The mainstream narrative depicts the dominant energy system, while the alternative narratives operate with different natures from the mainstream system. According to Lieu et al. (2020), the on-stream narrative occupies a niche within the mainstream but does not challenge the regime. Off-stream narratives represent niche clean energy technologies. Transformative narratives encompass radical technological innovations and fundamentally new ways of reorganising the socio-energy system. In Q-methodology, the features of transformative visions were explored beyond technological change. For example, key agents are initiating new political structures and modes of social-ecological interactions aligned with sustainability (a positive tipping point).

4 Results: Narratives-Network Dynamics of Current and Future Energy Systems in Indonesia

We summarise the different perspectives identified from agents' interactions and desktop research into mainstream and alternative narratives as follows:

4.1 Mainstream Narratives

The mainstream narrative emphasises the significance and continuation of oil and coal as the main primary energy sources. The background of this narrative is that before resource depletion made the nation a net importer in 2004, oil was considered the national energy backbone (Asia Pacific Energy Research Centre, 2016, p. 48; Iswahyudi, 2016). Indonesia then prioritised coal to meet rising energy needs, and Banten and Bali were no exception. For instance, the electricity demand of Banten Province is mainly supplied by coal-fired power plants (approximately 19 units owned by PLN and private companies). Moreover, the region ranks first in the country in installed coal-fired power plants (MEMR, 2020). Similarly, Bali has seven power generation plants that are fossil-fuel-based. The energy demand in Bali mainly comes from tourism and agricultural activities. Since the energy demand is higher than the supply capacity, Bali imports electricity from Java. Thus, coal is currently the dominant fuel for the Java-Bali system, as depicted in Fig. 4.

Regarding the agents, the policy system at the national level is actively governed by the Ministry of National Development Planning (Bappenas) and MEMR. In addition to private enterprises, PLN (a state-owned power company) implements and maintains the nation's electricity sector. Although private enterprises can only produce and sell electricity to PLN, PLN controls most electricity supply, transmission, and distribution. On the other hand, PERTAMINA oversees both upstream and downstream activities in the Indonesian oil and gas sector. These agents are commonly mentioned in the literature and interviews as crucial players in the sector to

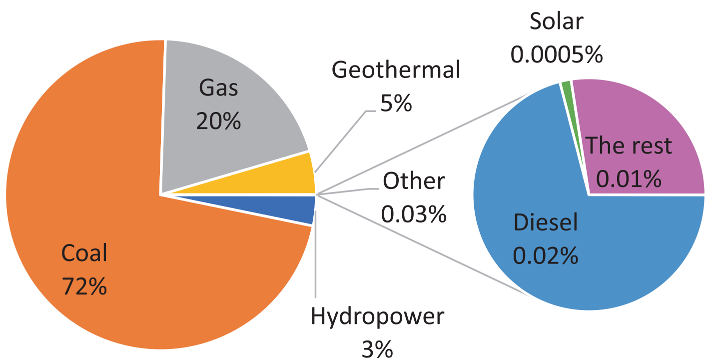

Fig. 4 Electricity Mixes of Java-Bali Interconnection in 2018 (BPS Indonesia, 2020)

trigger a systemic transformation towards sustainability (e.g., Maulidia et al., 2019; Setyowati, 2020; Shojaeddini et al., 2019).

Current energy policies allow lush fossil fuel growth that aims to provide 100% electrification. The national energy policy (Government Regulation No. 79/2014) emphasises energy conservation, oil reduction, renewable use, gas optimisation, and coal as security. This implies coal still occupies a fundamental position in the country's electricity system, including the regions of Banten and Bali, until 2030, as reported by Perusahaan Listrik Negara or PLN (2021).

4.2 Alternative Narratives

4.2.1 On-stream Narrative

The on-stream narrative argues for using natural gas as an alternative to coal to lessen oil dependency and address problems with air pollution. This narrative also describes several lower-carbon solutions, such as co-firing coal power plants with biomass, clean coal technologies/CCT (i.e., supercritical and subcritical boilers) and hybrid systems (i.e., clean energy coupled with diesel). The Indonesian government intends to build nuclear power plants in the future, but this is still subject to feasibility studies. Some power plants in Banten and Bali have already started using such suggested on-stream technologies. There are two coal power plants in Banten using CCT (about 2600 MW out of 8494 MW). With the central government and PLN (state-owned electricity company), Banten's local government plans to use up to 5% biomass in co-firing mode at the province's coal power plants. On the other hand, Bali only uses natural gas, supplemented by diesel power plants during peak hours. Also, the province imports additional electricity from Java Island (PLN, 2021).

4.2.2 Off-stream Narrative

The off-stream narratives emphasise the growth of clean energy. The off-stream narrative suggests hydropower, geothermal, solar, and wind have undiscovered potential in Indonesia. PLN amended its 2021–2030 electricity supply business plan (RUPTL) to include 51.6 per cent renewables by 2030. This shows PLN's commitment to diversifying the country's electrical system, including the Banten and Bali Provinces. At the provincial level, Bali and Banten's local governments perceive that solar energy has a promising potential to transform into clean energy in the electricity system. ESDM Banten and PLN also intend waste-to-energy, geothermal, bioenergy, and micro-hydro power. The Bali government noted that micro-hydro is practical but difficult because it often negatively affects tourism destinations. However, Banten private enterprises reported that "greener" approaches are poorly communicated, and some "green" initiatives are voluntary. In contrast, more inclusive interactions were observed among agents in Bali Province. The Bali government actively collaborates with green companies, NGOs, universities, and research institutions for collective actions.

4.2.3 Transformative Visions

Transformative narratives or visions are not only about energy transitions. They also include other socio-economic, political and cultural aspects of the kinds of relationships that agents wish to have in their interactions with ecological systems. In the case of Indonesia, transformative narratives are related to critical issues like women's empowerment and access to education, the democratisation of governance arrangements, providing a voice to social movements (Temper et al., 2018) and, more broadly, the achievement of the UN Sustainable Development Goals (SDGs). Developing resilient local socio-energy systems can contribute to local and global climate mitigation and adaptation.

The study generated two *factors* or perspectives on who could be involved in developing the socio-political conditions for the emergence of positive tipping points in these regions based on z-scores from Ken-Q analysis (see Table 3). These two perspectives elucidated the variance between the participants' views (Fig. 5). They revealed two guiding visions towards clean energy futures: (i) transformations emphasising governance coordination and (ii) transformations focusing on economic diversification.

Vision 1: "Governance Coordination"
Vision 1 (V1) underlined that a systemic change in the country required the interventions of government and international agencies to enable clean energy (e.g., carbon tax) because of its authority and resources to do so. Most participants agree that the government and international agencies are the tipping agents. Given their

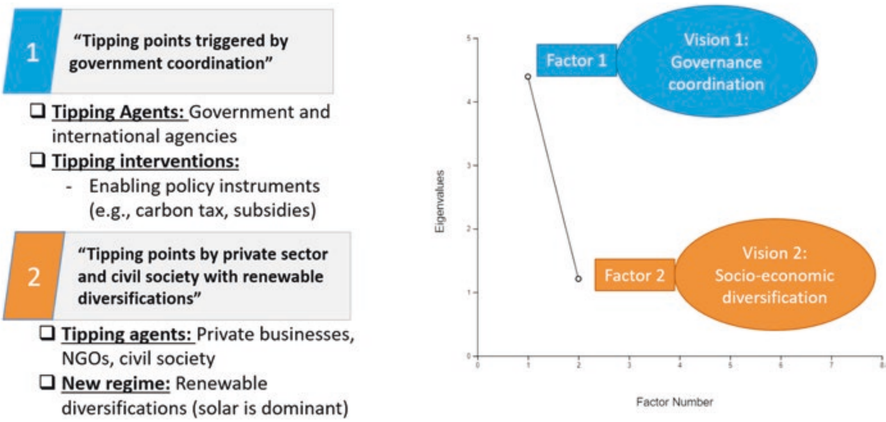

Fig. 5 Results of the Q-method on the perspectives on transformative narrative towards clean energy in Banten and Bali

authority and resources, these agents would build conditions for enacting deliberate systemic tipping points. Many participants, including private companies and NGOs, opined that the existing policies still promote mainstream narratives that hinder the development of technology for renewables. For instance, Banten private enterprises await government directives to replace business-as-usual. However, some private companies in Bali recognise the Bali government's objective of clean and green energy as a "green light" for clean energy investment.

Vision 2: "Socio-economic diversification"
Vision 2 (V2) favours tipping points triggered by agents other than government agencies. In this perspective, private firms, universities/research institutions, NGOs, and civil society must collaborate to spark local systemic change, rather than relying on the government. This group promotes non-governmental agents and more polycentric approaches to energy governance to build sufficient human resources and capacities to enable sustainable transformations. Private companies are often seen as the innovation sources that make new technologies more competitive. NGOs and universities or research institutions are important as the bridging agents between the government and society to endow them with adequate knowledge and sustainability awareness. This perspective promotes the diversification of renewable energy from solar, wind and bioenergy, particularly in decentralised and remote areas. It also envisions a more complex socio-economic structure and decision-making processes. For example, private firms install solar panels for community use and to facilitate economic diversification.

4.3 Narratives within Social-ecological Networks of the Indonesian Energy System

The network of relevant agents in the Banten and Bali Province's energy sector is derived from interviews and focus group discussions. From their perspectives, we positioned the agents according to which narratives they were promoting (See Figs. 6 and 7). Government agencies such as BAPPENAS, PLN, PERTAMINA and local governments advocate fossil fuels and renewable energy, placing them between the Mainstream and Alternative narratives.

By deploying degree centrality with Gephi, we identified the potential agents that could steer the current system toward sustainability, given their connectivity. The networks centre on MEMR and PLN (see Figs. 8 and 9). Using regions as the ecological element for agents' authority and the resource flow of energy, the results highlighted the key roles of PLN, local governments (ESDM Banten and ESDM Bali), and civil society.

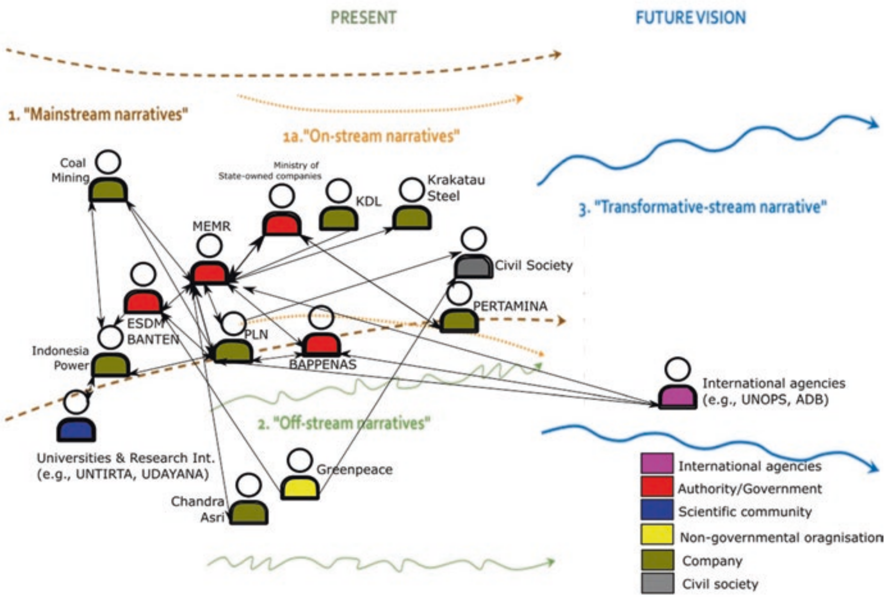

Fig. 6 Narrative position within agents' network in the energy sector in Banten based on APF

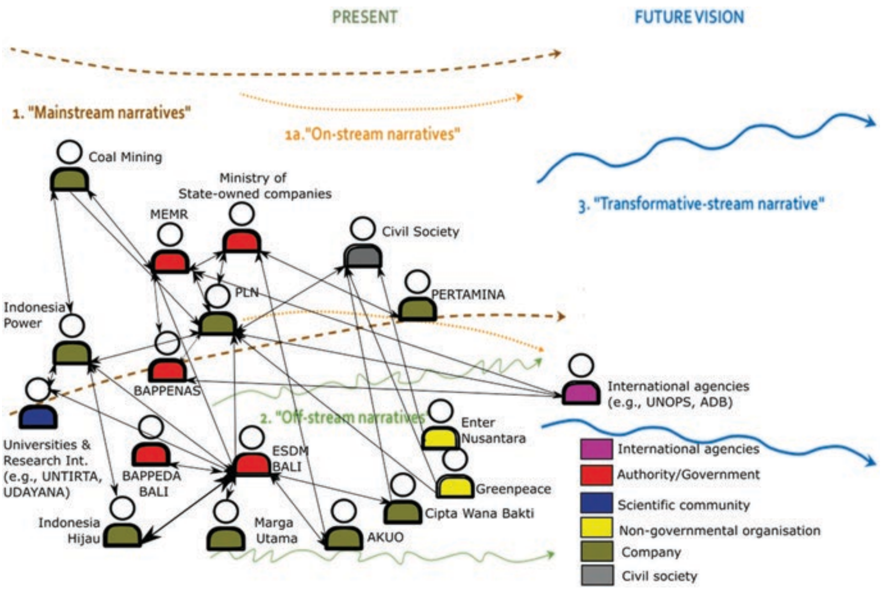

Fig. 7 Narrative position within agents' network in the energy sector in Bali based on APF

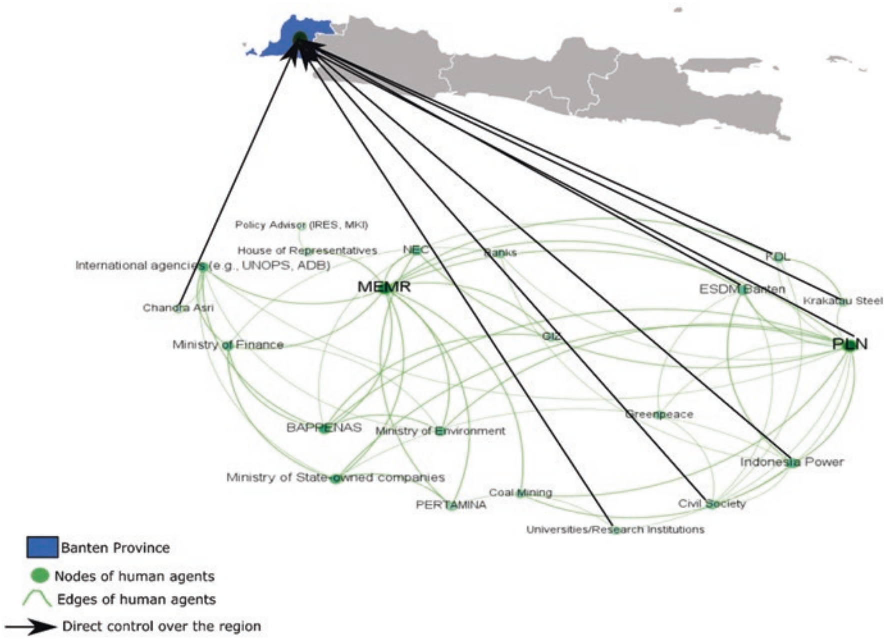

Fig. 8 The social-ecological networks for energy operationalisation in Banten

5 Discussion: Network Dynamics and the Diffusion of Transformative Visions

Our study looked at the role of narratives and network configuration in creating the cognitive policy and social conditions for tipping systems toward desirable, sustainable futures. We conducted discourse analyses with SNA (with an ecological element) to check to what extent agents' actions and visions could serve as components of anticipatory social tipping signals for positive tipping points. The Banten and Bali case studies indicated that narratives take time to become actions and create the conditions for transforming social-ecological structures, whilst some narratives may fail to influence reality. Social-ecological network analysis also revealed that some significant agents in the network were central to shifting narrative discourses and energy policies. These results offered two visions that, by making them explicit and allowing them to be discussed, could help mutual learning among different networks.

Most interviewees agreed that renewable diversification is feasible in Indonesia in the future, yet transformative visions about sustainable futures take time to ensure systemic changes. As noticed by other studies (such as Lenton et al., 2022; Pereno & Barbero, 2020; Tàbara et al., 2018), large systemic changes occur due to the interplay of actions at different scales. Understanding tipping dynamics at lower

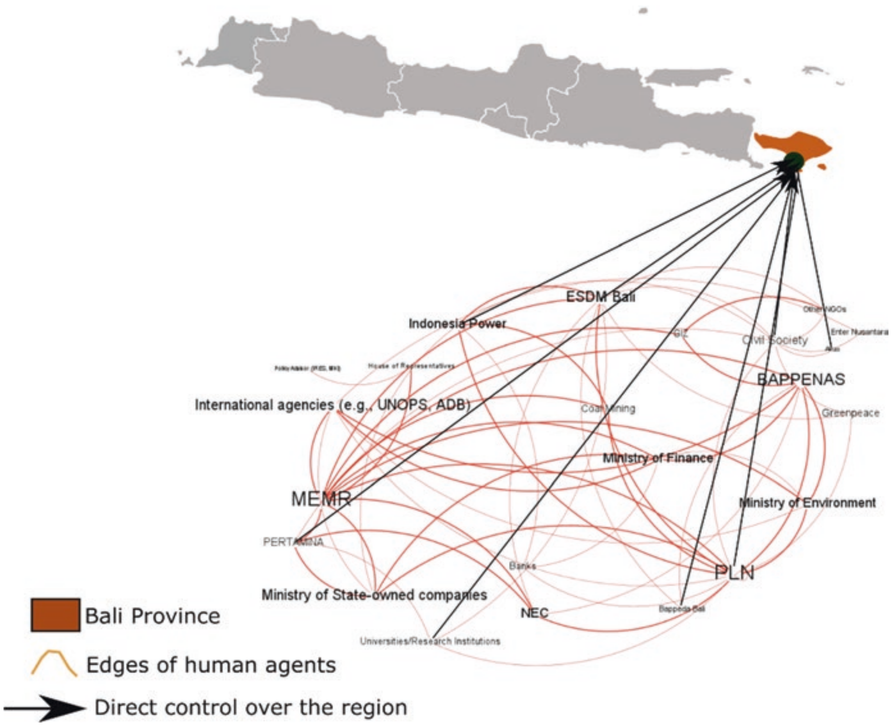

Fig. 9 The social-ecological networks for energy operationalisation in Bali

scales, such as communities, may serve as social anticipatory signals of tipping points, either positive or negative, that may occur in larger social-ecological configurations (Gangwal et al., 2020; Lenton et al., 2022; Tàbara et al., 2018). For instance, NGOs like the Indonesian Renewable Energy Society (IRES) and Greenpeace bridge government and communities according to their Vision 1 to influence the governments' narrative position towards off-stream technologies. Therefore, mapping how different agents learn and interact across scales is crucial to understanding positive tipping points' potential and complex dynamics.

Whilst transformative visions alone may not be sufficient to trigger and consolidate change, we argue that the different configurations of network structures play a crucial and differentiated role in enacting systemic change. Targeting specific nodes or subgroups in the networks that contribute simultaneously to narrative building and policymaking can be extremely effective in knowing where to target actionable tipping interventions. For example, most agents driven by Vision 1 aim to interact with the government in amending the government's narrative position from mainstream to off-stream technologies. Other international organisations are also increasingly playing a role in the socio-energy network configuration, as is the case of the assistance from the United Kingdom for constructing a dam and hydropower plant in the Buleleng Regency, Bali (Investor Daily, 2019). Another example is that the proportion of clean energy in Banten's electricity rose to 5.9% according to Local Regulation of Banten No. 7/2022 when PLN moved towards clean energy deployment, given its access to human-made resources and direct control over the region (Banten Local Government, personal communication, 2021).

At the same time, other weak-tie agents in the social energy network, such as civil society organisations and small businesses, are also important, albeit performing different functions in the energy transformation processes. Some private companies with Vision 2 in both provinces are beginning to deploy clean energies despite the absence of local directives. For instance, one company in Banten disclosed that their green initiatives were voluntary and contributing to national GHG reduction pledges. Ultimately, SNA with ecological elements helped identify a centrality approach over a concrete region and its power dynamics to trigger or hinder change.

This study also demonstrates that the analysis of narrative-network dynamics can constitute an appropriate methodology to identify anticipatory social tipping points (ASTS) that create the previous conditions of systemic change, new opportunities for mutual learning and joint transformative strategy building among diverse social networks. The energy sector is projected to change rapidly and systemically if agents with different visions can collaborate (Pereira et al., 2015). Understanding these complex socio-economic and political processes is paramount in non-Western countries with vast amounts of fossil fuels like Indonesia. For instance, agents that aim to influence the government (Vision 1) could utilise best practices such as private sector installation of clean energy sources to influence the mainstream narrative of governmental agencies. A shift from the mainstream to the off-stream narrative can signal positive or negative tipping points before interventions, such as policies favouring renewable diversification (off-stream narrative) through carbon pricing or subsidies.

6 Conclusion

Using participatory discourse analyses and social-ecological network analysis, our study looked at the role of narratives and network configuration in creating the conditions for tipping systems toward desirable sustainable futures. Discourse and network analyses are used to check to what extent the actions and visions of agents in networks can serve as components of anticipatory social tipping signals for positive tipping points. The Banten and Bali case studies revealed that transformative visions of sustainability can inspire positive tipping points. Still, time and effort are required for narratives to become actions and change social-ecological structures. Furthermore, not all narratives successfully influence the conditions leading to transformative changes. Through network analysis, it was possible to discover some key agents within the networks that could be identified as having a centrality position in changing narrative discourses and energy policies. These results also offered two kinds of visions that, if combined or reconciled, may help mutual learning among different networks.

Most interviewees agreed that renewable diversification is feasible in Indonesia, but transformative visions of sustainability do not ensure instant systemic changes. Precedent studies showed that large systemic changes result from the interplay of actions at different scales. Tipping dynamics at lower scales, such as in communities, can indicate potential tipping points in larger social-ecological systems, either positive or negative. For example, local actions like Indonesia's micro-hydro and geothermal energy can lead to rapid and systemic changes in the national energy sector if combined with other small-scale actions. Therefore, it is important to map the role of multiple learning networks and feedback loops by all relevant agents at different scales to understand the possible emergence of positive tipping points. Whilst transformative visions alone may not be sufficient to trigger and consolidate change, we argue that the different configurations of network structures affect in various and, in some cases, complementary ways the building of conditions for systemic change. Targeting specific nodes or subgroups in the networks that contribute to narrative building and policy-making simultaneously can be an effective approach to knowing where to target actionable tipping interventions. In this case study, social network analysis with ecological elements helped identify a centrality approach over a concrete region and the power dynamics to trigger- or hinder-change.

With discourse-network analysis, the case studies showed that PLN and MEMR were powerful national agents, yet their discursive positions were still halfway between mainstream and off-stream narratives. These findings imply the importance of empirically tracking social network dynamics and the benefits of a mixed-method approach with modified ISA to assess their relationships by constructing alternative, transformation-oriented narratives. The results also underlined the need to consider the views of weak-ties agents such as civil society organisations and private companies operating at lower scales, given their direct and key participation in achieving broader social and sustainable development goals at the regional levels. Therefore, this study suggests that narrative-network dynamics may serve as *anticipatory social tipping signals* (ASTS) in socio-energy systems to learn from each other and develop transformative strategies.

Nevertheless, this research also acknowledges two important limitations: first, the social networks were observed at a certain time, so their long-term effects on broader structural dynamics cannot be fully assessed. Second, this study only focused on one ecological element, the energy flows and resources of the selected regions. Empirical research may need to explore other biophysical components and interaction features to obtain a more comprehensive view of social-ecological agents and tipping dynamics.

Appendix

Table 3 Q statements and their z-scores

Statement No.	Statement	Z-score	
		Factor 1	Factor 2
1	Policy turbulence and technological barriers are the most challenging issues in energy transformation towards clean energy.	1.56	−1.16
2	Due to their intermittency, the great challenges in solar and wind uptake include storage technology and transmission and distribution infrastructure.	0.69	1.2
3	Solar, wind, biogas and biomass are for decentralised and remote electricity systems.	−1.11	1.62
4	Solar energy can replace the old and inefficient fossil fuel power plants (i.e., oil and coal)	0.47	0.2
5	The key agents at the regional level are national and local governments to implement energy transformation.	0.09	1.47
6	The citizens can be the agents of change in the collective mode in deciding clean energy adoption (related to social acceptance and communal funding)	0.9	0.86
7	The government should be more committed to implementing clean energy transformation with its enabling policy and regulations.	2.15	−1.38
8	The Government should consider fiscal incentives (e.g., subsidies and tax incentives) for accelerating renewable energy.	1.7	0.38
9	Renewable investment from the business and industry sectors is crucial to transforming the coal and carbon-intensive regions combined before policy intervention.	−0.19	0.59
10	NGOs, village-owned companies and cooperatives are the key agents to ensure the implementation of renewable uptake at the local level.	−0.36	1.53
11	The role of the young generation is crucial for wide clean energy awareness.	0.79	0.74
12	The tipping point towards clean energy also depends on fossil fuel availability.	−1.5	−1.68
13	Clear visioning and targeting in energy transformation accelerate clean energy uptake. Hence, a more ambitious target is needed.	1.01	−1.96
14	Leadership is an important attribute owned by individual agents or collective agents.	0.53	0.55
15	International pressure and support can accelerate Indonesia’s energy Transformation towards clean energy.	0.83	−0.4
16	Overdevelopment in forest areas and the high cost and risk of exploration are the main concerns in geothermal development.	−0.88	−0.22

(continued)

Table 3 (continued)

Statement No.	Statement	Z-score	
		Factor 1	Factor 2
17	Hydrogen is separate from the energy transformation towards clean energy in 10–20 years due to its high cost.	−0.87	0.73
18	The Law (Undang-Undang) is the preferable policy intervention to ensure the resilient energy transformation towards clean energy.	−0.01	−0.87
19	The Government Regulation (*Peraturan Pemerintah*) is the minimum requirement to corroborate the position of the hub agent.	−0.32	−0.31
20	Unfavourable and bureaucratic process for renewable operating permit hinders renewable uptake.	0.02	−1.04
21	Innovation in multiple sectors is crucial to change the regime system. However, policy innovation is essential to enable market growth.	−0.24	−0.34
22	Energy affordability and access are preferable to the concern regarding climate change impacts.	−1.03	0.16
23	Capacity building for financiers regarding clean energy uptake is important.	0.44	0.28
24	If we only depend on the state budget, it is almost impossible to achieve clean energy. Thus, the private sector and banks are vital for energy transformation.	0.31	1.14
25	Migration brings a paradigm shift regarding the importance of energy transformation towards renewable.	−1.31	0
26	Research and reliable data are required to increase the technology and social readiness for renewable energy implementation.	0.79	1.17
27	Knowing the importance of clean energy is crucial in determining social acceptance of clean energy uptake.	−0.17	−0.28
28	The pandemic forces the community to be prosumers in generating their energy (i.e., back to nature), for example, by using rooftop solar technology.	−1.99	−0.65
29	The carbon market is one of the triggers for renewable investment.	−0.26	−1.6
30	Engaging the indigenous (local) people with a good philosophy supports the preservation of nature, and they hold an important role in the social movement towards clean energy transformation at the local level.	−0.36	0.15
31	Under the scenario of energy transformation towards clean energy, coal should be used for downstream activities, e.g., the production of Dimethyl Ether for cooking.	−1.64	−0.87

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Situated Knowledge and Energy Transformations: A Socio-Anthropological Exploration

Elena Apostoli Cappello

Abstract This chapter focuses on San Pietro island case study and uses an ethnographic, micro and qualitative approach. San Pietro island is facing Sulcis, the southwestern corner of the Sardinia, a region of coal-mining and industrial vocation currently involved in a challenging energy transition. San Pietro local residents claim their ethnic difference as descendants of the eighteenth century settlers from Liguria. Today, contrary to Sulcis, the island benefits from several EU grants aiming to improve energy efficiency and renewables. I explore if the orientation of the community towards a shared idea of its past and future could be a determining factor in triggering a positive and stable tipping point towards decarbonization. I use energyscape framework to understand the spatial dimension and ethnography to explore local imaginaries on renewables as context for examination of social agency. I find that the attempt at deep transformations driven by policy plans may experience implementation difficulties, since local residents' futures and horizons do not align to the timescales, worldviews on humans or technology, or many other dimensions and narratives arriving "from outside" the community.

Keywords Ethnicism · Energyscape · Ethnography · Sardinia · Imaginaries · Agency · Renewables

1 Introduction

The case study focused here is located in a region, Sulcis, involved in the Just Transition Mechanism. This mechanism targets the regions of the EU regions with the highest carbon intensity and engagement in fossil fuel sectors, aiming among

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others to facilitate employment in transitioning sectors, particularly among vulnerable communities. Given this context, the current chapter reports on a situated ethnographic analysis conducted on the small-island community of San Pietro, just off the southwest shore of the administrative region of Sardinia, itself a larger Italian island. The community of San Pietro is the beneficiary of several EU grants aimed at upgrading energy efficiency in the housing stock, as well as facilitating access to safe, clean energy at affordable prices, and so combatting energy poverty in general. The research objectives are to better understand the sociocultural and community preconditions that could contribute to determining the engagement of local communities in rapid policy-driven energy transition processes, and to explore alternative routes for such developments considering the dimensions of "justice", and the real-world transformation processes already under way. Sociocultural transformations are complex, non-linear processes that need to consider multiple ethnographic dimensions. The specific questions examined are: (i) What are the aspirations, and imaginaries of the local community about its own future? (ii) How are these founded in the existing economic conditions and cultural constructs? (iii) How is "sustainability" understood at the local level? (iv) What margins and opportunities for community social agency? (v) How are official policies, in particular descending from the EU Just Transition Fund, being interpreted by local communities, in terms of advantage or even suffering.

The approach is to explore the roles, perceptions and dynamics of agency at the local level, and from this the ability of communities to participate in decision-making processes at the regional, national, and EU scales, as pivotal elements of just and rapid energy transitions. The research method is to contrast a model of a socially just transition, involving strong engagement of local communities and fostering of their transformative agency capacities, against the exploitive and exclusive model of "business-as-usual", inherent in the production systems of the energy sector as well as other extractive economic sectors, and which, in fact, is often replicated in the current policy energy transition processes (Sovacool et al., 2019). In more detail, the method proceeds through exploration of the **temporal and spatial** horizons, considered here as one of the suitable contexts for examination of **agency**.

2 Anthropological Framework

The ethnographic work reported here is focused on energy transition, in particular on the potential divergences/similarities of projects for green versus carbon-based energy (Sovacool et al., 2019), and how the transitions towards the former may involve the concerns and perceptions (material and discursive) of local communities in regard to their territories. The approach of my ethnographic research, placed within a broader anthropological debate, is to explore the identities materialised in imaginaries of the spatial dimensions of the local territories. Indeed, several now classic anthropological works such as Finney's, of 2014, and others, mostly by American scholars (Cole & Foster, 2020; Ybarra, 2017; Mendez, 2010; Zimring, 2016; Jarratt-Snider & Nielsen, 2020) have examined how distinct socio-cultural groups have understood and "commodified" natural resources, and even the entire environment. These works illustrate how power asymmetries, economic ratios, and issues of race and ethnicity profoundly influence cultural understandings of the environment, and determine who should have access to it and on what terms. In this regard, anthropologists have made significant contributions in developing social theory on the meaning and role of agency, and recognising the multiple expressions of agency, also as indicators of social justice, in socio-ecological transformation processes. The current analysis pursues the classic ethno-anthropological axes of ethnicity, intergenerational relations and gender. Seeing as the communities studied here are involved (in the sense of affected, much more than engaged), at archetypal local level, in the EU processes of "just transition", the aim is then to better understand whether and how the conditions for radical breakthroughs could arise: in particular, what could be margin of agency for the local communities, in these processes?

The cardinal work of Appadurai offers theoretical insights useful to several aspects of the current research, particularly in examining **temporal and spatial** horizons, which are here considered as contexts for examination of **agency**.

This study is situated within the anthropological debate on spatiality, temporality and the scales of different imaginaries of energy futures, as recently illustrated by Abram, Waltrop, Ortar and Pink (2023). The approach accounts for the evolutions in collective narratives about the future and visions of the local dimension of the territory (i.e. the island and its relationship with Sardinia and the rest of Italy), focusing on the abilities and inabilities of local agents in transformation of the economic system, and from a perspective of locally perceived justice in the ongoing and desired transformations.

The anthropological study proposed here, through the analysis of collective systems of meaning located in precise spatial and temporal contexts, contributes to identifying the potential tipping points in the decarbonization processes, illustrating the relative issues of social justice, and to an understanding the cultural and symbolic factors involved in such processes.

2.1 Temporality: Who Owns the Future?

The anthropological contribution to research on tipping point rests on the theoretical conception that cultural systems of meaning go through phases and transformations, which may be hetero- or self-induced. The first phases of research were thus based in the notion of the future understood as a cultural phenomenon (Appadurai, 2013), and as a potentially important cognitive resource with regard to a group's ability to implement projects aimed at transforming their living conditions. This theoretical device enables a focus on social experiences of dispossession, and/or appropriation of individual and group capacities to "aspire". Reading the ethnographic data in this key led to the development of two perspectives, emic and etic, with the relative triggers, breakouts and further dynamics.

In *The Future as a Cultural Fact*, Appudarai proposes an analysis of the temporal category of future as a form strategic adaptation to reality, in a manner interactive with social expectations. In an ethnographic study of an NGO operating in the slums of Bombay, the anthropologist describes what he calls “deep democracy”, or “cosmopolitanism from below”, and the “capacity to develop aspirations”. In articulating these aspects, he is then able to define the future as a cultural fact, developed through planning and intentional design. In this construction, the notion of the future becomes a human right, the right of making choices and building a life project, by first aspiring for things good and better. He contrasts the ethics of probability versus those of possibility, and insists that a genuinely democratic polity must augment the latter.

Embedding this notion of the future, we can better understand how different constructions of the future may be determinant in permitting the existence (or not) of communities compactly oriented towards energy transition projects. The existence of this kind of community-this is a premise of our work-could be a determining factor in triggering a positive and stable tipping point over time. Moreover, the perspective offered by Appadurai could overcome the substantivist-formalist dialectic inherent in economics and economic anthropology, instead proposing a more dynamic approach to the reading of material exchanges and prestige. For this current research on tipping points in systems of cultural meanings, this has meant focusing, at the local level, on the intangible aspects and logics of gifts and counter-gifts in the symbolic and material negotiations concerning pivotal infrastructures in energy transition, at the various levels of household and community photovoltaic panels, the large project of a prototype wind farm, and a proposed very large offshore wind farms.

2.2 Energyscapes

The anthropologist Arjun Appadurai had first introduced “scapes” as a concept useful in the analysis of identity-making processes in a globalised landscape, focusing in particular on the chains and flows of global “cultural transactions”, and the locally situated outcomes of these interactions.

Viewed through the energyscape conceptual prism, energy becomes a dimension inherent in multiple aspects of everyday life, and constitutes a cultural artifact, manifest in different ways in different spatial and temporal arrangements, and in different scales (Strauss et al., 2013, 10–11).

Through application of the notions of energyscapes, in parallel with those such as mediascapes, technoscapes, and finance-scapes, we can better understand how the cultural dimension of energy and the infra-political role of the “energopower apparatus” in building “the experience of modernity” (Boyer, 2015: 352), are intrinsic to societies, technologies, and economies. Within the sub-field of the "anthropology of energy", seminal authors (Loloum et al., 2021; Pink et al., in press) have illustrated the permeating effect of these scapes, and how they intertwine with other dimensions, extending far beyond institutional policies and markets. Again referencing Appadurai's key work, several scholars have recently adopted this scape-centred approach in the anthropological study of energy issues. For example, Lempinen (2019):

> Approaching the regional energy concern and its societal intertwinements as a "scape" indicates that the relations associated with energy are not objectively given or that they "look the same from every angle of vision but, rather, that they are deeply perspectival constructs, inflected by the historical, linguistic and political situatedness of different sort of actors. (Appadurai, 1996, 33).
>
> On the other hand, the way in which the notion of energyscape understands and constructs the energy concern as situated and as a situation is particularly useful, as it does not imply that the content of this energyscape would be the same across different temporal and spatial scales. (Lempinen, 2019: 22)

Referencing the seminal work of Appadurai, Lempinen (2019) and Strauss et al. (2013) I have used "energyscape" as a conceptual prism, concentrating and constructing the energy concern as a situated context and entity. Other authors have applied the concept in interpretative frameworks, among these Smith and High (2017), as a tool in socio-anthropological analysis, and also a number of geographers (Thomas & Erikson, 2021), in addressing the study of energy transitions. Pasqualetti and Stremke (2018) propose a system of classification for "energy landscapes", and more recently Delina (2020) applies the concept in the analysis of dissent narratives developed by indigenous peoples of the Philippines, against large-scale development projects. Oskarsson et al. (2021) use energyscape in the sense of the "coal geography" of energy infrastructure, and the policies enabling still greater exploitation of coal-fired energy in India. Other scholars examine the energyscape as relational space (Roberts & Henwood, 2018). Departing from the cited literature, my study uses the interpretive frame of "energyscape" by integrating with agency understood as the capacity to inhale, as described by Appadurai (2013).

3 Context

The ethnographic study is conducted in the community of Carloforte, sole town of the island of San Pietro, situated six kilometres across from Portoscuso, the nearest community on the main island of Sardinia. Both Caloforte and Portoscuso fall in the south Sardinian area traditionally known as Sulcis, which has long focused on an economy of coal-based, energy production and ore processing. The core industrial area, known as Portovesme, is situated on the outskirts of Portoscuso. The total land area of San Pietro is five square kilometres. Although the registered inhabitants total some 6000, about a thousand of these maintain their homes as second residences, while living and working most of the year elsewhere.

The Tabarkine colony in Carloforte was founded on the basis of a gift from King Carlo Emanuele III of Savoy (Tiragallo, 2015), who awarded each settler two parcels of land: one in Carloforte town and one agricultural. The primary sources reached through field work agreed with the local historian Vallebona (1975), who reports that Carloforte is an island of "parcel owners". This peculiarity may cognitively and politically structure participatory processes on the island, including those of appropriation of the energy transition.

In terms of the implementation and effects of policies on rapid decarbonisation and energy transitions, the micro-insular community of Caloforte is integrally bound into the larger dynamics of the Sulcis Coal and Carbon Intensive Region, of Sardinia as a whole, and finally the national Italian and European levels. The current case study responds to these realities.

The citizens of Caloforte claim a unique identity as descendants from a people of Ligurian origin, [1] granted the island in 1738, when they were forced to leave an earlier placement on the Tunisian island of Tabarka, where they had long operated in coral fishing and commerce. The micro-island, however, has also long been included in the functions of the larger Sulcis region, therefore with economic roles in coal mining and the other energy and extractive industries noted above. Given the deep economic crisis affecting all of Sulcis, resulting from the divestment of various heavy industries already underway, the island community is considering how to approach the possibility of installing new large-scale national infrastructure projects aimed at decarbonization through off-shore wind farms, but also smaller-scale initiatives such as the institutional promotion of the island's energy autonomy through the installation of solar panels, also aimed at better exploitation of renewable energy.

The port of Carloforte, at one time second only to that of Cagliari (capital of Sardinia Region) and especially active in trans-shipping of coal and ores, entered into economic decline in the early twentieth century. The harbour and its docks remain important in a wide range of tourism functions, including as the terminus of ferry routes linking with the main island, and also as point of arrival for the submarine power cable arriving from Portovesme. The Carlofortinian's historic economic jobs as sailors and fishers, in particular in the traditional tuna fishery, have more recently been somewhat supplanted by a conversion of the local economy to the micro-tourism. The most important local institutions are the municipal government and the two higher-level secondary schools, in particular a Technical Institute (Istituto Globale Carloforte) offering programmes in marine navigation and systems, which attracts students from throughout Sulcis.[2] This example of a flow of people looking for high level education towards San Pietro, along with that from all Sulcis for the

[1] Known as the "Tabarchini" or "Tabarkini" people, sharing the Tabarchino dialect, itself a variety of the Ligurian language (one of the Gallo-Italic languages characteristic of northern Italy), and economic/working traditions as sailors, mechanics, operators in commerce, more recently in tourism.

[2] The current "Transport and Logistics Technical Educational Institution" inherits the traditions of more than a century of preceding institutional organisations, responsible for forming generations of sailors, navigators and marine officers.

earlier presence of a nautical high-school, are an example of the historic reciprocity of interchanges between Caloforte and the near communities of the larger island (Sardinia).

In recent years, a narrative of Carloforte as a "vanguard island community" has taken hold among local hegemonic socioeconomic actors (institutional representatives, entrepreneurs), but also promoted by external actors (environmental NGOs, journalists, public institutions at higher administrative levels, up to European). In fact, as early as 1993, the island hosted a prototype wind-farm constructed by Ansaldo Industria S.p.A., in what is known as the Nasca locality, followed in 2002 by a municipal photovoltaic system (1 GW capacity), in the same locality. The Nasca area and its energy infrastructures, on the opposite side of the island from Carloforte harbour and town centre, are difficult to reach by vehicle, and in fact although readily mentioned as part of general community knowledge, have been difficult to research in the sense of gaining detailed information about the technologies employed and the current and planned states of function.

3.1 Claiming Cultural Diversity

As stated by Felice Tiragallo (2015), anthropologist specialised in Sardinian cultures:

> Sardinians and Tabarkines have co-created an accumulation of representations of each other; views and models of vision have stratified over time, in idioms, commonplaces and stories. (...) However, in this context it does not seem appropriate to identify the relationship in the manner of a Sardinian self-narrative that encompasses and includes the "minority" narrative of Tabarkans. Indeed, in observation, there is no discourse of subordination. And the founding myth of the Tabarkina community may encounter, gloss over, or ignore its Sardinian analogue (or is constellation of variants) but does not present itself as necessary for nor dependent on it. (Tiragallo, 2015, pp. 220, translation by the current author)

Tiragallo also identifies the lines of the social poetics (Herzfeld, 1996) that structure the local hegemonic representations, stressing how the San Pietrans present themselves as a group that has been (and still is) "celebrated in the country as the worthy representatives of an ethnic and technical identity that has been considered unique (Vallebona, 1975, p. 196)", and also celebrating the historic event of the "success of colonisation, intending to eternalise it as a distinctive feature of the social group" (Tiragallo, 2015: 221). According to this anthropologist, the success of this representational effort has been achieved through moral values, including "a spirit of sacrifice, an almost obsessive dedication to work, a peaceful disposition, and a contradictory, unspoken mixture of a spirit of solidarity and a completely ruthless individualism" (*ibidem*). These ethicistic narrative express a "shared image of self, emerging in recent times, in which the strongest feature is that of a community that is able and adept, pledged to modernity and industriousness" (Tiragallo, 2015: 227).

Thus, for addressing the research questions though the fieldwork, we chosed a community involved in the decarbonisation processes, but in a marginal manner, allowing us to observe the processes of distancing between the communities of San Pietro and that of the larger Sulcis district, all involved in the crisis arising from the deactivation of the coal economy.

The municipality of Carloforte, comprising the homonymous town and the rest of San Pietro Island, has maintained an economy of maritime focus, radically different from the main island agro-pastoral context, since the eighteenth century. Carloforte has long deployed sailors and high-rank officers, and today still boasts the sailors "Nautical" high-school quoted above, attracting many students from the neighbouring main-island provinces (mainly Carbonia and Iglesias). Historically, the San Pietro community has been richer than those of main-island Sulcis, thanks to sailors' and officer's earnings, and greater involvement in shipping and trade. Still today, given these structural realities, Carloforte has not suffered the alarming unemployment rates of Sulcis, and in fact is perceived as radically different from all of Sardinia, even as the main island has moved from an agro-pastoral to industrial context.

> A technological culture in mechanics, iron and steel arose in the early 20th century. Such trades were imported by a French workshop manager, who in the town found some brilliant apprentices, able to respond to orders from the mining industry. In little more than a decade, a body of technical tradesmen had formed, able to both export their skills and use them locally, opening companies that would last long as key elements of the Carloforte economy. Through the remainder of the twentieth century, the community valued the aptitude of their young people in the maritime arts and mechanical technologies, particularly in the naval sector, also treating this as a true export commodity. The petrochemical plants of larger Sardinia, and the Portovesme industrial hub, in particular, welcomed many workers from the island of San Pietro. (Tiragallo, 2015: 227, translation by the current author)

Compared to its historic cosmopolitan positioning within the Mediterranean, Carloforte and San Pietro have since declined to a marginal status with respect to the other communities of Sardinia, and even those of Sulcis. From the view of collective mobility and the related cognitive geographies, both arrival and departure from Carloforte require passage on a privately operated ferry, at substantial cost. The traveller arrives first in Portovesme, then goes on to the larger town of Carbonia, still within historic Sulcis: locations of modern-day frontier, passage and interface.

Looking at the San Pietro community from outside, some processes of marginalization can be observed: aging of the population, as young people migrate in search of work; an upward trend in unemployment; pollution lingering from coal and ore operations, and marginalising or dependency also in some practices involving the use of EU funding for installation of solar panels in private and public buildings. Some of these processes can be perceived in both material and symbolic senses.

The rising prevalence of adult and elderly inhabitants is intertwined with the economic trends of Carloforte. The primary sources (informal talks with local informers), backed by statistical data, [3] illustrate rates of unemployment still relatively contained, thanks in part to the reported conversion of inactive steelworkers and marine officials to small-enterprise activities in tourism. Notwithstanding, in

[3] http://italia.indettaglio.it/ita/sardegna/carloforte.html#dati_istat.

2016, of the 6190 reported residents of Carloforte, 4945 were 15 years of age or more. Considering the subpopulation of working age, 1738 were employed and 186 were previously employed but are now unemployed and seeking new employment. Breaking down still further, among male residents aged 15 and over, 1106 were employed and 113 previously employed, now unemployed and seeking new employment; for female residents the relative figures were 632 employed and 73 previously employed but seeking anew.

4 Methodology

Methodologically, the study relies on ethnographic work, locally situated and started in 2021, with other fieldwork activities including, in addition to participant observation and informal exchanges, stakeholders' workshops, and participatory mapping with local groups chosen by age and gender (female retirees) aimed at investigating specificities of the gender and generational dimensions.

Through the ethnographic fieldwork and through the additional, project-related activities, workshops, focus groups, participatory mapping, remote interviews), the research has investigated how the notion of the future is intertwined with local imaginaries on energy infrastructure, and the community practices of their use. Leveraging the notion of agency, ultimately connected with that of justice, this has then allowed illustration of the evolution of collective narratives and visions, and the capacity of actors to transform the system, or more often, the lack of capacity. The main focus was on imaginaries.

The research integrates the overall ethnographic view with the results from group workshops with cultural actors (writers; radio-journalists; adjoints; intellectuals from or outside the academia) of the area, from other workshops with industrial and political actors on a regional scale, from focus groups involving island participants in a project for installation of private photovoltaic systems, and finally from participatory mapping conducted with a group of older women from a reading group. In this way, the research is able to delve into the gender and generational perspectives, both found to be specific to the island, where the population is aging ever more, and where many males are absent because of long periods at sea for working reasons. Particularly important among the interlocutors were the retired women of Carloforte, mostly born there, and others from the participants in the local reading group, given the developed reflective capacities of these persons.

The mapping workshop began by asking the participants to individually produce a map of the island (see three examples in figures). We then proceeded to discuss the individual representations and work towards a shared map, incorporating the various conceptional points (last map of the figures).

The ethnographic research conducted between May 2021 and October 2022 included: (i) participant observation; (ii) 12 remote structured interviews; (iii) 20 in-person structured interviews; (iv) focus groups (in particular, 12 participants in the EU Horizon 2020 REACT project, [4] funding installation and upgrading of single-building photovoltaic systems); (v) a stakeholder workshop with four Carloforte citizens of higher education, or intellectuals, in February 2022; (vi) a stakeholder workshop with Carlofortini and Sulcitan local administrators and representatives of the two nationally relevant environmentalist NGOs, totalling 12 participants, in October 2022; (vii) analysis of secondary sources, among which local newspapers, locally created websites and other publications, and policy plans referring specifically to Sulcis. Finally, the analysis of secondary sources also extended to documents originating from the regional, national, and EU institutional levels, in particular the strategies laid out: for 50% sourcing of energy from renewables at the national level, and the phasing out of coal by 2025; for Sardinia, the construction of new infrastructures for supply and distribution of gas and electricity (National Energy Strategy – SEN 2017; *Piano nazionale integrato per l'Energia ed il Clima* (PNIEC), 2019; *Piano Sulcis*, 2013).

The research question was framed with the collaboration of local stakeholders, then developed and refined to completion in the manner of a hermeneutical loop, involving in particular: (i) Intellectuals and administrators with backgrounds in political science and social anthropology (epistemological loop); (ii) managers of the local tuna fishery; (iii) small business operators in the tourism sector; (iv) teachers; (v) former steelworkers, trade unionists; (vi) environmentalist activists; (vii) intellectuals living on the island, originally from other nations or parts of Italy; (vii) other persons present only part of the year, with principal residence elsewhere.

The design and completion of the case study then went ahead in dialogue with these local stakeholders, with care to also seek advice and views from minority groups, for example minorities in terms of political orientation.

Through direct and participant observation of formal (municipal assemblies at the Ex-Me community center, religious celebrations such as Festa di San Pietro, village festivals such as GiroTonno) and informal exchanges, and in parallel, through solicitation of interlocutors in semi-structured interviews, the ethnographic work was able to extract the different narratives relating to decarbonisation. The issue of social and environmental change, inherent in the idea of transition, constituted an ethnographic device useful for focusing on the social experiences of dispossession and/or appropriation of the individual and social "capacity to aspire" (Appadurai, 2013).

Also in parallel, the research used the "energyscape" framework in its predominantly spatial dimension, to anchor the empirical work of participatory mapping, as described below. To capture the specificities of the gender dimension, workshops were conducted with a focus group of 12 retired women, mostly native-born, in February and October 2022. These were invited from among the participants in the local reading group, intending to take advantage of the reflective capacities of these individuals.

[4] https://react2020.eu/.

5 Key Findings

The insights achieved by applying these methods confirmed previous observations, but suggested a unique finding on the relationships of the local community with the main-island industrial pole.

In particular, the research shed light on the local ethnicist "myth" of the ontologically different and high-ranking (technical, economic, cultural, ecological) identity of these descendants of the eighteenth-century colonist settlers, as compared with the main-island Sardinians, and within these, the inhabitants of main-island Sulcis.

The current research thus demonstrates how a micro and fully qualitative ethnographic approach can be successfully applied to a region of coal-mining and industrial vocation, now involved in an unhappy transition: in San Pietro Island case study, I focus a community that is situated in front of the coal-industrial district of Sulcis, at the southwestern corner of the main island administrative region of Sardinia.

The current chapter thus delves into and provides an overview of the overall body of data collected through ethnographic research, showing how the approach contributes to an understanding of the local-level tipping points (Tàbara et al., 2018), in emic and etic senses, [5] and what changes in systems of meaning lie upstream of these tipping points.

From daily ethnographic work with primary sources, it emerges that San Pietro and Carloforte are geographically situated in a manner exposed to pollution from the Portovesme thermoelectric and metal-processing plants. My interlocutors, however, will only report this after arriving at a certain level of confidence, and when specifically solicited, then describing the signs of pollution in epidemiological, material and aesthetic terms (Apostoli Cappello, 2023). It has not been possible to retrieve any epidemiological large and long-date data on cancer rates either for San Pietro Island or the Portovesme area, nevertheless, the fact that the relevant authorities have banned all crop cultivation in the lands adjacent to Portovesme industrial centre is highly suggestive of a concrete fact. An interlocutor, retired pharmacist of Carloforte, recounts that since the 1970s, she has noticed an increasing trend in oncological diseases on the island, evinced in the types and dosages of prescriptions presented by her customers. In short, although this issue of various harms from pollution is well known both on San Pietro and the main island, the greater fact is that it is widely dismissed.

These brief comments on the potential cultural diversity of San Pietro and Carloforte within the Sulcis and larger Sardinian contexts can contribute to understanding of some specifically local dynamics, such as the noted marginalisation and dispossession (West, 2016). They can also provide a basis for exploring locally valid factors and processes contributing to agency, either to trigger or to resist socio-environmental transformations, and to the relative "tipping points". More generally,

[5] In the interpretive anthropology of Clifford Geertz, the emic perspective represents the native's point of view and the etic perspective represents the analytical point of view of the researcher.

these basic facts provide place for understanding the evolution of the different narratives, both mainstream and non, that we detect on the island.

The attempts to enact positive tipping points toward a more just and ecologically sustainable development must consider, among others, the micro-cultural dimensions and perceptions on coping with climatic change and related socio-environmental crisis. A key finding is that for community members, the main future and horizon for transformation and enactment of positive tipping points is that of their own personal world and home. The attempt at deep transformations driven by policy and plans may experience difficulty in implementation, since it could be that the futures and horizons of the local residents would not adhere to the timescales, worldviews on humans or technology, or many other dimensions and narratives arriving “from outside” the community. Indeed, community imaginaries are in tension with those proposed in policies and plans.

The ethnographic research thus engaged with local attitudes on the possibilities or impossibilities of using their territory for energy transition, in particular: (i) adoption of household photovoltaic systems; (ii) potential transformation of the highly-polluting thermoelectric plants in Portovesme.

The local discourses on energy transition, arose during the ethnographic work, are used to read the local **positionings**.

5.1 The Home as Sole Horizon Subject to Individual Power of Change

All my interlocutors affirmed that the reason for investing in individual or community plants for electrical production from renewables would be the achievement of savings in consumption from the grid. I have argued elsewhere (Apostoli Cappello, 2023) that rather than being understood as an essentialized fact, this is correctly seen as the effect of local economic strategies, in turn revealing the critical positions of the local population face to top-down policy promises. In developing this argument, it is interesting to note that, in describing themselves solely as smart consumers or “pro-sumers”, rather than as citizens or actors of a socio-environmental or cultural change, the local interlocutors are illustrating a completely individualised participation in the transition to renewable sources, through projects led by the municipality and using EU funding.

As stated by a high-level local administrator in the energy security sector, native to the island:

> We had the curiosity to see in theory where I was wrong in using energy. This was our first curiosity. Then as we went deeper, we saw that there were many small things that can be improved, and I hope that these observations can serve in improving this project. (Carloforte, May 2021, translation by author)

However, a teacher retired from work on the island, and living alone near Carloforte town, states:

> "I wanted to build myself a passive house, but since it's not possible to move a house from its attachment to a border [adjacent structure], I had to give up, being attached to the border of another. [...] and so I couldn't make my dream come true … I'd wanted geothermal energy, and so on. And so I just bought into a normal house here, with a wood-pellet stove and air conditioner. " (Carloforte, May 2021, translation by author)

All ethnographic observations, including through interviews and informal conversation with interlocutors, confirmed the existence of an attitude among locals in which the privately-owned home is the only horizon over which they hold any power of transformation. An example of witness to this, for example, would be the reiteration of "borders" against action beyond, evoked by the teacher interlocutor. Energy transition, where it emerges, emerges as a private instance. [6] This household horizon and economic rationale seem to occur cross-gender.

We can interpret this as a retreat to the individual dimension in one's ability to transform living conditions, or as Appadurai would say, to aspire. This occurs in a community that is described by anthropologists and historians as, until a few decades ago, a group capable of collectively projecting itself across time and space, making economic investments and expanding their horizon of action through trade. The margin of agency, therefore, seems to be shrinking over time.

Further, this could mean that the energy meanings proposed by the EU energy policies may, somewhat counter-productively, tend to push individualised solutions to energy issues.

Many informal interactions in the field show that the economic rationale drives many individual choices, while collective choices, where present, do not concern actions aimed at energy transformation. Energy is not considered an issue that involves or affects the community as a whole. The energy infrastructure, however, is what enables the San Pietrans to accommodate substantial numbers of tourists, over the summer season arriving at totals of 40,000 visitors, with significant effects on energy needs. The achievement of energy autonomy through renewables is seen by interlocutors as a material tool to access, stabilise and perhaps increase the flow of private economic resources from tourism, recalling here that the island's tourist lodging and services are entirely micro or family-scale enterprises.

The research targeted the interlocutor's range of action, meaning the scape. As they might plan the installation of photovoltaic systems, and more generally in perceiving their relationships with renewables, by following their own range of action. The scape drawn is that of completely domestic perimeter, in which the only community reference, if any, is limited to family level.

The home, even more than its inhabitants, becomes the main actor, allowing or disallowing access to an H2020 funded[7] project aimed to support the installing of solar power plants, depending on the surfaces it offers for appropriate mounting of photovoltaic panels, and to more general sustainability, in the aspect of rainwater collection.

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[6] This element is also present in the maps provided below, from work by focus groups in February 2022, aimed in part at bringing out the gender dimension.

[7] REACT https://react2020.eu/.

The energy issue does not constitute a theme of informal exchanges between local acquaintances. What emerges is a discursive representation of renewable energy sources and devices as an instrumental issue for the safeguard of family economic assets. A separate study (Apostoli Cappello, 2023) focuses on the deep-seated socio-economic reasons and means of this mechanism, which is not at all the amoral familism one might first assume.

Only rarely does the community horizon emerge, not with reference to the roles of citizens, but as projects of past municipal administrations, in any case never completed, as one interlocutor testifies:

> "Then, for reasons that I honestly do not know and don't care to inquire into, it turned out not very well…. But the project was precisely aimed ... so it means that we have the will in our little selves. But the various administrations that have followed one another, and over the years I have seen different ones … On this point of view, every one really cares a lot." (Carloforte, May 2021, translation by author)

The excerpt interestingly underlines the fact that "every one really cares a lot" about photovoltaic i to the possibility of installing photovoltaic systems in every home. Instead, the only shared meanings that our interlocutors evoked are daily practices in domestic energy consumption. Similar results emerged during other informal and structured interviews and workshops, when our interlocutors stated that even apart from energy practices, there are no shared horizons of social transformation.

5.2 Participatory Mapping Experimentations

As can be seen in the drawings from these workshops, San Pietro is represented as distinctly separated from industrial Portovesme (Figs. 1, 2, 3, and 4), without indications of ferries or other tangible or symbolic links. The industrial area is almost always explicitly represented (Figs. 1, 3, and 4), possibly indicating that this visual method had achieved a different access to implicit knowledge. What would be more significant to the research questions is the hypothesis that this reflects a more limited propensity among women, compared to other interviewed actors, to hide (keep secret) the collective socio-environmental "bads" (as defined by Schlosberg, 2013).

I solicited my interlocutors for their interpretations on the implications of proximity with the industrial centre, aiming to deepen our understanding of the different aspect of their perceptions and verbalisations. The interlocutors consistently recognise the meanings of the industrial centre in terms of risks of pollution and economic dependency. Both in informal group discussions and in drawings, they concentrated, as might be expected, on portions of the energy landscape, and concerning these, but only when deeply solicited, certain implicatory dimension seemed to emerge, as the interlocutors reported present and past actions to counter the risks.

P., a 50-year-old hotelier, native-born, situated the link with Portoscuso in the past, and evoked a purely instrumental link concerning employment. She specifies that Sulcis is poor, building a conception of San Pietro Island in terms of differences:

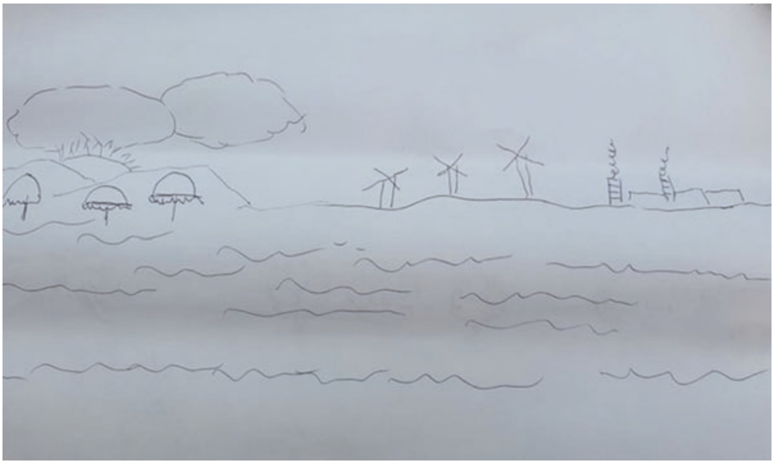

Fig. 1 San Pietro island and Portovesme coal-fired industry and onshore wind farms

Fig. 2 San Pietro island

> The only contact with Portoscuso was for people to get work, for the Carlofortini, because they had jobs there. But it wasn't something that felt like community. Speaking of the issue of industrialisation and what are the effects of industries ... in those years those plants were put there because everyone was going in that direction at the time, and we were even privileged compared to other sites. Now, unfortunately ... but then it was an opportunity because Sulcis was poor, even then, and certainly having these industries ... It's loaded us all with pollution. But we didn't know that. That came out later. (Carloforte, June 2021, translation by author).

But the hotelier then specifies that the diseases of main-island Sulcis, caused by Portovesme industrial air pollution, also afflict San Pietro, in this way indicating an

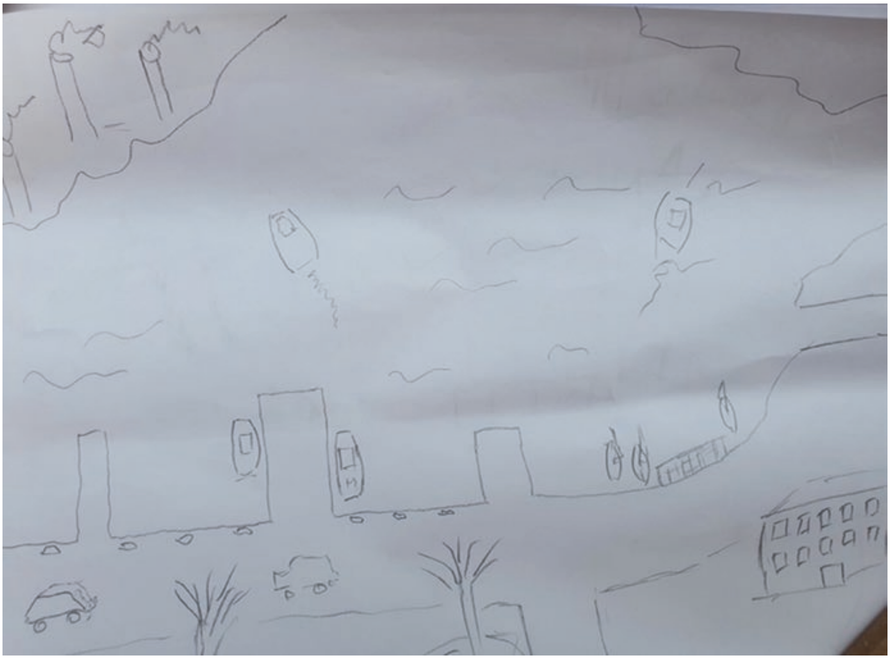

Fig. 3 Carloforte harbor, Portovesme steel industry on the bottom

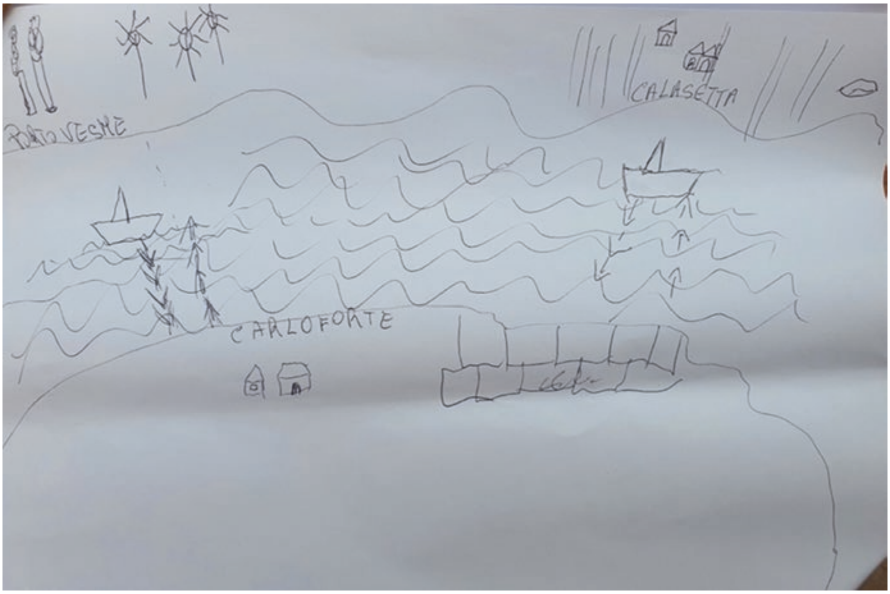

Fig. 4 Carloforte face to Portovesme coast

awareness of a common destiny. Only the wind, an external factor independent of local will, determines the better fate of the island:

> But we too are not that ... at Carloforte ... We are silent but ... there is a good percentage [of persons with ailments] We are lucky for the mistral wind that carries on, seawards. We could say the air pollution hardly reaches here. Water, rainfall and wells were often checked. There are many artesian wells, we have one and we have it checked every year but the search for metals is not normally done. Instead we did it ourselves, and there are none. Because it was often said that there was lead. Fortunately, we never found that. (Carloforte, June 2021, translation by author)

Pollution-related ailments are attributed to external actors, distant and different from the local population, formulated as unreachable entities. This substantiates the feeling of helplessness and the lack of agency at the local level.

The daughter of the above-noted hotelier, also engaged in the same business, and one of our main long-term interlocutors, recounts the Portovesme industrial hub as made up of impersonal actors (the plant, the chimney, the shovels, the ships). This depersonalisation offers roots and nourishment to the feelings of helplessness in the local population:

> Decarbonisation is a serious problem here because Portovesme, you know, still runs on coal. If I look out I see its chimney, because it stands large. Behind it, there are at least 37 wind turbines that have been mounted over the years, that should somehow help this decarbonisation in some way. And the truck constantly passes by to wash the ground. (Carloforte, May 2021, translation by author)

Among salient projects centered on sustainability, the island hosted the first prototype windfarm in Italy, installed by Ansaldo in the 1990s, in a locality known as Nasca, however the production served the national grid, consistent with a mechanism in which the island is simply a platform for energy experimentation, and any production would be owned and consumed by others. Indeed, the legitimacy of the municipal authorities comes in part from outside, in particular from contact with European funds, and tends to bypass the national sphere.

From the drawings, we can see that the home is the nodal point of representation. Some individuals (e.g. map 2) have also represented the three wind turbines of the Nasca prototype, although not necessarily in true geographic position. As one of the interviewees said, these are more a symbolic presence rather than a technologically concrete productive site. No communitarian vision of renewables emerges.

The first map is exemplary of representation of the three main elements of the San Pietran economic landscape: the Portovesme power station, next to this the wind turbines, and at the other side, the umbrellas and trees characterising the island, with tourist and nature-oriented vocations.

In summary, this section of the analysis has brought together discursive and figurative data, showing that our interlocutors' mental vision of their perimeter of action is very restricted, coinciding with the island, and that the main scape on the island are the private homes. Moreover, it emerges that the island coincides with the inhabited area of the Carloforte town, neglecting the rest. The electrical-industrial giant of Portovesme, opposite, is seen as a passive actor.

Overall, these results confirm the idea that the agency imagined by my interlocutors is very limited in perimeter, and that any energy transition arriving in the community is imposed from outside and above.

6 Ethnic Particularism: Double Edged Sword for EU Promotion of Energy Transitions

From the fieldwork it emerges that all the Carloforte inhabitants, native-born or later arrivals, stress the elements of wealth, competence and cosmopolitanism, as well as a construction of the historical diversity of the island, as a colony of Genoese-Ligurian families who migrated first to the Tunisian island of Tabarka and then to San Pietro Island. In this narrative, often the first recounted, the people of Carloforte are not Sardinians. When they take the ferry, they are “going to Sardinia”, which is discursively distanced not only by the logistical aspects, but also by verbs of displacement.

What is prominent here is the distancing of the main-island administrative region, in the local perceptual dimension. Given this, a next step in the analysis concerned the identitarian claims that might influence processes of the distribution of agency at the local level.

A range of different local actors perform a strong ethnic identity, with different aims (Apostoli Cappello, 2023), underpinning ongoing processes of local differentiation. This key phenomenon represents both an asset and obstacle to triggering radical transformation of energy meanings and practices**.** Taking an overall view of the primary and secondary sources, one is inclined to interpret the reinforcement of the identity discursive register as a reactive consequence to industrial policies imposed from outside and above: a mechanism accompanied by the already observed extreme individualisation of agency margins.

This chapter also raises an question that lays the groundwork for future insights: are the European and national policies on decarbonisation and energy transition experienced as yet another top-down imposition suffered by local communities, already feeling dispossessed from the decades of industrial policies that have impoverished theme in both socio-economic and environmental terms?

On the other hand, for some sectors of this obviously non-homogenous community, ethnic particularism is a symbolic element played for positioning of a claim on the sustainable future of Carloforte, differentiating themselves from the failed and passive politics of any main-island Sulcitans. These sectors, including the current local ruling class, are characterised by high social capital and professional experience of contact with the outside world (i.e. Sardinia, Italy, other European nations), incorporate greater agency, and maintain a proactive, generative vision of social change on energy transition in particular. These local professionals, technicians and administrators are now proposing to the community a whole alternative vision of the future, and of island territorial management, based on a still-embryonic project of founding a local energy community involving the large majority of the population, in which the entire island would be converted to a model of energy self-sufficiency drawing on wind, solar and other renewable sources. The ability to produce and disseminate socio-environmentally virtuous imaginaries, different energy futures and energyscapes, seems connected with the cosmopolitan education of the elites.

Ethnographic field research has shown that a strong shared imaginary regarding local identity - based on distinctiveness from poorer main-island Sulcis, and on their Genoese history and Tabarkine genealogy (Vallebona, 1975) - has enabled the people of Carloforte to develop a distinct idea of themselves and their futures, which they see as a cultural construct and collective resource. This, we expect, could enable them to acquire agency, or expand the margins of their agency. Such a strongly essentialised identity could help the San Pietran citizens to distance themselves from the logic of dispossession typical of the entire Sulcis area, navigating the island towards a horizon of ecological transition, as some inhabitants already claim.

7 Conclusions

San Pietro Island and the town of Carloforte were chosen as the focus of a case study for several reasons. On the one hand, the island has historically been connected with the Sulcis district, itself based on a carbon economy; for many decades it was a crucial maritime hub for trade in in the coal industry, and provided high skilled workers to the mining and related industries of all Sulcis. On the other hand, the change in the maritime routes beginning in the early twentieth century, and the processes of deindustrialisation and exit from coal begun in the 1970s have increasingly marginalized the San Pietro with respect to the rest Sulcis. Also, especially beginning in the 1970s and now still more in the dynamics of the twenty-first century, tourism has become a viable alternative, although the locals still refer to sailors and marine officers as the true backbone of the local economy. Both demographic data and qualitative evidences reveal the effects of an aging population, with the emigration of youth, and also the re-destination of family homes as tourist accommodation (an effect almost invisible in official records). The choice of study framework came thanks to preliminary interviews conducted with privileged observers, focused specifically on energy transition, which claimed Carloforte and at San Pietro Island as an exemplary case of sustainable transition.

The key point emerging from field research is the lack of familiarity of renewable energy devices by the local population, in many cases unaware that the technologies even exist: in other words, a lack of coupling of technological advancement with cultural transformation. The problems observed are present in in other coal regions and communities examined in this volume, and although the observations concerning San Pietro may not be representative, they could be illustrative of certain processes also happening in other places.

The evidence emerging from ethnography show a complex picture, in which the island could perhaps be on the cusp of an as yet unexpressed tipping point (Tàbara et al., 2018). This makes the case in examination of particular interest, precisely because of the possibility of observing the progress of such systemic transformation. The local construction of collective identities in ethnic logics seem a key factor, which could explain the inhabitants' potential to tackle system changes but also the persistence of old ones.

From the point of view of communitarian renewables, either installed by the municipality in properties under its own control around the end of the 1990s and early 2000s, or the photovoltaic and wind-power plants that sprung up in the uninhabited Nasca locality, these could have been ways of launching the island's own energy production, however the process were not carried through (for a description of this process see Apostoli Cappello, 2023).

From the emic point of view, household photovoltaic devices are instead of interest to the population as an agglomeration of individuals. Any local energy transition under way, in fact, seems to be driven by the household and the economic rationale of savings, limited to the boundaries of the home, and linked with support from European projects, attracted by local decision-makers and institutional administrators.

A conclusion from field research is that the narrative construction of collective identity would serve as the main local ideology. Rooted in shared memories and in an almost mythical reconstruction of the past, this represents a major resource for local identitarian rhetoric, and could easily trigger a true tipping point, understood as a change in productive paradigm. However, ethnography suggests that identity is the underlying factor in the structuring and organisation of energy narratives, through stress on the "ontologically positive and green" characteristics of the island, and that in fact this contributes to the continuation of the status quo.

Indeed, an ontological difference emically postulated by the islanders, with respect to the inhabitants of Sulcis, prevents the local actors from taking ownership of their own territory, beyond the household dimension, and prevents the population from claiming ownership of the economic and decision-making processes on transition, which although they "involve" the community, appear to taken in places distant and "above" their island. This can be read as the outcome of deep and long-lasting dispossessions occurring everywhere in the Sardinian administrative region, and even in Carloforte, despite its constant rhetorical distancing from the main island. Thus, the only horizon of agency that seems to emerge is that of individual choices: that of the conscious consumer rather than the fully sustainable community.

The actors who seem to have the most agency to activate positive socio-ecological transformations are the institutional ones, in particular local administrators and entrepreneurs, able to strategically (Spivak & Harasym, 1990) use the ethnical essentialism performed in the small island community of San Pietro.

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Tipping Away from Coal?: Exploring Narratives and Tipping Dynamics in the Phaseout of Coal on Svalbard

Siri Veland, Leticia Antunes Nogueira, and Vida Marie Daae Steiro

Abstract This chapter explores societal tipping points in energy transitions in the Arctic through the case of the phasing out of coal mining on Svalbard. The economy of the region, which has high geopolitical importance in the Arctic, was founded based on extractivism. More than a century ago, coal mining not only consolidated as Svalbard's main industrial activity, but also crystalized in the region's identity and in Norway's strategy for sustaining its presence on the archipelago. International agreements and debates concerning green transitions, in combination with fluctuating coal prices and ageing infrastructure, have provoked the emergence of various narratives concerning the future of the archipelago. These narratives entail both low-carbon alternatives for the local economy, and alternative energy sources to power human life on Svalbard. This chapter examines these narratives, focusing on the interplay between demographic and socio-economic developments of the past 20 years. Several kinds of societal tipping points can be observed, from politico-economic to demographic and socio-cultural tipping points. The question remains, however, whether the Svalbard case also exemplifies tipping points in the biophysical dimensions of social-ecological systems. This will in large part depend on the ability to find viable energy alternatives that harmonize with regional geopolitical security.

Keywords Svalbard · Coal · Regional development · Tipping points · Sustainability transitions · Energy transitions · Human geography

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1 Introduction

Studies of social-ecological tipping points have conventionally focused on the biophysical dimensions. As result, there is a maturity in how biophysical tipping points are discussed in the literature. They refer to thresholds at which the structure and function of a system radically changes to take on new characteristics that may be difficult or impossible to reverse (c.f Gunderson & Holling, 2002). By comparison, societal tipping points have been given a more passive or nebulous role in social-ecological systems thinking, and they are less well understood. Meanwhile, in the global efforts to meet the Paris Agreement targets by reducing reliance on coal and carbon intensive industries and energy generation, there is need to understand how societies in carbon and coal intensive regions (CCIRs) can transform and thereby enable energy systems to transform. The TIPPING+ research that forms the background for this edited volume has focused on societal tipping points, with particular attention to the narratives that accompany demographic, political, governance, and economic shifts (Lieu et al., 2020; Tàbara et al., 2018). A key motivation for the Tipping+ project has been to find positive tipping points that ensure just transitions and avoid the risk of populist and extremist political backlash.

Svalbard is an archipelago in the Artic whose local economy and identity have been intimately tied with coal mining for more than a century. Nonetheless, transitions away from coal are underway, and Longyearbyen, which is the largest township on Svalbard, is in the process of shutting down the only Norwegian coal power plant and the last remaining Norwegian-operated coal mine in Norway. [1] Svalbard has a crucial geopolitical importance, given its privileged location in the North Atlantic Ocean and the wealth of natural resources in the area. In addition, Svalbard is a unique case that is exposed to the balance of cross-national concerns, given the possibility of new maritime passages opening up for Artic shipping, and growing international interests in the region, exemplified in Chinese and Indian presence on Arctic policy, research, and industrial arenas. The 1920 Svalbard Treaty ensures Norwegian sovereignty over the archipelago, but all signatories to the Treaty have the right to engage in natural resource extraction and other economic activity.

The end of coal has been controversial in a local perspective where the majority of residents have historically been connected to the coal mines even if indirectly, as well as in national politics where climate commitments and energy security have been prominent concerns. The special geographical characteristics of Svalbard make it a unique case of challenging the supremacy of coal, and offers lessons for other regions seeking to induce positive tipping points that enable low-carbon transformations. Not being a lifecycle community, the decisions to phase out the coal

[1] To be precise, the coal mining and coal-based power generation will continue in Barentsburg, a Russian township on Svalbard. As this chapter will show, the Svalbard Treaty precludes the Norwegian government from interfering with other signatory countries rights to exploit natural resources. As the mine and power plant in Barentsburg are owned by the Russian state company Trust Arktikugol, decisions concerning it are outside the sphere of influence of the Norwegian government.

economy could be made top-down from the Norwegian National Government without the same level of concern of rising anti-democratic political mobilization as is the risk in other CCIRs. In that way, demographic and economic shifts resulting from the cessation of coal can be observed in a setting where local cultural and community history has limited power to influence the national government decisions on the future of the region. The Svalbard case described in this chapter exemplifies a flip into a fundamentally different development trajectory, where the narratives of clean-energy transitions has had profound impact on the local culture and the characteristics of the local economy and society, and will continue to influence energy security in the future. Moreover, the case illustrates several kinds of societal tipping points, from politico-economic to demographic and socio-cultural tipping points. The question remains, however, whether the Svalbard case also exemplifies tipping points in the biophysical dimensions of social-ecological systems. This will in large part depend on the ability to find viable energy alternatives, and for the foreseeable future, diesel will replace coal for energy production (c.f. Longyearbyen Lokalstyre (LL) 2023, Markussen, 2023).

In keeping with the aims of TIPPING+ and this edited volume, this chapter considers the stakeholders, policies, ideologies, institutions, and technologies, as well as the timeline of events, and/or lines of argument adopted by actors supporting different narratives (Tàbara et al., 2018; Lieu et al., 2020). Through these themes, this chapter seeks to understand the processes that led to the decision to end coal mining and how these changes affect the local economy, society and demographic trends. We examine different overarching narratives on coal and alternatives to coal on Svalbard. [2] The main research questions that guide our work are: (i) what precipitated the decision to end reliance on coal as a source of energy and economic activity on Svalbard? (ii) how has the decision to end reliance on coal affected the Svalbardian society? and (iii) do key events in the cessation of coal configure positive socio-ecological tipping points?

This chapter first presents the concept of tipping points in a human geography perspective, before describing the framework used for this study. We then outline our data collection methods before providing an overview of Svalbard, with emphasis on the politics and economics of coal in the archipelago and how this led to demographic and societal changes. A presentation and discussion of the competing narratives identified in the case follows. We conclude the chapter with some reflections on Svalbard's coal mining trajectories and on the concept of tipping points more generally.

[2] We refer to the Norwegian townships only, as the Russian activity on Svalbard is outside the scope of our research.

2 Tipping Points in Human Geography

The concept of tipping points has gained increasing attention over the past decade within the academic community as well as in the broader professional and political public (Milkoreit et al., 2018). The concept denotes a qualitative system change that has its roots in specialized chemical and mathematical nomenclature (Milkoreit et al., 2018), where it followed the nineteenth century bifurcation theories (Lenton, 2013). In human geography, the concept of tipping points belongs to at least three strands of literature.

The first strand of literature refers to demographic transitions in urban contexts, and other concerns climatic and environmental changes. On demography, the oldest paper dealing with the concept of tipping points concerns radical changes in the prevalence of different racial groups in urban neighborhoods (Wolf, 1963). Other major works in this vein include the work of Woods (1977) and Schwab and Marsh (1980). The second strand of literature can be exemplified by the work of Malcolm Gladwell (2000), who conceives of tipping points as the results of small interactions between knowledge brokers and individuals with large and diverse social networks; these interactions result in rapid and large change. The third strand of literature focuses on systems changes, mostly related to linked human and natural systems. Tipping points are defined as "the threshold at which a phenomenon, object, system, or process is displaced from a state of stable equilibrium into a new status that is dissimilar from the first, and which is difficult to reverse" (Castree et al., 2013). Synonymous terms such as threshold (Steele & Henderson, 1984; Gunderson & Holling, 2002) critical threshold (Dakos et al., 2015; Kopp et al., 2016), adaptation turning point (Werners et al., 2013) have similar uses in the literature on global change. A key similarity between all these terms is that they denote a major systems or regime shift or transformation from which it will be difficult or impossible to return.

The challenge in pin-pointing a tipping point has long been a topic of debate. Woods (1977) cautions that the tipping point in social-cultural contexts might be quite complicated to identify. First, precise, empirically detectable thresholds may be difficult to identify (c.f. Russill & Nyssa, 2009). Second, there are phenomena that may be considered as a consequence of the tipping point, and at the same time be considered as the tipping point itself. In other words, the tipping points are in some cases estimated and quantified (Card et al., 2008) and in other cases tipping points are used as a generic concept without specific indicators (Werners et al., 2013).

In this chapter, we rely on the TIPPING+ framework building on Tàbara et al. (2018), who introduce the concept of positive tipping points (PTPs) to examine the transformations required for achieving the 2–1.5 °C target. PTPs are understood as "as emergent properties of systems–including both human capacities and structural conditions — which would allow the fast deployment of evolutionary-like transformative solutions to successfully tackle the present socio-climate quandary" (ibid, p. 120). The TIPPING+ framework integrates these insights with Lieu et al. (2020), who examines the narratives that perpetuate, provide alternatives to, and transform the coal-intensive economy. This chapter contributes to the social science understanding of tipping points by examining narratives presented by interviewees, the media, reports, and scientific publication. These narratives are examined in the context of changes in population, migration, gender, age, and employment, as well as in coal mining and other economic activities.

3 Theoretical Framework

In combining the frameworks of Tàbara et al. (2018) and Lieu et al. (2020) the TIPPING+ consortium also sought to identify narrative tipping points in descriptions or plans for demographic, political, economic, or societal shifts in CCIRs. Through this shared framework, the aim was to synthesize findings of the role of narrative dynamics on positive tipping points across numerous cases. Tàbara et al. (2018) describe positive tipping points in social-ecological systems as inherently difficult to anticipate but possible to navigate. They highlight that these transitions into new social-ecological system configurations are often described as negative, but that positive tipping points are both necessary and possible to plan for. Through designing a series of recurrent processes of creating visions for a post-coal world, working with capacities, and finding solutions and pathways, Tàbara et al. (2018) suggest tipping points to post-carbon societies can be sparked by re-imagining possible desirable futures and harnessing capacities.

The ways in which the post-carbon transformation is storied, then, is critical for transformations toward sustainability (Tàbara et al., 2018; Lieu et al., 2020). Indeed, careful attention to the role of narratives in inducing societal shifts have been highlighted in recent years (Barad, 2014; Paschen & Ison, 2014; Olson, 2015; Veland et al., 2018). Stories about sustainability transitions are entangled in both deliberate and reflexive ways with material transformations, placing great possibility but also responsibility for change in how persons and our communities think about, write about, and in other ways express desirable change (see O'Brien, 2016, 2020). The ways in which the world is storied are multiple and place-based, and the effort to characterize these stories into narratives as we do in this chapter is necessarily an abstraction. Our aim in indicating narratives is to provide some analytic insight for other locations seeking to transition away from coal and carbon-intensive societies.

The TIPPING+ project has combined the theoretical framings of Tàbara et al. (2018) and Lieu et al. (2020). In this way, the transition from mainstream to transformed narratives conceptualized by Lieu et al. (2020), is induced through the processes of harnessing capacities and creating vision for the future as conceptualized in Tàbara et al. (2018). The discursive tipping point is an inflection point at which the mainstream narrative is shifted into a new mainstream narrative in the second cycle (Fig. 2). Following Tàbara et al. (2018), workshops and interviews have been performed in various case studies to either explore or induce shifts into a new way of narrating energy and economic conditions. It is important to note that in this framework, focus is on how the narratives evolve over time, while material changes in the social-ecological system have been given secondary importance. The aim of this approach has been to provide much needed insight on the societal dimensions of tipping points, and to seek mechanisms that might precipitate concomitant material transformations in economy, technology, and institutions. While some case studies in TIPPING+ have already materially transitioned into post-coal regions (tearing down coal infrastructures, constructing energy alternatives), most have not. Indeed, the global shift into the post-coal societies has not yet precipitated but remains at most in a narrative transition is yet to materialize to enable rapidly staying within 1.5 degrees climate change. It is the intention that the collection of this book chapters will contribute to insights on how narrative positive tipping points can be induced (Tàbara et al., 2018). From there, the hypothesis is that these narrative tipping points will contribute to creating the cognitive conditions to induce material changes in energy generation without negative disruptions to former coal and carbon intensive regions.

In order to use the combined Tàbara et al. (2018) and Lieu et al. (2020) frameworks for the Svalbard case study, some adjustments were needed (Fig. 1). Lieu et al. (2020) distinguish between mainstream and on-stream coal narratives, and off-stream and transformation-stream narratives in the overarching debate on coal and low-carbon transitions. The coal-intensive mainstream narrative on Svalbard has already been replaced by the transformation-stream narrative. As such, we have adapted the language of this case study to consider the coal narrative, an economic transition narrative, an energy transition narrative and a transformed integrated economy-energy-environment narrative. The statistical demographical data presented below is used to illustrate the transitions, or tipping points between the coal and transformation narratives.

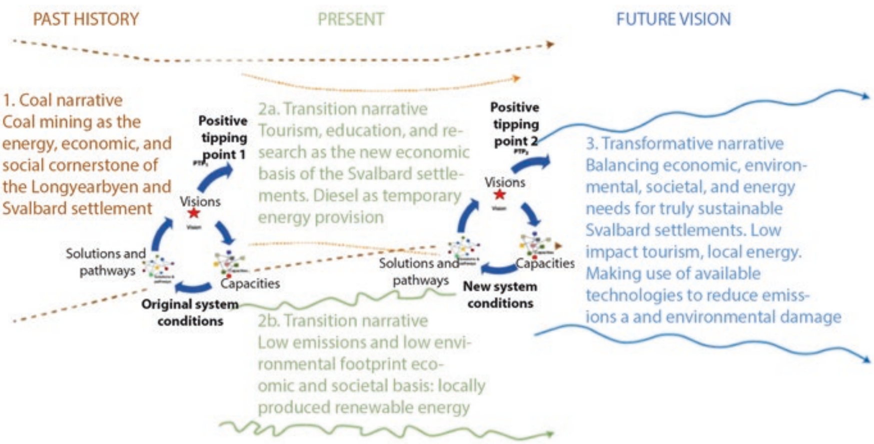

Fig. 1 The frameworks by Tàbara et al. (2018) and Lieu et al. (2020) adapted to the Svalbard case study in which the mainstream narrative is no longer coal based. Hence, we have chosen to present the coal narrative, two transition narratives, and a transformative narrative in this chapter. The cyclical processes of harnessing capacities, finding solutions and pathways, and creating a new vision mark the positive tipping point from one narrative to the next

4 Methods and Data

Our research strategy began by taking stock of our earlier research experiences concerning Svalbard and energy questions in the Arctic. For quantitative data, a database containing statistics on demographic and economic variables was created. Sources include Statistics Norway, the Norwegian Environment Agency, the Brønnøysund Register Center, and the Norwegian Ministry of Education. Data on population, employment, gender, business sectors, business revenue, and emissions were explored for possible tipping points from 2009 to the present. A key challenge for Svalbard is that statistical data is limited and patchy, such that the analysis lacks detail on, for instance, employment structure. Despite this limitation, possible tipping points have been identified.

For qualitative data, we consulted secondary sources, ranging from peer-reviewed literature, governmental strategies, reports and legal documents, and conventional media articles. We collected relevant news articles from national and regional sources, for the period between 2000 and 2021. These sources were used as basis for a preliminary document with information on: (i) the timeline of events and decisions, (ii) the main lines of argument in the coal discourse, (iii) the contrast between local and national political perspectives on the issue, and (iv) what energy alternatives appeared to be under discussion. Out of the pool of existing media articles, seventy-nine were actively employed in the writing of that preliminary analysis.

This preliminary analysis was also the baseline for forming our fieldwork strategy and interview guides. We conducted a nine-day fieldwork trip to Longyearbyen in October 2021, where 11 semi-structured interviews were conducted with key informants from business, government, volunteer organizations, and residents in Longyearbyen. Our fieldwork also allowed for rich observations, and informal interactions with residents, including a "welcome meeting" organized by the LL to newcomers on Svalbard, and participation in one internal meeting of the LL with representative politicians from different political parties. The fieldwork also involved a visit to Mine 3 (a decommissioned mine that became a touristic attraction), and a cruise trip to the Russian township of Pyramiden (a former coal community on Svalbard, now soviet-era tourist attraction).

The timing of the fieldwork coincided with fresh political developments in Longyearbyen concerning the interests of our research (that is, decisions concerning coal mining, demographic changes that resulted from earlier policies for economic diversification), which made the themes of interest subject to controversy and often led to a certain discomfort on the side of the informants. The first informant declined to give consent for the interview to be recorded. As a result, our data collection strategy was then adapted so that we relied little on having it recorded, with the intent to increase trust and minimize possible reasons for informants to hold back on details of their experiences. As a result, we proceeded to write detailed notes from each interview immediately after each interaction. Interviews occurred either in English or in Norwegian, depending on the language preferences of the informant.

We sought and received ethics approval from Norwegian Centre for Research Data.

5 The Growth and Decline of Coal on Svalbard

In this section, we present the main events in Svalbard's trajectory (see Table 1), with a focus on the politics and economics of coal, and the correspondent societal and demographic changes associated with these events.

The Norwegian Arctic is an example of how multifaceted and complex a region's dependence on carbon can be. Svalbard is part of an Arctic energy region that is characterized by severe weather, seasonal darkness, and ice/permafrost. This places limitations on the available alternative energy sources. The Arctic energy region as a whole is heavily reliant on carbon based fuels (diesel, coal, wood, etc.) for heating, cooking, and local electricity generation. For Svalbard in particular, coal mining has historically allowed for energy security in Svalbard, as well as an economic basis to support Norwegian presence in an area where geopolitical concerns abound. At the same time, coal represents 35 percent of global CO2 emissions from fossil fuel energy generation (International Energy Agency, IEA 2023), and 20 percent of EU emissions. The EU seeks pathways to decarbonization, and for Norway ending coal mining on Svalbard symbolizes an important contribution. The LL (2023) energy report stated the realistic potential to become carbon neutral by 2030, while a coalition of Norwegian state and private companies are collaborating to find the right secure energy mix to reach net zero (Skift, 2023).

The climatic and geological setting of Svalbard places some limitations energy alternatives. The archipelago of islands lies at 78 degrees North in the northern Atlantic Ocean (Fig. 2). In this region midnight sun persists between April 20th until August 23rd, while the sun is below the horizon between October 26th and February 16th. Hence, the possibility for solar power is limited to the summer months. The geology of Svalbard is mainly sedimentary, made up of layers of sediments laid down from the Cretaceous to Palaeogene in tropical ecosystems. These ecosystems today manifest as a high grade form of black coal (bituminous coal), and a rich fossil record that bear witness to this archipelago once having a much warmer climate. Today, temperatures are increasing rapidly, and the archipelago is an example of how arctic amplification – the process by which the Arctic heats up twice as fast as other regions (c.f. Previdi et al., 2021) – affect ecosystems and infrastructures. The warming climate has resulted in novel risk, such as from avalanches near Longyearbyen (Jaskólski et al., 2018), while accentuating the risks to the Svalbard Seed Vault (Asdal & Guarino, 2018) and providing challenges to windmill developments (c.f. Panfilov, 2018).

Svalbard is governed by Norway under the Svalbard Treaty of 1920. The treaty was negotiated in connection to the Versailles negotiations and allows for all signatories to exploit its natural resources. Recent discussions on the topic highlight that

Table 1 Timeline of key events, correlated with coal production and price (coal production from SNSK, 2023)

Year	Event	Coal production (1000 tons)
1596	Willem Barents names Spitsbergen	
1899	The first Svalbardian coal is sold in Tromsø	Artisanal volume
1906	Founding of Arctic Coal Company (ACC) by Longyear and establishment of Longyear City	
1910	Sweden establishes Pyramiden mining town	
1914	Beginning of World War I	
1916	Kings Bay Kull Company in Ny-Ålesund established	
1917	SNSK buys AVV and Longyear City renamed to Longyearbyen	20 (in 1917/1918)
1918	End of World War I	50 (in 1918/1919)
1920	Svalbard Treaty is signed	13 (in 1920/1921)
1925	The Svalbard Treaty enters into effect	154 (in 1925/1926)
1927	Pyramiden sold to Soviet Union	
1933	Kings Bay Kull Company nationalized	
1939	Beginning of World War II	291 (in 1939/1940)
1941	Mining operations are stopped; inhabitants are evacuated to Scotland and Arkangelsk	247 (in 1940/1941)
1943	Longyearbyen, Barentsburg and Grumant are bombed by Germans	
1944	Svea is destroyed by a German submarine	0
1945	End of World War II	
	Reconstruction of Longyearbyen begins	19 (in 1945/1946)
1964	Mining closed in Ny-Alesund after a series of mining disasters since 1945	435 (1964/1965)
1971	Establishment of a local Svalbardråd Reorganisation of SNSK	424 (in 1971/1972)
1973	Establishment of the first national parks and natural reserves on Svalbard	405 (in 1973/1974)
1975	Longyearbyen airport is opened	458 (in 1975/1976)
1978	Svalbard is connected to the telephone network	337 (in 1978/1979)
1983	Establishment of Longyearbyen powerplant	502
1990	Investment in tourism begins	303
1991	Dissolution of the Soviet Union	330
1993	UNIS is established	267
1998	Closure of Pyramiden mining operations	328

(continued)

Table 1 (continued)

Year	Event	Coal production (1000 tons)
1999	St. Meld 9: Coal is no longer central for Norwegian presence on Svalbard. Mine 7 should be closed	404
1999	New large coal reserves on Svea discovered	404
2001	Decision to establish Svea Nord mine	1788
2001	Svalbardmiljøloven: First consideration of renewable energy on Svalbard	1788
2002	Svalbardrådet is replaced by LL	2132
2002	Tourism, research and education emerge as alternative activities, in response to fluctuations in the price of coal	2132
2007	Record coal production on Svalbard 4,1 million tones: six times increase over production in 2000	4073
	First limitations on the development of cruise tourism are implemented with restrictions on number of passengers on East Svalbard and prohibition of fuel oil (tungolje)	
2008	Svalbard's seed vault is established	3430
2012	Introduction of new safety measures for ships navigating Svalbard waters (løsplikt innførelse)	1229
	Northeast shipping passage is free from ice in the summer	
2014	Lunckefjell mine established	1675
2015	The green party opens its local office in Longyearbyen	1098
	Mine 3 is opened for tourists	
	Longyearbyen serious avalanche in December	
2016	Clear positioning towards tourism, research and education	818
	Temporary decision to cease Svea coal mining due to low prices	
2017	Deloitte issues report saying coal no longer commercially justifiable on Svalbard	134
	Responsibility over King's Bay AS transferred from the ministry of trade Industry and Fisheries to the Ministry of Climate and Environment	
	Government decision to cease coal mining on Svea and Lunckefjell	
2018	Svea and Lunckefjell mines are closed permanently	1425
2020	LL begins to explore energy-shift projects	63
	Norconsult presented a report on the coal power plant that noted concern for the ageing facility and the urgent need for replacement	
Jan/2021	LL decides to close Longyearbyen power plant in 2023	
Sep/2021	Decision to close Mine 7 in the fall of 2023	121
Feb/2022	Russian invasion of the Ukraine causes uncertainty in energy supply in Europe	
Sep/2022	Decision to prolong operations in Mine 7 until summer 2025, Norwegian state budget continues support for coal energy generation for Longyearbyen	

(continued)

Table 1 (continued)

Year	Event	Coal production (1000 tons)
Dec 2022	New voting rights demanding 3 years of residence in mainland Norway municipality citing demographic shift on Svalbard. Green party closes its office.	117

the treaty was designed for a completely different socio-political and economic reality than the one Svalbard experiences today; hence, while Norwegian sovereignty is undisputed, the interpretation of the treaty's various articles is at times contested (High North News, 2020). The archipelago is governed by the Svalbard Sysselmester, who is appointed by the Norwegian State Government. The relevant institutions and administrative levels are the Longyearbyen Lokalstyre (LL) which is responsible for the local government, Sysselmesteren who administers the archipelago, the national government to which the Sysselmester is answerable, as well as to the Troms judiciary branch, located on northern mainland Norway.

Lying in the High North (78°N), the Longyearbyen township is not a 'lifecycle community', meaning that it does not have infrastructure for inhabitants to be born or die there. That is, pregnant women, elderly people and/or severely ill patients are directed to mainland Norway for medical assistance. Nevertheless, the archipelago has attracted a certain demographic of adventurous inhabitants. The population has remained stable at just over 2000 inhabitants over the past decade (SSB, 2023), despite the decline of coal mining. Nevertheless, as this chapter shows, changes in cultural and demographic aspects have been dramatic in recent years, and already present a tipping point in the Svalbard society.

5.1 Politics and Economics of Coal

Coal mining has for the past century been a crucial instrument for maintaining Norwegian presence on Svalbard. The early investments in coal were made by foreign governments subsidizing private actors. Over the years the subsidies were replaced by full nationalization by both Norway (ACC, SNSK, Svea) and Russia (Pyramiden, Barentsburg) (Table 1). The nationalized mining operations guaranteed the development of infrastructure and services on the archipelago. The process of nationalization was completed in 1976, when the Norwegian government nationalised the coal mining company Store Norske Spitsbergen Kulkompani (SNSK). [3] This happened during the cold war and energy crisis, as the operations of SNSK was increasingly uneconomical, while the geopolitical interests of maintaining the company active were ever more crucial. Coal mining operations on Svalbard until the

[3] SNSK is the parent company and owns 100% of SNSG. SNSG performs the coal mining, in parallel to the other parts, like the real estate and energy divisions of SNSK.

Fig. 2 Map of the Svalbard archipelago with townships including Longyearbyen (Source: Norwegian Polar Institute,2016)

early 2000s were not very profitable, when production value increased markedly (Fig. 3). SNSK has often been referred to as a cornerstone company—or even the lifeblood—of Longyearbyen society, both before and after nationalisation (Figenschou, 2014; Samuelsen, 2015; Ertsaas, 2020). For example, until the 1980s, the company issued a kind of local currency known as 'Spitsberg money', a practice that was not uncommon in company towns across the world.

Other natural resources have also been exploited on Svalbard. In addition to the historic practices of hunting and whaling, there have been drillings in search for oil and gas at different times; mining for metals has also been attempted, though short

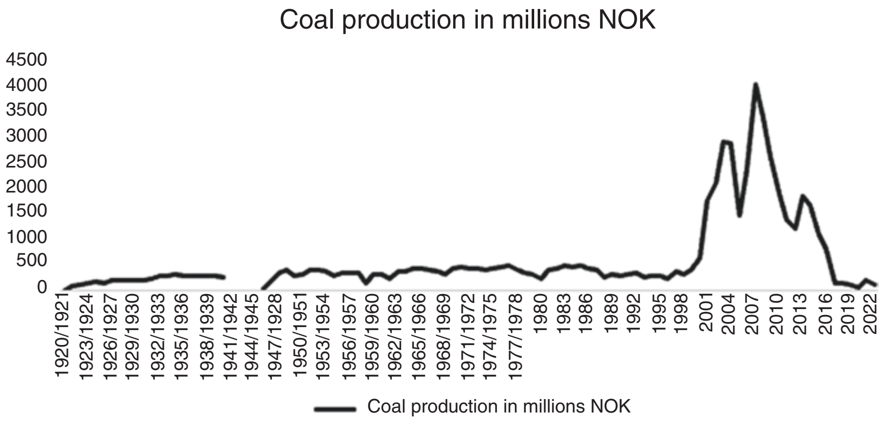

Fig. 3 Coal produced on Svalbard in millions of NOK in 2023 values (source: SSB, data after 2019 from SNSK, 2023)

lived. The scope of resources identified, combined with the harsh arctic environments and long distances have not sustained the continuation of these activities at commercial scales. In essence, economic activity was deemed necessary to maintain presence and stability in the region, but the lack of commercial appeal has meant the need for state support. As a result, life in Svalbard has existed in a symbiosis of political goals and economic activity, of which coal has been at the center.

Starting in the 1990s, the Norwegian state has sought to transition from coal dependency to alternative energy and economic industries that are intended to be more economically and environmentally sustainable than coal (Justis- og beredskapsdepartementet, 1999; Bjørnsen & Johansen, 2014; Palm, 2016; Olsen, 2017). Before then, the Norwegian government had been resistant to allow tourism on Svalbard. This changed with the promise to foster job creation and a diversified economic base as the government began to increase the budget allocation for research and higher education. In 1993, the University Centre in Svalbard (UNIS) was established. About a decade later, local democracy was implemented through the establishment of the LL in 2002. By 1999, coal mining was no longer perceived, by the government, as critical for maintaining a Norwegian society on the archipelago (Justis- og beredskapsdepartementet, 1999), even though two mines opened after this realization (Svea in 1999 and Lunckefjell in 2014).

After the early 2000s, coal prices increased and coal revenue on Svalbard increased to a peak in 2007 (Fig. 4). While prices have fluctuated over the past 20 years, and revenue peaked, mining turnover has decreased stepwise to near zero (Fig. 5). All the while, debates surrounding coal phase-out and green transitioning have persisted. For example, the Committee on Foreign Affairs called for an assessment on the possibility of a renewable energy system in Longyearbyen both in 2001 and 2009 (Utenrikskomiteen, 2001, 2009). In a white paper from 2009, the government communicated an interest in facilitating more research, education, and tourism

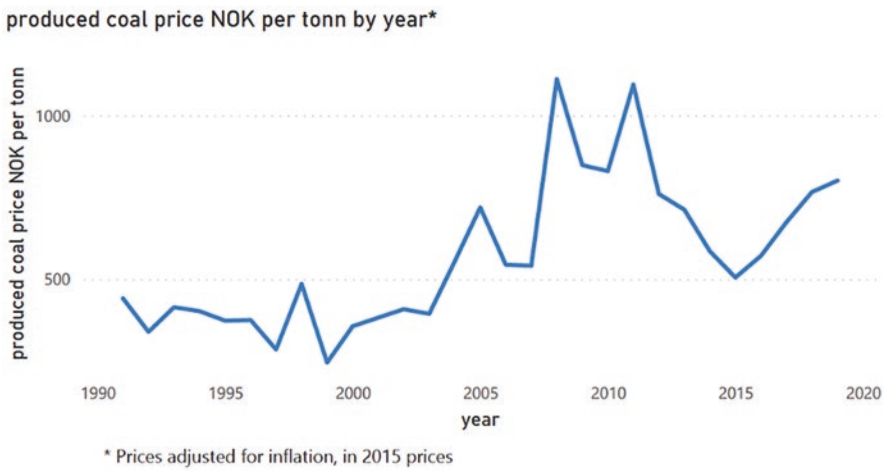

Fig. 4 Produced coal price per tonn 1990–2020 (Source: SSB)

Fig. 5 Turnover from coal mining (NOK) on Svalbard 2008–2021 (source: SSB)

due to the vulnerability of the coal industry to price fluctuations (Justis- og politidepartementet, 2009). The politicians' comments on the white paper were perceived as a signal for a phase-out of the Svea mine (Amundsen, 2009). Coal prices were plummeting after a record year in 2008, and SNSK was struggling to adapt and restructure (Aarskog, 2009). In 2012 and 2013 the company ran a large deficit and had production problems, resulting in the need to downsize and dismiss 70 employees (Amundsen, 2012, 2013). During and following this period, several articles and op-eds in Svalbardposten (local newspaper), as well as posts on the Facebook group 'Ros & info Longyearbyen', discussed the future of Svalbard and alternative energy sources.

The years 2014 and 2015 were marked by large restructurings and economic problems in SNSK (Olsen, 2017). Between 2011 and 2015, the coal prices

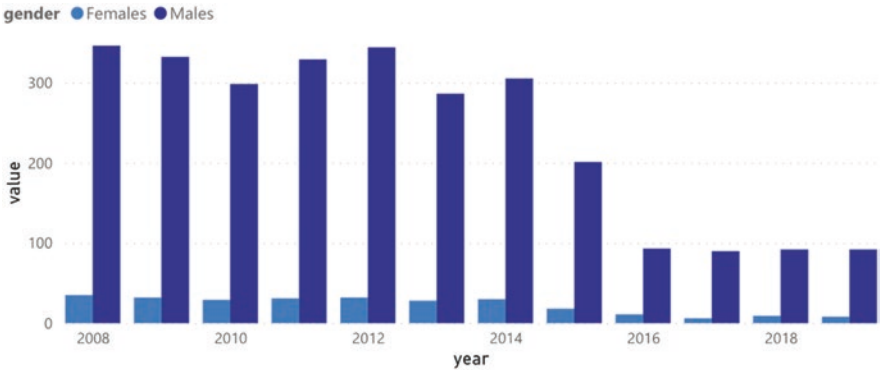

Fig. 6 Percentage women and men employed in mining on Svalbard 2008–2019 (Source: SSB)

plummeted again (Fig. 6) and SNSK had to resort to temporary downtime, financed by government support (Holdal, 2015; Palm, 2015). Consequently, the local community engaged in public debates concerning the sustainability of keeping the mining activity alive through subsidies. In the white paper on Svalbard in 2016, the government stated that coal mining was of reduced importance, both due to a great share of the workers commuting from the mainland (thereby not residing on Svalbard), and due to economic problems (Justis- og beredskapsdepartementet, 2016). However, it did state that continued activity could be possible if coal prices were to indicate profitability in the future. The importance of tourism was highlighted, and the government wished to facilitate a transition through increased employment in this sector, as well as in research and education.

The government recommended and allocated funding for the phase-out and clean-up of coal mining in the Svea and Lunckefjell mines in the national budget proposal for 2018 (Nærings- og fiskeridepartementet, 2017). This recommendation was partly based on a non-public report by Deloitte that concluded that continued operation would not be commercially justifiable (Nygaard, 2017). Before the recommendation was made, coal prices had risen and the local debate regarding the coal industry revived. The LL was already skeptical to parliamentary investments to re-open the mines after the downtime, in case they would not be profitable. The LL believed that the economy could benefit from reducing the dependency on SNSK, although it recognized mine no 7 as vital for local energy production and for the community.

In 2020, the LL decided to start an energy-shift project that could result in the closure of the coal power station. The end of Longyearbyen's coal power plant was confirmed in January 2021 (though planned for 2023) and prompted SNSK and the government to also decide on phasing out mine 7. This decision has been celebrated by environmentalist groups, but has been very controversial locally, not the least because no clear alternative energy source had been defined as a substitute at the time. Furthermore, the coal power station had been outfitted with filters to prevent black carbon emissions that might otherwise cause snow and permafrost to thaw and contribute to unstable structures and hillsides. While the filters caused some increase in CO2-emissions because more energy became needed to generate sufficient heat, the emissions from coal mining on Svalbard has been in steady decline over the past 15 years, with a sharp decrease in 2015–2016 as mining operations were near halted (SSB, 2023). Approaching 2020, these emissions became nearly zero (from peaks of around 25k tons CO2-equivalents in 2007 and 2015, SSB, 2023). Meanwhile, energy generation continues to produce CO2 emissions. As a temporary solution, diesel generators will supply the energy needed to power Longyearbyen. Over time, pilot projects based on renewables will be tested with the ambition to determine the best energy matrix for sustaining Longyearbyen.

Without the demand from the local power plant, the volume exported (c. 75 percent of total production to Germany for metallurgy) was insufficient justification to keeping mine 7 operational. SNSK has been exploring other activities that support their own transitions. With the imminent end of coal, SNSK has been investing increasingly on arctic logistics, real estate development in Longyearbyen, [4] as well as pilot projects for energy alternatives on Svalbard, that can be transferred to other Arctic off-grid locations. In the words of one interviewee: *"Vi produserer ikke kull. Vi produserer tilstedeværelse og stabilitet på Svalbard for Norge"* (*we do not produce coal, we produce presence and stability on Svalbard for Norway*). In this spirit, SNSK is finding their way towards achieving their core mission outside of coal mining.

Plans for shutting down the mine have been disturbed by Russia's invasion of the Ukraine in February 2022. First, Europe (and to some extent Norway) is facing a severe energy crisis, which has led the continent to look at Norway's abundant energy generation as a lifeline. Furthermore, fuel prices are also high and volatile as result of the war, which affects the cost and energy security of running power facilities based on diesel. Not insignificantly, coal prices are also at a historic high, representing increased revenues for SNSK. The energy supply security presented by a local coal source is also accentuated by this geopolitical context. In the context of the invasion of Ukraine, and in absence of clear and reliable alternatives for energy, coal mining will continue for 2 years longer than initially planned. Over the period between which the coal mine closes and renewable energy alternatives can be planned, diesel will be used for electricity generation (NTB 2022). Diesel is expected to reduce the emissions by around 50 percent (Longyearbyen Lokalstyre 2023).

The diversification of the economic base on Svalbard away from coal has some defining characteristics with implications for society, culture and demography. Not only have the Norwegian developmental strategies taken a step away from the coal mining economy, but they have also gone in the direction of the services economy.

[4] SNSK is the single largest owner of real estate in Lonyeargyen by a very large margin. As Longyearbyen is not a 'life-cycle community', purchasing a home there is not the norm, and SNSK owns most residences. This also allows for some control over a possible population growth, given the vulnerability of the local environment and the fact that the economy of Svalbard does not run on regular market-based principles.

This has implications for what types of knowledge and competences are needed in the local population, in order for the local economy to thrive. This also brings along changes in demographic characteristics, such as gender, age, ethnicity etc.

5.2 Demographic and Societal Characteristics and Changes

Svalbard's population has near doubled since the mid 1990s, from around 1250 to 2500 residents, while employment in mining has been in a decline. Following the fluctuations in coal prices and government subsidies, employment in coal mining began to decrease by 1989. By the time the decision was made to cease coal mining, a sharp decrease saw 200 of 300 coal mining jobs terminated (Fig. 6). At the same time, employment in private business, especially within the tourism industry, started to increase, with a sharp change over the first two decades of the 2000s. Between 2015 and 2021 alone, mining revenue saw a decrease from 600 to 100 million NOK, while transport, research, and teaching each increased significantly (Fig. 7). The Svalbard economy was severely impacted by the COVID pandemic, when tourism revenue was near absent, and the numbers for 2021 need to be seen in light of a recovering hospitality economy.

With this change in employment, the demographic make-up of Longyearbyen also changed. An influx of seasonal and short-term workers employed in hospitality and teaching reduced the residence time in Longyearbyen to months or years, while the long-term residents became fewer. Several have documented how these demographic shifts have influenced social cohesion and trust. For instance, people started

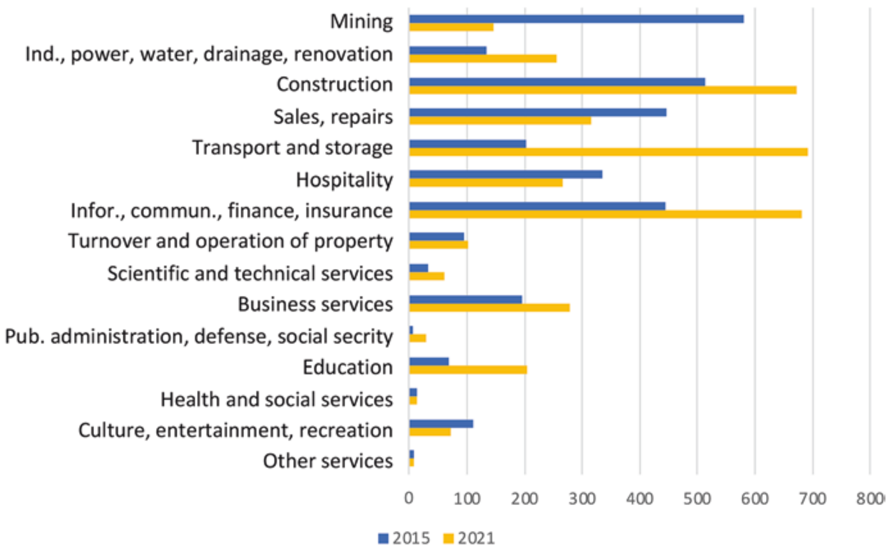

Fig. 7 Change in turnover in millions of NOK across businesses on Svalbard (source: SSB)

to lock the doors in homes (Eriksen, 2020) and cars (Mogård & Bergersen, 2017), marking a shift away from the close-knit relationships of the coal mining economy.

Our research suggests a stronger sense of political involvement in recent years. The Green Party established a local organization just prior to the 2015 elections to support cessation of coal. The cessation of coal appears to be connected with this mobilization. Residence on Svalbard is allowed only to persons who can support themselves financially. With the lower economic turnover during the pandemic there have been cases where persons have been forced to leave Svalbard and Norway due to lack of financial support. This need prompted discussions on the continued role of Svalbard as a non-lifecycle community, and the concomitant demands for sustaining rights of residency. The political ideologies are emerging both from Longyearbyen itself and the long-term residents there who have shaped their political views locally over many years, as well as from other parts of Norway and the world. The rapid loss of coal miners and their community values and political orientations has been matched by a rapid increase in new and short-term residents from all parts of the world.

In consequence of the changed demography of Svalbard, the Norwegian government in 2022 changed the voting laws (Justis- og beredskapsdepartementet, 2022a, 2022b). There is a local election for the Lokalstyre, for which until 2022 all residents on Svalbard had voting rights. Citing changed demographics, the Norwegian Government from 2022 grants voting rights only to persons who have lived at least 3 years in a municipality on mainland Norway (Justis- og beredskapsdepartementet, 2022a, 2022b). In practice this prevented around 700 residents from influencing governance of Svalbard in 2022. In 2019 1827 persons were eligible to vote, and by 2023 this number is around 1120 (SSB, 2023). Following this decision, the recently established Green Party ceased operations.

Today, the region is dominated by tourism, research and education activities, together with a variety of supporting businesses involved in construction and transportation. Longyearbyen is a hub for cruises and expeditions to natural areas across the islands and coast, and Ny-Ålesund is a research hub (but also a tourist destination) where 18 institutions from 11 countries work primarily on environmental and earth sciences.

6 Narrative Evolution of Svalbard's Energy and Economy

In this section we examine the developments coal mining on Svalbard described above through the lens of the two key TIPPING+ frameworks (Fig. 1). Where coal had the function of being an energy source, an economic activity, as well as a community cornerstone, the transition away from coal needs to take into account the needs for transformation in all these three strands. Looking more closely at these narratives, the coal economic narrative, the community narrative, and energy narrative on Svalbard are differentiating. We can see that the energy transition relies on at first, wood pellets and diesel imported from lower latitudes, before the energy system can transform into viable and important renewable alternatives. The cultural and economic transition emerges together through the 'three new legs' of the Svalbard economy, where residents no longer are coal miners, but work in tourism, research, and education. As an alternative and less important narrative, we also give attention to an economic transformation narrative that does not rely on mass tourism. A seventh transformation narrative not represented on this figure is an implicit militarization of the archipelago. The publication of the new *Svalbardmelding* (Norwegian Government White Paper for Svalbard politics) has been pushed forward to 2024 in response to the Russian invasion of Ukraine, and there is a sense of anticipation for what this white paper will entail for Longyearbyen.

In the following, we look more closely at each narrative transition. For each narrative, we also point to the material changes accompanying the narrative, and the degree to which it has been or is able to be materialized in the near future.

6.1 The Coal Energy, Cultural, and Economic Narrative

Mining has been a cornerstone of the Svalbard community for a century. In the narrative that enables and perpetuates coal, the coal mines and power plant plays the role as a securer of Norwegian presence on Svalbard, with the coal economic activity providing some return on the investment necessary to secure this presence (Fig. 8, 0). Coal has historically not generated large revenues on Svalbard (Fig. 3), until in the early 2000s when prices for black coal soared and production along with it (Fig. 5). It is worth noting that the intention to transition the economy toward tourism, education, and research came in the 1990s after 70 years of stably low coal

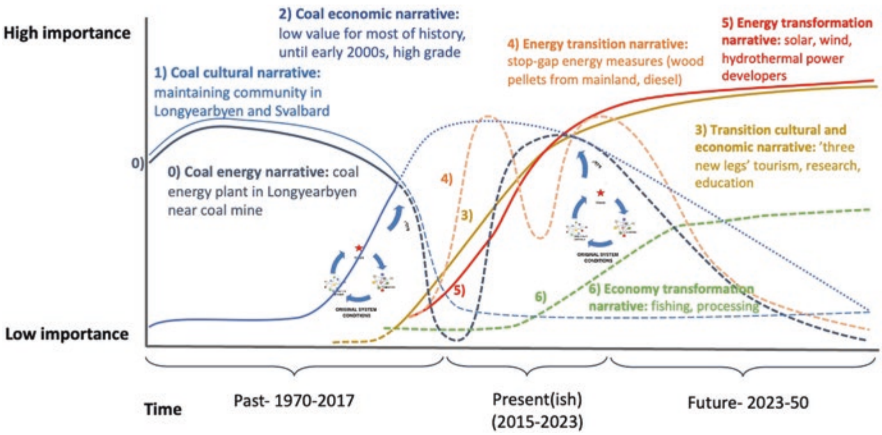

Fig. 8 Different narratives relevant to coal on mining on Svalbard, based on a Tipping+ synthesis framework

productivity. Hence the production of coal has not been motivated by economic gains over the course of the Norwegian mining operations.

The late 1990s marked a tipping point in Norway's Svalbard policies that set in motion the transition toward the 2017 decision to cease coal mining. As such, the coal narrative has not been mainstream (see Lieu et al., 2020) on Svalbard since the early 2000s (Fig. 8, 0). Meanwhile, a coal-legitimating narrative does persist, which puts forward energy security, the lack of energy alternatives, as well as abating technologies such as filtering coal power production and capturing carbon for storage (CCS). Another facet of this legitimizing narrative concerns the fact that the coal mined in Mine 7 is of a specific quality for use in metallurgy (bituminous coal), and that this use has lower emissions than coal energy production (Garte, 2021). Since this coal is not burnt it does not enter the accounting systems for greenhouse gas emissions; moreover, this narrative holds, metallurgical quality coal is used for manufacturing steel, given current scale and technological development, which in turn is necessary for the infrastructure needed for the green shift (Garte, 2021).

The coal narrative has once been espoused by the Norwegian national government, Longyearbyen local authorities and large parts of the Svalbardian society, in particular mine workers and their families, who up until the late 1990s corresponded to substantial shares of the local population. In the years leading up to Russia's invasion of the Ukraine, this narrative weakened substantially (Fig. 8, 0), but the geopolitical destabilization and concomitant concern for energy security is tied to the decision to delay closure of the last mine until 2025 and perhaps beyond.

6.2 Transition Narratives

Transition narratives stake out pathways to a low carbon society and economy. These narratives catalyze the replacement of coal by other means of generating energy, community, and economy (the offstream narrative in Lieu et al., 2020), but without themselves constituting the transformation into low-carbon societies and economies. In part, this catalysis is driven by the targets set out in the Paris agreement, but the process is driven also by the low economic profitability of black coal in Svalbard as in other regions. For coal more generally, the economic motivation for phase-out is illustrated by the observation by Lægreid et al. (2023) that peak coal production tends to precede by some period of time the decision to phase out coal. For Svalbard the decision to phase out coal came after 70 years of stable and low coal production (Fig. 3), precipitated by the confluence of the Norwegian State's need to replace the ageing coal energy plant and the growing concern for greenhouse gas emissions. Today, the decision to phase out coal is broadly supported, as exemplified in the director of SNSK, Jan Morten Ertsaas stating, "There is no economic value in coal mining on Svalbard. Our salary and freight costs are too high. In addition, the market is too uncertain. A majority of the world believes coal should be phased out, and that is our opinion also" (Andreassen, 2022). The Norwegian state redirects subsidies according to transition narratives, to help catalyze 'three new legs' for the Svalbard settlement to stand on, and new low carbon energy to power Longyearbyen; but these narratives have not yet materialized into self-sustaining alternatives to the coal society and economy.

The most established transition narrative focuses on establishing education, research and tourism as new economic and cultural cornerstones (Fig. 8, 3). This narrative has been under development since the 1990s and has gained momentum with the decline of coal in recent decades. Critics point, however, that it is far from given that tourism is a sustainable alternative. Tourists reach Svalbard by plane or cruise ships, and a popular tourist attraction involves energy-inefficient diesel-powered snowmobiles. Tourism also puts other types of pressures on the vulnerable ecosystems in the High Arctic, and a sustainable tourism enterprise depends on collectively balancing economic and environmental governance concerns (Hovelsrud et al., 2021). A fringe narrative focuses on fisheries and processing of fish as an additional possible source of jobs and economic activity (Fig. 8, 6). Fishing in the region is highly regulated, and marine ecosystems are undergoing changes associated with climate change that are driving boreal species such as cod northward. This shift may make the fisheries more profitable than they are today, but remoteness and technology render Longyearbyen a less appropriate landing (Misund et al., 2016).

When it comes to energy production, there is in 2023 no wide agreement concerning which specific alternative energy sources will be phased in. A Justis- og beredskapsdepartementet (2022a) white paper on renewable energy writes, "for a small society like Longyearbyen it is important to find a good shared energy solution that does not carry excessive energy cost for residents and businesses. The energy solution needs to be in line with Norway's climate goals, at the same time as it secures a safe provision of energy and heat for the residents of Longyearbyen. Failures in the energy provision on Svalbard can have serious consequences. Concern for provision security must therefore weigh heavily in the choice of new energy provision." The white paper considers a bouquet of energy efficiency measures, including solar, wind, green ammonia, and energy saving measures together with other technologies as the most viable and immediate alternatives (Longyearbyen Lokalstyre 2023). Citing the need for energy security, this report suggests diesel, pellets, or gas as viable transition solutions while more permanent renewable energy bases are developed and institutionalized (Fig. 8, 4–5). In the long-term, a range of renewable-based alternatives are being piloted by SNSK, and represent not only new energy sources for Svalbard, but also new business avenues for the company (Fig. 8). Nonetheless, the weather and environmental conditions on Svalbard as a high Arctic region are severely limiting of alternative energy sources. The Norwegian State and Longyearbyen local government have indicated diesel energy generation as the preferred alternative while viable alternatives are developed (Justis- og beredskapsdepartementet, 2022a, Markussen, 2023).

Transition narratives also have ideological underpinnings, and some stakeholders point to the way in which events unfolded as evidence for this. The timid end of Svea and Luckefjell mines in 2017 had a more substantial impact on the economy and demography of Svalbard, while the announced end of Mine 7 is perceived to be unpractical and of little actual impact, if not arbitrary. Because the end of Mine 7 is more of a side effect of the LL decision to shut down the power plant than it is a move from SNSK or the Norwegian government, some see it as a symbolic gesture and a missed opportunity for decisive political action that promote low-carbon transitions. In sum, the transition away from coal on Svalbard has since the 1990s been motivated more by coal prices and demand than it has by emissions reductions. The plans to prolong coal mining for two more years now that prices are high and the geopolitical context strained, give further support to this observation.

6.3 Transformation Narratives

The transformation narratives for Svalbard are emerging but are not yet well defined or of high importance in defining the Svalbard society. The transition narratives described above (Fig. 8, 3–4) mobilize diesel, gas, pellets, an energy cable from the mainland, CCS, biochar, and other alternatives for energy generation (Urke, 2021), and rely on high emissions and ecosystem impact activities through tourism, research, and education. The need for this transition at the present time is driven in part by the low profitability of coal and the old age of the coal energy plant, in part by the symbolism of coal mining as a major emitter or CO_2. To build a new coal power plant would not be in keeping with the commitment to the Paris Agreement, such that alternatives are needed even as renewable energy is not yet available. Hence, the transition narratives are not to be equated with the transformative narratives that will emerge or are emerging to render Longyearbyen a low carbon economy.

The cultural and economic narratives have to a large extent been transformed through the cessation of coal, given the dramatic change in demographics and the investments in tourism, research, and education that precipitated those shifts. The cultural and economic transformation narrative (Fig. 8, 3) has become well established and is likely to continue. Meanwhile, the contents of these narratives will need to change in order to avoid the considerable impacts of tourism, research, and education in this remote region on climate and ecosystems. In part this transformation relies on new technologies being available that will reduce or eliminate emissions from air travel and cruise ships, in part on novel tourism packages that avoid impacts on fragile arctic ecosystems (Hovelsrud et al., 2021). As such, this narrative is not well defined, although its ‘themes’ on tourism, education, and research is likely to remain.

The energy narrative (Fig. 8, 5) is under rapid development. The 2022 Energy Plan commissioned by the Longyearbyen Local Government lists wind, solar, and geothermal energy as potential alternatives, but this planning is at an early stage and considerable investment in impact assessments and development planning is needed for this narrative to become defined, shared, and mainstream. The principal concern in defining this narrative is energy security, ensuring a safe and stable energy source (Justis- og beredskapsdepartementet, 2022a).

A final potential transformation narrative concerns other economic and societal alternatives than those in the transition narratives. In particular, the potential for fishing (Fig. 8, 6) has been raised in the discussions over alternative economic activity. The strongest limiting factor here is the ease with which fishing vessels can process catch on board and transport directly to ports in Norway. Other alternatives that have been mentioned concern being a port for transportation along Arctic shipping routes, but the bathymetrical conditions in Longyearbyen, as well as its location vis a vis other North Atlantic ports, make this a less desirable location. Moreover, there may be other narratives under formation that are imagining a different economic, energy, and societal Longyearbyen and Svalbard that can resolve issues concerning emissions, ecosystem impacts, and cultural cohesion and trust.

7 Concluding Discussion

Longyearbyen is a valuable place to investigate how ceasing coal mining impacts politics, culture, and economy. The top-down manner in which the Svalbard society is governed allows for sweeping policy changes without the same concern for political backlash as is the case in many of the other CCIRs investigated in the Tipping+ project (see other chapters in this volume). Hence, the key turning points in the transition to a post-coal economy and society on Svalbard have been driven by processes external to local values, needs, and priorities. Four key events have contributed to the cessation of coal on Svalbard, although none of these can be said to have tipped the social-ecological system into a low carbon region. First, in 1999, the government stated the ambition to facilitate a more diversified economy on Svalbard, indicating an intention that coal mining should no longer be essential to ensuring Norwegian presence in the region (Justis- og beredskapsdepartementet, 1999). In 2017, at a time of low coal prices, the government recommended the Svea mine and Lunckefjell mine to be phased out. In 2020, Norconsult presented a report on the coal power plant that noted concern for the ageing facility and the urgent need for replacement. Finally, in 2021, the LL decided to stop using coal for power generation in 2023 (now delayed to 2025). A new turning point may be anticipated from the new Svalbardmelding (Government White Paper) to be published in 2024, which will stake out the new trajectory for the Longyearbyen settlement in the new geopolitical setting following the Russian invasion of Ukraine. The transformative shift in demographics seems to have been an unanticipated consequence of these policy changes, which were cited as cause for restrictions in voting rights in 2022 (Justis- og beredskapsdepartementet, 2022b).

The ways in which the post-carbon transformation is storied is critical for transformations toward sustainability (Tàbara et al., 2018; Lieu et al., 2020). This chapter and the book to which it belongs contribute insights on how narrative positive tipping points can be induced (Tàbara et al., 2018). At the outset of the chapter, we asked what precipitated the decision to end reliance on coal as a source of energy and economic activity on Svalbard, and how has the decision to end reliance on coal affected the Svalbardian society. For Svalbard, narrative tipping points induced by the national government have created the cognitive conditions to spark material changes toward low carbon energy generation, but they have also induced challenging disruptions to Svalbard culture and energy security.

We have shown that the post-coal narrative on Svalbard has followed national economic trends, such as low turnover and high cost of upgrading and repairing the coal mine and power plant. The redirection of state subsidies to support the reduction of greenhouse gas emissions from energy generation has played a central role in the National Norwegian political narrative. Meanwhile, there is an absence of initiatives to calculate and compare the emissions from coal mining and energy production with those of tourism, teaching, and research. This suggests that the decision to cease coal mining is not based on greenhouse gas accounting. Rather, it is based on a wish to move government subsidies from repair and upgrading of coal mines and coal power, to subsidizing net zero energy alternatives. Until such accounting is done, however, the combined carbon emissions of the human-natural system of Svalbard may or may not be virtually unchanged in the transition from the coal economy to the tourism-research-teaching-based economy. A credible post-carbon narrative for Svalbard requires this greenhouse gas accounting.

While the physical system has yet to transform to a low carbon trajectory, transition-related events have led to demographic and societal transformations on Svalbard. The coal worker population has been exchanged for a population working in the hospitality-related industry. New and shorter-term residents have replaced the longer-term former residents. The demographic transformation is recent, and its consequences for local democratic processes seemed unexpected given the sudden change in voting laws that rescinded the voting rights of persons who have not lived on mainland Norway for a minimum of 3 years. The demographic shift also altered the social fabric with impacts on the Longyearbyen culture, shown for instance in that people have started to lock their doors. In sum, the low carbon narrative has been fronted widely but the material transformation that has happened is so far limited to demographic patterns and economic activity. The Svalbard case suggests the need to consider narratives in the context of trends in the combined societal and earth system components of energy transitions and transformations toward sustainability.

Based on the lessons learned from the Svalbard case, we propose that a key enabler of positive tipping points in CCIRs are government actors who have previously incentivized coal mining as a community-building tool, and are looking to subsidize low carbon or zero emission alternatives. Potential barriers to the emergence of positive tipping points are the emissions levels, and other sustainability concerns, related to the economic alternatives, as well as the supply security of alternative energy sources. A more concerning insight from this case study and others in the TIPPING+ is that what triggers transformation in black (or hard) coal regions may not transfer directly to brown coal regions, where the economic profitability is very high.

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Confronting Local and Global Tipping Narratives: Green Energy Development in the Arctic and Why Greenland Is Not for Sale

Anne Merrild Hansen and J. David Tàbara

Abstract This research addresses a confrontation of narratives usually overlooked in global-local discourses about green energy futures by focusing on the case of Greenland. On the one hand, the call for keeping the vast amounts of Greenland's fossil fuel deposits in the ground, as one of the most efficient and fastest strategies to limit global GHG emissions and avoid a climate catastrophe -hence preventing a negative global climate tipping point. And on the other, the need to exploit and provide alternative mineral resources for the global green energy transformation – hence enabling a global positive tipping point towards a sustainable development trajectory. For that, we trace the historical local conditions and events that eventually led towards green development trajectory pathways. These include indigenous groups' opposition to oil drilling in the Arctic waters and more recently, the consideration of alternative resource governance mechanisms in support of a low-carbon transformation. We argue that overcoming such confrontation requires reconciling both Natural Resource Justice with Earth System Justice principles that consider the rights, needs, worldviews, and institutional traditions of local communities. Among them, the impossibility of privately owning land across generations in Greenland stems as a possible example of disruptive tipping intervention on how Western societies could learn to relate to biophysical systems in more sustainable ways to cope with accelerated global environmental change.

Keywords Earth tipping points · Positive tipping points · Greenland · Justice

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1 Introduction

The Arctic is perhaps the region in the world that is most affected by climate change (Walsh et al., 2011). Due to its high latitude and proximity to the poles, it is warming at a much faster rate than the rest of the planet (AMAP, 2017; ACIA, 2005). This rapid warming is leading to the melting of sea ice and permafrost, which, in turn, is increasing access to previously inaccessible resources such as oil, gas, and minerals. The extraction and use of these resources can contribute to the acceleration of climate change, creating a cascade of feedback loops that further impact the Arctic and its communities. In addition, the melting of sea ice and the vast deposits of untapped mineral resources are also leading to increased geopolitical tensions in the region, as countries compete for access to resources and shipping lanes (AMAP, 2017; IPCC, 2019). It may thus seem, from a climate perspective, like a very dangerous idea to extract further mineral resources in the Arctic. However, the Arctic also holds various minerals necessary for the development and production of green technologies, which, on the other hand, may contribute to a green transition and the prevention of negative global environmental tipping points.

The Arctic region has often been viewed through an extractive lens, with a focus on exploiting its natural resources for the benefit of multinational corporations and global consumers. While this has benefitted some global actors and private interests, it has not always been the case for the Arctic communities impacted by the activities, as extraction, in many cases, has happened without proper consideration of the interests and needs of local communities (Stammler, 2010; Gover & Fenge, 2019; Westley & Miller, 2017). This raises the question of how the use of resources in the Arctic can be harnessed in a way that contributes to preventing, rather than promoting, negative environmental tipping points, and in a manner that ensures a just distribution of risks and benefits, both globally as well as based on local values and interests.

Greenland is an example of an Arctic nation subject to mineral extraction for the green transition. It presents a unique case study in this regard due to its remote location, harsh climate, limited infrastructure, and communities highly dependent on natural resources, all of which call for special considerations. In 2019, then President of the USA, Donald Trump, declared his interest in buying Greenland from Denmark, motivated by a desire to access the expected attractive undeveloped mineral resources and hydrocarbons in the region. It has been argued that the exploitation of Greenland's natural resources, including oil and gas, as well as green energy resources, such as minerals for green technologies has the potential to yield significant economic benefits for both local communities and multinational corporations (Hansen & Johnstone, 2018). While the resources in Greenland have the potential to play a significant role in avoiding the negative global tipping point of a climate catastrophe, the resource extraction of rare earths and other materials, if not managed wisely, can cause irreversible and devastating impacts on local environments and communities, and the country as a whole.

In this chapter, by focusing on the case of Greenland, we examine a confrontation of narratives that is mostly materialized at local level when confronting different notions of resource property and rights that usually overlooked in global-local discourses about green energy futures. On the one hand, the international call for keeping the vast amounts of Greenland's fossil fuel deposits in the ground, as one of the most efficient and fastest strategies to limit global GHG emissions. Such goal is thus aligned with the UN Paris Accord of keeping global warming below the 2°-1.5 °C threshold to avoid a climate catastrophe and hence prevent a negative global tipping point. And on the other, the need to exploit and provide alternative mineral resources for the global green energy transformation, hence to support the enabling conditions to achieve a positive tipping point towards a global sustainable development trajectory. Local communities then confront the contradiction of not-extracting resources for one reason but extracting other resources for other reasons that may be perceived of little benefit at local level. To explain this, first we provide a brief introduction to the role of the Arctic region as a provider of energy resources for global consumption and its implications. On this, we discuss the cross-scale interactions and discourses among local actors, large international corporations, central national governments, and international agencies in preventing a potentially catastrophic global negative tipping point by letting transnational actors have unrestrained access to Greenland fossil fuels. Then, we also seek to contribute to the understanding of how Greenland can influence global positive tipping points by becoming a producer of green energy resources and technologies without compromising the interests and aspirations of their local populations. We argue that dealing with halting fossil fuel resources whilst also exploiting new minerals demands a serious consideration of the interplay and potential synergies that may be achieved by integrating both local natural resource justice perspectives with a Earth Systems justice one. Last but not least, we underline what can be learned, and particularly by Western societies, from the Greenland traditional institutional settings and recent developments with regard to integrating more sustainable equity and justice arrangements to support global transformations processes toward sustainability. These includes the fact that land in Greenland cannot be inherited across generations, an example that could be used to transform Western perceptions and traditions on crucial socio-economic mediating mechanisms such as property rights - often equated to exploitation and destruction rights -, that need to be adapted to cope with negative earth systems' tipping points.

2 The Arctic as a Source of Energy Resources for the Global Market

The Arctic has long been, and still is, a source of energy resources for the global market. Historically, whales were harvested for oil production and consumption in other parts of the world (Hacquebord, 2001). Later, oil and gas resources in the Arctic were developed and are still being exploited and exported globally for consumption. Today, minerals needed for renewable energy technologies are in high demand, so once again, the world looks towards the Arctic to exploit its resources for global needs.

Whales have been harvested in the Arctic for centuries, and this has had a significant impact on the communities living in the region (Hacquebord, 2001). In the past, whales were harvested using traditional hunting methods by indigenous communities in the Arctic (Hovelsrud et al., 2008). These communities had a deep understanding of the marine ecosystem and the behavior of whales, and they used their knowledge to sustainably harvest whales for their meat, skin, and oil. However, with the arrival of commercial whaling in the nineteenth century, the hunting of whales in the Arctic changed significantly. The exploitation of whale oil for global consumption led to an overhunting of whales and the collapse of their populations.

The decline of whale populations in the Arctic had long-term impacts on the ecosystem and the communities that depended on them. The loss of whales as a food source forced indigenous communities to adapt their hunting practices and seek alternative food sources. Furthermore, the decline in whale populations had ecological impacts, as whales play a critical role in the marine food chain and help regulate the ocean's ecosystem. In the traditional hunting practices of indigenous communities, the harvesting of whales was done in a way that was sustainable and ensured the well-being of the community.

The complex interactions and tensions occurring between the local and global exploitation of natural resources are particularly materialized in the case of Greenland. Over the past century, the unprecedented growth of the global economy and consumption has been fed by the extensive exploitation of fossil fuel reserves, including coal from Svalbard and oil and gas from Norway, Alaska, and Siberia. The subsequent boost in carbon-intensive industries has been a primary contributor to the acceleration of climate change. The consequences of fossil fuel extraction in the Arctic and its contribution to climate change have been particularly pronounced in communities near Svalbard, Norway, Alaska, and Siberia. As the Arctic experiences some of the most rapid and extreme effects of climate change, indigenous and local communities are facing a myriad of challenges that threaten their traditional ways of life and cultural heritage. Furthermore, the extraction process itself has also caused adverse impacts on the nearby communities (see Kröger, 2022).

In the past decade, a global narrative shift towards a green energy transition, driven by the imperative to combat climate change, has sparked a heightened interest in mining operations for minerals such as lithium, cobalt, nickel, and rare earth elements necessary for renewable energy technologies, electric vehicles, and low-carbon solutions. The Arctic, known to possess substantial mineral reserves, has become a focal point for these mining activities. Thus, the hunt for energy resources in the Arctic continues. Various countries are trying to legitimize their Arctic interests by promoting their 'Arctic-ness' through narratives of historical relationships, typically related to transport, logistics, collaboration, presence, trade, or others. While the green transition represents a crucial step towards a sustainable future, it can potentially have significant negative implications for the Arctic region. The Arctic ecosystems are highly sensitive to disturbances, and increased mining activities can introduce pollutants and alter the natural landscape, affecting Arctic flora and fauna. The loss of biodiversity and the disruption of food chains can have far-reaching consequences for both wildlife and indigenous communities that depend on these ecosystems for their livelihoods (see Zimmermannm et al., 2023). Mining activities furthermore experienced to cause significant socioeconomic impact on indigenous communities residing in the Arctic, which often have deep cultural and spiritual ties to the land (Hansen et al., 2016). Hence, there is a need to shift from narrow policy and technological discussions on energy transitions to broader full-systems transformations linking local interventions with a global systems' lens (Tàbara et al., 2021).

The growing influx of mining operations can lead to socio-cultural disruptions, increased pressure on resources, and potential conflicts over land use. It is essential to engage and consult with these communities to ensure their rights, traditional knowledge, and well-being are respected throughout the mineral extraction process. Acknowledging the unique challenges faced by Arctic communities in relation to the development and extraction of the resources for the green transition and the need to recognize their unique role in supporting global sustainability futures, it is crucial to prioritize their inclusion in decision-making processes and policy formulation. Empowering these communities with resources and knowledge to adapt to and mitigate climate change while preserving their cultural heritage and traditional knowledge, is of paramount importance. On the one hand, transitioning to sustainable energy alternatives can bring opportunities for economic diversification and reduce greenhouse gas emissions. Investments in renewable energy projects and sustainable infrastructure can create new green jobs and promote local economic growth. But on the other, traditional settings and new actions taken by local populations towards realizing their own green development futures can also generate new reflexive spaces for mutual learning and transformation of those 'foreign' societies and organizations that in the past have solely taken an extractive dominant role.

3 Greenland's Resource Confronting Narratives

Greenland's population of 56,000 is spread through in 18 towns (87% of population) and approximately 60 settlements (13% of population). The towns and settlements are geographically disconnected, so transportation takes place by air and/or sea (Statistics Greenland, 2020). 89% of the population is native to Greenland, and the majority of natives form the Government. An ongoing demographic trend is emigration from smaller towns and settlements to bigger, urban towns. The majority of the population livelihoods continues to be largely based on food from hunting and fishing. Food from wildlife accounts for half or more of the diet for 32% of the population (Greenlandic Perspectives, 2019). The public sector is the largest employer in Greenland (Greenland Statistics, 2020) where it employs 40% of the workforce. The GDP per capita is about 50.000 USD and 95% of exports come from the fishing industry. The economic grant from Denmark and from Europe constitute approximately 60% of Greenland's GDP (Greenland Statistics, 2020).

Greenland relatively small and sparsely populated country has also a unique cultural and institutional heritage built often on ancestral practices of traditional resource exploitation. Among these, there is a crucial tenet that have to do with the impossibility in Greenland of privately owning land across generations. Such principle is of particular importance given that often property, in Western countries, is often equated to the right of private exploitation -even though such exploitation could harm future generations. Thus, many residents are concerned about the potential social, cultural, and economic impacts of large-scale resource development projects driven by international actors who may disregard such cultural diversity. There are also concerns about the fairness and transparency of resource governance, and questions about how to ensure that local communities benefit from resource revenues in a meaningful and sustainable way. This conundrum requires careful consideration of the trade-offs involved and the development of innovative and inclusive policies and practices that can help to mitigate risks, maximize benefits, and promote long-term sustainability and resilience.

Hence, Greenland and its interactions with other international energy actors can be understood as a complex socio-energy system operating at multiple scales of action with potentially diverting tipping points that could unfold in a near future towards both positive and/or negative trajectories, not only locally but worldwide. Greenland, also shows a case in which relatively 'small' positive decisions taken at local level or by a relatively small number of people taken right now can have beneficial consequences at global level, so there is no need to wait for large international concerted actions (Ostrom, 2012). On the one hand, locally, Greenland is implementing hydropower solutions for electricity supply in most towns and experimenting with solar and wind power for smaller settlements, aiming to replace fuel-based energy supply. The national energy company, Nukissiorfiit, is actively working towards substituting fuel-based heat supply with electricity heating from hydropower and, to a smaller extent, heat from waste-incinerators. Moreover, like many Arctic communities, Greenland is an example of a place where off-grid electricity and heat solutions are prominent due to the remoteness and lack of infrastructure. However, globally, there are also expectations that huge oil deposits are located off- and onshore in Greenland. International companies are interested in accessing these deposits which could potentially meet the growing demands for international consumption, even though Greenland is aiming to become free of the national need for a carbon-based energy supply. Interest in exploiting minerals for the global green energy transition has been growing for several years, but it particularly accelerated in recent years as the world has become more focused on transitioning to renewable energy and reducing greenhouse gas emissions (Hansen & Johnstone, 2018). The challenge of developing Greenland's resources to support global climate action shows then the multiple tensions arising from the need to ensure an equitable distribution of benefits and risks between local communities and global consumers. In economic terms, it is argued that developing Greenland's minerals for export to other countries has the potential to generate significant revenue and create jobs, which could supposedly benefit local communities economically and support sustainable development. And supplying renewable energy materials to other countries could help halting the increase of global greenhouse gas emissions and mitigate the impacts of climate change, benefiting people worldwide.

However, there is also a risk that exploiting these resources could lead to a number of negative social and environmental impacts for local communities, such as displacement, pollution, and habitat destruction. Such negative effect could be abrupt, structural and irreversible, which constitute core characteristics of tipping points. Following exploitative institutional arrangements, the benefits of such resource extraction are likely not to be distributed equitably, so private multinational companies and consumers in other parts of the world may capture most of the economic benefits while local communities bear the social and environmental costs. Thus, the governance challenge of developing Greenland's resources and its role in supporting global climate action represents a normative clash in terms of balancing the potential benefits and risks for different stakeholders and social scales. It requires careful consideration to justice principles on how to ensure that local communities are involved in decision-making processes, that their rights, worldviews, traditional resource regimes, and interests are respected; while at the same time, that they benefit equitably, if eventually decided by fair procedures, from the extraction of rare earths for green energy development. It requires innovative approaches to governance and the implementation of resource management principles that can help promote sustainable, low-carbon development while minimizing negative impacts on local communities and the environment, that take also in to account both global and local considerations.

Box 1 Timeline for Key Events in Greenland's History of Natural Resource Extraction for Global Energy Consumption

1700s-1800s: Commercial whaling in Arctic waters led to the near-extinction of several whale species.

1968: The first offshore oil exploration well was drilled in Greenland's waters by Pan American Petroleum.

1973-74: A major oil crisis led to increased interest in Arctic oil reserves, and several new companies began exploration in Greenland.

1979: Greenland gains limited autonomy from Denmark, giving the country more control over its own natural resources.

2001: The Inuit Circumpolar Council and other indigenous groups declared their opposition to oil drilling in Arctic waters.

2009: Greenland gained self-rule with the Self-Rule Act, giving it greater autonomy from Denmark

2010: Greenland opened its mineral resources to international investment, leading to a surge in mining exploration.

2013: Cairn Energy's exploration in Greenland's waters failed to find significant oil reserves, leading to a slowdown in oil development in the region.

2019: The US governmental administration expressed interest in purchasing Greenland, sparking widespread criticism and opposition.

2021: Greenland's ice sheet experienced record-breaking melting due to climate change.

2021: The Inuit Ataqatigiit-led government made the decision on June 24 the Greenland will halt all oil exploration. This decision was taken despite the large ice cover retreat that makes the vast amounts of oil available. The government stated that it "takes the climate crisis seriously".*

* https://www.euronews.com/my-europe/2021/07/16/greenland-to-halt-all-oil-exploration-as-it-takes-climate-change-seriously.

4 Positive Tipping Points, Natural Resource Justice and Earth System Justice

In general, tipping points refer to thresholds or moments in time in which a relatively additional small force of change in a given system can lead to abrupt, structural and irreversible changes in its whole dynamics or development trajectory. At Earth systems scale, this can be translated in the collapse of large ecosystems, and global changes in patterns such as the North Atlantic current, as cascade of changes in other system, further reinforced by the current increasing release of large amounts of greenhouse gases. Recent assessments of negative Earth tipping points (Armstrong McKay et al., 2022; Willcock et al., 2023) indicate vast challenges for governance (Young, 2012) and indicate that some of them may be approaching sooner than expected; and that out of sixteen dangerous tipping points, five of them may have already been exceed due to the 1.1 °C global warming -being the collapse of the Greenland's ice cap one of the latter.

All these impending changes and increased risks of natural disasters have significant impacts on human societies, that at global level translate in additional pressures for human displacement, as well as mounting shortages in basic resources such as food and water. The consideration of tipping points calls for precautionary approaches and adaptive management strategies that can respond quickly to such global challenges. Finding ways to integrate the knowledge on tipping points both from the natural and social science has therefore important implications for the implementation of robust strategies that can avoid the worst effects of negative Earth System points. Most notably, such integration entails however a moral and ethical challenge. The implementation of fair and engaging development trajectories that link both local and global demands requires place justice at the core of social-energy transformations. New transformative approaches need to be guided by principles of fairness, equity, and social and environmental responsibility that ensure that the impacts of Earth tipping points are shared fairly and that marginalized communities are not disproportionately affected.

In contrast, positive tipping points can be defined as those moments in which due to the cumulative effects of previous deliberate social actions or policy interventions, a new better-off structural situation eventually emerges in a way that leads to subsequent self-propelling cycles of improvements in social-ecological systems' relationships. Such improvements can be assessed by the relative realization of explicit principles and goals, such as the Sustainable Development Goals (SDGs) or in more absolute terms, by examining net-positive gains and synergies achieved between improved capacities to deal with common problems and improved conditions our life-support systems (Tàbara, 2023; Tàbara et al., 2018; Milkoreit et al., 2018; Winkelmann et al., 2022).

Therefore, in social systems, justice is both a main driver and outcome of positive tipping points. The drive for a more equitable society by those groups often excluded or underrepresented in a system can create the conditions for systemic change -such as the case of the right to universal access to education. And at the same time, if the new fairer conditions are achieved, these can also create new forms of action and institutional reform conducive to new forms of deliberate transformations. For this reason, natural resource justice and earth system justice are important considerations in tipping points research because they highlight the need for fair and equitable management of natural resources and the protection of the earth's systems to prevent or mitigate the negative impacts of tipping points, whilst considering the possibilities for positive ones.

For a structural positive transformation to happen, the people conforming a social-ecological system must develop and implement new institutional long-lasting arrangements that ensure the redistribution of existing rights, responsibilities and power arrangements, e.g., according to new emerging interests or moral principles. Early gains in justice at local level, create the necessary transformative conditions for achieving positive tipping points at larger scales and also help to trigger chains of positive changes in other domains. Addressing inequalities from the start and providing possible mutual gains derived from tackling climate crisis, are can help local agents and decision-makers, even previously marginalized ones, to support energy and climate policies, and function as demonstrators for other places, showing that cross-scale positive transformations are possible (see Amundsen et al., 2018).

In particular, multiple dimensions of justice need to be considered in processes that have to do with the interlinkages of global decarbonization that have very clear local impacts and vice-versa. These include aspects of distributive justice, entailing an equitable distribution of resources and benefits, as well as of compensation of the burdens caused by the energy transition among the different groups. However, on the one hand, a more integrative approach to justice would entail moving beyond compensation approaches in dealing with (in)justices to local populations. That is, to consider those perspectives that, besides the traditional notions of distributive, representative and procedural justice, also into account a more ideal, radical or transformative notions of justice that aim to achieve a much broader cross-scale systems' transformations, in terms of redistributions of rights, harms, benefits and responsibilities. On this, capability approaches stand out as they emphasize the need to foster and transform the necessary means, such as political or community power of agents, necessary influence inclusive decarbonization decisions, relevant to climate change mitigation, adaptation or more broadly tipping processes towards systems' transformations.

On this, and at global level, an imperative may be considered to avoid trespassing planetary boundaries and to ensure a safe and just corridor for humanity. This entails the adoption of more nuanced conceptions of justice, which also consider intergenerational, intra-generational as well as interspecies dimensions of justice.

Natural resource justice and earth system justice are therefore closely related. They both focus on the fair and equitable distribution and management of resources and the impacts of human activities on the environment. Earth system justice is concerned with how to achieve in a fair way the long-term stability of the earth system and ensuring that a world population moving toward a possibly ten billion people by 2050 can have access to sufficient resources to ensure dignified levels of well-being. It recognizes that human activities, such as the burning of fossil fuels, deforestation, and pollution, are causing widespread harm to the Earth's systems and this impinges especially upon marginalized communities and future generations, who are likely to bear the greatest burden of these impacts. Similarly, natural resource justice addresses the distribution and management of resources critical to the health of humans and the planet. For example, access to clean water, air, and land is essential for human well-being and ecosystem health so the equitable distribution of these resources is a key component of natural resource justice. Ensuring that these resources are managed in a sustainable and equitable way at local level is therefore crucial to understanding how to contributing to meeting the basic needs of growing world populations, and thus to achieve both for resource and earth system justice.

5 Trump's Attempt to Buy Greenland, from a Resource Justice Perspective

In 2019, then president of the USA, Donald Trump, declared his interest in buying Greenland from Denmark, referring to it as a real estate deal, motivated by a desire for access to its expected attractive undeveloped mineral resources and hydrocarbons there. Although such attempt sounded like a bad joke to many, it can also be taken as representative of a particular colonial and extractive worldview, which in itself is reinforced by dominant institutional arrangements, as those that relate to the understanding of property rights. There is however a growing recognition that such worldviews and mechanisms that mediate our human interactions with the biophysical world require deep questioning and transformation if humans are to cope with accelerated global environmental change.

Despite its senseless and disproportionate character, Trumps proposed purchase of Greenland raises many questions that are relevant in our discussion on how to prevent global tipping points and enact positive ones in terms of substantial and long-term improvements in justice. It points out the impacts on the Earth's systems of the role of private markets in regulating the access and appropriation of resources that are critical both for Earth systems stability as the future of humanity in the face of negative earth tipping points. Hence, Trump's attempt to buy Greenland can also be examined in terms of its justice implications globally and at the long term, including the geopolitical and economic factors involved. From a natural resource justice perspective, the proposed purchase of Greenland raises questions about the legitimacy of the private ownership and management of global natural resources. The hypothetical purchase could have enormous local consequences for the indigenous communities who live in Greenland and depend on these resources for their livelihoods. It is very unlikely that only through market rules and deals, prioritizing profits and short-term gains over long-term sustainability, the indigenous rights, their autonomy and sustainable management practices would have been respected or enhanced. Whilst Greenland is, as mentioned, rich in natural resources, including oil, gas, and minerals, the proposed purchase could have potentially significant implications for corporate appropriation and distribution of these resources at global level. Given that Greenland is home to the second-largest ice sheet in the world, the proposed acquisition could have potentially further triggered the extraction of fossil fuels and have significant climate impacts globally and especially on the Arctic region. The negative tipping cascade would have accelerated by the melting of the Greenland ice sheet, contributing even more to rising sea levels.

Trump attempt to buy Greenland may be surprising for a number of reasons. But on the other hand, it may also show another conflict that occurs when local and short-term logics of trade are translated at the global level: a moment in which the irrationality underpinning the global commodification of the Earth achieves its more extreme expression. It may well be the case that if humanity is to decisively cope with negative Earth tipping points and move to creating the conditions for the emergence of positive ones, we may fast need start reconsidering some of these fundamental assumptions and contradictions that withstand our current forms of development -in which property rights constitutes a central pillar.

6 Final Reflections: Navigating the Narratives Confrontation

Coping with the challenge of minimizing the impending impacts of negative earth tipping points while redressing the current forms of development to create the necessary conditions for the emergence of positive tipping points entails confronting a series of potential narrative conflicts that often remain understated in dominant policy narrative on green energy developments. To address such confrontations, putting justice at the core of the discussions on tipping points could help to reframe the kinds of key questions that need to be asked when thinking about alternative futures towards global sustainability: because the challenge is not only about energy transitions or particular access and exploitation of minerals. Instead, the unavoidable challenge might better be conceived as to how reconstruct the social contract for a global society transformation upon criteria that merge both global principles of earth system justice and stability with those of local resource justice; and do so in ways that local communities are not only represented, have access and are involved in decision-making processes to benefit equitably from resources development, but they can also contribute to cross-scales transformations and sustainability learning at the global level.

Greenland could become a beacon of hope for sustainable development and natural resource justice, setting an example for other regions facing similar challenges. By harnessing its renewable energy potential, empowering and respecting the rights of indigenous communities, and engaging in responsible resource management, Greenland could successfully navigate the multiple tipping dissonances and contribute to preventing global negative environmental tipping points. The Arctic region, particularly Greenland, stands at a critical juncture, where local decisions about natural resource extraction and energy development can have large, irreversible and significant impacts on global sustainability and justice. By recognizing, reconciling and understanding the complex interactions of both biophysical and social tipping points in this context, we are in a good place to gain valuable insights into the potential global consequences of our local choices and decision in other contexts.

In short, transformative governance toward sustainability at the global level can strongly benefit from considering the value of the diversity of local worldviews, resource use arrangements and visions for a better world. Our research shows that full-systems transformations towards green futures are however not free: dealing with these perceived contradictions between local and global narratives face serious trade-offs and calls for rapid forms of institutional innovation. It also shows a clash between various worldviews regarding how humans ought to relate with biophysical systems and how many irrationalities emerge when certain logics of trade and appropriation of the Earth are extended at the global level.

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Assessing Macroeconomic Effects of a Carbon Tax as a Tipping Intervention in Economies Undergoing Coal Phase-Out: The Cases of Poland and Greece

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Abstract Introducing carbon taxation could accelerate systemic change towards a decarbonised future. In this book chapter, we aim to test to which extent this policy can be considered a tipping intervention that can encourage fast green technological innovation and infrastructure development in coal and carbon-intensive regions (CCIRs) and how this policy affects the sectoral structure of the economy. We use a dynamic stochastic general equilibrium model (MEMO) to assess the impacts of implementing a carbon tax on GDP and unemployment in Poland and Greece. These two countries are currently phasing out coal. Our results show that carbon tax implementation significantly affects the macroeconomic indicators and may also lead to considerable labour market effects on sectors other than mining, such as the light industry and construction in Greece and energy-intensive and advanced manufacturing industries in Poland. We also discuss funding and recycling revenue mech-

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anisms that could enable the successful implementation of a carbon tax. We conclude that it would be more reasonable to treat carbon tax as an additional political tool that must be combined with other interventions coordinated with an overall broader full-system transformation narrative rather than a single tool that can determine or ex-ante detect any future tipping point.

Keywords Tipping points · Carbon tax · Labour market · Poland · Greece · Coal and carbon intensive regions (CCIRs)

1 Introduction

The concept of tipping points has its origin in the climate sciences and has been developed to articulate the perspective of passing thresholds in the climate system or ecosystem (Gladwell, 2000; Kopp et al., 2016; Lenton, 2013). Milkoreit et al. emphasise that at a tipping point, the system triggers a non-linear change process that inevitably leads to a qualitatively different state, which is often irreversible (Milkoreit et al., 2018). Moreover, due to the interconnectedness between social and ecological system components, crossing an ecological tipping point leads to a qualitative change in the social and economic system, characterised by a different set of stabilising positive and negative feedback (Milkoreit et al., 2018). In the socioeconomic literature, tipping points are considered a moment or a period when the socioeconomic system shifts from the preceding development pathway to a new, fundamentally different state (van Ginkel et al., 2020). However, the potential existence of tipping points in socioeconomic systems has yet to be explored, and they might be highly policy-relevant (van Ginkel et al., 2020).

Reviews about advancing state-of-the-art research on tipping points in energy economics suggested immediate carbon tax implementation as a desirable trigger to accelerate decarbonisation and decrease policy costs in the long run (Maier et al., 2020; van der Ploeg & Rezai, 2020). Until now, a carbon tax was suggested rather as a necessary solution to mitigate climate tipping points (Lontzek et al., 2015) than the instrument being a trigger to stimulate qualitative structural change. However, even if the implementation of such a public intervention does not constitute a specific tipping event, it might boost energy and climate policy efforts and accelerate the decarbonisation pathway (Maier et al., 2020). From this perspective, implementing the carbon tax may enable fundamental changes in countries, regions and sectors highly prone to decarbonisation.

Therefore, given that carbon price dynamics and emissions reduction are essential factors in energy system development that determine the stability of coal and carbon-intensive regions (CCIRs), we test carbon tax as a potential tipping event to expedite a tipping point to accelerate decarbonisation.

Specifically, we aim to answer the following research question: How would the introduction of a carbon tax affect the energy transition process, value-added and labour market outcomes in selected sectors of the economy? The above research question is tackled by (1) describing possible policy scenarios of introducing carbon taxes from a medium-term perspective, (2) modelling the effects of the carbon tax uptake on the labour market and sectoral developments, (3) translating possible consequences to implications for two examined CCIRs. To simulate the macroeconomic effects of implementing a carbon tax, the dynamic stochastic general equilibrium Macroeconomic Mitigation Options Model (MEMO) (Antosiewicz & Kowal, 2016; Antosiewicz et al., 2022) is used. Two European countries with similar coal phase-out challenges but at different stages of decarbonisation (i.e., Greece and Poland) are used as testbeds, providing qualitative insights on labour market challenges and comparing the results to the existing research, funding options, revenue recycling mechanisms, and national and regional context.

The contributions of this book chapter are twofold. The results provide helpful insights into the discussion about decarbonisation consequences for European Union countries, especially those with coal regions. Secondly, policy implications of carbon tax implementation are provided, discussing the mechanisms that could enable its successful implementation.

Section 2 provides an economic perspective on carbon tax as a potential tipping event to adopt an alternative decarbonisation pathway. Section 3 provides basic information about the MEMO model, settings, and data sources used in the study. Section 4 defines and specifies the case studies and scenarios for the model application. Section 5 presents the results, and Sects. 6 and 7 discuss and summarise the findings.

2 An Economic Perspective on Carbon Tax Implementation

Arguably, carbon taxation offers the most cost-effective lever to reduce CO_2 emissions at the scale and speed required (Climate Leadership Council, 2023). Thus, the aim of the carbon tax should be to promote fair and sustainable energy consumption patterns and enforce sectors, firms and households to accommodate cleaner energy pathways—or pay more in exchange for external costs in the long run. Swedish or Finnish carbon tax is often used as an example of its transformative capacity. In these countries, the carbon tax implemented in the early 1990s triggered and accelerated the household heating transition towards cleaner energy carriers (Kerr & Winskel, 2021).

Most recent studies in scientific literature evaluate the effects of carbon tax adoption ex-ante. For example, recent results for the EU countries, using Input-Output models and Household Budget Surveys, pointed out overall regressive carbon pricing at the EU level and various national effects of additional taxation on different income groups. For example, in Poland, Romania and Hungary, the carbon tax was considered to be a regressive solution, opposite to Luxembourg (where high-income groups would pay the most), Greece and Cyprus (where the middle-income group would pay the most) (Feindt et al., 2021). A recent exhaustive overview of the distributional impacts of carbon pricing has indicated progressive effects of carbon taxation on households in developing countries where higher income households are more heavily burdened, and within general transportation policies, with a still limited discussion about revenue recycling mechanisms (Ohlendorf et al., 2021). On the other hand, the latest findings from five Central and Eastern European (CEE) countries (Bulgaria, Germany, Hungary, Poland, and Romania) suggested minor regressive effects of introducing a carbon tax on households (Postoiu et al., 2022). As such, there has yet to be a scientific consensus about the general impact of a carbon tax on the behaviours of firms operating in different sectors and households.

Considering that CCIRs will be directly affected by the decarbonisation process due to reduced activities related to coal mining and coal-fired power plants, introducing revenue recycling mechanisms would be a necessary tool for facilitating the transformation of regional economies (Vona, 2023). Such means aim to increase political acceptance of carbon taxes by compensating for immediate, adverse sectoral effects after carbon tax implementation and ensuring the economic safety of the most vulnerable households (van der Ploeg, 2022). Carbon tax supporters argue that recycling mechanisms are essential, as the most vulnerable households proportionally lose a larger share of their incomes in the case of excise tax and other typical taxes on energy services (Owen & Barrett, 2020). The choice of a particular revenue recycling mechanism should reflect the goals the public administration wants to achieve (Sokołowski et al., 2021, p. 202). Popular tools for revenue recycling are lowering pre-existing taxes (e.g., labour tax cuts), increasing pre-existing social transfers, and introducing differentiated and targeted cash transfers (Berry, 2019; García-Muros et al., 2021).

Recent results on the efficiency of revenue recycling mechanisms are debatable. The first five-wave panel survey on Canadian and Swiss citizens proved limited effects of current climate rebates on public attitudes regarding carbon pricing (Mildenberger et al., 2022). Also, a survey on 6000 German households indicated that spending carbon tax revenues on green investments "might run the risk of 'preaching to the converted' rather than building societal support with the groups that tend to oppose climate action" (Sommer et al., 2022, p. 11). These reasons may lead to perceiving the carbon tax as an additional burden for society, opposite to the other climate policy instruments such as direct renewable energy support schemes or energy efficiency regulations (Levi, 2021).

3 Methods

3.1 Macroeconomic Model: MEMO[1]

The dynamic stochastic general equilibrium Macroeconomic Mitigations Options Model (MEMO), prepared at the Institute for Structural Research (Antosiewicz et al., 2022; Antosiewicz & Kowal, 2016), is used to assess the macroeconomic effects of implementing a carbon tax. The model combines (1) input-output and (2)

[1] The technical description of the MEMO model is available in Antosiewicz and Kowal (2016) and Antosiewicz et al. (2022). To maintain clarity and consistency, the same phrasing was used in this book chapter as well.

general equilibrium modelling and is a well-grounded tool in terms of assessing the impact of energy and fiscal policies used in Horizon projects such as Transrisk (Antosiewicz et al., 2020; Nikas et al., 2020) and World Bank works (Antosiewicz et al., 2020; Antosiewicz et al., 2022). The model consists of the household sector, which maximises utility from consumption and leisure; the firm industry, which maximises profits; the government sector, responsible for collecting various taxes and financing public consumption; and a foreign sector, responsible for trade with other countries (Antosiewicz & Kowal, 2016). The model's main features include the sectoral firm's division, calibrated to the input-output matrix, search and matching on the labour market to the model transition of workers between industries, and endogenous adaptation of technology related to energy use.

The sectoral structure of the model is calibrated based on the 2015 Polish and Greek activity by activity, input-output matrix from the Eurostat statistics database (Eurostat, 2023), using the NACE Rev. 2 statistical classification of economic activities in the European Community (Eurostat, 2008). In the model, we distinguish (1) agriculture and forestry, (2) mining and quarrying, (3) light manufacturing, (4) energy-intensive manufacturing, (5) advanced manufacturing, (6) refined petroleum products, (7) energy, (8) construction, (9) transport, (10) market services, and (11) public services.

3.2 Input-Output Sector Structure and CO_2 Emissions

There are several distinct sets of parameters whose values need to be calculated. The main ones are the parameters governing the firm and production side of the model. These parameters can be further specified as those which govern the value-added structure of the sectors, investment, and compensation of employees in each industry, the intermediate use structure, which considers domestically produced and imported goods, and a final use structure, which also considers domestically produced and imported goods (Antosiewicz et al., 2022). Each firm operates a production function which utilises a nested constant elasticity of substitution (CES) specification to combine the factors of production. In the first stage, the firm combines capital and energy; the second stage consists of adding labour. This bundle is combined with materials (intermediate use) in the final step. The material bundle is composed of products of each sector, which are further disaggregated into imported and domestically produced parts. On the use side, the goods produced by each industry are purchased by households for private consumption, by the government for public consumption, by firms as investment, or they can be exported (Antosiewicz et al., 2020).

To calibrate the firm side of the model, the Eurostat database's input-output (I-O) matrix was used and modified to the scope of this study. In particular, it was necessary to disaggregate some sectors and products shown as a single activity in the I-O matrix to model the effects of energy and environmental policies.

MEMO directly models CO_2 emissions from coal, oil and gas. The volume of CO_2 emissions in a particular sector is modelled as a linear function of the use of these fuels, with coefficients set to match sectoral data regarding emissions (Antosiewicz et al., 2022). Other non-CO_2 emissions, such as those resulting from agriculture or captures in the forestry sector, industrial processes, and waste processing are not directly modelled. Such emissions are treated as indirect in the post-processing phase of the modelling exercises. In the case of a carbon tax simulation, the MEMO agents only react to the fossil fuel emissions, which are modelled directly and do not, for example, reduce output in the agriculture sector to cut non-carbon emissions.

4 Case Definition and Specification

4.1 Case Study Selection

Poland and Greece were selected as case study countries to assess the carbon tax as a potential trigger for the significant qualitative structural change in the decarbonisation pathway, considering (1) the lack of research regarding their potential for carbon tax implementation, (2) the differences between their coal phase-out horizons and economies, and (3) the similarities between carbon-intensive industries in their CCIRs.

Poland and Greece have not been the subject of many empirical studies on carbon tax implementation. For example, relevant analyses for Greece are limited to a couple of studies which assess the impact of a carbon tax on Greek manufacturing (Floros & Vlachou, 2005) and vehicle tax reforms (Adamou et al., 2012). For Poland, the exception is a few studies about the distributional effects of a carbon tax: direct and indirect effects and the employment channel, using macro and microeconomic models (Antosiewicz et al., 2022; Postoiu et al., 2022). These studies emphasised different distributional effects of revenue recycling mechanisms, dependent on the economic policy target. They suggested further research on countries with an existing share of coal in the energy mix (Antosiewicz et al., 2022).

As shown in Table 1, Greece had a slightly larger GDP per capita than Poland in 2020 and much lower emissions per capita in the same year. Poland has one of the most carbon-intensive economies in the EU (Alves Dias et al., 2018), which can be

Table 1 Critical macroeconomic and environmental parameters in 2020

Country	Population (million)	GDP (billion US$)/ GDP per capita (US$)	Emissions (million tonnes)/ emissions per capita (tonnes)	Unemployment rate (%)	The annual average wage (US$ PPPs)
Poland	38.0	594.2/15,636.8	299.6/7.9	3.2	33,330
Greece	10.7	189.4/17,700.9	52.2/4.9	16.3	25,630

Sources: Our World in Data (2020); World Bank (2022) mainly attributed to the contribution of the Polish CCIRs to the national economy (about 87,600 people working in coal mining and 51,200 more in associated industries only in Upper Silesia (Frankowski et al., 2022)). Both countries set different coal exit dates (Poland in 2049 and Greece in 2028) and, consequently, are at different stages of the coal phase-out. Moreover, Poland and Greece experienced other macroeconomic trends and implemented various fiscal and economic policies in the previous decade. After the financial crisis of 2008, Greece implemented many austerity measures, significantly increasing the unemployment rate and reducing wages (Table 1). On the contrary, Poland was the only EU Member State that maintained stable economic growth since 2000 and avoided the economic depression that followed the financial crisis (World Bank, 2023).

Both countries maintain carbon-intensive industries in CCIRs. In Poland, there are three hard coal regions (Upper Silesia, Lesser Poland, and Lubelskie Region) and three lignite regions (Greater Poland, Lower Silesia, Łódzkie); in Greece, there are two lignite areas: Western Macedonia and Megalopolis (Fig. 1). This book chapter examines sectoral transitions in two regions studied within the TIPPING+ project: hard coal mining and coal-based energy sector in Upper Silesia and lignite extraction and lignite-based energy sector in Megalopolis. During the project timeline (2020–2023), authorities in both regions discussed Territorial Just Transition Plans towards new development pathways.

Upper Silesia is Poland's second most populous region (4.4 million people, according to the most recent national census data from 2021). Most Upper Silesia inhabitants (76.5%) live in cities, and the region has the highest population density in Poland (357 people per km^2 in 2021; the national average is 122 people per km^2). The centre of the region is the Katowice conurbation, historically developed around coal mining and other traditional industry branches. Upper Silesia concentrates 80% of domestic hard coal extraction and the vast majority (89%) of total employment in coal mining (Mazurkiewicz et al., 2023).

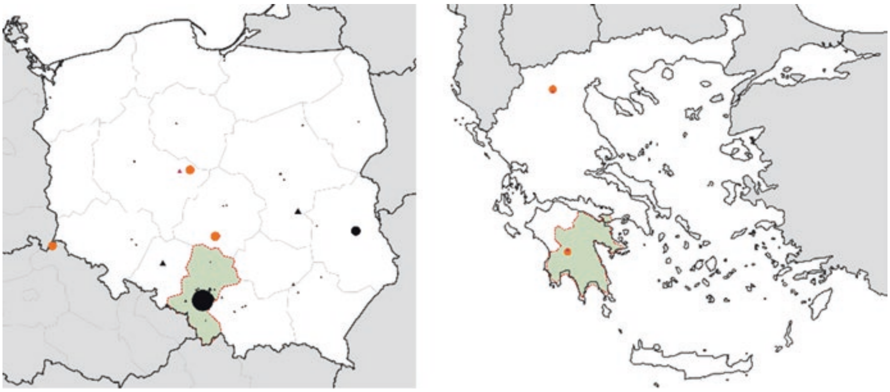

Fig. 1 Coal basins and power plants in Poland and Greece. Legend: **Black**: hard coal basins/power plants. **Orange**: lignite basins/lignite-fuelled power plants; **green**: Tipping Plus Case Study Regions. Size of the basins: number of employees. Scope of the powerplants: installed capacity. Source: own elaboration

Table 2 Values of the carbon tax scenarios in $/tonne of CO_2

	2022	2024	2026	2028	2030	2032
Tax 1	47.27	64.10	77.35	87.02	96.68	106.35
Tax 2	16.77	33.53	44.41	49.40	54.39	57.92

Source: own elaboration based on the MESSAGE-GLOBIOM and REMIND-MAgPIE models (NGFS, 2021)

Megalopolis is part of the Arcadia regional unit, which is part of the Peloponnese region. According to the most recent census (2021), the municipality of Megalopolis has a population of 8784 people and covers an area of approximately 722.6 km^2 (Hellenic Statistical Authority, 2011). Megalopolis retained a rural character until 1970, when the Public Power Corporation (PPC) began lignite extraction in its deposit, establishing the region as both an upstream and downstream CCIR. Hence, Megalopolis became an important energy centre due to the abundance of lignite reserves in its basin subsoil. Since then, the dominant activities in Megalopolis have been lignite mining and lignite-based power generation, employing a significant percentage of the local workforce (Independent Power Transmission Operator, 2021). Indicatively, 1600 direct and 3100 indirect jobs are provided from the total lignite value chain, constituting 60% of all Arcadian regional energy sector (Baker et al., 2022).

4.2 *Scenario Specifications*

We consider two carbon tax scenarios representing a rapid (Tax 1) and a moderate (Tax 2) increase trend along the years. The scenarios are based on the Network for Greening the Financial System outputs, generated by state-of-the-art, well-established integrated assessment models (IAMs), namely MESSAGE-GLOBIOM and REMIND-MAgPIE (NGFS, 2021). Both tax scenarios achieve a CO_2 reduction target in Poland and Greece (Table 2), which is in line with the 2 °C Paris Agreement climate mitigation target. Tax 1 is calculated based on the MESSAGE-GLOBIOM, and Tax 2 is based on the REMIND-MAgPIE. In the two scenarios, the values of carbon taxes are identical in both countries, yet they yield different results regarding CO_2 emission reduction. We applied a short-term perspective (until 2032)—considering that a 10-year horizon is, on the one hand, a relevant period to observe some specific macroeconomic shifts and, on the other hand, keep a relevant and understandable policy perspective.

5 Results

We focused on the impact of a carbon tax on three main modelling outputs: (1) gross domestic product, (2) unemployment rate and (3) value added and employment in specific sectors in Poland and Greece. These are key macroeconomic variables

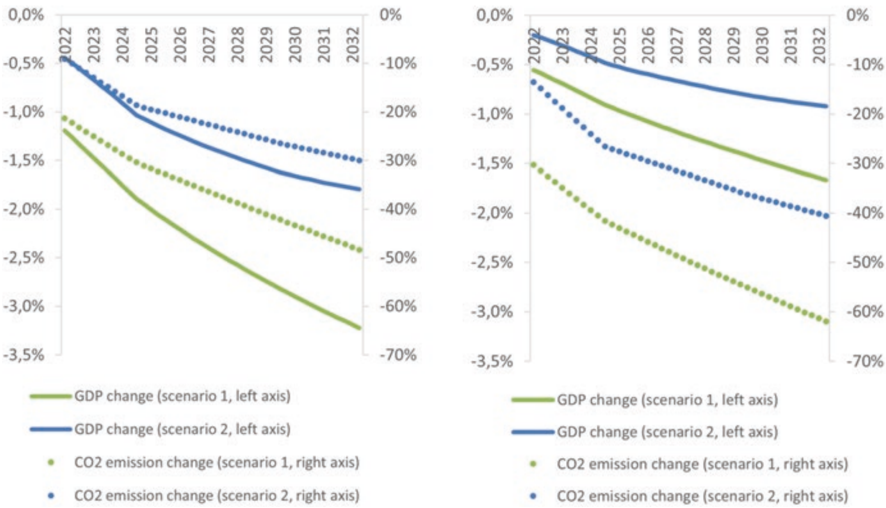

Fig. 2 The differences in the GDP and CO_2 emissions if particular carbon tax scenarios are applied in Poland (left panel) and Greece (right panel) between 2022 and 2032 (% deviation from no carbon tax scenario). Source: own elaboration based on the MEMO model

present in the carbon tax debate (Köppl & Schratzenstaller, 2022) and can be comparable with other studies on the macroeconomic performance of taxes; it is also a policy-relevant approach, attracting policymakers' attention (Timilsina, 2022), especially considering poor quantification of effects of the new ecological instruments such as the European Green Deal and the planned carbon taxation on individual transport and housing sector (ETS-II).

The overall effect of a carbon tax on Polish GDP (Fig. 2) ranges from –1.8 to –3.2% in 2032.[2] Importantly, this decrease in GDP does not mean a recession, and even after introducing a carbon tax, according to the OECD forecast for Poland, the Polish GDP will expand in the short run (OECD, 2021). Moreover, the carbon tax would help to substantially reduce CO_2 emissions by 30–48% by 2032, depending on the country and tax rate.

Therefore, introducing a carbon tax in Poland at an even lower rate (between 16–58 $ per tonne of CO_2) could be considered a tipping event from the aggregate economic effects point of view and the resulting reduction of the economy's carbon intensity. Alternatively, higher carbon tax levels may result in a more considerable GDP decline. Consequently, politicians must further consider and address this trade-off to choose between economic and ecological goals. A recent study estimates the willingness to sacrifice 15% of monthly incomes to hamper climate change's adverse effects, reduce air pollution, and guarantee a secure energy system

[2] In comparison to the scenario without the carbon tax. The initial GDP forecast by the OECD remains the same in the scenarios with and without carbon tax implementation.

through the carbon tax (Sokołowski et al., 2023). So, any considered carbon tax threshold should refer to these figures.

For Greece, introducing a carbon tax yields lower GDP impacts than Poland (Fig. 2). The GDP would change by –0.9 to –1.7% by 2032. Notably, even the lower value of a carbon tax reduces CO_2 emissions by 40%. If a higher value of carbon tax is implemented, emissions will decrease by more than 60% by 2032, which matches the decarbonisation target of the Greek government. In this case, the results show a drop ranging from 39.5 to 59.3% in the carbon intensity of the Greek GDP.

Overall, achieving the same percentage of CO_2 reduction in Greece and Poland would require a higher carbon tax in Poland. In both cases, we evaluate the carbon tax as a tipping event that results in a moderate impact on the economy in this particular period and a substantial reduction of CO_2 emissions, in line with other studies (Köppl & Schratzenstaller, 2022). The crucial point here is the protection of the most vulnerable groups, as in terms of energy, the carbon tax in Poland could cause regressive effects (Postoiu et al., 2022).

The effects of the carbon tax, channelled through changes in employment and wage levels, are presented in Fig. 3. We estimate the unemployment rate in Po-land to change by 5.4–9.9% compared to the reference scenario by 2032, depending on the tax rate. Higher carbon tax rates result in an increased unemployment rate. These changes would also be channelled through lowered wages (between –4.9 and –9.0% compared to the no-carbon tax scenario by 2032). Compared to Poland, the labour market effects of introducing a carbon tax in Greece are substantially softer due to lower occupation in carbon-intensive industries. Carbon tax increases the unemployment rate by 2.4–4.3% and causes a wage drop of 1.6–3.6%.

In this way, we note that the adverse effects of the carbon tax on the labour market may affect carbon-intensive industries and trigger opposition against the climate

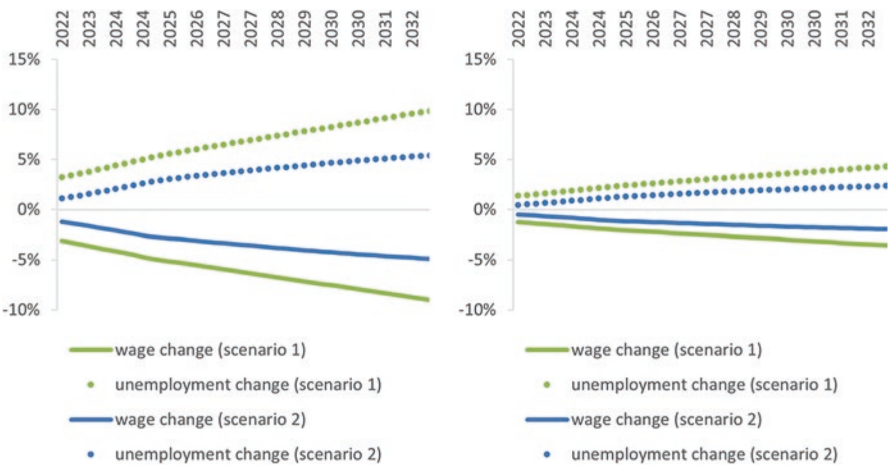

Fig. 3 The differences in wages and unemployment rates of particular carbon tax scenarios in Poland and Greece between 2022 and 2032 (% deviation from no carbon tax scenario). Source: own elaboration based on the MEMO model

policy more in Poland than in Greece. Therefore, the carbon tax introduction must be followed by socio-economic mitigation support policies on the labour market, which are elaborated on in the next section.

Regarding structural shifts, implementing a carbon tax would yield different effects in Poland and Greece (Fig. 4). The service sector would be the most exposed to the aggregate macroeconomic changes induced by the carbon tax in both countries. In Greece, this result is because the service sector contributes the most to the GDP (Nama_10_a64, Eurostat, 2023) and is also highly exposed to the volatility of energy prices. The increase in energy prices due to the imposition of a carbon tax would directly impact the service sector's profitability. The rise in energy prices caused by the carbon tax would raise the costs reflected in higher prices. Businesses must reduce expenses to maintain economic viability, including employee salaries and wages. However, a higher level of economic resilience is expected in services than the less prepared industry to change in response to the new market conditions. In Poland, the contribution of different sectors to the value-added decrease is substantially higher than in Greece, mainly because of the relatively high share of mining and quarrying, construction and advanced manufacturing. Among the industry sector in Greece, light manufacturing would primarily lower the added value (as in the case of the services) due to high exposure to price changes and its contribution to GDP (Nama_10_a64, Eurostat, 2023).

The most significant differences between Poland and Greece are visible in the structure of employment decrease (Fig. 5). In Poland, more than half of the decline in employment would concern industry and construction jobs—especially in mining and energy-intensive activities. Therefore, these sectors in Poland are particularly vulnerable to the social consequences of decarbonisation. In Greece, the share of the industry section in terms of employment decline is higher than in terms of added value and accounts for almost 30% of the total decrease. Interestingly, carbon tax implementation will also significantly reduce the number of jobs in agriculture. Both countries noted high employment in this sector compared to the European

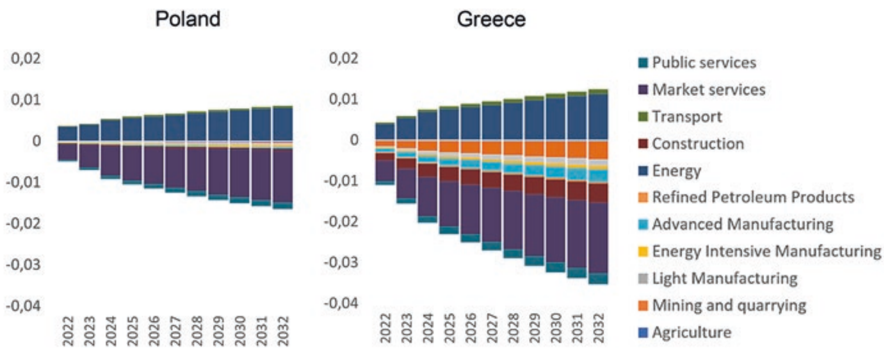

Fig. 4 The impact of a carbon tax on value added broken down by sectors in Poland (left panel) and Greece (right panel). Source: own elaboration based on the MEMO model, MESSAGEix, and Eurostat

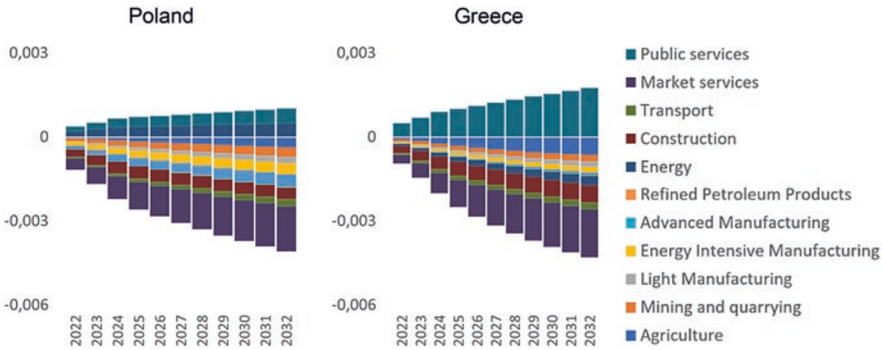

Fig. 5 The impact of a carbon tax on employment broken by sectors in Poland (left panel) and Greece (right panel). Source: own elaboration based on the MEMO model, MESSAGEix, and Eurostat

average (World Bank, 2023). More new jobs are expected to be in the energy sector in Greece than in Poland; as in the latter country, the adjustments concern high employment in the coal-based energy sector, which the similar impulse would not compensate for in terms of energy employment.

6 Discussion

6.1 *Implications of Carbon Tax Application at the National Level*

Our findings highlight that countries with more carbon-intensive economies, such as Poland, achieve a lower reduction in GDP carbon intensity than countries with less carbon-intensive economies, like Greece, for the same carbon tax levels. This means that countries with more carbon-intensive economies require higher carbon taxes to follow carbon-intensity trajectories similar to those of less carbon-intensive economies. Therefore, a carbon tax could be considered a tipping intervention for the decarbonisation of the economy. However, the tipping point triggered by the intervention could negatively affect the GDP of carbon-intensive economies. Consequently, such potential adverse effects must be minimised with direct support for economic and social adjustments, such as investment subsidies, employment programmes and direct transfers.

The results of this study confirm more substantial socioeconomic impacts of a carbon tax in terms of GDP and unemployment in the highly industrial and carbon-intensive Polish economy. In Poland, the significant decrease in total employment concerns mining, as a primary sector prone to decarbonisation, construction and also energy-intensive and advanced manufacturing. The potential employment losses suggest that carbon tax would accelerate coal phase-out and cause structural changes in the mining industry. For Upper Silesia, the largest Polish coal region, due to demographic and economic trends and favourable institutional arrangements, the future employment outlook of the coal phase-out is more advantageous and easier to manage than in the past (Sokołowski et al., 2022). The challenge would be salaries and working conditions, as only some companies in coal phase-out regions can meet the expected compensation and security (Christiaensen et al., 2022).

Nevertheless, Polish large-scale companies' strategies consider the increasing role of climate policy in the global economy and supply chains. These strategies of both state-led and private companies should be treated as early signals for accommodating a more dynamic energy transition pathway in Poland, which can further lead to a tipping point. Regardless of the planned form of carbon pricing, Polish businesses declared adopting cleaner energy technologies to maintain competitiveness in the long run, also considering recent energy price hikes. In 2021, KGHM, a copper company from Lower Silesia and Synthos, a chemical industry from Lesser Poland, announced readiness to invest in small nuclear reactors. ZEPAK, a private lignite mining and energy conglomerate in the region of Greater Poland, switched from lignite-fired power generation to biomass and started investing in photovoltaics and hydrogen technologies, as well as lobbying for locating a second nuclear power plant in the area of previous extraction. Also, state-led energy conglomerates announced their carbon neutrality plans earlier than the Energy Policy of Poland, which finally declared coal phase-out until 2049. Implementation of a carbon tax (or other carbon pricing mechanism) could probably accelerate such moves, seek innovative solutions, and enforce investments.

On the other hand, the carbon tax may cause various tensions, especially in the short run. In Poland, the effects of a carbon tax could be tough to address for vulnerable households that use coal and gas heating (Sokołowski et al., 2023). With a high inflation rate (almost 15% in 2022), the additional burden on the fuel tanked, or the price of coal would lead to social discontent and undermine overall climate policy efforts. Therefore, mitigation redistributive policies are needed to avoid escalating energy poverty, losing jobs, and growing social discontent. Particular attention in terms of national policy, except necessary large-scale energy transition investments, should be paid to mitigate possible new inequalities and provide decent working conditions in the activities that the energy transition will foster.

In Greece, the effect of carbon tax implementation would be more modest and mainly affect the value-added in the service sector. In terms of employment, the carbon tax would mainly affect the services employees, as well as agriculture and construction workers, due to the exposures of these sectors to the price changes and their contributions to the overall employment. Yet, the effect on the energy sector, especially for CCIRs, would not be negligible. According to the new Greek National Energy and Climate Plan proposal, all lignite power plants are planned to be shut down by 2028. A recent analysis of the socioeconomic impacts of the lignite phase-out process at the national level has shown that, in the absence of compensatory measures, the lignite phase-out could reduce the country's annual GDP by 1.6 billion €, total employment in the country by 19,200 jobs, and income by 425 million € in 2029 compared to 2019. The impacts will mostly affect the local economies of

Greek CCIRs in Arcadia, Florina, and Kozani (Maniatis et al., 2020). Furthermore, with this decision, Greece would shut down its only non-renewable, dispatchable generation fleet, which operates with domestic resources. Thus gas would serve as the intermediate fuel towards a RES-dominated energy system. Even with the ambition for accelerated RES investments, a fully RES-based system might take decades to materialize. Therefore, imposing a carbon tax on a country with no alternatives besides renewables could impede employment and economic viability in the short term since it would pose an extra burden to the current regime, which is already stressed. However, in a long time, as renewable capacity increases and given the lessons learnt from relying almost solely on imported fuel for power generation during the energy crisis, a carbon tax could foster quicker decarbonisation efforts and accelerated green power investments, which could also increase the employment opportunities, especially during the construction phase.

6.2 Implications of Carbon Tax Application at the Regional Level

The carbon tax will disproportionally affect CCIRs. The sectoral statistics and bottom-up studies allow us to conclude that CCIRs and their inhabitants may face more substantial consequences than people in other country areas. It is noteworthy that the coal industry employees and those indirectly associated with mining will be affected. Studies about Megalopolis and Upper Silesia suggested similar second-tier affected sectors, i.e., manufacturing and trading basic metals, fabricated metal products, machinery and equipment in coal mining (Frankowski et al., 2023; Hellenic Ministry of Environment and Energy, 2021). These industries should be strongly considered in the discussion about decarbonisation in countries conducting coal phase-out, as they soon face the consequences of decreasing demand for their services.

Based on the results of this study, we show that the consequences of a carbon tax adoption would affect both coal regions. However, Upper Silesia possesses relatively higher transformative capacities, such as a dense institutional ecosystem, a clear development vision, relatively favourable economic conditions, and a diversified economy for the gradual pathway towards coal exit. Regarding megatrends in labour supply, Upper Silesia is in a relatively stable market, as the region experiences positive educational and labour market shifts. Through 30 years of transformation, the socio-economic structure is more resilient to external shocks, with various industries and a better-educated and qualified workforce (Sokołowski et al., 2022). Nevertheless, because of the scale of the coal and carbon-intensive activities, Upper Silesia will require financial support and institutional efforts to shift towards modern, advanced industries, such as advanced automotive (e.g. electromobility) or endogenously developed IT services (Micek et al., 2022). Regarding possible effects on households, the regional government proactively decided to prepare coal region citizens to adopt cleaner heating modes. The domestic household transition in Upper Silesia is relatively fast, mainly where the state provides convenient subsidies (Mazurkiewicz et al., 2023). Many people also use coal-based district heating, which ETS-I already covers, so the region—especially in light of the coal shortage in 2022—should smoothly adapt to the new heating modes compared to the more rural, dispersed areas of the country. Upper Silesia also remains the region with the lowest energy poverty rate in Poland, less than 5% in 2021. The issue here is costs, as many people before the Russian aggression in Ukraine preferred to install gas, and still, a lot, including miners, use coal which can be bought directly from the mine. So, in this way, the regional authorities still need to accelerate policies to secure clean and affordable energy services at home.

On the contrary, the economy of the Megalopolis, which is mainly based on the energy and mining sector, will undergo an abrupt pathway towards lignite phase-out (Hellenic Statistical Authority, 2019). At the Megalopolis level, by 2025 (when the lignite-fired units will close), Arcadia's gross domestic product, employment, and income could fall by 18%, 9%, and 19%, respectively, compared to 2019 levels (Maniatis et al., 2020). These impacts could be particularly severe because they are geographically concentrated in Megalopolis. Given the positive effects of the carbon tax on creating new green jobs in the Greek energy sector and the solar energy potential of Megalopolis, the region could seize this opportunity to reskill the local workforce in green technologies and thus retain its role as an energy hub. However, as mentioned by local stakeholders during the consultation process held in early 2023, renewable energy technologies can absorb a significant workforce during the construction process. Still, during operation, job opportunities would be few. To mention an indicative number, the 100 MW of photovoltaics, currently being constructed in Megalopolis, will temporarily provide jobs for 300 people at the construction stage. When the construction is complete, the job openings for operation and maintenance are not expected to be more than 30. Considering that 400 employees are expected to lose their jobs with the coal phase-out (half of the employees; the other half is at retirement age), Megalopolis needs a more diversified business model for its just energy transition. The plans for establishing a business park in the region are not promising since spatial restrictions (i.e., required distance from train stations, temples, and natural gas networks) hinder its realization.

Decentralised generation and formation of energy communities could be an opportunity for increased job opportunities and actively engaged citizens. In parallel, building energy upgrades could decrease citizen' energy costs, limiting the effect of wage decreases. Nevertheless, Megalopolis is missing an opportunity for just transition. Through the Just Transition Fund, the installation of gas boilers is underway free of charge for all the households of Megalopolis. While this might look attractive for the citizens, a relevant analysis from the authors highlights that investing in electrification from the beginning instead of using natural gas as a transition fuel yields better economic and environmental benefits in the long term (Katiforis et al., 2022). Therefore, Megalopolis might be headed towards a new fossil fuel lock-in, at least in the household sector. Especially with relevance to the carbon tax implementation, when applied to households (for example, through an expanded ETS to the building sector), investing in natural gas for heating could increase the energy poverty phenomenon of the city.

To some extent, this remains the case in Upper Silesia, where under the rationale of clean air rather than climate policy, many people in 2018–2021 used public subsidies to replace coal sources with gas in most cases (Mazurkiewicz et al., 2023). Although the situation changed in 2022 (Matczak et al., 2023), adapting modern and cleanest domestic technologies remains moderate as the society has not yet been prepared to do the 'leap frog' due to economic and cultural reasons.

6.3 How to Support Ambitious Climate Policy in CCIRs?

In September 2022, the European Commission and the European Investment Bank (EIB) agreed on a public-sector loan mechanism (part of the Just Transition Mechanism) which will provide funding of up to 10 billion € in the form of EIB loans, combined with 1.5 billion € in EU budget grants for public investments in CCIRs (European Investment Bank, 2022). This agreement followed announcements made in July 2021 that CCIRs across Western Macedonia and Peloponnese would benefit from new investments of up to 325 million € supported by the European Investment Bank, as well as related grants provided by the European Union in support of the Greek Just Transition Development Plan (European Investment Bank, 2022). In Poland, multiple subregions (e.g., Koniński, Wałbrzski, Rybnicki, Bytomski, Gliwicki, Sosnowiecki, Tyski, Katowicki, Bielski) can count on support from the Just Transition Mechanism which will be channelled in regional operational programmes. The highest amount of JTF funds, almost 2.5 billion €, went to the Silesia region with seven subregions. Hence, the additionality of these funds is also strongly visible against the background of other Polish coal regions' regional programmes (Fig. 6). However, it does not provide the highest allocation per capita as Lubelskie, a region located in Eastern Poland with one sizeable hard coal mine (Bogdanka) without plans to downscale the production (and JTF allocation), got a first place due to other regional policies focused on levelling the play-fields between various areas of Poland.

Funds from the Just Transition Mechanism can be a catalyser of potential tipping point triggers. The issue is the appropriate policy operator and political decision, namely who and in what way will manage and redistribute the available funds, as these can be spent on various aims—e.g., direct cash transfers to the households to mitigate the regressive budget effects or subsidies to clean and more efficient technologies. In this way, the Just Transition Mechanism can compensate for the external effects of ambitious climate policy in CCIRs. However, other compensatory mechanisms should also be considered, such as direct transfers with targeted energy support and subsidies for less affluent members of society to enable them to participate in the energy transition, funds recycled from the existing Emissions Trading System (ETS), and compensatory mechanisms in relation to ETS-II, such as the

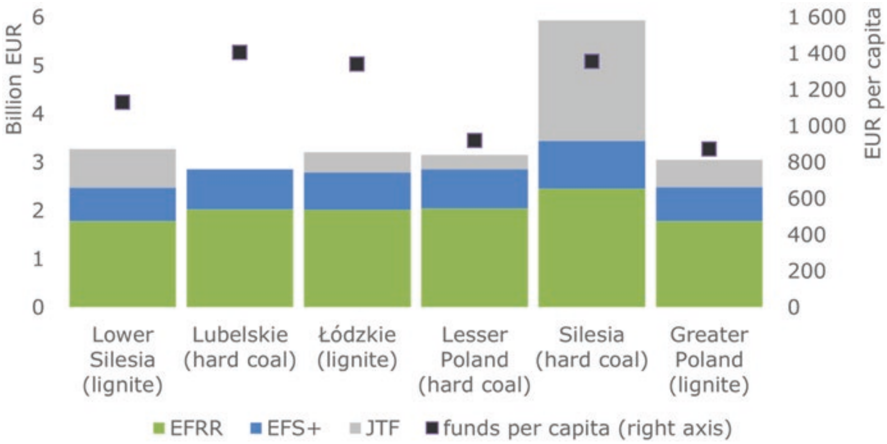

Fig. 6 The allocation for the coal regions' operational programmes 2021–2027 in Poland. Source: own elaboration based on the Partnership Agreement (Ministry of Development Funds & Regional Policy, 2022)

Social Climate Fund which should be operating since 2026 (European Parliament, 2022a, 2022b).

Carbon tax implementation requires policy interventions to mitigate the social costs of the transition. The resources collected from the carbon tax should boost the financial transfer for the transition of CCIRs. Guided by these suggestions, the revenues collected from carbon tax should (1) be earmarked and targeted to avoid transferring revenues for purposes other than mitigation and compensatory policies, (2) boost Territorial Just Transition Plans in CCIRs and sectors particularly vulnerable to decarbonisation (not spatially concentrated), and (3) ensure safety nets and retraining programmes for at-risk employees, and support regional and local institutions such as SMEs and cooperatives to build transformation capacities.

However, one of the most crucial challenges would be establishing a tangible link between the recycling revenues and current policy to make this mechanism understandable to society (Mildenberger et al., 2022). Even though the macroeconomic consequences of a carbon tax in both countries seem manageable, it would be tough to proceed with this tool under the present unstable socio-economic situation, including energy price spikes and very high inflation rates. In that way, there is a need to strengthen the combined narrative of decarbonisation and geopolitics and communicate revenue recycling mechanisms (Sokołowski et al., 2021). With such tools in place, the carbon tax could help accelerate and adapt new energy policies and technology solutions to finally break both countries' dependence on fossil fuels, challenge a durable regime shift in the energy sector, and enable a positive tipping point towards a more sustainable and less carbon-intensive economy.

The debate about economic interventions in the coal regions could be broader than providing information about existing compensation schemes, such as the Just Transition Fund or the Social Climate Fund. The local societies should know more about the long-term regional policy vision, programme logic, the scale of their compensation, and other nationwide policies at the intersection of social and environmental aims limiting the carbon tax burden. With such information, it could be easier to set ambitious climate policy tools and defeat the climate policy opponents' arguments, which could eventually lead to a positive tipping point in the region's development trajectory.

Finally, more long-term structural measures are needed to transform regional socio-economic systems. Further research is required to understand better how other energy and climate policies can offset the socioeconomic consequences of decarbonisation in CCIRs and how different tools, such as carbon tax, can be effectively combined with appropriate mechanisms that can highlight their benefits and limit their costs to foster decarbonisation efforts. Additionally, we observe a need for further regional investigations and sector-specific, granular analysis about the labour market trade-offs in other affected sectors besides mining, such as energy-intensive and advanced industries, which have yet to receive much policy attention so far. Finally, more empirical research is required to dive deeper into the regional and local levels where the socioeconomic impacts of decarbonisation are more visible. To provide a full-system transformation, we need various activities beyond economics and touching the sociocultural and institutional aspects. These will help address non-measurable elements of the energy transition connected with the history, identity, social capital, and sense of place, which are essential but often neglected aspects of regional development.

6.4 Limitations of This Work and Outlook

As always, macroeconomic modelling has limitations, and we would like to focus on three crucial ones for this work. First, the most recent Input-Output (I-O) tables available were from 2015. Moreover, because of the need for more information at the regional and national statistical offices (i.e., regional I-O tables for the Upper Silesia and Megalopolis), we combined insights about decarbonisation challenges at the national level with the regional economic context. Second, I-O tables from 2015, as well as the unavailability of macroeconomic data, do not allow us to introduce the implications of the COVID pandemic (2020), the energy price shock caused by increased global demand after the crisis combined with lower gas supplies and high prices of GHG emission allowances (2021) and the energy crisis stemming from the invasion of Russia to Ukraine (2022), which were undoubtedly essential events in both studied countries. As a result, the values of carbon taxation considered in the modelling might be significantly lower compared to the current reality. If the current situation persists, these findings should be treated as a historical exercise, as they provide relevant findings only regarding the structure rather than a scale. Third, following García-Muros et al. work, the exact numerical values should be treated with great caution, given that many aspects of the labour market and other details are simplified or beneath the level of model aggregation (García-Muros et al., 2021).

7 Conclusions

In this book chapter, we test carbon taxation as a tipping intervention towards accelerated decarbonisation efforts. To assess the macroeconomic effects of implementing a carbon tax, the MEMO model is used, which combines two strands of research—input-output and general equilibrium modelling. We apply the model in two case studies, Poland and Greece, with significant differences in their coal phase-out horizons and economies. The results confirm more substantial consequences of the carbon tax on GDP and unemployment in the highly industrial and carbon-intensive Polish economy. Still, imposing a carbon tax in Greece could have some impeding effects in the short term; however, it could foster quicker decarbonisation efforts in the long term. The results also suggested considerable labour market effects on sectors other than mining, such as light industry and construction in Greece and energy-intensive and advanced manufacturing industries in Poland.

CCIRs and their inhabitants will be primarily exposed to the consequences of the decarbonisation process due to the bulk of activities directly and indirectly related to coal mining and coal-fired power plants. We argue that implementing a carbon tax could disproportionally affect CCIRs since its effects will be most notable in larger regions. However, larger regions might possess higher institutional and economic capacities to enable smoother socio-economic transformation. Nevertheless, larger and smaller CCIRs will require adequate funding and appropriate compensatory mechanisms to achieve their decarbonisation and socioeconomic goals.

Compensatory mechanisms should address critical regional needs in decarbonisation, provide safety nets and retraining programmes for at-risk employees, and support SMEs and overall economic diversification to build transformation capacities and make the regions resilient. Under these conditions, introducing a carbon tax could be a tipping event that could accelerate systemic change towards the desired trajectory. However, based on this exercise, it is more reasonable to treat carbon tax as an additional political trigger proving a particular narrator's agency than the tool allowing us to determine or ex-ante detect any future tipping point. We recommend uncovering all distributional trade-offs during the discussion regarding carbon taxes and any new climate policy instruments and ensuring fair procedures to prepare and communicate such a mechanism.

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Transformative Emergence: Research Challenges for Enabling Social-ecological Tipping Points Toward Regional Sustainability Transformations

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Abstract A crucial task to accelerate global decarbonisation is to understand how to enable fast, equitable, low-carbon transformations in Coal and Carbon Intensive Regions (CCIRs). In this early literature review we underlined the relevance of the boundary concept of social-ecological tipping points (SETPs) and showed that the research and policy usage of SETPs applied to accelerate structural regional sustainability transformations faces three key challenges: (I) integrating theoretical and empirical contributions from diverse social and ecological sciences, together with complexity theory (II) designing open transdisciplinary assessment processes able to represent multiple qualities of systemic change and enable regionally situated transformative capacities, and (III) moving away from one-directional metaphors of social change, or static or homogeneous conceptions of individual agency and single equilibrium in energy transitions; and instead, focus on understanding the conditions and capacities for the emergence of systemic transformations and regenerative processes across multiple levels and forms of agency. We refer to these complex and place-situated processes as learning to enable regional transformative emergence.

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1 Introduction

Accelerating global decarbonisation requires fast social learning on how to enact rapid, equitable, transformative change towards sustainability in those regions of the world most intensive in the fossil fuel production and use. However, an operational integrated theoretical corpus on how to accelerate systemic change through strategic actions toward this end is missing. For this reason, in the TIPPING+ project we underlined the relevance of the boundary concept of tipping points as a way to improve our understanding on how to approach the complexity of rapid sustainability transformations at the regional level. Tipping points and their related terms, such as leverage points, turning points, or regime shifts adopt many diverse meanings and uses in the literature (Winkelmann et al., 2022; Biggs et al., 2018; Otto et al., 2020; Farmer et al., 2019; van Ginkel et al., 2020; Shrivastava et al., 2020; Leventon et al., 2021; Fischer & Riechers, 2019; Tàbara et al., 2018; Werners et al., 2013) and this in practice shows a high polysemy and ambiguity. Based on a

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synthesis from various social sciences contributions carried out by the TIPPING+ project (Sarrica, 2020; Frantál, 2020; Mey & Lilliestam, 2020; Martínez Reyes et al., 2020; Steininger, 2020), we introduced the notion of 'social-ecological tipping points' (SETPs) and underlined three key challenges that face its robust conceptualisation, empirical operationalisation and policy use to assess and accelerate low-carbon regional sustainability transformations: first, acknowledging and integrating contributions from diverse social sciences; second, design open and transdisciplinary processes able to represent multiple qualities of systemic change; and third, support processes for the emergence of transformative place-based situated capacities at regional level. In this regard, 'positive' tipping points, as a basic, bottom-line, minimum definition was originally understood in our regional contexts as those moments of structural change derived from additional strategic but cumulative interventions that decisively contribute to create the conditions for the realisation of sustainable development goals. Whilst tipping points cannot be fully predicted when or whether they will happen, we assumed that the transformative capacities and conditions for their emergence could deliberately be enabled. Tipping points could can then be conceived as those moment in which multiple transformations may emerge across multiple levels of agency—from individual, organisational and systems levels-generating multiple learning processes and virtuous circles of regenerative feedbacks between social and biophysical systems.

2 Social-ecological Tipping Points Towards Sustainability

Traditionally, the notion of tipping points was used in environmental sciences in a negative sense, e.g., to refer to catastrophic futures or show the effects of overshooting planetary boundaries (Folke et al., 2021). However, the concept is being reframed to address the potential of positive ones and in particular to identify social actions which at one point have attained or could attain deliberate visions such as those related to sustainability or climate resilience (Sharpe & Lenton, 2021; Lenton, 2020; Tàbara et al., 2018). In the TIPPING+ project we originally defined SETPs as those hybrid thresholds derived from intertwined social and biophysical forces in which a relatively small action pushes a given social-ecological system towards an alternative development trajectory or basin of attraction. In the case of *positive* SETPs in terms of regional sustainability, such moments would occur when due to previous deliberate actions or interventions, tangible gains in terms of Sustainable Development Goals (SDGs), improvements in justice—e.g., distributive, recognition and procedural—, as well as in endogenous transformative capacities or better adapted social-ecological interactions and institutions, would be created.

SETPs may constitute an abrupt departure from an original social-ecological systems' dynamics or the creation of a completely different kind of system's configuration. Because of their inseparable nature of coupled social and biophysical interactions, SETPs lead to multiple transformations, feedbacks and qualitative changes both in economic, policy and social practices as well as in life-support systems (Tàbara et al., 2021; Tàbara, 2023). Such transformative processes comprise of three main kinds of elements: (1) *an original context or system of reference*, the dynamics of which are driven both by social and biophysical components (2) a *tipping event or disruptive process* which may be brought about by a deliberate intervention or exogenous force, and (3) a set of *impact*s, ultimately changing *fundamentally* the original context conditions. Such consequences may be limited to one single system of reference or extend into a cascade of qualitative reactions in other systems. Conceptually, it is useful to distinguish between *sectorial tipping points*, those that occur in specific sectors or domains—as in the case of turning private mobility from fossil fuels to electric sources but without much broader institutional or cultural changes; and those *systemic tipping points* which affect a whole array of interconnected systems, and do so across a whole sort of personal, organisational and political arrangements and value-systems. The former are often referred to as transitions tipping points whereby system's end-points, policy targets, or the new system equilibria are assumed to exist, can be decided or are known beforehand (e.g., 'achieving a carbon-neutral Europe by 2050'). In contrast, in systemic tipping points such final outcomes, policy goals or new system states cannot fully be known beforehand or specified—hence no equilibrium or final system configuration is assumed (see Stirling, 2015); the latter is the case of constantly evolving social systems addressing justice claims in which no equilibria is to be expected. However, note that in regional research and policy both approaches may be complementary. Eventually, enabling the emergence of a systemic tipping point may only be possible by creating the enabling conditions for multiple sectorial tipping points in a way that then can be combined across many kinds of systems, also referred as deep transitions (Schot & Kangera, 2018). For instance, in some regions the former dependence on carbon-intense activities in the energy sector at one point in time was abandoned or 'released' in a way that the system moved towards a new basin of attraction and reorganized itself around new governance, economic, energy, and socio-cultural foundations (Coenen et al., 2018; Cowell, 2020; Crowther et al., 2021; Gailing et al., 2020).

Although it is hard to know when or whether a tipping point will happen, it is also true that when they happen, as it would be in the case of achieving climate neutrality, they rarely occur by chance. This means that in the case of social-ecological systems, the conditions for their emergence can be—at least partially—described and then possibly influenced by conscious and intentional actions. In this vein, we define tipping interventions as those deliberate actions aimed at building the necessary transformative conditions and capacities for positive transformations to happen at multiple levels of agency in a dynamic way—that is, not only regarding the large system conditions, but also with regard the individuals within that system —, thus yielding desired structural effects in a given system of reference.

3 SETPs in Regional Sustainability Transformations Research. Three Challenges Ahead

3.1 Challenge I: Acknowledging and Integrating Diverse Contributions from Social Sciences

Tipping points can be observed in individual life trajectories as well as in community arrangements and behaviours, but also in economic and distributional structures; in political, governance and institutional arrangements; in geographical and population dynamics (as those which could be derived from climatic risks, Owen & Wesselbaum, 2020; McLeman, 2017); but also in worldviews and beliefs systems, including conventions and public opinion trends (Galam & Cheon, 2020). Hence acknowledging the diverse interpretations of the notion and usages of tipping points by various social science disciplines is a first step for a robust conceptualisation and use in sustainability transformations research and action.

In psychology, models and theories of cognitive, socio-ecological and systemic processes are key to understanding qualitative change involved in socio-ecological tipping points at individual or community levels. Recent studies in human information processing investigate tipping points as 'the point at which people begin to perceive noise as signal' (O'Brien & Klein, 2017), and show asymmetries between individual expectations and the actual moment at which this point is reached (O'Brien, 2020). Going beyond the individual level of analysis, further insights on radical system transformation can be found in socio-ecological psychology, dynamical system approach, and models of change based on critical junctures theory (Liu & Pratto, 2018; Reed & Vallacher, 2020; Uskul & Oishi, 2020). Rooted in general system theory and in cultural and societal psychology, these models stress that interrelationships among elements, sub-systems and systems determine the forms of adaptation to internal and/or external factors. However, and despite the centrality of models of change, psychological studies barely refer to tipping points in energy transition (Otto et al., 2020). Thus, research could fruitfully mobilize insights from other social science fields to better understand psychological tipping points and support the emergence of sustainable development pathways. Individual, social and cultural psychological models of change should be integrated with studies on decarbonization, which use tipping point as an interpretative tool (Schmitz, 2017), for decision making (Cuppen et al., 2015), as a threshold (Strauch, 2020; Weng et al., 2018), or associated with speed and scale in non-linear transformations (Messner, 2015).

In economics, the emphasis lies on the identification, modelling and quantification of possible economic interventions such as investments in disruptive technologies (Berger et al., 2020; Lawrence, 2020; Jaakkola & van der Ploeg, 2019; Bretschger & Schaefer, 2017) and their effects in terms of structural changes in the composition of employment or GDP, competitiveness or in financial assets (Oei et al., 2020; Berger et al., 2020; Bovari et al., 2020; Semieniuk et al., 2020; Tàbara et al., 2018). A main contrast exists between those analyses being made with single equilibrium models (Nordhaus, 2019; Lemoine & Traeger, 2016) seeking an optimal policy response and those models that account for the existence of multiple equilibria (Lamperti et al., 2018). The latter represent the move towards integrating system dynamics and agent-based approaches in future research on the economic determinants of tipping points (Hafner et al., 2020). For instance, an economic tipping point may be quantified or even partly anticipated when the costs of a technology decrease to a level which is able to replace an old one and create the conditions for the energy system to jump into a new enduring state or development dynamics (see also Patt & Lilliestam, 2018). However, many other social, cultural or political factors may contribute to adopting such new trajectory besides costs, as it is the case with electric mobility (Strauch, 2020). In this regard, several econometric methods are capable to detect structural change at macro and regional levels (Berger et al., 2020).

In policy science and governance research, an obvious focus lies on fundamental changes in power dynamics and redistribution, the role of social mobilisation or particular events inducing radical modifications in institutional arrangements bringing about new constitutional regimes or breaking down former ones (Schmitz, 2017; Linnér & Wibeck, 2021). This is the case, for instance, with those new regimes which emerged out of the fall of the Berlin wall, or more recently the attempts to change of the Chilean constitution following the uprising triggered by a relatively small increase in public transport fees (Heiss, 2021; Arias-Loyola, 2021), the failure of such structural reform may be explained due to the lack of previous necessary enabling conditions for transformative change. This line of enquiry also addresses how governance and innovation networks develop within and across time and space to the point that unfold new institutions or forms of durable collaboration or transformative agency (Galaz et al., 2016; Westley & McGowan, 2017). Tipping processes modify the degrees of freedom and the opportunity space for system transformation (Herrfahrdt-Pähle et al., 2020; Folke et al., 2021). That is, either reducing or expanding it. The latter case is when some institutional constraints are removed, or new access to resources, networks or knowledge systems are created and facilitate new forms of innovation and agents' interaction (Amundsen et al., 2018; Füg & Ibert, 2020; Jaakkola & van der Ploeg, 2019; Lutz et al., 2017; Oei et al., 2020; Wiseman, 2018; Schaffrin & Fohr, 2017). In this guise the notion of transformative governance is of special relevance to map out and identify the different kinds of capacities which may lead to tipping points towards sustainability (Hölscher & Frantzeskaki, 2020).

In inter and transdisciplinary approaches, the insights from social-ecological systems (SES) and resilience research (Folke et al., 2021; Hahn & Nykvist, 2017; Lauerburg et al., 2020) on social and natural systems are combined to understand how they mutually influence or change together. These approaches are usually conceptualized with notions such as the adaptive cycle (Walker et al., 2020) whereby successively repeated periods of stability/conservation, release, reorganization, and exploitation make up the 'panarchy' process. There may be tipping points in between each phase, but critical thresholds certainly occur in the release phase, whenever the system loses key societal or environmental components or processes that would otherwise allow reorganization to its original form. Moreover, sustainability transformations research is developing new interpretative lens and metaphors derived from social quantum theory (O'Brien, 2016, 2018, 2021) that can be also related to ideas of tipping points. Following these perspectives, it could be argued that a tipping point would occur when a new consciousness about alternative plausible worlds, qualitative kinds of relationships and realities across personal, political and practical configurations and of the role of individual agency in turning them actionable and meaningful emerge. In this vein, sustainability transformations call for problematising current value systems and worldviews (Berzonsky & Moser, 2017) so profound changes in worldviews can also be interpreted through the perspective of deep leverage points (Davelaar, 2021). Systemic tipping points in culture, education and policy processes are largely dependent on the role played by human information and knowledge systems (HIKS; Tàbara & Chabay, 2013; van der Leeuw & Folke, 2021) and normative values (Horcea-Milcu et al., 2019; Jacobson et al., 2020); and as argued by Nyborg et al. (2016), tipping points can also be understood as the moments in which vicious circles in collective behaviour turn into positive ones, e.g., by a change of social norms and perceptions, which in turn can be induced by deliberate policies or the role of minority groups reaching a critical mass (Centola et al., 2018). Justice in particular is also considered a key driver for sustainability transformations and a crucial component to understand radical shifts in power dynamics regarding gender, ethnicity youth inclusion or the social recognition of disadvantaged groups (Allen et al., 2019; Blythe et al., 2018; Ziervogel et al., 2017) and it is also of especial significance in energy transitions research (Cronin et al., 2021; Doyon, 2019; Patterson et al., 2018; Bouzarovski & Simcock, 2017). And in this regard, justice is both a driver and an outcome of positive tipping points.

3.2 Challenge II: Designing Open Transdisciplinary Assessment Processes Able to Represent Multiple Qualities of Systemic Change and Enable Regionally Situated Transformative Capacities

When considering deep structural change, different disciplines often portray and refer to very different kinds of systems and of how their dynamic components operate. Even within those disciplines using a 'systemic approach' to sustainability transformations (Scoones et al., 2020; Fazey et al., 2017) one can find important contrasts, as it is the case with transition theory (Köhler et al., 2019), resilience and social-ecological systems research (Folke et al., 2021; Moore et al., 2014), coupled natural-human systems (CNHS; Liu et al., 2021) or organisational science (Hestad et al., 2021; Westley et al., 2011) where the use of terms as 'ecosystems' can have little to do with what natural scientists refer to. This means that they also tend to emphasize different temporal and spatial scales or conceive the role of social agency in them in different modes.

In addition, the position of the researcher with respect to the systems of reference is not independent of their analyses. Systems are always defined in relational ways and are inevitably influenced by previous socially-constructed conceptual categories. Moreover, systems operate under different logics, agents and complex dynamics (Hestad et al., 2020). Using an open, pluralistic, transdisciplinary approach it is necessary to help to overcome such limitations. However, the difficulties for providing a transdisciplinary methodology for the research of tipping points in sustainability science derives, among other reasons, from the existence of different ontologies as well as for conflicts in epistemologies and normative criteria used to describe and assess the systems of interest in which different disciplines operate (Tàbara et al., 2021; Milkoreit et al., 2018).

A key task then is how to design open, plural and transdisciplinary assessment processes for the assessment of SETPs, given that complex systems can only be described partially by one single perspective. This in turn would entail: (a) identifying and assessing different qualities of deep structural change occurring in the different kinds of systems in which transformations are needed, even though they may not necessarily or immediately appear to be connected, and (b) to represent complex dynamics derived from alternative interventions according to multiple time, spatial and social scales or dimensions. In particular, and regarding time scales, the causality of events and the apparently trivial fact that 'timing matters' are crucial elements for investigation of tipping processes in regional transformations processes: 'what happens when' - the sequence of events - is important, since actions from the distant past can initiate particular chains of reactions that have effects in the present - some largely unexpected. As Pierson (2000) suggested, 'small' events early on may have a big impact, while 'large' events at later stages may be less consequential. And in this sense, tipping points can be understood as the breaking of previous path-dependencies and lock-in situations that mark the entry to new locked-in states. However, using the chronologies, methods and time, spatial or social conceptual boundaries from one single discipline limits our ability to fully understand the complexity of addressing the full complexity of SETPs processes. To understand these complex processes, a systematic exploration of the underlying conditions and how they are conceived by different perspectives—e.g., in terms of transformability, resilience and specially, regarding systems' sensibility to possible tipping interventions—subject to multiple time lags including social hysteresis—is necessary.

3.3 Challenge III: Enabling Transformative Emergence in Coal and Carbon-Intensive Regions

Sustainability transformations, whilst occurring at multiple levels of agency, they eventually materialise in places (Salomaa & Juhola, 2020). In fact, it can be argued that sustainability science is always a situated science. Research on the transformations of energy systems needs to pay especial attention to particular places, human geographies, spatial configurations and dynamics of networks within which deep transitions are embedded (Köhler et al., 2019; Bridge & Gailing, 2020; Coenen et al., 2021; Mattes et al., 2015; Naumann & Rudolph, 2020; Hansen & Coenen, 2015). Changing the configuration of energy production systems towards a distributed generation system based on renewables and multi-scale geographical shifts in energy demand underlines the importance of situating possible tipping points in socio-energy systems in specific places (Bridge, 2018). However, when trying to apply the concept of SETPs to sustainability transformations in places, the actual meaning of regions and communities also needs to be reconceptualised and novel modes of analysis of trans-local and trans-regional action are required. In terms of tipping points, cross-scale interactions may be better assessed and mapped out by examining the extent to which positive synergies between different kinds of actors and networks around transformative solutions are being formed, rather than using other more rigid and less action-oriented operationalisation criteria. Thus, collective action in regional contexts is very much dependent on many intertwined and complex factors which cannot easily or simply be reduced to 'bottom-up/top-down dynamics' nor to the simple aggregation of fixed individual patterns of behaviour within larger systems configurations (Byrne & Callaghan, 2014). Sustainability transformation processes do not occur only as a result of vertical and one-directional phenomena but in a much more complex, overlapping and dynamic processes of collaboration and competition between changing agents who operate under different perspectives, personal roles, interests, organisational logics or capacity of influence.

A novel approach in this regard would require a further elaboration on the notion of regions so as to integrate new components necessary to understand and enable sustainability transformations. That is, to consider not only the *formal regions* based on the 'sameness' in geographic, administrative, cultural or economic attributes; or the *functional regions* defined in terms of their operational links, flows and interactions; or *the perceptual or cultural region* related to areas socially constructed by cultural beliefs, feelings or attachment, or other collective imaginaries. This new approach may entail extending the functional category of region based on identifying what would be needed to be transformed for achieving a positive tipping point in sustainability terms. This would be close to what the EU refered to the Accelerator Regions (Hedegaard et al., 2020), although a *transformative region*, would also encompass dynamic transformations at multiple levels of agency, as well as in the other formal and cultural defining categories.

However, considering such a novel approach to regional change would also need to move away from simple and one-directional metaphors of causality in socio-cultural and technological change (see Hughes et al., 2022) towards understanding and enabling the conditions for *transformative emergence*. Using the notion of transformative emergence in tipping points would mean to abandon fixed and static ideas of individual agency (e.g., the rational actor paradigm) in their interactions with other organisational or large systems' levels. That is, moving from synchronic perspectives of systems' reconfigurations and changes occurring only at one point in time or one single level—e.g., at individual and organisational level with direct dependency among them—to understanding what multiple transformations of properties may emerge and influence in a recursive way multiple configurations at multiple periods of time—and also to acknowledge that no single or direct dependency relationships between agents and systems may occur among them (van Dijk, 2020; Humphreys, 2020; Schot & Kangera, 2018; Guay & Sartenaer, 2016). Further research using such dynamic understanding of agency-systems interactions in which both agents and systems do and need to change at the same time, may have profound implications for sustainability science and policy. And in particular for those approaches, such as in modelling, aimed at identifying positive tipping points derived from coupling multiple systems of solutions at different scales or domains of action.

In short, instead of one-directional and single end-point approaches, we advocate for a better understanding of those kinds of tipping interventions which may help to create the conditions for the emergence of more lasting and profound systemic effects in diverse but coupled social-ecological systems of reference; and do so at different levels of agency with special attention to be placed to individuals, communities and regions with higher potential for fast, positive systemic impact. Transforming systems require empowered transformative agency operating in enabling environments which induce to such transformations in a recursive, 'multichronic' mode. This novel approach to accelerating transformative actions in regions and communities would also call for the integration of both human and biophysical forces of change, insofar that improvements in biophysical conditions translate into improvements in human quality of life conditions and in turn generate multiple positive retroactive feedbacks in many kinds of systems (for the case of food systems see (Pereira et al., 2020)). But in any case, the possibility of such self-reinforcing positive learning loops leading to a systemic positive tipping point would be conditioned by the agents, networks and capacities required to implement transformative visions, and strategies in each particular regional contexts of action (Tàbara et al., 2018).

4 Conclusion

The need for understanding how to accelerate systemic and qualitative change towards sustainability derived from relative strategic and sensitive interventions is opening a large corpus of research on social-ecological tipping points. One additional reason for the attractiveness of this concept in sustainability science may lie in the belief—or hope—that few relatively small actions or marginal additional forces can eventually lead to large, desirable and profound system' changes, as when seemingly trivial or imperceivable events trigger irreversible and accelerating chains of reactions (Nuttall, 2012). However, in the case of deliberate sustainability transformations, such belief has not yet been fully proven to be true in empirical or at large-scale terms. Or at least, such belief will only be confirmed when we better understand the previous and complex conditions and deliberate interventions that made such large systems' change possible in the first place. Whilst it may be the case that a disruptive event, intentional policy action, individual behaviour or technology may precipitate rapid change in a given system, whether it will eventually contribute to wider sustainability will depend very much on the extent to which many other conditions, contextual factors, previous forces of change come into play.

The EU funded TIPPING+ project was an attempt to dealt mostly with Challenge I, insofar that it aimed to explore in an open way how different social science disciplines, and in particular human geography, anthropology, social psychology, economics and sustainability policy analysis understood the complex notion of tipping points and then how these could be used to understand regional decarbonisations processes. From this plural approach, it also aimed to provide empirical insights on fast structural change which could be also relevant to inform public policies. The COVID pandemic affected about two thirds of duration of the project which meant that many interactions with stakeholders and other potential methodological innovations regarding Challenge II could not be carried out. Under these conditions, a particular emphasis was placed on developing theoretical perspectives that could help the potential for transformations in coal and carbon intensive regions, such as the Just Social-Ecological Tipping Scales (Mangalagiu et al., 2023) or more generally, using non-linear, complex social-ecological systems approaches, also the conditions to move towards regenerative development pathways (Tàbara, 2023).

Current research on tipping points is carried out at a very theoretical or still using stylised modelling approaches that are hard to be applied to inform and support real-life social and political processes of deliberate sustainability transformations. The TIPPING+ project found out that definitions and understandings on tipping points vary considerably among different disciplines, which also makes it difficult a cross-disciplinary understanding of the kinds of systems, structural changes or effects of the different tipping phenomena that they refer to. In the future, further human interfacing capacities and transdisciplinary research spaces will be needed able to address such complex boundary concepts in a way that can engage, facilitate dialogue and support second-order learning (doing things different under a different cognitive and normative paradigm or vision) among relevant actors in the present conditions of accelerated environmental change.

Tipping points, conceptualised as discontinuities in a development trajectory, as thresholds of qualitative structural change or as a move toward new basins of attraction, occur in many different kinds of systems, relationships and levels of agency; so, they can hardly be circumscribed to one single system of reference. However, positive tipping points, when they happen they rarely occur by chance. The building conditions by which SEPTs eventually unfold can be systematically described and analysed, albeit always partially and limited to the perspectives and tools that researchers use in their descriptions. But for this knowledge to become a solid basis for action, our review underlined three key challenges for research. First, acknowledging and connecting the contributions from diverse social sciences with complexity theory (Byrne & Callaghan, 2014), also using a situated, place-based approach. Second, designing open transdisciplinary assessment processes able to assess multiple understandings of qualitative change in social-ecological systems, with special attention paid to supporting transformative capacities; and third, rethinking the nature and interactions between agents and systems from a transformative emergence perspective in which multiple transformations and learning feedbacks can emerge—in a ‘multi-synchronic’ way over multiple periods of time and across different levels and forms of social-ecological agency.

A better understanding of the social, economic and environmental challenges that individuals and groups encounter before, during, and after a given regional systemic transformation might also help clarify to whom the tipping points may impact positively or negatively, e.g., in terms of justice and sustainability. Some of these challenges or injustices might originate from power asymmetries already in the system, such as social discrimination preventing participation in decision making spaces and gender inequities (Clancy et al., 2020; Johnson et al., 2020). Therefore, once both a target or directly affected group(s) and non-target ones have been identified, the sustainability potential of tipping interventions may be better tailored accordingly.

In this contribution we argued that one of the most urgent tasks to move human societies towards sustainability has to do with learning how to accelerate sustainability change in those areas most intensive in the extraction and use of fossil fuels. Sustainability transformations research needs then to pay special attention to understanding the conditions by which coal and carbon intensive regions have managed to move to alternative, better-off structural situations and/or how radically clean-energy and socially just trajectories could be taken in other regions. However, and although the exact moment in which positive tipping points may occur cannot be known beforehand, we have argued that it is possible for sustainability and interdisciplinary social-environmental sciences to contribute meaningfully to identifying and assessing the societal and policy learning processes to build the transformative conditions and capacities for their emergence.

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