Sustainability Transitions in German Livestock Farming:

The Role of Innovations, Incumbents, and Imagined Futures

Dissertation
for the award of the degree
"Doctor rerum naturalium" (Dr.rer.nat.)
of the Georg-August-Universität Göttingen
within the doctoral program Geography
of the Georg-August University School of Science (GAUSS)

submitted by
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from Stuttgart

Berlin, 2023

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Tag der mündlichen Prüfung: 21.07.2023

Articles included in the dissertation:

Friedrich J, Bunker I, Uthes S, Zscheischler J. 2021. The potential of bioeconomic innovations to contribute to a social-ecological transformation – A case study in the livestock system. *Journal of Agricultural and Environmental Ethics 34: 24.*

Friedrich J, Najork K, Keck M, Zscheischler J. 2022. Bioeconomic fiction between narrative dynamics and a fixed imaginary: Evidence from India and Germany. *Sustainable Production and Consumption 30: 584-595.*

Friedrich J, Zscheischler J, Faust H. 2022. Preservation, Modernization, and Transformation: Contesting bioeconomic imaginations of "manure futures" and trajectories toward a sustainable livestock system. *Sustainability Science 17:2221-2235.*

Friedrich J, Faust H, Zscheischler J. 2023, *forthcoming*. Incumbents' in/ability to drive endogenous sustainability transitions in livestock farming: Lessons from Rotenburg (Germany). *Environmental Innovation and Societal Transitions.*

Articles that emerged out of the dissertation (not included in the dissertation):

Friedrich J, Zscheischler J, Faust H. 2021. Social-ecological transformation and COVID-19: The need to revisit working-class environmentalism. *GAIA – Ecological Perspectives for Science and Society 30(1): 18-22.*

Friedrich J, Holz J, Koch P, Pungas L, Eversberg D, Zscheischler J. 2023. Rural bioeconomies in Europe: Socio-ecological conflicts, marginalized people and practices. *GAIA – Ecological Perspectives for Science and Society 32(2): 219-224.*

Abstract

Environmental degradation, climate change, and issues of social justice highlight the need to develop and transition to more sustainable modes of production, consumption, and living. Livestock farming in Germany is a sector that is concerned to transition, being characterized by a multitude of socio-ecological issues and both discursive and legislative pressure to change. While this sector is marked by persistent mechanisms in culture and practices, bioeconomic innovation actors are developing innovations that may contribute to sustainability-oriented transitions in this sector. This context presents the possibility to observe transitions in the making. Against this backdrop, in this dissertation, I aim at understanding the mechanisms, actors, and processes of currently unfolding transitions in livestock farming by a focus on innovations, incumbents, and imagined futures. I operationalize this focus via four complementary qualitative case studies, focusing on (i) contesting imaginations of manure futures and how these shape trajectories of livestock farming, (ii) the role of bioeconomic innovations in contributing toward transitions in livestock farming, (iii) the role of bioeconomic actors as being shaped by technological fixes, and last, a focus on (iv) livestock farmers as incumbents being embedded in the existing regime and their in/ability to drive institutional changes.

My empirical results show three different trajectories of livestock transitions, namely preservation, modernization, and transformation. These are characterized by contesting imaginations of manure futures. Bioeconomic innovations in the intensive livestock system are shaped by imaginaries of technological fixes, follow classical innovation paradigms, and have a rather low ability toward reconfiguring the existing regime beyond actor-technology configurations. On the contrary, as they are accompanied by expectations, these innovations attract capital investments, which pose the risk of "colonizing" the future through sunken costs and extra-semiotic inscription of imaginaries in material and physical infrastructures. Farmers as incumbents are embedded in very stable systems, externalize the locale to change, and experience low agency for change. Transitions in livestock farming are thus currently mainly visible in changes of the actor-technology configuration as a result of the adoption of bioeconomic innovations and are driven by exogenous actors such as NGOs and political-legislative changes (e.g., the EU's nitrate directive and the German fertilizer ordinance) in the semiotic space. Farmers may currently lack the capacity to imagine real alternatives and navigate changes by themselves.

In addition to these empirical results, my dissertation elucidates the important role of imagined futures in sustainability transitions. Imagined futures not only provide the semiotic spirit for change, but they are also at the same time a diagnosis of the present and of the problem(s) that individuals and collectives regard as important to change. Without the ability to imagine alternative futures, the ability to transition and reconfigure is limited. Actors with material-semiotic relationships to livestock farming often have reductionist problem frames on issues, while actors such as NGOs with semiotic relationships have more complex problem frames. In order to be able to act purposefully despite complexity and uncertainty, actors with material-semiotic relations rely on reductionist problem frames, established and inscribed forms of change through technological fixes, or on conceptions of no change. Relying on these reductionist conceptions of change may result in cognitive path dependencies and a colonization of the future. The underlying dissertation

underscores that to avoid such phenomena appearing, it is of great importance to integrate different actors' views of problems, e.g., by means of transdisciplinary research projects. Here, different actors can discuss their normative orientations, conflicting problem views, and develop meaningful imaginations of how to change the current system. This can not only support new forms of innovation design to be implemented, but could also help individuals in navigating transitions and experiencing agency in the moment of change.

Based on a synthesis of the empirical and theoretical contributions of my research, this dissertation sketches four research avenues for an in-depth understanding of the complex mechanisms in livestock transitions and how to govern and drive these. I conclude that for persistent systems such as livestock farming, it is important to allow for exchange of knowledge and social contacts and to bring in new perspectives that can drive changes in the persistent culture of these systems. Without new actors, the capacity to imagine different futures for livestock farming and practices, how to achieve these, and how to drive genuine sustainability transitions in livestock farming is limited because, without new cultural and imaginative input, the regime of livestock farming will merely reproduce itself. In such processes, the future must be treated as a social arena characterized by different imaginations, ontologies, and perspectives to develop transformative imaginations. To avoid reproducing and reinforcing existing imaginations, the power relations and hegemonies that structure current deliberative processes must be challenged to develop both adaptive and plural conceptions of imagined futures that can accordingly drive genuine and just transformations in livestock farming and beyond.

Acknowledgements

I want firstly to acknowledge the invaluable support of my supervisors Jana, Heiko, and Sandra during my dissertation. You always kept me on track, pushed me when needed, and I'm grateful for the constructive feedback and comments that helped me improve my writing, my general research skills, and my development as an independent scholar. Thanks for always keeping your ears and minds open whenever I wanted to discuss research ideas and problems. It was always a pleasure to work with you and I'm already looking forward to future projects.

I would also like to thank the co-authors of the articles that comprise this dissertation, namely Jana, Heiko, Katharina, Markus, Sandra, and Ingrid. Thanks for your productive support and the constructive (and sometimes elaborate) discussions that helped me enhance the manuscripts on their journey toward publication. I'm also grateful to my working group, Co-Design of Change and Innovation, and my junior research team "Biokum", both based at the Leibniz Centre for Agricultural Landscape Research. You gave constructive and helpful feedback on earlier versions of my methodological approaches, strengthened my knowledge of a range of theoretical and empirical topics, and shared the sunshine with me during those all-too-brief lunch breaks at work.

I also appreciate the supportive and constructive feedback of the reviewers of the peer-reviewed articles published in this dissertation. Your rigorous input helped me and my co-authors in polishing these articles for publication.

In addition, I have great memories of the stimulating discussions and generous feedback at multiple conferences and workshops where I was invited to present my work. In particular, I want to highlight discussions on the sustainability of bioeconomic approaches with members of the Junior Research Group "flumen", based at the Friedrich Schiller University in Jena, which deepened my understanding and knowledge of bioeconomy research. In particular, to Jana, Lilli, and Philip, many thanks for the interesting and reflective discussions on bioeconomic topics and beyond.

I am also thankful to Felix, Lilian, and Ronja who provided valuable feedback on earlier versions of this dissertation that helped me improve both my arguments and my writing.

Furthermore, I want to thank all the people I was privileged to interview and without whom it wouldn't have been possible to finish this work. Thank you for your time, thoughts, and insights into your working and day-to-day practices that were so crucial for my work on this thesis.

Lastly, I am grateful for the emotional and social support that my family and friends provided while I was writing this dissertation. Thank you for always being there, for celebrating achievements, and for supporting me during the hard times.

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List of Abbreviations

ABLE	Association of Biotechnology Led Enterprises
BMBF	Bundesministerium für Bildung und Forschung
BMEL	Bundesministerium für Ernährung und Landwirtschaft
BMU	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz
BMWi	Bundesministerium für Wirtschaft und Klimaschutz
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
Bt	Bacillus thuringiensis
CAP	Common Agricultural Policy
CE	Circular economy
CDU	Christlich Demokratische Union
CIFA	Consortium of Indian Farmers Association
EU	European Union
FDP	Freie Demokratische Partei
GEO	Genetically engineered organisms
Ger	German
IP	Interviewpartner
l	Liter
LBEG	Landesamt für Bergbau, Energie und Geologie
LWK	Landwirtschaftskammer
mg	Milligram
MLP	Multi-Level-Perspective
N	Nitrogen
NGO	Non-governmental Organization
NPK fertilizer	Nitrogen, Phosphor, Potassium fertilizer
OECD	Organization for Economic Co-operation and Development
PBW	Pink bollworm
R&D	Research and development
RQ	Research question
SABC	South Asian Biotechnology Center
SDG	Sustainable development goal
SET	Social-ecological transformation
STCA	Sociotechnical configuration analysis
STS	Science and Technology Studies
UBA	Umweltbundesamt
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen

1 Introduction

Our world is currently in need to transitioning toward more sustainable modes of living, producing, and consuming. Different, often overlapping crises, such as those relating to environmental degradation, climate change, biodiversity loss, but also social injustices exemplify the widely claimed need for change in practices, values, and norms in multiple societal sub-systems of different spatial levels. How this change may unfold is open and under debate as the problems to solve are often "wicked", i.e., subjective to different actors' meanings, perception, and values; and characterized to a large extent by uncertainty regarding the future (e.g., Duckett et al., 2016). Hence, different actors from civil society to science and policy are pursuing different visions, approaches, and understandings of (sustainable) transformations and what these would entail, characterized by different imaginations of the future, and the ambiguity of the term sustainability (e.g., Adloff et al., 2020; Adloff and Neckel, 2019; Schneider et al., 2019). As an example, there are social and scientific actors that are both in favor of and against the idea of transformations through a technology-oriented and managerial focus with respect to climate change (Nightingale et al., 2020), while others criticize the fallacy of green growth (Hickel and Kallis, 2020) or a green economy (Brand, 2012) as models for achieving sustainability. Some further ideas of how to move toward sustainability include different visions of a sustainable bioeconomy that appear in bioeconomic strategy papers and academic discourses (e.g., Bugge et al., 2016; Hausknost et al., 2017; Vivien et al., 2019), an envisioned circular economy as a policy approach (Kovacic et al., 2020), and more far-reaching understandings of social change such as those based on the concepts of degrowth or agroecology (Escobar, 2015; Kothari et al., 2014; McGreevy et al., 2022), that often inherently present a critique of capitalist modes of production and consumption, including global externalizations, "imperial modes of living" (e.g., Brand and Wissen, 2018), and "logics" of growth and acceleration in capitalist modernity (Rosa et al., 2017).

While the ideas and concepts of sustainability-oriented social change elucidated above refer largely to academic debates, how these concepts take shape in practice is contested and under dispute as well. Transitions toward sustainability in different societal sub-systems and sectors show the contested and normative nature of these processes and the importance of actors and their cultural configurations (e.g., Fischer and Newig, 2016; Loorbach et al., 2017; Schlaile et al., 2017). Here, it becomes visible how actors are struggling for and against sustainability-oriented change for different reasons. Some actors that are campaigning against changes are permeated by persistent culture and locked-in cultural and discursive configurations of unsustainability, while other actors envision and leverage change for aspects of sustainable production systems (e.g., Fischer and Newig, 2016; Fuenfschilling and Truffer, 2014; Gürtler and Herberg, 2021; Simoens et al., 2022; Turnheim and Sovacool, 2020).

The research field of sustainability transitions (e.g., Köhler et al., 2019; Loorbach et al., 2017; Markard et al., 2012) focuses on these processes, how they can be leveraged and governed. In this way, the research field provides comprehensive understandings of the actors, concept, and contexts through which socio-technical systems reconfigure toward sustainability alongside providing robust orientations for policymakers in terms the governance of these changes. In the past years, this research field has especially been concerned with analyzing and describing how specific sectors and societal sub-systems transition toward more sustainable ways of producing and living. The

MLP (Multi-Level Perspective) as a long-standing theory of change in this research field has highlighted that transitions are an emergent process and a product of the interaction of niches (in which innovations may get designed) and the socio-technical regime (the existing, relatively stable combination of producers, science, and policy) resulting in so-called socio-technical transition pathways (Geels, 2002; Geels and Schot, 2007; Markard and Truffer, 2008). This theory, often used for ex-post analyses of transition processes, sets out how innovations, as developed in niches, can transition the existing regime through windows of opportunity triggered by landscape changes (e.g., discourses, political changes) (Geels and Schot, 2007).

Recently, other approaches have also appeared that describe and discuss how transitions unfold, e.g., inspired by practice theory (Svennevik, 2022), aspects of power and agency in transitions (Avelino, 2017; Avelino and Wittmayer, 2016; Duygan et al., 2019), related to culture as deep structures that form institutional logics and which may inhibit transitions accordingly (Fuenfschilling and Truffer, 2014; Runhaar et al., 2020), and the roles of actors in these processes (Farla et al., 2012; Fischer and Newig, 2016). Some of these aspects have fed into frameworks such as the X-curve framework that extents the understanding of transitions beyond the MLP as it presents the opportunity to research emerging transitions (Hebinck et al., 2022; Loorbach et al., 2017).

Innovation actors and incumbencies are regarded as having major roles in transitions. The interaction between (novel) actors developing innovation and actors that constitute the existing (stable) combination of technologies and institutions is regarded as highly relevant for the outcome of sustainability transitions in specific sectors (Farla et al., 2012; Fischer and Newig, 2016; Turnheim and Sovacool, 2020). Innovations need to be accepted and adopted by consumers to have the capacity to diffuse and reconfigure the existing regime and accelerate change toward sustainability (Markard et al., 2020).

In the underlying dissertation, I will look specifically at livestock farming in Germany as an example of a sector for sustainability transitions. Livestock farming is a sector in which multiple socio-environmental crises overlap and become visible. These crises provoke the need for sustainability-oriented change and transformation. At the same time, livestock farming currently forms a relatively stable socio-technical system. It is a sector that receives subsidies through the EU's Common Agricultural Policy framework (Alons, 2017; Barnes et al., 2016), characterized by stable and persistent culture, and historically institutionalized, globally entangled, yet locally embedded practices (Franz et al., 2018; Tamásy, 2013), that makes change rather difficult. Simultaneously, the sector must change its configuration to cope with new environmental legislation (e.g., new nitrate directive and fertilizer ordinance, Stuhr et al., 2021; Vogeler et al., 2019) and changing societal discourse that aims at more sustainable forms of agriculture, as exemplified by the German call for small-scale agriculture (Busch et al., 2022; Nowack and Hoffmann, 2020; Nowack et al., 2019). German livestock farming is also a sector in which the socio-ecological implications of the political project of a sustainable bioeconomy (Lühmann and Vogelpohl, 2023) become tangible as livestock residues may be used for bioeconomic innovations. In Germany, this political project describes the ideas both of using biological knowledge to develop innovations and of substituting fossil materials by biological materials, with a focus on agriculture and forestry as sectors for input materials (BMEL and BMBF, 2020).

Accordingly, I regard livestock farming in Germany as a social arena in which socio-environmental crises and the pressure to change toward sustainability become tangible, and a site

in which to research the practical constitution of the political project of a bioeconomy. In this sector, it is possible to analyze different dimensions, dynamics, and aspects of sustainability transitions in the making. Livestock farming in Germany and parts of the EU is under pressure to change due to environmental degradation that is attributed to methane emissions, eutrophication of water bodies as a consequence of a regional manure surplus that leads to biodiversity decrease and odor (BMEL and BMU, 2020; Häußermann et al., 2019; Sundermann et al., 2020). Ethical aspects with regard to animal welfare (e.g., Busse et al., 2019), working conditions in slaughterhouses and the processing industry (Wagner and Hassel, 2016), and land rights of indigenous people in South America in the case of soy bean cultivation as livestock fodder (Sauer, 2018) underline issues beyond socio-ecological aspects, thereby exemplify overlapping aspects of the multiple crises. Two of the claimed endangered planetary boundaries, namely "biosphere integrity" and "biogeochemical flows" (Steffen et al., 2015) relate explicitly to livestock farming via manure surpluses and the consequences for global phosphor and nitrogen cycles, and local biodiversity loss through eutrophication of water bodies. While all these aspects underline the normative need for change and transformation, farmers and other actors along the value chain are embedded in the system as *incumbents*. While these actors may accordingly torpedo change as being afraid of losing control, resources, and power, yet they can also have a "disposition to change" (Turnheim and Sovacool, 2020). In an attempt to present ideas of how to green this sector and reduce the environmental degradation attributed to manure as a product of livestock farming, bioeconomic innovation actors are currently developing innovations that present ways of using manure for purposes other than local on-field application or methods of applying manure that produce fewer emissions (e.g., Čičková et al., 2015; Darapuneni et al., 2019; Pintucci et al., 2017; Stadtlander et al., 2019). These innovations may alter the existing regime and provide solutions for a more sustainable livestock farming. At the same time, these innovations present an analytical category for analyzing the real-world implications of the political project of a sustainable bioeconomy.

This briefly sketched background of livestock farming in Germany underlines that this sector is concerned with multiple crises, the pressure to change from both society and policy, and is characterized by persistent, often even rigid, structures. Hence, open questions remain for both science and policy regarding how transitions in this sector may unfold, what models of transitions are currently being discussed in this sector, and which actors have the potential and power to drive these transitions.

There have been attempts[1] to fill these research gaps with regard to the attitude of consumers toward livestock farming (e.g., Busch et al., 2022; Schulze et al., 2023), the agency of farmers in coping with new environmental legislation (Stuhr et al., 2021), the role of different actors in livestock transitions in agri-food systems (Bünger and Schiller, 2022), and on how farmers relate to transitions as "warme Sanierung"[2] (Thiermann et al., 2021). However, the questions of how transitions can and do unfold as an emergent process in livestock farming still remain to a large extent unanswered for Europe and in particular the German context (see chapter 3 for more details on this matter). In particular, it is not yet known which approaches of transitions in livestock farming are currently being discussed, to what extent bioeconomic developments such as manure-

[1] All these studies were published after I started working on the topic. For an in-depth overview, see chapter 3.

[2] Translated to English, this would read as warm redevelopment and refers to financial programs from the government that help farmers transition and build new innovative forms of livestock farming.

based bioeconomic innovations can contribute toward a sustainable livestock system, and what role farmers as incumbent actors in the existing regime have in contributing toward a sustainability-oriented transformation of livestock farming.

Against this background, my dissertation aims at filling these gaps and in contributing to generating knowledge that can be used to manage, govern, and navigate transitions in German livestock farming. In particular, I start from the observation that livestock farming is characterized by numerous socio-environmental issues, societal debate and new environmental legislation that specifies the need for change while bioeconomic innovations may provide solutions to these issues (Figure 1, see chapter 1.1 for details). From this observation, I derive the research hypothesis[3] that the current situation may provide the opportunity to research transitions in the making and in particular the mechanisms, typologies, actors, and dynamics through which transitions in livestock farming may and can occur. Hence, my aim is to understand and unpack currently unfolding transitions and their mechanisms in German livestock farming. The aim feeds into four research questions that I lay out in chapter 1.1 (in the context of Figure 1) from which to depict the process of arriving at the different case studies. I address this aim and research questions via a threefold focus on *innovations*, *incumbents,* and *imagined futures* (see Figure 1) through multiple yet complementary case studies. This focus, I argue, will allow me to gain a comprehensive picture of the contested nature of sustainability transitions in livestock farming, the different roles of actors, and how transitions in sectors with very stable semiotic and extra-semiotic[4] structures may unfold. I take this threefold focus due to the following reasons.

Firstly, as sustainability transitions are oriented toward the future and are embedded in imaginations of the future, researching imagined futures and imaginaries that shape transitions allows me to unravel the contested nature of transitions in livestock farming. The future-orientation of sustainability transitions means that these processes are deeply normative, based as they are on desires and hopes of what ought or ought not to be (Hölscher et al., 2018; Schlaile et al., 2017; Schneider et al., 2019). Transitions and transformations are inspired by future imaginations, projections and anticipations. Dystopian pictures of climate change and planetary collapse and visions of a better life motivate actor collectives such as Extinction Rebellion to protest and to pursue changes in their collective or individual activities, while it is climate anxiety in terms of not feeling able to change anything, by experiencing non-agency and "ontological insecurity" that has been argued to be a reason for climate change denial (Hochschild, 2016; Neckel and Hasenfratz, 2021; Norgaard, 2006). For innovation actors, imagined futures are the creative source for their developments (Geels, 2020; Jasanoff and Kim, 2009). While imagined futures provide the semiotic spirit for the design of innovations and transitions, they can at the same time "colonize" the future by leading to cognitive path dependencies and materialized sunken costs (Beckert, 2013, 2016). Therefore, a focus on imagined futures presents an important explanatory dimension for processes

[3] I am aware that the term hypothesis is contested in qualitative research. I will use the term carefully as a way to relate to and describe my a priori considerations as a researcher that led me to conduct research and with which I entered the process of empirical data collection. Hence, the term allows me to unpack and be open about my theoretical and empirical deductions. Accordingly, the term is not meant in a way similar to the notion of a testable and falsifiable hypothesis in quantitative research.

[4] The differentiation of semiotic and extra-semiotic follows Jessop (2006: 172): "While semiosis initially refers to the inter-subjective production of meaning, it is also an important element/moment of "the social" more generally. Semiosis involves more than (verbal) language, including, for example, different forms of visual language." Extra-semiotic aspects refer to elements outside this definition, e.g., material artifacts or physical infrastructures, which are socially constructed and shaped by semiosis.

of change and non-change in German livestock farming and the contested normative nature of these processes. I operationalize this focus throughout my dissertation by always including a focus on the future. However, this relates in particular to two case studies, namely how contesting imaginations of manure futures shape trajectories of livestock transitions, and how imaginaries of technological fixes shape and accompany bioeconomic innovations (see chapters 5 and 7).

Secondly, I focus on innovation actors and innovations. I derive this focus on innovation actors from the dualistic relationship with incumbents that has been argued to apply in sustainability transitions (e.g., Fischer and Newig, 2016). Innovations and innovation actors are a major focus of sustainability transitions scholarship: innovation actors are conceptualized as important actors for socio-technical change such as theorized in the MLP of sustainability transitions (Geels et al., 2016; Geels and Schot, 2007), and in agricultural transitions (Bui et al., 2016). These often novel actors that enter existing systems and which may shift discursive boundaries are therefore important in their role as carriers of the new and different, of alternatives to that which exists. By a focus on innovation actors, I argue that potentially novel imagined futures are visible, imaginaries that shape transitions in the present. I operationalize this by a focus on bioeconomic actors and bioeconomic innovations that may alter livestock farming and contribute toward sustainability transition in this sector (see chapter 6 and 7).

Thirdly, I focus on livestock farmers as incumbents and as an important explanatory dimension of sustainability transformations and changes in livestock farming. In theories of sustainability transitions, these actors are viewed as established actors often resistant to change, thereby contrasting with novel innovation actors (e.g., Hockerts and Wüstenhagen, 2010; Schlaile et al., 2017; Turnheim and Sovacool, 2020). Similar to innovation actors, they have a material and semiotic relationship with livestock farming as they shape and are embedded in the existing system or regime. For a long time, these actors have been viewed as having a dualistic relationship with innovation actors (Geels et al., 2016). However, recently, their role in sustainability transitions has gained increasing attention as they are often argued to be equipped with the resources to effect change (e.g., Galeano Galvan et al., 2020; Lee and Hess, 2019) and to play different yet changing roles in processes of transition (e.g., Turnheim and Sovacool, 2020). In livestock farming, these actors have an especially relevant role for sustainability transitions because of the property relations that make it difficult for new actors to enter the organizational field. I operationalize this via a focus on farmers as incumbents embedded in livestock farming and their ability (or otherwise) to contribute to endogenous sustainable change (see chapter 8).

The following chapter (1.1) will provide an overview of the structure of this dissertation, briefly sketch how I derived the above describe focuses through an iterative and inductive process, and how this threefold focus contributes to answering my research aim and research questions.

1.1 Overview of the structure and research questions

The underlying dissertation unpacks how transitions are unfolding in German livestock farming. I do this, as outlined above, by a threefold focus on *innovation*, *incumbents*, and *imagined futures*, which I operationalize by following a multiple qualitative case-study approach (see Figure 1). I derive my structure through an iterative process of empirical data collection and analysis that lead me to focus on bioeconomic innovations, imagined futures, and incumbent actors as important aspects of transitions in livestock farming.

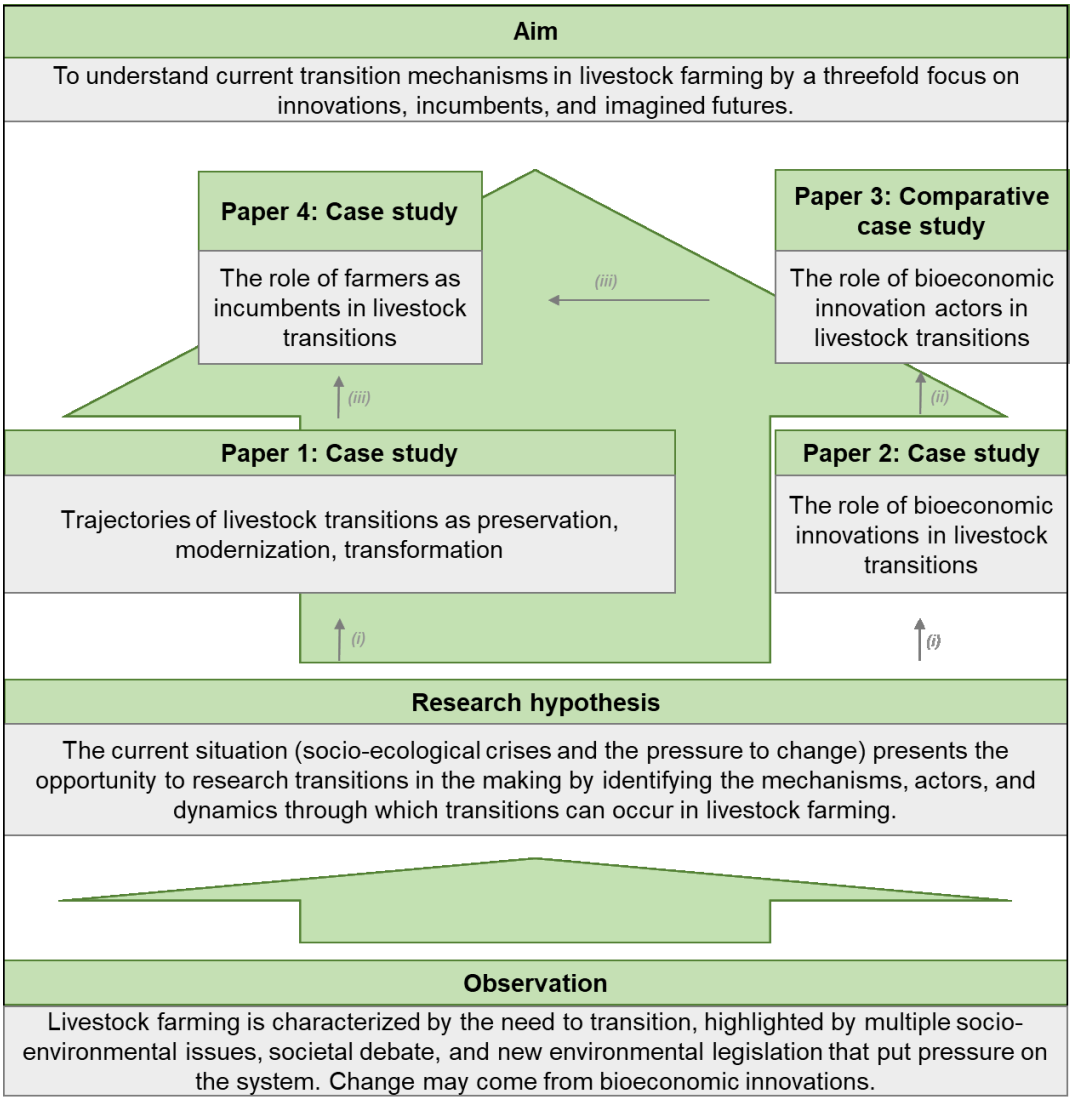

Figure 1: Combined qualitative case-study approach to the study of transiton in German livestock farming and overview of research papers included in this dissertation.

In particular, this means that I start from the observation (see Figure 1) that livestock farming is characterized by multiple crises, such as those arising from socio-environmental issues related to manure surpluses and eutrophication of water bodies, and the normative need to transition as formulated by societal debate and e.g., the call for a small-scale agriculture, as well as new environmental legislation (e.g., fertilizer ordinance). Bioeconomic innovations are currently being developed and present potential solutions to environmental issues, in particular to the problem of manure surpluses. This setting, which informs my research hypothesis[5] (see Figure 1), offers the possibility to research and understand transition dynamics and mechanisms in livestock farming in the making as they may unfold as emergent processes. The crisis and the need to transition formulated by way of different aspects is thus a good starting point to identify potential transition pathways, actors that are important for transitions, and potential solutions that are being discussed. Based on this hypothesis, I developed the aim of understanding transition mechanisms in German

[5] See footnote 3 for a brief reflection on the use of the term hypothesis in qualitative research.

livestock farming. I will contribute to answering this aim via four research questions.[6] These are addressed via the threefold focus on *innovation*, *incumbents*, and *imagined futures*. The research questions are:

(1) What types of transitions are imagined in German livestock farming?
(2) How and what kind of transitions are unfolding in German livestock farming?
(3) What are the actors in these processes and what are their roles?
(4) What is the role of bioeconomic innovations in contributing toward sustainability-oriented change?

My research aim and the research questions are addressed through different complementary case studies. First, starting from my research hypothesis, I focus on different conceivable trajectories of a sustainable livestock system and on the role of bioeconomic innovations in contributing toward sustainability-oriented transitions (see Figure 1 (i)). The first focus on trajectories of livestock farming (Figure 1 (case study 1)) contributes toward answering the research questions (1), (2), and (3). This means that I will first explore contested imaginations of manure futures that shape trajectories out of manure surpluses and toward sustainable livestock systems (Friedrich et al., 2022a; see chapter 5; Figure 1 (case study 1)). This focus on imaginations reveals the contested nature of livestock transitions, the normativity of these transitions, and in particular their different trajectories, as well as the actors that have semiotic relationships with transitions in livestock farming.

Second, I will explore innovations (Figure 1 (case study 2)) and innovation actors (Figure 1 (case study 3)) that not only have semiotic relations with livestock farming but material-semiotic relations. Specifically, this means that I will contribute toward answering research questions (2), (3), and (4). By this focus, I explore the potentially new and emerging bioeconomic approaches to the use of manure surpluses in livestock farming by a focus on innovations (Friedrich et al., 2021a; see chapter 6) and innovation actors (Friedrich et al., 2022b; see chapter 7). I started from a focus on bioeconomic innovations from which I arrived at the actors behind the innovations and which are developing these (Figure 1 (ii)). In particular, I analyze these bioeconomic innovations and the actors to describe the changes that these actors envision in their development of innovations and how they may contribute toward a sustainable livestock system. This allows me to unpack the normativity of these innovations and the envisioned transitions. In addition, I analyze how imaginaries of technological fixes serve as a rationale for transitions, shape the design of bioeconomic innovations, and what problems may arise from the stability of these imaginaries.

Lastly, I will put particular focus on the role of farmers as incumbents (actors that are well-established in the current system) in sustainability transitions in livestock farming (Friedrich et al., 2023, *unpublished manuscript*; see chapter 8; Figure 1 (case study 4)). This focus contributes to answering research questions (1), (2), and (3). I arrived at this focus through the empirical results of the previous studies that led me to focus on the role of farmers as important actors for transitions in livestock farming (Figure 1 (iii)). First, farmers are relevant adopters of bioeconomic innovations and constitute parts of the existing socio-technical regime. In addition, I found livestock farming to be characterized by contesting imaginations of "manure futures" and especially farmers lobbying

[6] Please note that the empirical chapters of this dissertation outline more detailed and context-specific research questions that are then addressed via empirical research. The questions elaborated at this point relate to overarching and integrative research questions of this thesis that are addressed via different yet complementary case studies.

for a preservation of the status quo (Friedrich et al., 2022a). At the same time, these actors are relevant in the context of sustainability transitions in livestock farming as they are equipped with the resources to lever changes and they are among the stakeholders that need to accept and adopt bioeconomic innovations. My aim was to gain insights into the motives of these actors in preserving the status quo. I operationalize this by a case study in the Lower Saxony town of Rotenburg an der Wümme in which I use an institutional focus to analyze the in/ability of livestock farmers as incumbents to drive changes in livestock farming.

Figure 1 describes how these chapter relate to each other and toward the overall aim of unpacking and understanding sustainability transitions in livestock farming concerning *innovations*, *incumbents*, and *imagined futures*. Chapter 1.1.1 described the author contributions of these chapters as these are based on articles published in different journals. An overview of the research designs assembled in these chapters can be seen in chapter 4.2.

To briefly sketch an overview of the remaining chapters of this dissertation, I will first introduce the versatile and complementary theoretical angles from which I regard the topic of sustainability transitions in livestock farming. This relates in particular to my understanding of transitions as reconfigurations both of practices and of the socio-technical regime, and the study of imagined futures through the lens of imaginaries and imaginations in transition (see chapter 2). As a next step, I will introduce the empirical setting of livestock farming by briefly covering the economics, current trends and developments with regard to socio-environmental issues of livestock farming and the need for changes in current practices; as well as giving a brief introduction to bioeconomic innovations and the concept of a bioeconomy (see chapter 3). In a next step, I will introduce my methodological approach to the study of innovation, imagined futures, and incumbents based on multiple qualitative case studies (see Figure 1), including reflections on epistemology and empirical research practice (see chapter 4). After these introductory chapters, I will present four case studies in German livestock farming that I have carried out in recent years and which form the empirical core of this dissertation (see chapters 5 to 8). I will then synthesize the major empirical findings and theoretical contributions before discussing potential research avenues, and conclude with some remarks on what my dissertation could contribute to understanding and managing sustainability transitions in livestock farming (see chapter 9).

1.1.1 Author contributions of the empirical chapters

The following table (Table 1) provides a chronological overview of the author contributions in the empirical case studies of this dissertation. I hold a single first authorship for three articles and a shared first authorship for one article.

Table 1: Author contributions to publications featured in this dissertation

Published publication: Preservation, Modernization, and Transformation: Contesting bioeconomic imaginations of "manure futures" and trajectories toward a sustainable livestock system (chapter 5)	
Journal: *Sustainability Science*	
Author contributions	**Authors**
First authorship	Jonathan Friedrich
Conceptualization	Jonathan Friedrich, Jana Zscheischler
Research design and methods	Jonathan Friedrich, Jana Zscheischler, Heiko Faust
Empirical research, data analysis	Jonathan Friedrich
Original draft preparation	Jonathan Friedrich, Jana Zscheischler, Heiko Faust
Review and editing	Jonathan Friedrich, Jana Zscheischler, Heiko Faust
Visualization	Jonathan Friedrich

Supervision	Jana Zscheischler, Heiko Faust
Project administration	Jana Zscheischler
Published publication: The Potential of Bioeconomic Innovations to Contribute to a Social-Ecological Transformation: A Case Study in the Livestock System (chapter 6)	
Journal: ***Journal of Agricultural and Environmental Ethics***	
Author contributions	**Authors**
First authorship	Jonathan Friedrich
Conceptualization	Jonathan Friedrich, Jana Zscheischler
Research design and methods	Jonathan Friedrich, Jana Zscheischler
Empirical research, data analysis	Jonathan Friedrich, Ingrid Bunker, Jana Zscheischler
Original draft preparation	Jonathan Friedrich, Ingrid Bunker, Sandra Uthes, Jana Zscheischler
Review and editing	Jonathan Friedrich, Ingrid Bunker, Sandra Uthes, Jana Zscheischler
Supervision	Sandra Uthes, Jana Zscheischler
Project administration	Sandra Uthes, Jana Zscheischler
Published publication: Bioeconomic fiction between narrative dynamics and a fixed imaginary: Evidence from India and Germany (chapter 7)	
Journal: ***Sustainable Production and Consumption***	
Author contributions	**Authors**
First authorship	Jonathan Friedrich, Katharina Najork
Conceptualization	Jonathan Friedrich, Katharina Najork
Research design and methods	Jonathan Friedrich, Katharina Najork
Empirical research, data analysis	Jonathan Friedrich, Katharina Najork, Markus Keck
Original draft preparation	Jonathan Friedrich, Katharina Najork, Markus Keck, Jana Zscheischler
Review and editing	Jonathan Friedrich, Katharina Najork, Markus Keck, Jana Zscheischler
Visualization	Jonathan Friedrich, Katharina Najork, Markus Keck, Jana Zscheischler
Supervision	Markus Keck, Jana Zscheischler
Unpublished manuscript (revised and resubmitted): Incumbents' in/ability to drive endogenous sustainability transitions in livestock farming: Lessons from Rotenburg (Germany) (chapter 8)	
Journal: ***Environmental Innovation and Societal Transitions***	
Author contributions	**Authors**
First authorship	Jonathan Friedrich
Conceptualization	Jonathan Friedrich, Heiko Faust, Jana Zscheischler
Research design and methods	Jonathan Friedrich, Heiko Faust, Jana Zscheischler
Empirical research, data analysis	Jonathan Friedrich
Original draft preparation	Jonathan Friedrich
Review and editing	Jonathan Friedrich, Heiko Faust, Jana Zscheischler
Visualization	Jonathan Friedrich, Heiko Faust, Jana Zscheischler
Supervision	Heiko Faust, Jana Zscheischler
Project administration	Jana Zscheischler

2 Theoretical frameworks

In the following chapter, I will introduce the theoretical approaches that my dissertation is built upon. I have used versatile theoretical approaches to answer the specific research questions in the empirical chapters 5 to 8 (Friedrich et al., 2021a; Friedrich et al., 2022a, 2023, *unpublished manuscript*; Friedrich et al., 2022b), dependent on the context and perspective of the particular empirical research. What all these approaches have in common is that they are future-oriented and focused on the semiotic sphere of social life and order and how this informs subjects' doings with respect to sustainability.

As an overview of the structure of the section, I will first elaborate on my interpretation of transformations as reconfiguration (2.1). In a next step, I provide introductions to imagined futures in transitions and specifically reconfigurations, which I approach through the theoretical constructs of imaginaries and imaginations (2.2). Lastly, I introduce actors, and in particular innovation actors and incumbents (2.3) in these transition processes, as my empirical focus. In general, I follow a semiotic approach to the social, inspired by social constructivist thought (Berger and Luckmann, 1966) and the "wicked problem" of sustainability and environmental issues (Duckett et al., 2016) that lead me to a major focus on meaning systems of individuals and collectives and in particular their imaginative sphere which is relevant for future-oriented sustainability transformations.

As a clarification beforehand, I view this dissertation as originating out of the interdisciplinary sustainability community, in which I situate myself as social and cultural geographer of sustainable resource management. Unlike any other field, this research community deals with real-world problems that are often spatially explicit and time-specific, being entangled in complex global developments such as climate change. The multiplicity of problems that need context-specific theoretical approaches thus require versatile and dynamic theoretical constructs (Schlüter et al., 2022). In this way, the following theoretical framings and reflections may present contours and fragments that interact with each other as heuristics in my work. Hence, this should not be read, and does not aim to be, a comprehensive theory of imagined futures and change. Rather, I present complementary theoretical ways of approaching socio-environmental issues and sustainability transitions in German livestock farming by a focus on the future.

2.1 Transformation as reconfiguration

In the following, I want to outline how change and transformation can be understood as a reconfiguration of existing practices and structures in society. This reconfiguration can be approached from different theoretical perspectives and with different empirical focuses, some of which I have followed in this dissertation. I regard transformations as "radical, non-linear and structural change in complex adaptive systems" following Hölscher et al. (2018: 1). This is a broad understanding of the term transformation and therefore can imply "plural, emergent and unruly political re-alignments, involving social and technological innovations" (Stirling, 2014: 1).

Change and transformation has been envisioned and analyzed from various theoretical approaches and with versatile empirical case studies that have refined, expanded, and advanced the theories. In different schools of thought, multifaceted approaches have appeared. Some of the most prominent include the MLP (Multi-Level Perspective, Geels and Schot, 2007) or the X-curve framework (Hebinck et al., 2022; Loorbach et al., 2017) to describe socio-technical change and

societal transitions toward sustainability. Further, the concept of transformative adaptation is especially prominent in dealing with climate change in the context of vulnerability and resilience building (e.g., Adger, 2006; O'Brien, 2012; Wise et al., 2014) or the "leverage points" perspective (Abson et al., 2017) to understand change in socio-ecological systems. There is also a growing body of scholarship in sociology and political science that focuses on aspects of social change (often referred to as social-ecological transformation) by challenging capitalist production and consumption practices (e.g., Brand and Wissen, 2018; Temper et al., 2018), or via cultural changes in society by so-called "mindshifts" (Göpel, 2016).

There has been some confusion in recent years with respect to the terminology of change and transformation and especially the difference between transition and transformation. Hölscher et al. (2018) view the difference between transition and transformation as lying in the scale and aim of the approaches. Transitions thereby focus on societal sub-systems while transformations focus on often large-scale change processes of (coupled) socio-ecological systems at any spatial scale (regional, national, global). Both are deeply normative approaches. They can complement each other in the former being related to shifting systems toward "sustainability" and the latter being linked to developing social (and socio-ecological) resilience to be able to navigate through current and future threats (Hölscher et al., 2018).

In the following, I regard these different approaches as complementary and partly overlapping in their description of change. In general, processes of change (in terms of transitions and transformations) are unruly, diverse, emergent, time-specific, and spatially explicit. These processes can imply cultural changes in norms and values, they can imply radical change or incremental and cumulative change, and they can be leveraged through different actors and actor constellations, dependent on their agency and the situation they are embedded in. In the following, however, I want to elaborate on what characterizes all these processes and what makes change observable and describable. I relate this to regarding transformations through social practice theories as reconfiguration of the orders of social practices (see chapter 2.1.1) and as a reconfiguration of the existing socio-technical regime (see chapter 2.1.2).

2.1.1 Transformation as reconfiguration of the orders of social practices

One approach to a reconfiguration of existing practices and structures that I have built on is theories of social practices. Social practice theories functions as a heuristic ideal for me through which to understand change on an abstract and theoretical level. Hence, I did not use social practice theories as an empirical tool but as a theory-driven heuristic.

Theories of social practices have been much inspired by the work of Bourdieu (1977) and the author's conceptualization of social practices and habitus as well as by Giddens' (1984) work on agency and structure in society (Schäfer, 2016). In theories of social practices, the social is the amount of social practices and material arrangements that are globally entangled and discovered. A social phenomenon is a time-specific part of this sum of practices and material arrangements (Schatzki, 2016).

According to Schatzki (2016), theories of social practices follow a "flat ontology" in that they do not differentiate between micro and macro, between individual and structure. Every social phenomenon is regarded as an arrangement of social practices that gets embodied by social actors. The (often complex) combination of social practices and material arrangements in bundles constitutes different spheres of social life such as "the economy" (Schatzki, 2016). For Schatzki

(2016), "practices imply open, [a] spatio-temporally distributed set of doing and speaking, which is organized by common understandings, teleoaffectivity (purposes, goals, emotions) and rules" (ibid.: 33). Reckwitz (2021) views practices as having similarities with the concept of "cultural techniques" because practices are beyond individualistic and describe aspects that can be embodied by different social actors over and over again. Schatzki (2016) defines material arrangements as the relations between humans and non-humans. Practices and material arrangements as a combination form up in so-called bundles. These bundles can be thought of in different spatial scales of social life. Thus, this conceptualization of social life allows us to zoom in and out to practices, material arrangements, and bundles whereby different bundles can form up to another bundle and material arrangements may have been a bundle of practices and another material arrangement before. As an example, a nail (as a material artifact) in its production was the combination of social practices and material arrangements whereas, after becoming a nail, it can form a new bundle together with other social practices (e.g. thinking of a nail as an attachment of a picture to a wall). Social practice theories also underline physicality as they need to be embodied by social actors. Therefore, Schäfer (2016) speaks of practices that exist before individuals act, and that are an inherent part of that action as they structure it as much as they constrain it. In this way, practices are independent of social actors, they are around them and are only embodied or performed by them (Schäfer, 2016). This also means that the embodiment of social practices is spatially and temporally explicit, while social practices are not.

For Reckwitz (2021), bundles and combinations of social practices can lead to orders of social practices. These orders present social structures in specific spheres of social life. When following this perspective, these orders can become very stable, gain hegemony and in this way structure the embodiment of social practices by individuals. Examples are collectively understood meaning systems or cultural aspects such as norms and values (Reckwitz, 2003).

Livestock farming, the object of this dissertation, can in this way be regarded as an order of social practices characterized by multiple practices and material arrangements that form and continually reproduce this order. I follow this perspective in chapter 5 of this dissertation. Here, sustainable transitions in livestock farming are viewed as change in the orders of social practices, i.e., the reconfiguration of these orders with regard to practices and material arrangements. Changes in these social practices are shaped by imaginations of the future (Adloff and Neckel, 2019), and therefore depend on semiotic aspects such as meaning systems and changes in culture, in norms and values (see chapter 2.2). As outlined above, in my research in chapter 5, social practice theory serves as a heuristic by which to interpret the social as shaped by imaginations of the future. My empirical focus in this chapter accordingly lies on the imaginations of the future instead of on the practices shaped by these.

2.1.2 Transformation as reconfiguration of the socio-technical regime

The approach of reconfigurations of socio-technical regimes differs from viewing reconfigurations in specific sectors and spheres of social life through social practice theories. This approach relates to research in sustainability transitions on specific sectors and changes in these sectors' systems. In particular, the approach is concerned with reconfigurations of the socio-technical regime (Fuenfschilling and Truffer, 2014, 2016). The notion of the socio-technical regime developed out of the MLP and describes the relatively stable combination of actors, technologies, and culture that form a particular system and which may be challenged through innovation

development in niches and by landscape pressures (Geels and Schot, 2007). This understanding of the socio-technical regime has been extended by incorporating insights from institutional theory (Fuenfschilling and Truffer, 2014). These insights have highlighted the cultural structures that form institutions as persistent mechanisms that configure these systems. In particular, this relates to institutional logics by which these systems function and that need to change to present a reconfiguration of the system (Fuenfschilling and Truffer, 2014). The stability of institutions can lead to path dependencies in these systems and forces of inertia reproducing the status quo.

The focus on shared meanings and culture of regimes to analyse transitions is a semiotic approach to change and transformation, inspired by social constructivist thought. Changes in institutional logics, e.g., from "market logic" to a "sustainable logic" (Runhaar et al., 2020) displays a reconfiguration of the existing regime and its structure and thus marks a transition. Thus, a reconfiguration can be understood through changes in norms and values as well as meaning systems. These changes in the configuration also account for the combination of actors and their use of technologies in these systems as a consequence of the configuration of norms, values, and meaning systems. Hence, a reconfiguration also relates to new innovative developments and new actors that alter the configuration of the existing regime and the stable combination of actors, technologies, and culture.

In general, these changes are driven, accompanied, and embedded in imagined futures: imaginations of the future and imaginaries of how to achieve these futures accompany and drive transitions in societal sub-systems, they provide the semiotic spirit for the capacity to change as well as the risk of semiotic and extra-semiotic lock-ins that may result in path dependencies that stabilize the existing configuration of the regime (see chapter 2.2.1.1). Changes in the configuration of the socio-technical regime are thus accompanied both by actor-specific visions of the future and by socially shared, historically institutionalized imaginations of contesting futures and the conceptions of how to achieve these (Adloff and Neckel, 2019; Jasanoff and Kim, 2015).

However, reconfigurations of regimes need not only be viewed through a reconfiguration of the institutional logics of this regime but more generally through a focus on changing values and norms in the regime, possibly as a result of innovative development and diffusion, as well as social learning through new social relations and interaction (Reed et al., 2010). In chapter 6, I followed this perspective to unravel the ability of bioeconomic innovations to alter or reconfigure the existing regime through different transformation pathways (Geels and Schot, 2007), thus presenting a sustainability-oriented transition through new norms and values that characterize the socio-technical regime. Chapter 6 will provide more in-depth theoretical reflections on this topic and in particular the analytical categories through which to analyse innovation's capacity to contribute to sustainability-oriented change and transformation.

The configuration of socio-technical regimes is marked by a continuous process of institutionalization that, by definition, builds institutions (Fuenfschilling and Truffer, 2014). The degree of institutionalization (Zucker, 1977) describes both how persistent the regime is and how resistant to change it may be. The aspect of persistence is of relevance for livestock farming in Germany as this sector can be viewed as characterized by very stable semiotic and extra-semiotic structures on different levels of societal organization that are difficult to change (see chapter 3.1.1). I have approached this topic and in particular the question of how such a stable regime might change in chapter 8. Here, I view livestock farming as marked by a high degree of institutionalization (Zucker, 1977), described by routines in values, norms, and practices that form stable and persistent

cultural formations and configurations as well as extra-semiotic structures (e.g., technologies and farm equipment).

The approach of institutional logics (Fuenfschilling and Truffer, 2014, 2016) is concerned with changes in these stable systems in focusing and departing from the deep structures of these regimes and how this permeates the culture and practices of individuals. In chapter 8, I have used a different yet complementing lens to study change in the institutionalized regime of livestock farming. I focus on the role of actors, and particularly incumbents as embedded in the regime, in their ability to drive changes of the regime in terms of a reconfiguration. I operationalize the issue of incumbents in this process by focusing on the role of farmers as incumbents who are embedded in regime structures. In being embedded in these structures, these actors are "institutional workers" (Lawrence et al., 2011) who are constantly changing regime structures through their semiotic and extra-semiotic doings. As I will outline in detail in chapter 8, whether the institutional work of these actors leads to institutional changes depends upon the agency of these actors (Emirbayer and Mische, 1998), their ability to leverage resources, and their perceptions of the organizational field (Dorado, 2005). This builds on the approach of Dorado (2005) to institutional change and complements work on intuitional logics by placing emphasis on the role of actors and their agency in this processes. This is relevant for the study of transitions in livestock farming in terms of the property and accumulated resources that incumbents have and which make it difficult for new actors to enter the system (see chapter 8).

2.2 Imagined futures and transformations

In this dissertation, I have placed particular emphasis on the role of imagined futures in processes of transformation as reconfigurations in livestock farming (see in particular chapters 5 to 7; Friedrich et al., 2021a; Friedrich et al., 2022a; Friedrich et al., 2022b). I have approached these topics through the theoretical constructs of imaginations and imaginaries. These are based on the argument that transformations are oriented toward the future, toward meanings of new and different states. Imaginations of the future and/or imaginaries of how to transition to an envisioned state are especially relevant in these processes, as they shape and accompany transformations. In particular, innovations, as deviations from the standard reproduction of the economy, are driven, shaped, and accompanied by imagined futures (Beckert, 2016; Jasanoff and Kim, 2009). In the following chapter, I will outline how imaginaries and imaginations are central to transitions and transformations and how I regard them as a particularly relevant explanatory dimension for reconfigurations in social practices and the socio-technical regime (Adloff and Neckel, 2019; Jasanoff and Kim, 2009). Before I approach these topics in chapter 2.2.1, I want to briefly elaborate on the origins of theories about imaginations and imaginaries.

The terms imagination and imaginary are often used synonymously and I used them in versatile yet complementary ways in the empirical chapters 5 to 8 of this dissertation. Here, I want to differentiate their complementary meanings that I will follow in the underlying chapter: as imagination, I understand an envisioned future state of the world (Adloff and Neckel, 2019). As imaginary, I understand the envisioned process or model of how to transition to an envisioned state (Jasanoff and Kim, 2009). This means that the term imaginary refers to a process-oriented focus such as could be attained through economic or scientific progress, while imaginations refer to ideal, utopian, or dystopian imagined future states of the world. Both terms are closely linked and

complement each other in practice; they are socially embedded and shared by describing a socially constructed and imagined reality (Berger and Luckmann, 1966).

Imaginations and imaginaries are central in various spheres of social life, as argued by many social scientists (for the most prominent, see e.g. Anderson, 1983; Beckert, 2016; Castoriadis, 1990; Jasanoff, 2015a; Taylor, 2003). The notion of imagination can be found in the writings of Weber and throughout the 20th century in the work of Durkheim or Althusser in explaining social life through shared meanings, understandings, beliefs, and as part of ideologies (for an overview of sociological perspectives on imagined futures, see Suckert, 2022).

Social imaginaries present the collectively envisioned form of social life that is obtained in social orders. In this way, social imaginaries are not merely cultural meanings, they also include aspects of power and politics (Adams et al., 2015; Taylor, 2003). Castoriadis (1990) describes the element that societies' create, with which they describe the relations to the world and among themselves, and that is their source of sense as societal imaginary. These conceptualizations of social or societal imaginaries have diffused into other aspects of social theory and empirical conceptualizations and applications. While their theory has diffused, their content is temporally explicit. As an example, the social imaginary of social upward mobility in modernity, also described as the "elevator effect" by Beck (1986), has turned into a "paternoster effect" in late modern according to Reckwitz (2019) in that both upward and downward social mobility are possible.

The original work on social imaginaries (Taylor, 2003) or societal imaginaries (Castoriadis, 1990) has fed other disciplines as well. As an example, STS (science and technology studies) scholars have put forward the notion of sociotechnical imaginaries that can materialize in innovations and technological projects (Jasanoff and Kim, 2009, 2015), economic sociology has brought forward aspects of imagined futures that explains economic practices and the role of imaginations and expectation in economies (Beckert, 2013, 2016; Beckert and Bronk, 2018; Bronk, 2009), cultural political economy speaks of economic imaginaries that are culturally embedded and conditioned and that can e.g., characterize specific regions or sectors (Sum and Jessop, 2013), and sociologists of sustainability have developed the notion of imaginations of sustainability by integrating some of the above-described conceptualizations (Adloff et al., 2020; Adloff and Neckel, 2019). All these approaches describe the imaginative sphere of social life from different perspectives. I now use the following section to elaborate on the relevance of these approaches in the context of sustainability transitions.

2.2.1 Imagined futures in sustainability transitions

Scholarship in sustainability transitions is concerned with the future, with the new and different ways in which change may occur and how sustainability-oriented economic sectors can be designed. At the same time, transitions researchers are also concerned with the future as an object via which risks are anticipated and solutions found to mitigate (projected) socio-environmental problems. Hence, in the following, I regard futures (and imaginations and imaginaries thereof) as important explanatory dimensions to describe transitions in specific sectors, such as in livestock farming. Of course, the future is not a fixed entity, but is instead an ontologically diverse and versatile space which is contested and marked by uncertainty and complexity (Kovacic et al., 2020; Stirling, 2010). The future is collectively and individually approached through imaginations, imaginaries, and expectations that describe how socially embedded actors and/or collectives envision the future and attribute meanings to it (Adloff and Neckel, 2019; Beckert, 2016; Longhurst

and Chilvers, 2019). Imagined futures hence reflect normativity and power structures with respect to whose future counts and to the imagined social order (Jasanoff and Kim, 2015; Knappe et al., 2019). Imagining – whether implicitly or explicitly – is a cultural technique and a social practice (Reckwitz, 2003) that (re)produces values and norms in society by outlining future states of these (Jasanoff and Kim, 2015). However, imagining is not an empty exercise, but is rather what actors and/or collectives envision, expect or imagine, which informs their doings and shapes their social practices in the present (Adloff and Neckel, 2019). Hence, imaginations and imaginaries are an important explanatory dimension for social phenomena of the present, and the contested nature of these (Beckert, 2016).

In literature on sustainability transitions and transformations, imagined futures and their relation to the present has so far received rather fragmentary focus. It has been acknowledged that imaginations and visions are important aspects for the design of sustainability-oriented changes and that a lack in imagination can be seen as major obstacle to the capacity to change (Hajer and Versteeg, 2019). While the future in general has always interested scholars, also with regard to sustainability and the notion of possible visions and futures, what has received less scientific attention so far is the relationship between future imaginations or anticipations and how they shape or materialize in present practices, as well as the politics of futures that underline the dominance of some futures over others (Knappe et al., 2019). The future used to be an object of projection in most research rather than an explanation for present and day-to-day action. Often a focus on the future has implied forecasts or technological risk assessments with respect to sustainability (Beck et al., 2017). Hajer and Pelzer (2018) have extended this argument by outlining how especially a focus on the construction of futures has so far been neglected. The authors argue that "sustainability transitions scholarship tends to see constructions of the future (visions, scenarios, predictions etc.) as *explanans* (that what explains) while constructions of the future are rarely seen as *explanandum* (that what should be explained)" (ibid.: 222). In recent years has this gap been addressed and scholars have approached questions of how the future is constructed and how these constructions and their politics shapes the present (or presents) with respect to sustainability and sustainability transformations (e.g., Adloff et al., 2020; Adloff and Neckel, 2019; Hajer and Versteeg, 2019; Knappe et al., 2019; Moore and Milkoreit, 2020; Scoones and Stirling, 2020).

In recent years, this body of research has focused on the politics of making and unmaking futures by interpreting futures as deeply normative and as a co-product of scientific discourse and social practices, thereby explicating power dimensions, inequalities, and conflicts (Knappe et al., 2019). Moore and Milkoreit (2020) argue that imaginations lie at the heart of transformative politics toward sustainable and just transformations because imaginations embed the transformative agency of social actors. Adloff and Neckel (2019) have devised a theoretical framework that describes how social practices and mutually dependent sociomaterial structures are embedded in contesting imaginations of sustainability. The authors thereby argue that contesting imaginations of "modernization", "transformation", and "control" shape different social practices and mutually dependent sociomaterial structures and accordingly lead to different (and contesting) trajectories of sustainability. This framework suggests how imaginations are central to shaping changes in social practices and the orders of social practices. The embodiment of social practices by individuals is shaped by imaginations of the future (with respect to sustainability) and mutually dependent on sociomaterial structures. These refer to the infrastructures through which social life takes place, e.g., streets, sanitation but also bicycle lanes or with respect to livestock farming, the farming

equipment and spatial organization. Practices and structures are mutually dependent: social actors will only change their routines of social practices when the sociomaterial structures for doing so are available, and the structures will only change if the practices change (Adloff and Neckel, 2019). I have built on the framework of Adloff and Neckel (2019) in chapter 5 to research contesting imaginations of manure futures and their relevance for changes in structures and practices of livestock farming. Hence, the chapter provides an empirical operationalization of the concept and more details regarding its theory. In addition, the framework of Adloff and Neckel (2019), together with other approaches such as those of Beckert (2016) and Jasanoff and Kim (2015), functioned as a theory-driven perspective on sustainability transitions as inherently shaped by imagined futures.

2.2.1.1 Imagined futures and innovations in the economy

Imaginations of the future shape social practices (Adloff and Neckel, 2019) and thus shape what innovation actors and incumbents do in the emergent process of change toward different notions of sustainability and a reconfiguration of the existing socio-technical regime (see chapter 2.1). In this way, I regard imaginations and imaginaries as the semiotic spirit for extra-semiotic changes by envisioning states of the future that inform individual doings and potential reconfigurations (Beckert, 2016). Imagining is a cultural technique that reconfigures the semiosis of the existing regime and its culture, thereby inherently and emergently reconfiguring its cultural condition. I approach imaginations and imaginaries as social constructs as they are produced through social interaction, characterized by normative judgments and individual meanings, and are historically institutionalized and socially embedded (see also chapter 2.2.2).

Socio-technical innovation design presents practices that are shaped by specific visions or imaginations of the future (Geels, 2020). In the following, I want to lay out the importance of imaginations and imaginaries for processes of innovation design and doings of economic actors. I have used this theoretical lens to view bioeconomic innovation's capacity to contribute to sustainable change (see chapter 6) and to gain insights into the fictional expectations that inform bioeconomic actors' doings (see chapter 7).

Technological developments and innovations are often viewed as opening up the future, as they give room for creativity and imagination and are characteristic for modernity and its ideals of growth, progress, and development (Hong, 2022). Hence, imaginations and visions of the future are characteristic for innovative development. Without visions of the future, innovative development would simply be impossible. Innovations are results of societal imagination on the micro level. They can be regarded as the carriers of meaning of broader sociotechnical imaginaries that are co-constituted by individual socio-technical visions, co-produced through science and society (Jasanoff and Kim, 2015; Longhurst and Chilvers, 2019). In this perspective, socio-technical innovations are the materialized result of society's imagination and creativity (Jasanoff, 2015a). Geels (2020: 13) emphasizes the connection both between creativity and imagination and between the development and diffusion of innovation: "search activities [for innovation] can be seen as guided by visions and expectations; technological development involves not just firms, but also broader social network; technological selection occurs not just in markets, but also through policies, cultural discourses, [and] social acceptance". Jasanoff (2015a) argues that innovations are a product of imaginaries materializing in innovation, such as through science fiction, and more specifically through sociotechnical imaginaries. For this author (ibid.: 4), sociotechnical imaginaries are "collectively held, institutionally stabilized, and publicly performed visions of desirable futures,

animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology." In this way, they are co-produced through science and society. Technologies and technological projects allow insights into these imaginaries as their design and conceptualization reflect imagined futures that are shaped by sociotechnical imaginaries (Longhurst and Chilvers, 2019). Political strategies and/or projects such as the circular economy or the bioeconomy in an abstract conception can be regarded as sociotechnical imaginaries that shape specific technological development, social life, and social order (Giampietro and Funtowicz, 2020; Kovacic et al., 2020). Beck et al. (2021) argue that one can view "sustainability" as the "grandest sociotechnical imaginary of our time, as it projects both human and planetary futures into unlimited time" (ibid.: 143). In this sense, sustainability as a sociotechnical imaginary shapes specific technological designs that in turn aim to contribute to their devisers' own notions of "sustainability".

Sociotechnical imaginaries and the question of which future "counts" and what perspectives are included and reflected in their construction betrays their political nature (Jasanoff and Kim, 2015; Kovacic et al., 2020). As an example, Longhurst and Chilvers (2019) describe how individual visions of energy transitions are related to sociotechnical imaginaries and vice versa. The authors (ibid.) find dominant imaginaries of specific technologies undermining alternative and counter-hegemonic visions of transitions. This shows firstly how technological development is shaped by shared understandings of how to transition and, second, how the question of what futures count and what imaginaries are relevant is deeply political with respect to social life (Jasanoff and Kim, 2015; Longhurst and Chilvers, 2019).

Above, I have briefly explained how visions and imaginations of the future are relevant to innovative development. Beckert (2016) goes beyond this focus on innovation to argue that imaginaries and expectations are the driving force of capitalism and the economy, in that expectations accompanying economic activity and vice versa, helping to lay the conditions for economic investment and development. Beckert (2016: 13) argues that "[c]apitalism needs the evocative overload of fictional expectations in order to operate." Fictional expectation and imagined futures drive the capitalist system with ever-newer possibilities for venture capital to be invested, and which shapes the economic actors' doings. In this way, Beckert (2016) complements the ideal of *Homo oeconomicus* with a theory of imagination. The uncertainty, ambiguity, and complexity of the future (Stirling, 2010) and the impossibility for economic actors to take rational choices in such a situation, leads actors to implicitly rely on imaginaries of the future to bridge the prevalent uncertainty and to act purposefully. Economic actors rely on these fictions to implicitly navigate the uncertainty of the future. These fictions can be individually held yet are often socially stabilized and politically institutionalized, such as by means of political strategy papers (e.g., Giampietro and Funtowicz, 2020). They are relevant on different levels of societal organization. On a societal level, imaginaries are socially shared visions or imaginations of the futures that societies have and which are historically institutionalized and inscribed in society. On the micro level, i.e., the actor level, Beckert (2016) describes these imaginaries of the futures as fictional expectations, being subjective to the actors' position and knowledge, and shaped by socially shared imaginaries. These fictional expectations help to bridge the prevalent uncertainty about the future and allow actors to make decisions in economic settings (Beckert, 2016). So imagined futures are not only an important explanatory dimension for economic processes of innovation design, but offer theoretical insights into the role of imagination for the economy and its practices on different levels of organization.

However, while imaginations of the future and imaginaries of how to get there represent an important source of creativity, of progress and development, of the new and innovative, they can also be barriers of change on the individual and collective level of societal organization and relations through, e.g., discursive lock-ins (Simoens et al., 2022), or cognitive lock-ins and resulting path dependencies (Weituschat et al., 2022). For Beckert (2016), imaginations can lead to a so-called "colonization of the future" arising from "cognitive path dependencies". The author speaks of these phenomena when past expectations encourage economic actors to invest, lead to sunken costs, and consequently limit the economic opportunities of actors in the present and future. Because imaginations of the future are uncertain and constantly on the cusp of becoming real, a future reality other than the imagined can lead to sunken costs and investments that limit the economic actors' ability to act, thereby "colonizing" their future. This exemplifies the ambivalent role of imaginaries and the uncertainty of the future: while imagined futures are a source of creativity, of progress, and of the new and different, thereby often revealing a need for social actors to act with purpose, they are at the same time constantly at risk of becoming real and of consequently leading individuals and collectives to semiotic and extra-semiotic path dependencies in terms of financial and material path dependencies, characterized as a "colonization" of the future.

This is of particular relevance for the field of sustainability transitions and aspects of sustainability transitions in specific sectors. Here, both the semiotic aspects of potential lock-ins to drive path dependencies and the extra-semiotic aspects relate to the capacity to reconfigure existing socio-technical regimes (see chapter 2.1.2). With regard to semiotic aspects, this relates to persistent values and norms that may be leveraged through specific imaginaries and actor-specific expectations, thereby stabilizing the configuration of the socio-technical regime, making change difficult by presenting cognitive lock-ins and consequently leading to path dependencies in societal systems. In terms of extra-semiotic aspects, this can relate to infrastructural lock-ins in specific technologies and/or incumbent actors that are constrained by past investments and sunken costs and which make a reconfiguration of the existing regime more difficult. This means that the ability and capacity to imagine is inevitably important for reconfigurations of the existing regime, characterized through the capacity to change (Hajer and Versteeg, 2019). At the same time, both semiotic and extra-semiotic path dependencies, brought forward by exactly these imaginaries, threaten to delay transitions and transformations, even resulting in ongoing environmental degradation. Which futures are imagined and which of these counts is thus an essentially political question. Or, in the words of Kovacic et al. (2020: 82), "while there might be an indefinite amount of present futures, there will be only one future present". What future counts thereby does not only relate to the present but will also ultimately affect future generations, making this a deeply normative and ethical question.

2.2.2 Imagined futures as social constructs

In this dissertation, I take the position that imagined futures are social constructs in that they present an imagined future reality (Berger and Luckmann, 1966). They are produced through social interaction, through shared knowledge and meaning systems, and through epistemic practices and cultures on individual and collective levels of society (Knorr-Cetina, 1999). I follow this perspective and regard imagined futures as social constructs that are produced through the interaction of social actors on different levels of organization and their knowledge. Knowledge in this viewpoint "is the sum total of 'what everybody knows' about a social world, an assemblage of

maxims, morals, proverbial nuggets of wisdom, values and beliefs, myths, and so forth" (Berger and Luckmann, 1966: 83). Epistemic practices, i.e., the practices for generating knowledge, and the cognitive frames through which this is interpreted, are thus the practices and techniques through which imaginaries are constructed. As an example, Hirsch (2020) describes the epistemic practices of ecologists in setting their baselines. As climate change threatens ecological habitats, ecologists tend to anticipate the future for their baseline setting rather than relying on idealized past states of ecological wellbeing. The epistemic practices of doing so, characterized as "trained judgement", construct the environmental imaginary and in turn shape the condition in which the ecosystem ought to be (Hirsch, 2020). This empirical example shows how imagined futures are socially constructed through the sum of epistemic practices of individuals that are embedded and shaped by meaning systems, forms of knowledge, and that in their turn co-constitute these. In this way, imagined futures are subjective to individuals' notion of reality, ultimately normative, and in a constant process of flux and adaptation as being confronted with the realities of the present.

2.3 Actors and imagined futures in transitions

In the previous chapters, I outlined how transformations and transitions can be viewed as a reconfiguration of social practices and/or the socio-technical regime (see chapter 2.1). I argued that imagined futures can be approached by means of theories of imaginaries and imagination. Imagined futures have a central role in shaping (changes in) social practices and they characterize a cultural technique that can alter the semiosis of the existing regimes. In the following, I want to outline how one can observe this change by focusing on actors that both construct and embody imagined futures as part of their perceptions of reality. I have conceptualized imaginations as "imagined reality" by following the phenomenological approach of Berger and Luckmann (1966). In this way, I view imaginations as subject to actors' perceptions and knowledge and hence they are observable through a focus on these actors, their communications, and their doings. I want to relate this briefly to actors in sustainability transitions and their roles in shaping imagined futures and in turn being shaped by these. A focus on the different actors in transitions of a specific sector, I argue, allows me to uncover and detect contesting imagined futures and their role in transitions. I treat these actors as research focuses through which to examine imagined futures.

In sustainability transitions, different actors are relevant for the outcome of reconfigurations in sectors and systems of social life (Farla et al., 2012; Fischer and Newig, 2016). In a review of actors and their conceptualizations and differentiations in the scholarship on sustainability transitions, Fischer and Newig (2016) identified the following actors with relevance for transitions: niche actors, regime actors, and landscape actors following an understanding of transitions through the MLP; government actors, market actors, and civil society when clustering actors according to societal realm. Additionally, they also identify actors on different levels of governance (from local to global) and supporting and opposing actors with regard to transitions. The authors (ibid.) found that roles of actors may change over time in the process of transitions, e.g., when niche actors become established in the regime or when initially opposing actors become convinced of the need to transition. This is also stressed by Turnheim and Sovacool (2020), who highlight the heterogeneity of incumbencies and how a characterization of incumbent actors may change over time due to transitions or for other reasons.

In my research, I have built upon these conceptualizations of actors in transitions. Since I am concerned with how the particular sector of livestock farming may transition, I have differentiated

actors between innovation actors and regime actors and put conceptualizations of governance actors to one side. These actor groups both have at a minimum semiotic if not material-semiotic relationships with livestock farming, thereby constantly reproducing imagined futures of this sector. Innovation actors, as regards bioeconomic innovations, encompass actors or institutions that are currently developing innovations related to "substitute products", "new processes", "new products", or "new behavior" (Bröring et al., 2020). Regime actors encompass key societal actors such as those from policy, science, civil society, and users that constitute the current stable regime (Geels and Schot, 2007). This also includes farmers as incumbent actors that are of special relevance to transitions in agriculture in terms of their property relations (see chapter 8). Fischer and Newig (2016) suggest that regime actors may tend to oppose transitions while niche actors may rather be in favor of transition as this suits their interests. I use this differentiation to research imagined futures in German livestock farming as I followed the working hypothesis that actors in the existing regime may have different imaginations of the future than innovation actors. Hence, such a differentiation can reveal insights into the contested nature of imagined futures in transitions and their negotiations when it comes to reconfigurations of the regime. It also allows me to uncover opposing imaginaries that shape conflicting practices which may need to form new orders of social practices to represent genuine transition in a sector. Alongside the contested nature of imagined futures, a focus on the actor level additionally allows me to examine how imagined futures can lead to cognitive path dependencies on an individual level (for more details, see chapter 2.2.1.1).

3 The empirical setting

The following chapter provides an overview of the empirical setting in which I conducted research. This encompasses an overview of the multiple socio-environmental issues attributed to livestock farming and the historical developments of livestock farming in Germany with a specific focus on livestock-intense regions in lower Saxony characterized by manure surpluses (see chapter 3.1). In a next step, I will provide some background knowledge on the bioeconomy[7] as an abstract concept that shapes different policy strategy papers and on bioeconomic realities that I approach through the lens of manure-based bioeconomic innovations (see chapter 3.2).

3.1 Livestock farming in Germany and the need to transition to sustainability

Germany is an important livestock producer globally. Especially the north-west of Germany (west of lower Saxony and northern parts of North Rhine-Westphalia) are characterized by intensive livestock production. The Thünen Institute (Deblitz, 2022) provides yearly overviews of German livestock farming and its developments. According to this data, in 2021, livestock amounting to 8.3 million tons of meat were slaughtered in Germany. The amount of slaughtered meat decreased from 2016 peak of 9.1 million tons. Since 2005 Germany has been a net exporter of meat, which means that Germany is exporting more meat than it imports. The latest figures for animals show that in 2020, the number of poultry amounted to 170 million birds. In 2022, Germany bred 22.3 million pigs and 11 million cattle, and 1.8 million sheep were kept in 2021 (Deblitz, 2022).

The north-west of Germany has formed a cluster of livestock production during the previous decades. Nutrient-poor soils that limit arable farming and the spatial proximity to the North Sea and its harbors that allow feed to be imported and meat to be exported have driven the specialization of this region. Alongside an increase in livestock numbers in these regions over recent decades, a cluster of companies has developed that specialize in livestock farming as well as slaughterhouses and a processing industry (Franz et al., 2018; Tamásy, 2013). This has been accompanied by a restructuring of the agricultural sector in terms of its size and the number of farms. In keeping with the mantra “grow or die” and economies of scale, small farms have left livestock farming and agriculture, with larger farms taking over these farms and expanding their production and territory, resulting in a concentration of agricultural and livestock production in fewer farms with bigger livestock numbers and farmland acreage (Nowack et al., 2019). The example of the region around Rotenburg (see also chapter 8) demonstrates this process. In the town of Rotenburg an der Wümme, farm size increased from an average of 20 hectares in 1979 to almost 70 hectares in 2010, while simultaneously the absolute number of farms has declined by 60% (LWK Niedersachsen, 2015). The net export of meat in Germany has been decreasing over the past years due to the Covid-19 pandemic, volatile value chains, and African swine fever-related import bans from China. After Germany confirmed its first case of African swine fever, China (a major importer of German pork products) banned the import of further pork from Germany.

[7] It can be useful to differentiate between the bioeconomy as an abstract concept and bioeconomies as the bioeconomic realities governing how these abstract concepts take shape in empirical settings. This differentiation originates from an article by Friedrich et al. (2023, *forthcoming*).

Livestock farming is part of global commodity chains and production networks, having intense regional economic development pathways and global entanglements with regard to import of fodder from South America and the export of meat to, e.g., China (Franz et al., 2018). This intensive regional economic development of livestock farming (Tamásy, 2013) and its global entanglements does not come without socio-environmental issues (Franz et al., 2018). While some of the issues are only visible in the global and telecoupled[8] relations within livestock farming, others are observable on a local level. On a global level, these issues relate to climate change-relevant emissions from livestock farming such as methane through bovine digestion and emissions resulting from land-use change for fodder production, thereby threatening and undermining indigenous land rights in South America (Sauer, 2018). On a national level, issues appear in other, though similar, forms. These include societal debates concerning the ethics of, e.g., piglet castration and its consequences for pork farmers (Lin-Schilstra and Ingenbleek, 2022), the normative need for dietary changes and livestock reduction to meet EU emission targets to mitigate climate change (Rasche et al., 2023) and to stay within planetary boundaries (Steffen et al., 2015), as well as working conditions in the downstream meat processing industry and slaughterhouses (Friedrich et al., 2021b; Wagner and Hassel, 2016). In addition, diets are linked to the sustainability of the planet (Tilman and Clark, 2014) and Germany is experiencing changing consumption patterns and diets shifting toward more vegetarian and vegan consumption. Despite these changes in diet, the country has not markedly reduced its meat consumption over the years as meat consumption has only decreased from 7.3 million tons per year in 2014-2019 to 6.8 million tons in 2021 (Deblitz, 2022), possibly as an effect of social actors still favoring meat consumption even though they may perceive this as morally problematic (Hartmann and Siegrist, 2020). On a local level, environmental issues of livestock farming relate to the eutrophication of water bodies and surroundings as a consequence of too much manure application on the field in livestock intense regions in Germany (Sundermann et al., 2020). Manure over-application not only threatens local environments and biodiversity via eutrophication, it also may result in odors and the non-use of eutrophied water bodies for recreational purposes such as swimming or angling.

All these aspects underline the importance of sustainability-oriented transitions in German livestock farming. Alongside that, it has also become a theme of wider societal relevance: how transitions can be leveraged in livestock farming to mitigate environmental damage, and address the social and ethical issues related to it, is a topic that has attracted widespread media coverage, societal debates, and conflicts, including demonstrations by farmers against new environmental legislations and advocacy from NGOs and civil society in favor of new regulations (e.g., Nowack and Hoffmann, 2020). Dürnberger (2020) find that the debate has even reached veterinarians who are overwhelmed with dealing with the situation of being a part of industrialized livestock farming and the moral questions that the debate provokes in them.

I regard livestock farming and the socio-environmental aspects of manure surpluses as an arena from which conclusions regarding broader agricultural sustainability transitions can be drawn (see also chapter 5; Friedrich et al., 2022a). This is similar to research that has used livestock farming and its socio-environmental issues as a case to study nexus-oriented approaches such as the water–energy–food nexus (e.g., Franz et al., 2018; Vogeler et al., 2021; Vogeler et al., 2019). Based on these nexus approaches, the authors were able to assess global entanglements and dependencies of

[8] By telecoupling, I refer to interactions between distant places, for details see Liu et al. (2013).

food production (Franz et al., 2018; Franz and Schumacher, 2020) and aspects of rural–urban governance (Vogeler et al., 2021; Vogeler et al., 2019). Artner-Nehls and Uthes (2023) argue that the framing of manure in newspaper coverage presents broader perceptions of agriculture, namely "(i) the dichotomy of agricultural industrialization and family farming; (ii) contrasting actualities of factory farming and animal welfare; and (iii) the responsibility of policy for the emergence, existence and solution of livestock and slurry-related problems" (ibid.: 1). This framing shows the societal relevance of this topic and the different conceptions that social actors have with regard to agriculture and transitions in agriculture. Gesing (2023) characterized conceptions of manure and their relevance for broader topics in terms of "ontological multiplicity" with regard to manure on the "water–fertilizer continuum". The author argues that the ontology of manure is an important explanatory dimension for solutions that are envisioned to the problem, such as technological ideas surrounding manure use. These debates surrounding manure thus provide an entry point to larger ontological struggles. Manure surpluses and the issue of how to drive which transition in livestock farming can be viewed as examples of a "wicked problem", because the topic is characterized by value-laden statements and subjective perceptions alongside uncertainty regarding the question of how to transition and the potential consequences (Duckett et al., 2016).

German politicians and policymakers have reacted late to the issue of manure surpluses and associated eutrophication of water bodies. Germany transferred the EU nitrate directive into its national law by issuing a fertilizer ordinance only in 2020. This ordinance aims at reducing nitrate leaching into water bodies to meet the standards of 50 mg of nitrogen per litre (N/l) of water that the EU regards as environmentally acceptable for supporting biodiversity and drinking-water quality. Currently, many regions in Germany exceed the value of 50mg N/l (BMEL and BMU, 2020), many of which are characterized by intense livestock farming. Especially the north-west of Germany (the northern part of North Rhine-Westphalia and the western part of lower Saxony) is marked by a lot of measuring sites that report values above 50mg N/l (BMEL and BMU, 2020). In these regions, the German environmental agency regards groundwater bodies as in a bad condition with regard to nitrate (Sundermann et al., 2020; Umweltbundesamt, 2023). As Germany is currently violating the thresholds of nitrate for several water bodies in these regions by exceeding the 50mg N/l value, it is facing lawsuits from the EU amounting to €850,000 for every day that thresholds are exceeded (Sundermann et al., 2020).

Thus, issuing a new fertilizer ordinance only in 2020 can be seen as a late reaction from German politicians to EU law, the lawsuits and the general condition of water bodies and its consequences for biodiversity and human health. With this late reaction, German politics has long favored the interests of the agrarian sector and this may now risk disrupting the agrarian sector because piecemeal adaptation is no longer possible (Vogeler et al., 2019). The late reaction, however, may be a result of the political coalitions that debated the environmental issues related to livestock farming and agriculture from different perspectives. Especially an "agrarian coalition" consisting of the CDU, FDP, farmers and regions with a dominant agricultural sector has lobbied against new environmental regulations while an opposing coalition of SPD, Green Party, and NGOs tried to develop more rigorous environmental regulations (Vogeler et al., 2021). From 2017 onwards, when the Green Party was replaced by the CDU in the parliament of lower Saxony, Vogeler et al. (2021) found that ministries have in fact adopted a more pro-agrarian policy.

When the fertilizer ordinance in Germany was issued in 2020, this led to protests against the regulation from farmers and farming-lobby organizations. This may be because the new legislation

presents difficulties for farmers to follow and they experience low agency to do so (Stuhr et al., 2021). It is unclear whether and how the new legislative regulations will be followed by farmers. Kuhn et al. (2019), by building on a bio-economic farm model, found high compliance costs for farmers to meet the standards of the new legislation. The authors conclude that this may result in a lot of farmers violating the rules so as to avoid these costs. In addition, Stuhr et al. (2021) argued that many farmers experience low agency in coping with legislative changes due to their perception of ever-changing policies and regulations that make it difficult to follow rules and make strategic decisions. Whether the new legislative regulations will lead to reduced manure application on the field and reduced eutrophication of water bodies remains an open question. Nonetheless, in being regulated by directives and in providing high compliance costs to take care of, manure has thus become a "risk" product for global agricultural production networks, as argued by Franz and Schumacher (2020).

The above-described research underlines the need to transition in livestock farming, the difficulties in doing so, in being able to cope with environmental legislation, and reducing socio-environmental issues. The empirical chapters (5 to 8) address this nexus of topics by a focus on bioeconomic innovations, incumbents, and contested imaginations of the future. Simultaneously, this links to studies that have emerged in the last years which loosely focus on the topic of how to navigate transition in livestock farming. There has been research addressing questions in relation to transitions in livestock farming outside Germany (e.g., Burton and Farstad, 2020; Maes and van Passel, 2017, 2019; Runhaar et al., 2020; Sutherland et al., 2012; van Oers et al., 2021) that I will not address here. In Germany only recently has a body of scholarship tried to address this question from different perspectives. With respect to livestock farmers, Thiermann et al. (2021) found that these actors envision a "warme Sanierung" (financial programs from the government that help farmers transition and build new innovative forms of livestock farming), a concept that originated in the Netherlands. With regard to the societal discourse around intensive livestock farming in Germany, Germans can be simplistically separated into two groups regarding transitions in livestock farming. While one group envisions sustainable change and is also willing to change individual consumption practices, another group (of roughly the same size) whose members want to continue the status quo as they are unwilling to change their consumption practices although they acknowledge the environmental issues arising from livestock farming (Schulze et al., 2023). Nevertheless, Busch et al. (2022), in a quantitative survey of consumer preferences, found that the majority of their German participants envision small-scale animal farming, which clearly contrasts with current intensive livestock farming. The visions of intensive livestock farming have led to the protest of "we are fed up" that favors small-scale agricultural systems (Nowack and Hoffmann, 2020), despite the unknown evidence regarding the sustainability of small-scale agriculture in contrast to large-scale agriculture (Busch et al., 2022; Nowack et al., 2019). In the context of potential transition processes, Bünger and Schiller (2022) highlight the relevance of different actor types in livestock farming and the special role of hybrid actors as potential change agents. These actors are viewed as intermediaries that translate between regime and niche actors in sustainability transitions in agriculture and livestock farming (Bünger and Schiller, 2022).

Despite all these studies loosely addressing the topic of sustainability transitions in livestock farming in Germany, there has not yet been a comprehensive analysis of how this change may be leveraged and how this may unfold. In this dissertation, I aim at contributing to closing these gaps and at contributing knowledge to design policies and practices that aim at further reducing the socio-

environmental issues associated with livestock farming alongside driving transitions. In the following, I want to elaborate on why and how livestock farming can be characterized as an institutionalized system, the different actors relevant for change in transitions, and in particular livestock farming, and the role that bioeconomic policies and innovations play with regard to livestock transitions.

3.1.1 The institutionalized livestock system

There is the above sketched pressure to transition in livestock farming in Germany, as specified by changing legislative aspects such as via the new fertilizer ordinance, societal discourse on socio-environmental issues associated with both manure surpluses and livestock farming in general, and the normative need to reduce environmental degradation. However, livestock farming in Germany has only slightly reduced livestock numbers over recent years (Deblitz, 2022). One can attribute the reasons for this to the institutionalization of current livestock farming that make changes difficult as there would be a need to question routines and historically institutionalized values, practices, and structures from a multitude of actors.[9] By institutionalization, I refer to Zucker (1977) who describes persistent culture as an institutionalized form of values and norms. Hence, specific societal sub-systems or organizational fields, such as livestock farming, can become institutionalized with regard to the culture they are structured by, and the routines and practices that characterize these fields and systems. My own research builds upon this characterization of institutionalization in the organizational field of livestock farming by focusing on how endogenous institutional change can be leveraged by farmers as incumbents (see chapter 8; Friedrich et al., 2023, *unpublished manuscript*).

In the following, I want to describe different aspects of livestock farming in the semiotic and extra-semiotic spheres of social life that relate to livestock farming as an organizational field. By focusing on semiotic and extra-semiotic aspects of social life, the mutual dependency of social practices, such as value-making, and sociomaterial structures, such as physical infrastructures, and their relation to changes in the imaginative sphere of a system, can be included (Adloff and Neckel, 2019).

Livestock farming is a sector that is characterized by institutionalized practices and culture that build very stable structures on different spatial levels. Hence, this sector is institutionalized through both global entanglements and production networks (Franz et al., 2018), local embeddedness in specific regional developments (Franz et al., 2018; Tamásy, 2013), and the historically institutionalized path dependency of both more general agri-food systems (Conti et al., 2021) and of the corporate food regime of the present (McMichael, 2009).

Livestock farming is characterized by stable semiotic structures such as discourses and culture in terms of values and norms, and stable extra-semiotic aspects, such as regional production infrastructures and global production networks. In particular, these stable mechanisms relate to input of material and processing of products along the value chain. The input can depend upon global networks and the spatial proximity of transport infrastructure and facilities, such as harbors (Franz et al., 2018). Processing along the value chain is often locally embedded as in the case of

[9] This is of course a perspective heavily inspired by cultural sociology in which I do not explicitly refer to the economic needs of individuals that inform their doings but rather view these needs as institutionalized forms of culture.

the region of Vechta, where an agricultural cluster and food processing industry has sprung up in close proximity to intensive livestock farming (Tamásy, 2013).

In addition to these economic and place-specific dependencies, historically institutionalized logics of growth – such as those provoked by the restructuring of farming in the past four decades that lead to an increase in farm size and livestock numbers per farm while reducing the number of farms – stabilize the system (Nowack et al., 2019). While this aspect has rarely been addressed with respect to German agriculture, Runhaar et al. (2020) argue how institutional logics of growth can impede sustainability transitions in livestock farming systems in the Netherlands as these logics often contrast with interpretations of sustainability. These growth- and market-oriented logics are often reproduced through dominant actors such as the German Bauernverband (e.g., with respect to livestock farming and the importance of value creation for farms, see Deutscher Bauernverband, 2013) that have a hegemonic position in discourse and within the farming community. Accordingly, these actors structure the meanings of this community and organizational field by arguing for a preservation of the status quo (see chapter 5; Friedrich et al., 2022a). With regard to sustainability transitions, these stable values and logics through which systems function can reflect wider so-called discursive lock-ins that torpedo change and instead maintain the status quo by leading to path dependencies and ultimately hindering transitions from emerging (Simoens et al., 2022).

However, livestock farming and more generally agriculture also become stabilized on the policy level via subsidies. Comparing subsidies for agriculture between Germany and Brazil, Pintor et al. (2022) found that German agriculture receives three times more subsidy than Brazilian agriculture. The largest shares of these subsidies come from the EU's Common Agricultural Policy (CAP). Through the definition of the conditions of funding, this political instrument shapes and stabilizes existing agricultural practices and structures (Alons, 2017; Barnes et al., 2016). However, the CAP is at the same time also a major instrument by which transitions could be driven. Agriculture in general has also received less political support and funding for transitioning than has the energy sector with regard to renewable energy sources in the past years (Heyen and Wolff, 2019). This lack of support can lead farmers on the individual level to experience low agency and to rely on routines and incremental improvements, thereby reproducing and maintaining the status quo (Stuhr et al., 2021). Other aspects also stabilize and maintain the status quo on the individual level. Sunken costs as a consequence of past investments may "colonize" the present or even future (Beckert, 2016) and make change difficult. This relates to entrepreneurial decisions and investment periods in agriculture, the rhythms through which agriculture is performed that depend on livestock, climate, farm inheritance, and other, often personal aspects, that create path dependencies on the individual level and which shrink the "action space" of farmers (see chapter 8; Friedrich et al., 2023, *unpublished manuscript*).

Considering these multifaceted aspects, livestock farming as an organizational field can be regarded as characterized by a high degree of institutionalization that relates to both semiotic and extra-semiotic aspects and which make the existing regime stable and difficult to change.

3.1.2 Actors in livestock farming

The actors in livestock farming and the livestock system depend upon the scale of analyses and the perspective that one takes in this analysis. I have taken the perspective of acknowledging the global, telecoupled entanglements of livestock farming (e.g., Franz et al., 2018) and focusing on the local as well as regional developments and issues relevant in livestock farming. Livestock

farming is characterized by numerous actors, among whom are a heterogeneous group of farmers, downstream actors such as slaughterhouses and food retailers, innovation actors, NGOs and other actors such as those from governance bodies that have a semiotic relationship with livestock farming in their discursive and political practices. One can also view consumers as part of livestock farming in their relations through their consumption decisions and diets (e.g., Schulze et al., 2023).

One way to differentiate these actors is to separate them into innovation actors and regime actors, following the MLP (Geels and Schot, 2007). While the theory is often criticized for neglecting important aspects of transition, such as deep structures (e.g., Fuenfschilling and Truffer, 2014), this conception of different actors can help to identify established and new actors (see also Fischer and Newig, 2016) and to identify interview partners (see also chapter 2.3 and chapter 4.3.1). This links to the research of Bünger and Schiller (2022) and their elaboration of different types of actor in agri-food transitions and in particular livestock farming. By building on surveys in different European countries, they find a major proportion of actors that belong to the socio-technical regime while only few actors can be characterized as niche actors that may foster innovative developments. In their analysis, they found an additional type that they regard of high relevance for transitions in livestock farming: hybrid actors, that originate from the regime but that have turned toward innovative developments and through their intermediary position between regime and niche actors may function as potential change agents (Bünger and Schiller, 2022). When focusing on livestock farmers only, Stuhr et al. (2021), for the case of pig farmers and how they cope with the nitrate legislative, found different farmer types with regard to their perceived agency. This includes a type that experiences low agency as being overburdened by requirements; another type that relies on routines and incremental changes; and a third type that can be characterized as early adopters, who try to find ways to cope with the new legislative requirements. However, all three types report low experienced agency and difficulties in coping with ever changing political legislatives (Stuhr et al., 2021).

In my research, I have mainly focused on bioeconomic innovation actors[10] (see chapter 4.3.1), farmers as incumbent actors of the existing regime, and NGOs and actors from civil society that participate in discourses. Since actors from civil society have semiotic relations with livestock farming, they were also viewed as part of the existing regime. I have purposely neglected other actors along the value chain such as slaughterhouses, food retailers, and consumers to allow for an in-depth analysis of the above-mentioned actors (see chapter 9.4.2). In addition, this helped me to remain focused on these actors, their ideas and practices of transitions in livestock farming, and the particular focus on socio-environmental issues of livestock farming.

3.2 Bioeconomic innovations and the bioeconomy as scientific and political project

The bioeconomy is a political project and abstract scientific concept. In this role, the bioeconomy promises certain contributions to sustainability such as by being conducive to multiple SDGs. In the past years, the bioeconomy in its role as both political and scientific project has gained increasing prominence. With respect to scientific attention, a major increase in publication output

[10] Bioeconomic innovation actors comprise actors that are currently developing bioeconomic innovations based on a characterization of these as “substitute products”, “new processes”, “new products”, or “new behavior”; cf. Bröring et al. (2020).

favoring the term "bioeconomy" is visible: While in 2010, 121 documents listed in Scopus mentioned the term "bioeconom*", in 2022 this number was 6067 documents, 1238 of which were published just in 2022 (Scopus, 2023).[11] Among these documents, only 7.5% of published literature relates to the social sciences. The US and Germany have the largest share of publications (Scopus, 2023).

The bioeconomy is not a clearly defined concept. It can have multiple connotations and there are different approaches relating to bioeconomy that belong to the umbrella term "bioeconomy". Bugge et al. (2016) aimed at providing an overview of the different definitions and concepts of a bioeconomy. The authors (ibid.) clustered these approaches into three visions that define bioeconomy: a "bio-resource", a "bio-technology", and a "bio-ecology" vision. The bio-resource vision focuses on a substitution of fossil resources with renewable resources, while the bio-technology vision favors technological innovation and economic growth, and the bio-ecology vision focuses on biodiversity conservation and ecosystem functioning. (Bugge et al., 2016).[12] These different visions are exemplary for the contestation and multiplicity of bioeconomic approaches and realities that are currently being scientifically discussed.

In addition to the term and concept of a bioeconomy receiving increasing scientific attention, more and more policymakers are developing and spelling out bioeconomic strategies, among others the EU (European Commission, 2018), OECD (OECD, 2009), and national governments such as Germany's (BMEL and BMBF, 2020). The German government issued a bioeconomy strategy in 2020 (BMEL and BMBF, 2020). In this strategy, the government placed special relevance to the substitution of fossil resources through renewable resource use and the use of biological knowledge for the design of innovations. The bioeconomy is furthermore viewed as a strategy to remain internationally competitive and to allow for economic growth in related business sectors (BMEL and BMBF, 2020). This strategy argues that a transition to a bioeconomy will lead to contributing toward various SDGs (BMEL and BMBF, 2020). In particular, a bioeconomic transition would contribute toward SDG 2 "zero hunger", SDG 3 "good health and wellbeing", SDG 6 "clean water and sanitation", SDG 7 "affordable and clean energy", SDG 8 "decent work and economic growth", SDG 9 "industry, innovation and infrastructure", SDG 11 "sustainable cities and communities", SDG 12 "responsible consumption and production", SDG 13 "climate action", SDG 14 "life below water", and SDG 15 "life on land" (BMEL and BMBF, 2020). The German government aims to operationalize this contribution by a twofold focus concerning both (i) financial support and funding for scientific research and (ii) through policy changes that relate to topics regarding innovation, bioeconomic clusters, the bioeconomy as offering the potential to create more equal living conditions in rural regions, or new legislation such as the fertilizer ordinance to secure sustainable resource use (BMEL and BMBF, 2020).

In these and other political concepts and strategy papers, the bioeconomy is envisioned as a "panacea" (Giampietro and Funtowicz, 2020) for solving multiple environmental, social, and economic issues. Recently there have been many critiques of bioeconomic strategies and bioeconomic developments. These critiques relate to bioeconomic developments leading to increasing land-use conflicts, global inequalities, driving land-grabbing, and leading to a marginalizing of NGO actors (e.g., Ashukem, 2020; Backhouse et al., 2021; Lühmann, 2020;

[11] Part of this increase may also be attributed to a general growth in scientific output during these years.

[12] There have been similar clusterings made by Hausknost et al. (2017) and Vivien et al. (2019); for a brief discussion, see chapter 7.

Riemann et al., 2022). This has led to a growing body of scholarship that reflects upon the bioeconomy as a "failed political project" in Germany (Lühmann and Vogelpohl, 2023), arguing that it tends to maintain unsustainable social orders (Eversberg et al., 2023; Friedrich et al., 2023; Lühmann, 2020). Furthermore, the question has been brought forward of whether the bioeconomy in Germany, that does not rely on any specific bioeconomic innovation policy, can actually lead to sustainable transformations of systems of production and consumption, because these transformations may also require new innovation policies (Bogner and Dahlke, 2022) that challenge existing paradigms regarding innovation (Schlaile et al., 2017).

While political strategy papers and policies can be assessed, it is not yet clear whether the practices that are being shaped by bioeconomic strategies – the specific bioeconomic realities – are contributing toward sustainability and, if so, toward what kind of interpretation of sustainability. In this dissertation, I contribute to filling this gap by analyzing these bioeconomic realities in terms of bioeconomic innovations in the context of manure surpluses. This allows me to focus on bioeconomic innovations as a lens through which to examine the bioeconomy as a political and scientific product and through which to account for bioeconomic transitions and their realities. Bröring et al. (2020) define bioeconomic innovations as substitute products, new processes, new products and new behavior. Substitute products are described as "old function, new resources", new processes are marked by "allocation of biomass", new products mean "new inputs/products with disruptive [effects] and applications in many industry sectors", and new behavior through the "reuse of already exploited biomass[, the] use [of] biomass for energy after extraction of more valuable compounds[,] new combinations/value chain connections (cascade)" (Bröring et al., 2020: 6).

In the context of livestock farming and manure surpluses in particular, there are several innovations that I have characterized as falling into this definition and that build one particular focus of this dissertation with regard to their ability to contribute toward sustainability-oriented reconfigurations in German livestock farming (see chapters 6 and 7). These bioeconomic innovations include: manure exchange between arable and livestock intense regions (e.g., Asai et al., 2018), new manure application techniques that reduce on-field emissions during application (e.g., Darapuneni et al., 2019), the breeding of insects on manure (e.g., Čičková et al., 2015), the cultivation of duckweed on manure (e.g., Stadtlander et al., 2019), and different techniques for processing manure in NPK (nitrogen, phosphorus, potassium) fertilizer that can be used in a globally and spatially unbound manner (e.g., Pintucci et al., 2017). These innovations aim at contributing toward sustainable use of manure through recycling phosphor, nitrate, and other elements of manure, using manure as basis for the cultivation of insects that can be used as livestock feed or insect-based food afterwards, or for the cultivation of duckweed that in turn may be used as fodder for livestock production again. Other approaches that are currently being used relate to manure exchange between different regions (e.g., arable and livestock regions, see Asai et al., 2018) through so-called "Güllebörsen", or new techniques for on-field application of manure that can improve the accuracy of application and reduce odor and nitrogen oxide during the process (Darapuneni et al., 2019). In addition, manure is frequently used as input material for anaerobic digestion in biogas plants. After digestion, the digested material can be spread on fields, although this has been criticized as being more damaging to the environment than manure application (Nkoa, 2014).

In the following empirical chapters (6 and 7) of this dissertation, there will be more in-depth description of these innovations. I regard these innovations as a tool for analyzing bioeconomic

transitions in German livestock farming (see chapter 6). Alongside their value for the analysis of transition in livestock farming, a focus on these innovations and the actors that are designing these innovations allows me to describe bioeconomic realities in terms of innovation in general. This also enables me to contribute to an understanding of contesting meanings of sustainability that these innovations follow and are shaped by, as well as the imaginaries that materialize in innovation design and which accompany the development and diffusion of innovation.

4 Methodological approach

My methodological approach followed a qualitative research design using different case studies. The empirical basis consists of documents and qualitative interviews. I developed different research designs to answer the specific research questions of the case studies (see Figure 2 and Table 2). All these research designs followed the ideal of theory building on the basis of empirical research and vice versa (Swedberg, 2014). I refined existing theories of different scope by means of empirical research, the context of the specific setting, and new discoveries. Thereby, I built upon open deductive-inductive approaches drawn from a priori knowledge of theories and empirical settings that researchers have in combination with inductive discoveries (Kelle and Kluge, 2010). In the following, my overarching approach will be outlined more generally while further in-depth details of the case studies can be found in the corresponding methods section of the empirical articles (see chapters 5.3, 6.3, 7.3, and 8.4). First, I will briefly elaborate on situating my methodological approaches by reflecting on epistemic and ontological perspectives of my research. Second, I introduce my case study-based research designs, the interviewees, and their roles. Third, I will briefly sketch the data analyses performed in the dissertation (more details can be found in the empirical chapters of this dissertation) before I close with reflecting on some limitations of my research designs and data collection (an in-depth reflection of limitations of this dissertation can be found in chapter 9.3).

4.1 A social constructivist approach

I now briefly sketch my epistemological approach to what I regard as acceptable knowledge as well as my ontological position regarding the social. My ontological considerations can best be described as following constructionism in that I view social actors as a product of accumulated (historical) social interactions and order (Bryman, 2008). My epistemological considerations are influenced by this consideration as well as by the choice to discard positivist approaches, which means not following deduction-based and objectivist ideals of knowledge production in the "natural" sciences. I base my epistemological accounts to a large extent on Berger and Luckmann (1966) in following their account of the social as a constructed reality that is subjective to actors' meaning systems, knowledge, and one that is supported by phenomenological accounts.

In particular, in the empirical chapters of this dissertation, I followed a social constructivist approach to knowledge, the social, and consequently technological artifacts. In this way, I build upon an understanding of social practices as embedded in imagined futures that are imagined realities. These semiotic worlds are shaped through collective forms of understanding and meaning (Berger and Luckmann, 1966; Reckwitz, 2003). What social actors experience as reality informs their activities and the embodiment of social practices by these actors, and the extra-semiotic consequences more generally (Berger and Luckmann, 1966; Reckwitz, 2003). This reality is being continually (re)produced due to the emergent and continuous interactions of actors as embedded in social structures and shaped by historically institutionalized practices, with all the consequences this has for meaning systems, subworlds of meaning, and practices.

In the design of technological artifacts, the notion of social construction becomes more tangible. Here, the design of technological artifacts or projects is a co-product of multiple groups of social actors and their meaning systems (Bijker et al., 1987; Pinch and Bijker, 1984). These actor

groups define a problem and how the technological artifact can solve this problem in that they assign meaning to this artifact. Actors that contest meaning with respect to the artifacts are also producing the artifact's meaning (Pinch and Bijker, 1984). Pinch and Bijker (1984) refer to the historical design processes of bicycles to describe this phenomenon. The authors (ibid.) argue that a bicycle is constructed through social interaction and discourse, through the meanings that different groups of social actors assign to different types of bicycle and the potency they gain in shaping the technological design of the bikes we know and use today. Bicycles, according to these authors, have not always had the shape and widespread use of today. Their design significantly depends on the meanings that actors have attributed to these. Historically, these meanings have transformed bicycles with one big wheel (penny farthings) into bicycles with wheels of equal size, and have later on informed the design of specialized bicycles like those for racing or off-road cycling.

Building on this perspective, technological artifacts are a social product, as is knowledge in general and scientific knowledge in particular. With respect to this aspect of knowledge, I follow Berger and Luckmann (1966) in their interpretation of social realities as produced through knowledge and meaning systems in society and among groups of social actors. I regard all types of knowledge as relevant to research as they inform the activities of social actors. Knowledge, against this background, "is the sum total of 'what everybody knows' about a social world, an assemblage of maxims, morals, proverbial nuggets of wisdom, values and beliefs, myths, and so forth" (Berger and Luckmann, 1966: 83).

For the methodological approach of my research, this meant to account for the social realities and the categories that social actors use. These actors, their categories, and realities are relationally embedded in groups, collectives, and wider society as they are constantly constructed and reconstructed through social interaction. In following a social constructivist account, I argue that the reality of social actors, what they experience, is an explanatory dimension of their doings, of social change and order. This reality is constructed out of knowledge that can range from experienced knowledge to tacit knowledge to scientific knowledge. Consequently, meanings in society and of social actors are contested, as they are constantly reconstructed by new experiences and through new knowledge. My interest concerns how these acquire their force for social actors in the context of sustainability transformations in livestock farming in Germany.

This also means that the contribution to knowledge I am producing here is a product of the social interactions I had prior to starting this project and during the time of this project (both with scientists and my interviewees), of the methods I chose, and of the theories I absorbed. In general, scientific knowledge is produced through laboratories, epistemic cultures, and epistemic practices (Knorr-Cetina, 1981, 1999; Latour and Woolgar, 1979). What is perceived as scientific knowledge depends upon the choices of social actors, their knowledge of the world, the experiments one carries out, and the materials and instruments one has at hand. Objective science in the normal paradigm is rather a chimera because its products are partly based on the normative choices of people who are conditioned by, and embedded within, cultures that shape scientific knowledge and knowledge more generally. Accordingly, with my dissertation, I am not just describing phenomena but am in turn reproducing knowledge and reconstructing what I have seen in my words or through the view of my social-science glasses. My research should thus be seen as a product of the social interactions I engaged in as a social actor, and of the meaning systems I am shaped by. In institutional theory, Suddaby and Viale (2011) have called this the "professional project". According to this perspective, professionals are through their narratives constantly reproducing and reconstructing institutions,

i.e., culture and practices and/or the social in a more general sense. I view this also as relevant in the context of my empirical work. Through analyzing data from my interviews, the conversations I had with interviewees, and the questions I asked, I am actively reconstructing realities, participating in organizational changes, and thus play an active part concerning transitions in livestock farming.

4.2 Qualitative case study approaches

In my research, I followed an approach based on different though complementary qualitative case studies (see Figure 2). Case studies tend to focus on a specific problem, location or community and are argued to be most frequently approached with qualitative research methods (Bryman, 2008; Creswell, 2013). Especially single case studies by their nature cannot be generalized to other cases, locations, and communities. While this is often criticized, it is – and indeed cannot be – the aim of single case studies to provide generalizable data and information that are transferable to other contexts. It is precisely the extensive and detailed work within cases that is a strength and a benefit of case-study approaches (Flyvbjerg, 2006). By using qualitative research methods, these cases can be investigated with relatively small sample sizes (compared to quantitative approaches) as they do not aim at generalizable data and their distribution among specific sample populations. Qualitative case studies follow qualitative sampling techniques based on the idea of focusing on different, contrasting, and complementary arguments or perspectives in contrast to socioeconomic characteristics often used as discriminators for representative sampling techniques and the sample size in quantitative research (Kelle and Kluge, 2010; Kruse, 2015). By this sampling technique of different though complementary actors and perspectives on issues, qualitative case studies allow for comprehensive and detailed views of the issues and topics that form the focus of the research.

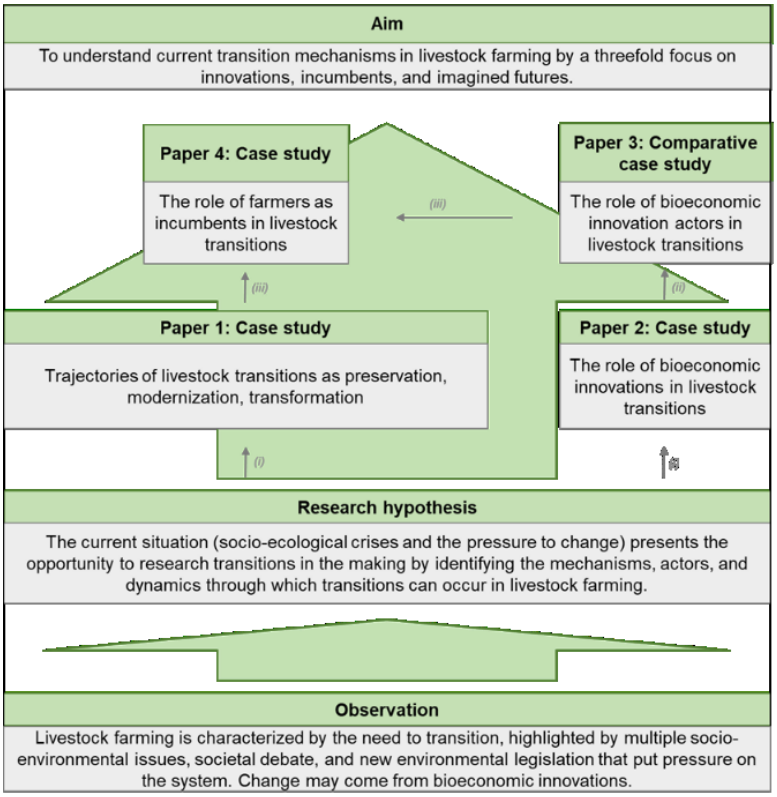

Figure 2: Structure and different case studies of the dissertation and their interaction in answering the research aim; for a detailed overview of the linkages, see Figure 1 and chapter 1.1.

In this dissertation, I built upon different case-study approaches that followed a variety of research designs and theoretical considerations. These case studies complement and contrast each other and therefore give insights into sustainability transitions in livestock farming and the particular roles played by innovation, incumbents, and imagined futures. At the same time, these case studies reflect the nature of sustainability issues as being spatially and temporally explicit, which calls for a range of theoretical and empirical approaches that suit the context (Schlüter et al., 2022). Table 2 provides an overview of the research designs and research strategies employed in the dissertation. Figure 2 describes how the case studies interact toward the aim of this dissertation to research sustainability transitions in livestock farming, starting from the research hypothesis that livestock farming is characterized by the need to transition and by bioeconomic innovations that may contribute to such a transition.

Table 2: Overview of research designs and research strategies employed in the dissertation. Note that research designs often not only follow one approach but rather that these approaches are the main rationale for choosing the case (cf. Bryman, 2008)

Chapter	Case study 1 (chapter 5)	Case study 2 (chapter 6)	Case study 3 (chapter 7)	Case study 4 (chapter 8)
Research design	Exemplifying case study livestock system, critical case study: imaginations of sustainability (Bryman, 2008)	Exemplifying case study: livestock system (Bryman, 2008)	Comparative case study of diverse cases in India and Germany (Seawright and Gerring, 2008)	Single case study: livestock farming, Rotenburg an der Wümme (Flyvbjerg, 2006)
Research strategy	Qualitative interviews (problem-centered, cf. Witzel, 2000) with actors that have semiotic relationships with livestock farming	Document analysis of bioeconomic innovation actors	Qualitative interviews (problem-centered, cf. Witzel, 2000, and expert interviews) with bioeconomic actors	Qualitative interviews (problem-centered, cf. Witzel, 2000) with farmers, farming representatives, and extension services
Sampling strategy	Aiming for contesting imaginations of manure futures (search for counterexamples, cf. Kelle and Kluge, 2010): start from a first characterization of actors in regime and innovation actors, further actors derived via snowball sampling, stop after content saturation (Saunders et al., 2018) is reached (see details in chapter 5)	Purposive selection of online documents of different bioeconomic, manure-based innovations	Mapping contesting framings of manure futures and political landscape and discourse of Bt cotton (search for counterexamples, cf. Kelle and Kluge, 2010), stop after content saturation is reached (Saunders et al., 2018)	Selection of interviewees by means of different perspectives on issues (search for counterexamples, cf. Kelle and Kluge, 2010), start from key actors, further actors derived via snowball sampling, stop after content saturation is reached (Saunders et al., 2018)
Data analysis	Type-building qualitative content analysis (Kuckartz, 2014)	Content analysis of documents of the innovation actors	Qualitative content analysis (Kuckartz, 2014)	Qualitative content analysis (Kuckartz, 2014)

While my research designs (Figure 2) followed different and complementary case-study approaches and research designs, in the following I want to lay out these approaches in more detail. The first case study of bioeconomic imaginations (see chapter 5 for more details) follows a exemplifying case-study approach combined with a critical case-study approach (Bryman, 2008). This case aimed to find evidence for theoretical arguments made by Adloff and Neckel (2019), thereby presenting a typical socio-environmental problem. This socio-environmental problem also proved to be a critical one in that I identified an additional trajectory that complements the theoretical framework of Adloff and Neckel (2019). The second case study (see chapter 6 for more details) analyzes the capacity of bioeconomic innovations to contribute to socio-ecological transformation. The case study exemplifies this aim by a focus on manure-based bioeconomic innovations as an exemplifying case study for bioeconomic innovations and their ability to lever transitions (Bryman, 2008). In the third case study (see chapter 7 for more details), I follow a comparative case-study approach looking at two contrasting and complementary cases (Bryman, 2008), in Germany and India. The comparative research design allows me to generate generalizable insights beyond the case-study context by focusing on the similarities and differences between the cases. The two cases of this comparative approach are diverse (see Seawright and Gerring, 2008) in terms of their respective contexts of socio-environmental issues in Germany and socioeconomic issues in India, of global North and South, and because they are shaped by different visions of the bioeconomy (Bugge et al., 2016). The remaining chapter (8) follows a single case-study approach (Flyvbjerg, 2006). Its focus is on the typical rural case of Rotenburg an der Wümme, in an area characterized by livestock production. This case contrasts regions in Germany that are characterized by higher livestock density and locally specialized industries such as around the town of Vechta and the "Oldenburger Münsterland" (for more details, see chapter 8).

4.3 Empirical research strategies

As outlined in Table 2, I have employed different case study-based research designs that are accompanied by different research strategies that match their context and research questions. In the following, I will lay out the empirical focus of these case studies, the sampling techniques and how I developed guiding questions for the problem-centered interviews (Witzel, 2000) that are incorporated in this work. The detailed descriptions of methodological approaches are described in the corresponding methods sections of the empirical chapters of this dissertation (see chapters 5 to 8).

4.3.1 Empirical focus: Different actors and documents

Among the different case studies, my empirical focus for undertaking my research strategy (see Table 2) was on interviews and documents. I conducted 28 interviews on my own while 6 additional interviews were incorporated during ongoing research (these relate to the comparative case study, see chapter 7) amounting to 34 interviews that form the empirical basis of this dissertation. In addition, I conducted a content analysis of online documents to analyze the ability of bioeconomic innovations to contribute to a socio-ecological transformation on the basis of analytical categories. For this purpose, online documents published by the innovation actors were used as an empirical basis.

In chapter 2.3, I outlined how I view actors as an empirical focus for researching imagined futures in sustainability transitions in livestock farming. This means that actors are an empirical

object through which one can analyze sustainability transitions in livestock farming. For my empirical approaches, I focused on actors that have semiotic relationships with livestock farming. In the following section, I will outline the considerations that guided my sampling of interview partners and the selection of innovations.

4.3.2 Sampling: Selection of interview partners

Concerning the sampling of interview partners and my selection of innovation as a research object, I followed sampling techniques (see

Table 2) that were driven by the rationale of qualitative sampling to incorporate different perspectives and by the aim of theory building (Kelle and Kluge, 2010; Kruse, 2015; Swedberg, 2014). In this process, I combined three aspects to sample my interview partners: (1) search for counterexamples; (2) qualitative sampling plans; (3) snowball sampling (Bryman, 2008; Kelle and Kluge, 2010; Reed et al., 2009).

With regard to the first aspect, I built upon the search for contrasting cases among the arguments and interviewees of my case studies. This has been described as a "search for counterexamples" by Kelle and Kluge (2010: 43f.). The idea builds upon the search for critical/crucial cases that contrast and complement a priori theoretical deductions. This is inspired by the research strategy of falsification (Karl Popper) and aims at the empirical reconstruction and renewing of deductive hypotheses (Kelle and Kluge, 2010). For my research, I used this idea in combination with initial plans about distribution of perspectives and knowledge. These initial plans, called qualitative sampling plans (cf. Kelle and Kluge, 2010), build upon different theoretical hypotheses. One example of such a theory-inspired plan proposes the hypothesis that actors of the existing socio-technical regime may have different views about certain issues than new (innovation) actors entering the field. This hypothesis was inspired by the MLP on socio-technical transitions (cf. Geels, 2002; Geels et al., 2016; Geels and Schot, 2007). Accordingly, I sampled the actors as either belonging to the existing socio-technical regime or as new actors (e.g., niche innovation actors) entering the field. Another sampling plan refers to the hypothesis that interviewed livestock farmers should have different farm sizes, animals, and types of production (conventional vs. organic) as these aspects may inform their perspectives on issues and solutions. This led to my focus on incorporating farmers covering different types and variations of these categories within my sample.

I constantly built upon these theoretical considerations and sampling plans to develop an a priori set of guidelines for my sample that I refined throughout the process of data collection. As a third step, I sampled further actors matching the aforementioned categories by means of snowball sampling (Reed et al., 2009; Rubin, 2021). Snowball sampling as a method is often criticized for being selective (as the interviewees recommend further actors to conduct research with) but which addresses some of the difficulties in conducting empirical research by offering a practical path to new interview partners. I used snowball sampling to ask for contrasting cases or "counterexamples" (cf. Kelle and Kluge, 2010). As my results show, the topics and issues that I conducted (problem-centred) interviews on are quite contested. This helped me in sampling because interviewees always knew another contrasting example that would be characterized by contrasting ideas and perspectives and which would therefore serve as a counterexample. This strategy also helped me to achieve "content saturation" (Rubin, 2021; Saunders et al., 2018), the point at which I stopped the sampling process. "Content saturation" means that the interviews offered recurring arguments,

perspectives, and that even new actors that covered different categories of the a priori sampling plan did not add any new knowledge with regard to the research questions, the aim of the research in general, and the theoretical frameworks in particular (Saunders et al., 2018). This state is what I understood as "content saturation" and at which I stopped conducting further interviews.

Details of how all these sampling techniques and the selection of interviewees took shape in the different empirical research strategies (see Table 2) are described in the corresponding methods sections of the empirical chapters (see chapters 5 to 8).

4.3.3 Selection of innovations

My research was concerned with an analysis of bioeconomic innovations as both a potential solution to sustainability issues and as driving transitions in livestock farming (see Figure 2). This means that I explored bioeconomic innovation's capacity to induce transitions in livestock farming, and in particular a reconfiguration of livestock farming. As I am concerned with livestock farming and manure surpluses in Germany, I build my focus on manure-based bioeconomic innovations. According to Bröring et al. (2020), bioeconomic innovations can take different forms: substitute products, new processes, new products and new behavior (see chapter 3.2 for details). Based on an online search and a characterization of manure-based bioeconomic innovations by following the definition of Bröring et al. (2020), I came up with several innovations as objects of study. These ranged from different techniques for recycling manure, the use of mineral fertilizer, the cultivation of duckweed, the breeding on manure of insects, and the manure–land exchange beyond the region. What unites these innovations is that they are based on manure as an input material as well as having a focus beyond the farm, including extra-farm cooperation, new actors or actors from other regions. Details about these innovations are found in the empirical chapters (see especially chapter 6) of this dissertation and in chapter 3.2.

4.3.4 Qualitative interviews: questionnaire development

Different ideas exist regarding whether questionnaires[13] and guiding questions should be used in qualitative, interview-based research. This especially relates to whether deductive hypotheses and a priori knowledge that guides the interview or data collection more generally are spelled out prior to the interview situation, or whether the interviewer attends the interview situation in as open a way as possible, only guided by the pure and objective epistemic interest of the researcher (Kelle and Kluge, 2010).

As I outlined above (see chapter 4.1), every researcher has (theoretical) deductions that inform research strategies and data collection more generally. Researchers and their focuses of interest are a product of the theories they engage with and the laboratories and institutes they work in. These deductions should not stand in contrast to the ideal of openness in qualitative research. Rather, the ideal of being open for new meanings, discoveries, and explanations of the social go well beyond a priori hypotheses, assumptions, or theory-driven guesswork. Outlining these deductions in the form of working hypotheses or guiding questions helps researchers become aware of the own theories and processes of deduction.

I have built upon semi-structured interview questions to outline my theoretical deductions in terms of interview questions and to limit the open-endedness of interview situations so as to focus

[13] Questionnaires in qualitative research are a collection of the guiding questions and are much different to questionnaires in quantitative research: they consist of open questions that can be adapted to the interview situation.

my research. Or, as Helfferich (2022: 879) put it, "The considerations on interview design as open as possible" should be supplemented by the suffix 'and as structured as necessary'" (original in German, own translation). This means that guiding questions or a questionnaire that is used in semi-structured interviews helps to address this issue. Such approaches help to translate qualitative research questions from their reflexive design (Agee, 2009) to the specific interview situations. Guiding questions thus help the researcher to be able to replicate the research, to incorporate deductions as questions, and at the same time support the researcher in gathering data via interviews.

In developing my guiding questions, I built upon the SPSS[14] method (Helfferich, 2022) to develop, sort and select guiding questions that can support me in finding answers to my research questions (see also Kruse, 2015). The SPSS method consists out of four steps: (1) collect (Ger.: sammeln), (2) test (prüfen), (3) sort (sortieren), (4) subsume (subsumieren). By following this method, one at first collects potential interview questions. This can be done via brainstorming methods or written down, alone or as a group (groups are obviously more diverse in terms of the range of opinion). These questions are then sorted with regard to their relevance for addressing the research questions – also ideally done in a group setting. Next, they are sorted regarding their focus and content, at what time during the interview one wants to ask these questions (relevance), and other criteria that a researcher can devise. In a last step, the questions are subsumed. This means that similar questions are collected, duplicates are deleted, and main questions are developed that can comprise different sub-questions.

Afterwards, the questions may be transferred to any preferred format of interview questions. I followed the format of questions offered by Kruse (2015) that is exemplarily sketched for one question in Table 3. This format consists of a guiding question or stimuli to encourage the interviewee to start talking, a column in which the content of the question is laid out, a further column with exemplary questions to maintain the conversation, and a third column with additional questions for delving deeper into the issue. This format helps the researcher during the interview to conduct an appropriate interview and to collect comparative data among various interviews (Kruse, 2015). The original guiding questions that followed this format and were used for the research in this dissertation appear in the annex (chapter 11).

Table 3: Example of a guiding question employed in the qualitative research process, based on Kruse (2015), translated to English by the author.

Guiding question/stimuli		
What current challenges do you have to deal with on your farm right now?		
content	**Sustaining questions**	**Inquiries**
"Hot" topics of the farm Difference between agriculture and livestock Problems and causes	What else can you think of? Has it always been like this?	How do you deal with it? How are other farmers in your region doing? What do you think is the cause?

4.4 Data recording, processing, and analysis

Data recording and processing is an important aspect of qualitative research. Nowadays, this is usually done via audio recording and consequent transcription of the audio file, while in earlier times handwritten notes played a central role (Kruse, 2015). During my interviews, I collected the

[14] Not to be confused with the statistics software.

data via audio recording, and I used memos and notes at the end of the interview to summarize my initial insights and to sketch out potential analytical and interpretative patterns. I used a transcription service to transcribe the audio files. These transcripts were corrected for quality and accuracy,[15] anonymized regarding personal identifiers, and finally transferred to MAXQDA for further analysis.

Data analysis was performed with the software program MAXQDA and on the basis of Kuckartz's (2014) guide to qualitative text analysis. Depending on the research questions and the case study, I conducted different types of qualitative text analysis, namely qualitative content analysis and type-building qualitative content analysis (see Table 2 for a brief overview and the corresponding methods sections in chapters 5 to 8 for more details), all of which were derived from Kuckartz (2014) and performed in MAXQDA. First, I stared with brief case descriptions to gain an overview of the material. Next, I followed a deductive-inductive process to data analysis. In this process, a priori categories derived from the relevant literature or from my own deductions are combined with inductive categories derived from the material. This combination of approaches accounts for the theoretical deductions of researchers and allowed me to follow the ideal of a general openness in qualitative research by adding further categories that refine the taxonomy directly from the material.

More details on the coding processes of the interviews including the coding trees are given in the corresponding methods sections of chapters 5 to 8.

4.5 Reflections on empirical research practice

In the following, I want to take time to briefly reflect on my empirical research practices regarding the limitations that I regard as important to acknowledge and discuss (some broader reflections on limitations of my dissertation are discussed in chapter 9.3, while case-specific limitations and reflections also feature in chapters 5 to 8).

One important aspect in qualitative research is the inter-coder reliability that is usually obtained from two or more coders and their comparison of their own independent codings of the same material (Kuckartz, 2014). In my case, I used code snippets, or exemplary codes and their definitions, to enable inter-coder reliability. In particular, I discussed preliminary codes and their definitions with colleagues and further refined my category systems on this basis. Such an approach has limitations with regard to inter-coder reliability since the material has not been independently coded by more than one coder and obviously no comparison of these two coding systems is possible. However, this reflects the reality of research, and the time and work constraints that limit the ability to ensure ideal inter-coder reliability. Against this background, I regard my approach of discussing code snippets and categories with other scholars as a research-pragmatic one that allowed me to ensure at least a broad level of inter-coder reliability and which was the inevitable outcome of time and work constraints in my research.

I also want to briefly discuss the predominant nature of male interview partners included in my sample. Prior to the data collection procedure, I thought of an intersectional approach to empirical social science research (see e.g., Ganz and Hausotter, 2020). However, because of the empirical reality of a majority of men being the owners of farms or innovation actors, I needed to reject ideas

[15] The transcription service did not understand some technical terms and made some minor mistakes that I corrected afterwards.

of a quoted sample. Nonetheless, I tried to incorporate as many non-male perspectives in the sample as possible.

When I started my position in October 2019, Covid-19 was not yet a worldwide crisis. When Covid-19 changed our lives, for me this meant not being able to carry out my data collection as I had initially planned, as personal meetings were temporarily prohibited and later discouraged (both by law and by the institute I was working for). Hence, I conducted interviews using online software and via telephone. This has some benefits and disadvantages that I briefly want to sketch. First, it saves a lot of time as I did not need to travel to the region and to the interview partners for conducting field work. It was also quite easy to find interview partners that (sometimes spontaneously) wanted to participate in the study. Especially for farmers, it was less complicated because we could use evenings and other time slots not usually available to farmers. The pandemic in a sense made my data collection more efficient and reduced both time and travel costs when it came to gathering data.

Alongside these benefits that applied when conducting remote interviews, there were also disadvantages. These relate to a reduced ability to interpret gestures and intonations that can be seen online or heard over the telephone. This made the interview situation more complicated to structure and perhaps made it harder to anticipate or interpret the dynamics in some interviews. In addition, I always prefer to get an impression of the broader situation an interviewee is in, of the context that an interviewee experiences every day, by conducting interviews at their home or place of work. This allows me to gain a more complete picture of their day-to-day lives and environments. Conducting interviews by software and telephone does not allow me to attain this picture. Hence, my thoughts about online and telephone data collection in qualitative research are ambivalent: while this approach can save time and money, allows for flexibility and takes into account the needs of interviewees, it also influences the context and thereby the impressions that a researcher might get.

5 Trajectories of livestock transitions as preservation, modernization, transformation[16]

Sustainability Science
https://doi.org/10.1007/s11625-022-01161-8

SPECIAL FEATURE: ORIGINAL ARTICLE

Sustainability in Agri-Food Systems: Transformative Trajectories toward the Post-Anthropocene

Preservation, modernization, and transformation: contesting bioeconomic imaginations of "manure futures" and trajectories toward a sustainable livestock system

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Received: 12 August 2021 / Accepted: 13 April 2022

Abstract
In discourses on sustainability, its underlying conceptualizations and meanings, the role of imaginations and their influence on concrete social practices and mutually dependent sociomaterial structures have been overlooked. Therefore, our article uses Adloff and Neckel's (Sustain Sci 14(4):1015-1025, 2019) conceptual framework to explore the role of imaginations in generating different trajectories from a concrete environmental problem, namely issues attributed to manure surpluses in Germany, to assess the hurdles and conflicting goals of a transformation toward a sustainable livestock system. Our study builds on qualitative, semistructured, and problem-centered interviews with both new innovation actors and incumbent actors in the current system. Our results show that different trajectories of "manure futures" exist, as we identify "preservation", "modernization" and "transformation" as trajectories representing ideal types of change. We discuss the results in light of the theory of imaginations and reflect on the usefulness of the concept of imaginations for analyzing environmental discourses and practices. Furthermore, we find that normative framings of problems rather than factual knowledge describe contesting imaginations as barriers to sustainability transformations, a point that must be acknowledged when developing a sustainable livestock system. We conclude that contesting imaginations could result in conflicts that must be moderated as drivers for change yet could also point to transformations that are already underway.

Keywords Imaginaries · Socio-technical transitions · Future visions · Agriculture · Socio-ecological conflicts

[16] This chapter has been published as Friedrich, Jonathan; Zscheischler, Jana; Faust, Heiko in *Sustainability Science* (2022): Preservation, modernization, and transformation: contesting bioeconomic imaginations of "manure futures" and trajectories toward a sustainable livestock system. doi: 10.1007/s11625-022-01161-8. An earlier version of this chapter has been presented and published at GEWISOLA conference 2021 as Friedrich and Zscheischler (2021).

5.1 Introduction

The contemporary geological epoch, which is characterized as either the Anthropocene (Lewis and Maslin, 2015) or the Capitalocene (Malm and Hornborg, 2014; Moore, 2017), has increased the pressure on global socioecological systems, thereby creating a need for sustainable change and transformation (Folke et al., 2021; Steffen et al., 2015). However, what exactly this change means remains an open question. Sustainability is a strongly normative concept that has multiple meanings and definitions and can even present conflicting goals (Luks and Siebenhüner, 2007; Schneider et al., 2019; Schneider and Rist, 2014).

In general, the term "sustainability" is oriented toward the future and thus necessitates imagining (contested) desired future states of social, economic, cultural and ecologic development (Adloff and Neckel, 2019; Priebe et al., 2021). Various studies have aimed to cluster the different narratives, imaginations, future visions and potential pathways of sustainability at different scales and spatialities, such as in different sectors or in relation to specific issues, and with different methodologies (e.g., Constance, 2018; Davidson, 2014; Knappe et al., 2019; Longhurst and Chilvers, 2019; Soetebeer, 2015; Steffen et al., 2007). Such attempts include discourses such as those on degrowth, just transitions, green growth, social-ecological transformations and sustainable intensification (e.g., Brand and Wissen, 2018; Constance and Moseley, 2018; Friedrich et al., 2021b; Hickel and Kallis, 2020; Kothari et al., 2014; Levidow, 2018; Swilling, 2020).

Recently, Adloff and Neckel (2019) have introduced a conceptual framework of "futures of sustainability" to grasp how imagined futures, i.e., imaginations, currently influence concrete practices and mutually dependent sociomaterial structures. The novelty of the framework is that it highlights and acknowledges the role of imagined futures in shaping the present in terms of practices and sociomaterial structures. Thus, the framework understands the human embodiment of social practices (following theories of social practices, e.g., Bourdieu, 1977; Reckwitz, 2002, 2003) as being embedded in imaginations and mutually dependent on sociomaterial structures.

Based on the three analytical categories of social practices, sociomaterial structures and imaginations and their interplay, Adloff and Neckel (2019) conceptualize and differentiate among three different trajectories of sustainability: modernization, transformation, and preservation. The modernization trajectory is shaped by imaginations such as "faith in technological progress", "adaptation to environmental challenges", and a "green economy" and thus is manifested in innovation design and results in support for existing socioeconomic structures. The transformation trajectory imagines "real utopias" and a "fundamental societal transformation" and is embodied in practices such as care and sufficiency, thereby aiming to implement new structures to align with the earth system. The control trajectory is based on imaginations such as "technocratic ideals of immunity and resilience", shaping practices such as geoengineering and surveillance and producing sociomaterial structures of military and state control (Adloff and Neckel, 2019). These three trajectories and their imaginations, practices and structures are not mutually exclusive and may intersect in practical arenas of sustainability transformations.

Adloff and Neckel (2019) argue that their theoretical concept must be substantiated with empirical evidence to prove the identified trajectories and the applicability of the sociological concept in specific socioenvironmental contexts. This need is underlined by Delanty (2021), who has called for more empirically grounded research regarding the framework and how imaginations shape "trajectories out of the Anthropocene" (cf. Keck, 2021). Furthermore, researching

imaginations also allows us to reflect on potential challenges associated with these (desired) future states to modify ongoing change processes. Beckert (2018) has shown that past expectations and imaginations that led to past practices "colonize" the present through, e.g., financial commitments and investments in the economy (see also Friedrich et al., 2022b). We argue that, in turn, current practices are not only influenced by future imaginations but can also "colonize" the future, thereby influencing future generations and their living environment. In the context of the sustainability debate, particularly the ethical and philosophical debate, these questions have been described as questions of intergenerational justice (e.g., Meyer, 2018).

Against this background, our article uses the German livestock system (see chapter 5.4.1) as a case study of a concrete socioenvironmental issue to prove the empirical applicability of the theoretical concept. This approach allows us to uncover trajectories of "manure futures" and how imaginations shape specific practices and structures of the present and future, thereby contributing to an empirical reflection and substantiation of Adloff and Neckel's (2019) conceptual framework. In regard to the special issue (cf. Keck, 2021), our article contributes to the overarching aim of what futures are imagined and how. Thus, our article answers the following research questions:

- What trajectories of manure futures are visible in the livestock system with respect to imaginations, social practices and mutually dependent sociomaterial structures, and how are they constructed?
- What conclusions can be drawn regarding the design of transformative action and existing barriers for the design of a sustainable livestock system?

First, we will theoretically elaborate on imaginations and their role in explaining and shaping social practices and structures more broadly before presenting the results of our case study. We will discuss our findings in relation to implications for both the theory and practice of researching imaginations and designing a sustainable livestock system.

5.2 Imaginations, social practices and sociomaterial structures

5.2.1 Clarification of terms

Research on imagination and imaginaries[17] has been evoked in recent times based on the work of Castoriadis (1990) on social imaginaries (Adams et al., 2015). Imaginations express fictional future states of living. These include desired states of living and dystopian imaginations that ought not to come into being. However, imaginations not only allow researchers to semantically describe potential future states of living but also arguably influence current social practices and the development of sociomaterial structures (Adloff and Neckel, 2019). They can materialize in innovation design as so-called sociotechnical imaginaries[18] (Jasanoff, 2015a; Jasanoff and Kim, 2009) and are incarnated in economic decisions, ultimately accompanying future expectations (Beckert, 2013, 2018).

[17] We understand both imaginations and imaginaries as being socially embedded and thus use the terms synonymously in the following; see also Adloff and Neckel (2019).

[18] The concept of sociotechnical imaginaries was initially developed by Jasanoff and Kim (2009) to analyze "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects". This definition was further adjusted by Jasanoff (2015) to accommodate the visions of different groups of stakeholders or collectives in aiming to create a desirable future.

Imaginations can be described as bundles of hopes, wishes, expectations, and narrations, including moral and affective dimensions (Adloff and Neckel, 2019; Beckert, 2018). They can be both individually and/or collectively held, but they are socially embedded and constructed. They are fictional in that the future cannot yet be known and is uncertain, therefore, it is described through stories or narratives that ought to happen (Beckert, 2018; Esposito, 2007). Imaginations are theoretically linked to ideologies. Ideologies, according to Althusser (1968), have an imaginative sphere that captures the relation of subjects to the surrounding material sphere. Here, imaginations are part of ideologies, which are somewhat global and touch upon multiple spheres of subjective and collective behavior.

Beckert (2018) emphasizes that imaginations are oriented toward the future. Nevertheless, they are based on their institutional and social embeddedness, so historical developments are also important in their construction (see also Priebe et al., 2021 for an example of how historical frames of sustainability influence future imaginations of sustainability). Therefore, knowledge and perceived realities such as those described in the problem frames of actors are central to the construction of imaginations at both the individual and collective levels of society. For example, Fladvad and Hasenfratz (2020) show how contemporary and future diagnoses of "unsustainability" mutually interact in imaginations of sustainability. Thus, the imagination of "crisis" leads to other desired futures than, e.g., "normalization", in that "crisis" specifies the need for change, whereas "normalization" justifies business as usual. Based on these theoretical considerations of imaginations, in the following, we will develop categories from the literature to guide us in answering our research questions.

5.2.2 Theoretical-conceptual considerations for the analysis of manure futures

Adloff and Neckel (2019) theoretically elaborate on potential future trajectories of sustainability. As the aim of this study is to empirically uncover different trajectories for the specific socioenvironmental problem of manure surplus (see chapter 5.4.1), we have extended the framework by adding categories from the literature (cf. Adloff and Neckel, 2019; Beckert, 2018; Berger and Luckmann, 1966) to structure our analysis. Adloff and Neckel's (2019) conceptual framework describes our central considerations, but in an attempt also to grasp the construction, development and embeddedness of imaginations through a social constructivist approach (and to make imaginations empirically tangible), we have extended the framework by understanding imaginations as socially constructed realities[19] (see Figure 3, cf. Berger and Luckmann, 1966).

As an overview (detailed description below), we understand imaginations (4) as being constructed (i) through sources and types of knowledge (1) as well as the meanings of subjects that are detectable in the frames of problems (2) and manure (3). Imaginations shape (ii) present and future social practices (5) and mutually dependent sociomaterial structures (6), thereby (re)producing (iii) the knowledge and meanings of individuals or collectives (Adloff and Neckel, 2019; Beckert, 2018; Berger and Luckmann, 1966; Longhurst and Chilvers, 2019).

[19] Adloff and Neckel (2019) do not explicitly exclude this view, as imaginations are embodied in social practices, which are foremost reproducing orders of knowledge and cultural interpretive patterns (cf. Reckwitz 2021, p. 56f.). However, Adloff and Neckel (2019) do not clearly highlight that they understand imaginations as socially constructed (fragmented) reality through a social constructivist approach, whereas we are highlighting this point in the following, thereby following the call of Longo et al. (2021) to include social constructivist and social realist approaches in sustainability science.

Adloff and Neckel (2019) center their theoretical framework around imaginations (4), social practices (5), and sociomaterial structures (6). They argue that imaginations shape and reproduce both practices and mutually dependent structures in society. In their focus on social practices, they build on theories of praxeology as an alternative to theories of action (cf. Reckwitz, 2002, 2003). By sociomaterial structures, they refer to infrastructures, such as communication and biophysical infrastructures that are mutually dependent on social practices and (may) need to be transformed to meet imagined futures of sustainability.

As "imaginations tie together cognitive, evaluative, and affective dimensions—knowledge, values and emotions" (Adloff and Neckel, 2019: 1017), (past) knowledge and experiences are a central category in the construction of imaginations. Following a social constructivist approach, we understand imaginations as imagined (fragmented) future realities, thus, knowledge (1), including the meanings of subjects (2), (3), which is central to the construction of realities, "is the sum total of 'what everybody knows' about a social world, an assemblage of maxims, morals, proverbial nuggets of wisdom, values and beliefs, myths, and so forth […]" (Berger and Luckmann, 1966: 83). Knowledge in this respect circulates within society and is embedded in (sub) worlds of meaning. Accordingly, collectives in society create (fragmented) realities based on their knowledge circulation, the sources of this knowledge (1), and the meanings of subjects (2), (3). Subsequently, individual actors can function as representatives for specific (sub) worlds of meaning, as their knowledge is socially constructed, circulated and embedded[20].

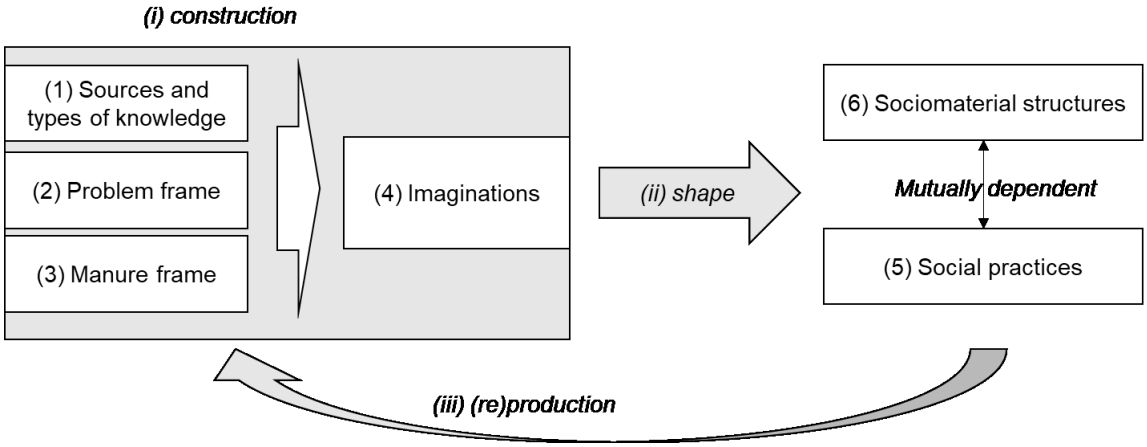

Figure 3: Framework: construction of imaginations and the shaping of social practices and sociomaterial structures

Social practices are shaped by imaginations (Adloff and Neckel, 2019), as explained through theories of social practices (also called praxeology), and made observable through interpretive understandings of practical knowledge (Reckwitz, 2002, 2003, 2021). For example, technological design as a social practice is shaped by and responsively reproduces imagined realities. Hence, knowledge is also central to explaining the social practices of innovation design (Geels, 2020). In this respect, Longhurst and Chilvers (2019) have shown how sociomaterial answers (sociotechnical practice) relate to the contested perceptions of problems (in their framework covered by the "meanings" dimension), which in turn are related to knowledge, values and beliefs because they express the perceived reality of subjects or collectives and are embedded and entangled in sociocultural norms and values (Friedrich et al., 2021a). Problem frame (2) thus functions not only

[20] We focus on the shared understandings of meanings and knowledge rather than individual differences that may be created through the situatedness and positionality of individual subjects.

as an example of the meanings of subjects but also as a contemporary diagnosis of the present that marks the starting point for the development of imaginations. Cognitive frames that describe this contemporary diagnosis and build the basis for future imagination are a product of the historical knowledge and experience of both society and individuals (Beckert, 2018; Priebe et al., 2021). Thus, practices and structures are not only embedded in imaginations but also reproduce (iii) knowledge and frames of problems (see also Reckwitz, 2002, 2003, 2021).

Regarding the context of our case study, by attempting to unravel the trajectories of manure futures, we explicitly integrate the meaning of manure (3), in terms of its cognitive framing, as an individual category that can affect the final imaginations of individuals and collectives. Furthermore, in the design of sociotechnical innovation, the motivation to design an innovation requires assembling the problem frame through the knowledge and experiences as well as the imaginations and expectations of the actors. We thus include motivation as an additional category that refers only to the reasons for developing innovations.

5.3 Methods and research design

This study is part of the research project BioKum (Cumulative effects of bio-economic strategies for a more sustainable agriculture) that aims to gain a better understanding of current sustainability challenges in the German livestock system, with a specific focus on nitrogen surpluses (for a detailed case study description, see chapter 5.4.1). For us, the livestock system, with its practices, complex sociocultural and ecological interactions, diverse perspectives and ethical conflicts, global interdependencies and economic constraints, is a promising unit of investigation for the application of Adloff and Neckel's (2019) framework. To uncover the multiple trajectories of manure futures in various regions of Germany, we chose a qualitative approach that followed a deductive–inductive research strategy across twelve problem-centered interviews.

5.3.1 Data collection

We clustered our interview partner collection according to the multi-level-perspective (MLP) of sociotechnical transitions (Geels and Schot, 2007). Thus, our population consists of both (bioeconomic) innovation actors and actors of the existing socio-technical regime (see detailed description below). We followed the working hypothesis that actors in the existing sociotechnical regime[21] will have different worldviews, knowledge, perceptions of problems, and future imaginations than innovation actors. This fact means that the actors can be viewed as carriers of alternative practices that are embedded in imaginations. As innovation adoption and diffusion depend upon the interactions of niches and the sociotechnical regime (as well as the landscape level), this understanding allowed us to uncover a wide range of different imaginations as well as potential differences and conflicts associated with conflicting future imaginations, practices and structures. Thus, before the interviews were conducted, potential interviewees were clustered based on whether they belonged to the group of bioeconomic innovation actors or actors who constituted the socio-technical regime. Thus, key societal actors included those from policy, science and civil society that constitute the current regime. Bioeconomic innovation actors were defined as people or institutions that had been or currently were designing new practices for reusing or recycling

[21] We refer to the sociotechnical regime as the current existing dynamic-stable coalescence and interplay of different actors such as consumers, science, and economy of a particular sector or topical issue. This view highlights their (embodied) rules and (social) practices (for more details, see Geels and Schot (2007)).

manure, including the development of new products, new processes, substitute products or new behaviors (Bröring et al., 2020). A list of actors creating sustainable manure solutions was based on online research on this topic and included actors from academia and the economy. For both groups, a list of potential interviewees was specified on the basis of online research and discussion. Based on this list, snowball sampling (cf. Reed et al., 2009) was used to identify potential additional interviewees, starting with actors who were randomly chosen beforehand. The interviewed actors are representatives of the organizations we identified through our sampling. There was no spatial focus on one specific region, however, because the manure surplus occurs predominantly in the German states of Lower Saxony and North Rhine-Westphalia, actors from this area were disproportionately included in the sample. Table 4 specifies the interviewed actors.

In total, twelve interviews were conducted between May 2020 and October 2020: six with innovation actors and six with actors associated with the socio-technical regime. Due to the COVID-19 pandemic, we avoided personal meetings and conducted online video interviews. The interviews took between 39 and 82 min and were conducted in German[22]. The interviews were stopped after content saturation was achieved. This principle applied to recurring arguments that were similar to the content of prior interviews.

During the process of conducting the interviews, we realized that it was impossible to separate the collective and individual opinions of our interviewees. While we aimed to understand the opinions of collectives represented by the corresponding actors, the empirical reality showed that these are ultimately intertwined with personal experiences and perspectives. Thus, both sides are subject to a co-constitutive relationship, and separation is ultimately not possible. We, therefore, understand the presented views of the actors as hybrids of collective and individual opinions that also result from experiences and social entanglements beyond the institutional context.

Table 4: Overview of the interviewed actors incorporated into the sample (interviewees are representatives of the respective actors)

Actor description	Number of actors interviewed
Bioeconomic innovation actors from the economy	4 (IP 1, 2, 5, 6)
Bioeconomic innovation actors from science	2 (IP 3, 4)
NGO actors representing nature and environmental conservation	2 (IP 7, 10)
Organic farmers organization	1 (IP 9)
Farming consultancy	1 (IP 8)
Farmers organization	1 (IP 11)
Water suppliers organization	1 (IP 12)

5.3.2 Data analysis

All interviews were recorded, fully transcribed, evaluated, and interpreted according to the "type-building qualitative content analysis" guidance from Kuckartz (2014). Data processing was performed with "MAXQDA" software. The analysis was based on an iterative deductive–inductive research strategy. In the first step, we coded the data deductively by applying the deductive category of the analytical framework developed in Figure 3. These categories describe the attribute space (Kuckartz, 2014). In the second step, additional inductive categories were derived from the material to build subcategories for the attribute space (Figure 3) in response to the specific empirical

[22] As the interviews were conducted in German, the excerpts used in this article have been translated to English by the authors.

example. We followed the proposed trajectories of Adloff and Neckel (2019) in building our types but also refined the category system for the material through coding. Additional trajectories were identified through "polythetic type building" (Kuckartz, 2014). The individual cases were attributed to the trajectories in relation to their proximity (see Figure 4). The coder subjectively located the cases in the graph by qualitatively matching the content of the ideal types (see also Kuckartz, 2014.

5.4 Case study and results: contesting manure futures as preservation, modernization and transformation

The next section first introduces the specifics of our case study in the German livestock system (chapter 5.4.1) before we present our empirical results. As an overview, based on the analysis of the qualitative interviews, we identified three different trajectories (see Table 5): preservation, modernization and transformation. The following sections (chapter 5.4.2, chapter 5.4.2, and chapter 5.4.4) describe the trajectories in detail. As these trajectories present ideal types of change, chapter 5.4.2 describes the proximity of the interviewed actors to these ideal trajectories.

5.4.1 The case study of the German livestock system

Most sustainability challenges can be viewed as wicked problems or complex socioenvironmental issues, including multiple practices and politics of unsustainability, which thereby threaten the biophysical conditions of life on earth. These conditions and their limits are well described by the planetary boundaries concept (see Rockström et al., 2009; Steffen et al., 2015).

The livestock system is one in which different dimensions of unsustainability (such as biophysical conditions of life, practices, structures, and politics) become explicit and place pressure on the system to change. There is an ongoing discussion about how to transform agrifood systems, and specifically livestock systems, in (sustainability) science and the public debate (e.g., Franz et al., 2018; Friedrich et al., 2021a; Friedrich et al., 2022b; Friedrich et al., 2021b; Nowack and Hoffmann, 2020; Tamásy, 2013). This system is, therefore, a prospective unit of investigation, as it intersects biophysical, social, cultural and societal aspects of sustainability on a local, national and even global level (for a detailed description of the intersections, see below). On the one hand, these entanglements (such as those described in Nexus approaches, e.g., Franz et al., 2018) make it difficult to research, but on the other hand, they offer the possibility of generating results that can be transferred to other socioenvironmental contexts (under consideration of the specific context and system boundaries).

In the following, we outline the current sustainability issues attributed to the livestock system that make it a complex socioenvironmental issue. Biophysical issues include high emissions of methane and nitrous oxides, which contribute to climate change (Tilman and Clark, 2014) and fine dust pollution, and nitrate surpluses, which pollute waters and soils, leading to eutrophication. In addition, social issues are attributed to precarious working conditions in the meat processing industry (Friedrich et al., 2021b; Wagner and Hassel, 2016), and poor animal welfare has raised questions about ethical responsibility, as have telecoupled effects such as that of land-use change for fodder production in South America on indigenous land rights (Franz et al., 2018; Friedrich et al., 2021a; Sauer, 2018). Cultural aspects of diets, such as those associated with meat consumption among individuals or collectives as well as vegetarian or vegan diets, complete the picture of a complex socioenvironmental issue.

To disentangle such complex global interlinkages, we focused our case study on local developments in relation to the nitrogen surplus associated with manure as a product of the German livestock system. Manure and nutrient surpluses are the most perceptible symptoms of an unsustainable system: the odor is well known to neighbors; the eutrophication of groundwater threatens drinking water quality, leading to increased denitrification costs; and the eutrophication of surface water bodies impacts aquatic ecosystems, leads to biodiversity loss (Umweltbundesamt, 2019), and even impacts the use of water for bathing. These local issues associated with manure are substantiated by the nitrogen cycle, which has been specified as a high-risk biochemical flow in the planetary boundaries concept (Rockström et al., 2009; Steffen et al., 2015). In addition, legal actions against member states such as Germany by the European Union (EU) have reinforced the pressure to change.

In terms of sustainability-oriented transformations in agrifood systems and beyond, the concept of a sustainable (circular) bioeconomy has recently been evoked (Giampietro, 2019). Several policy actors (e.g., the EU and Germany) have published bioeconomic strategies highlighting the role of innovation actors in the development of bioeconomic innovations and international competition in moving toward a bioeconomic future. This role also applies to the case of manure, as bioeconomic innovations such as recycling fertilizer (e.g., Pintucci et al., 2017) and cultivating insects (e.g., Čičková et al., 2015) and duckweed (e.g., Stadtlander et al., 2019) are currently being developed to (partially) close nitrogen cycles with the aim of contributing to a more sustainable agrifood system (Friedrich et al., 2021a; Friedrich et al., 2022b).

In the context of these developments, how manure futures are imagined by these actors, which imaginations guide which practices and the development of which structures, what other ideas from civil society and farmers exist to solve the issues associated with manure and what future these are aiming toward remain open questions.

Table 5: Overview of trajectories of "manure futures": preservation, modernization and transformation; for attribute space description, see Figure 3 and chapter 5.2.1

Attribute space	**Trajectory**		
	The preservation trajectory (chapter 5.4.2)	**The modernization trajectory (chapter 5.4.2)**	**The transformation trajectory (chapter 5.4.4)**
(1) Sources and types of knowledge integrated	Reductionist: work context: experiences, networks; scientific sources	Intrasectoral: work context: experience, networks	Diverse/complex: scientific sources; discussion formats; societal debate; work context
(2) Manure problem frame	Legal rules of application; other actors are responsible; no manure problem (anymore)	Stakeholder interest; deregulation, globalization, nitrogen cycle, legal rules of application	Integrative: usage of manure; environmental issues; nitrogen cycle and planetary boundaries; deregulation; globalization; social consumption
(3) Manure frame	Resource, fertilizer	Recyclable material, resource, fertilizer	Resource; fertilizer; "environmental disaster"
(4) Imaginations	(Economic) growth, preservation of status quo	Green growth, technological fix/faith in technological progress, sustainability through spatial decoupling and closing the loop	Fundamental transformation; changed human-nature relationship; challenging economic growth (dystopia)
(5) Practices	Free market; innovations: transport and recycling; politics that are reliable for farmers	Innovations: recycling, circularity; free market; labels of sustainability; political support for innovations; science-based practices	Innovations: circular, recycling; consumption practices (sufficiency); cultural change; regulations/laws
(6) Structures	Preservation of existing structures	Adaptation of existing structures; structural support for innovations	Structural change to preserve the value of nature; small-scale agriculture
Motivation of innovation actors	Legal reasons: to meet legal requirements through innovations	Economic reasons: capital accumulation through innovations	Ecological reasons: innovations can contribute to more sustainable agriculture

5.4.2 The preservation trajectory

The preservation trajectory is characterized by imaginations of a preservation of the status quo; thus, it focuses on economic productivity and growth in the agricultural sector and livestock system (see Table 5). Practices that are shaped by these imaginations are related to regulation aversion in terms of demanding a free market: "The economy always has to come up with something on its own somewhere […]. But if subsidies play a role, if someone somehow applies for something from Brussels or from another side, then that is actually always short-lived. Or even if the state intervenes with restrictions or subsidies, [or] somehow wants to promote something, then that is always only seen quite shortsightedly" (IP 6). However, innovations such as the reciprocal transport of manure and fodder between arable and livestock regions or the recycling of manure are viewed as complementing the existing system and are practices that are embedded in this trajectory. This trajectory also relates to the mutually dependent preservation of existing structures of livestock production and agriculture against the background of feeding the population in Germany (in terms of an obligation): "We believe that Germany, with its favorable production locations, also has a responsibility to use the production opportunities here. And to do so as productively as possible, but also as sustainably and efficiently as possible. So we shouldn't give ourselves a slender foot in Germany and say we're going to extensify our production in Germany. And then we import all our food. Instead, we have to use Germany as a production location to ensure security of supply" (IP 11). What is regarded as a manure issue in this regard is the regulation of manure application (such as through the nitrate directive), as manure problems are no longer perceived, as described by IP 6: "And therefore, these surpluses are actually only marginal. So, with these surpluses, to transport them or to get rid of them here, we can always cope with that or have actually already coped with it" (IP 6). The issue of nitrate surplus is thus regarded as a matter of the past. Nonetheless, other sources than livestock farmers are regarded as responsible for the (past) issues that led to the introduction of the nitrate directive—in particular, biogas plants. Manure is framed as a resource and fertilizer as a valuable component of agricultural production. Knowledge of this trajectory is generated in work contexts, such as personal and work-based experiences, and through agricultural networks as well as scientific sources, leading to a rather "reductionist" framing.

5.4.3 The modernization trajectory

The modernization trajectory is characterized by imaginations of green growth, a technological fix for environmental issues, as is attributed to the manure surplus, and a general faith in technological progress (see Table 5). The green growth imagination relates to the development of innovations that are expected to be highly profitable due to the pressure for solutions that accompanies the manure topic and thus also acknowledges the associated environmental issues: "And I can say that if you have a solution today that works, you're a millionaire. Because the pressure is just there. So the pressure is immense, and there is no solution that actually helps here" (IP 1). Sustainability is imagined through a spatial decoupling of the production and application of manure and the circular idea of closing loops that both feed into the green growth imagination. Spatial decoupling thereby relates to the introduction of manure-based bioeconomic innovations, such as a circular orientation and manure recycling, which in turn allow manure to be spatially decoupled as a product of livestock production from the legal rules of area-bound application on the field, thereby allowing farmers to close cycles: "That means that we have a surplus of manure here, which is caused by feeding that does not come from here. The cycle is no longer right. That's

why I said earlier: 150 years ago, we had exactly this cycle, didn't we? […]. And with our technology [recycling fertilizer], you can say that we can do that [close the cycle as we did 150 years ago] on a larger scale. Across farms" (IP 5). As innovations are viewed as pivotal for closing the loops, political support that simplifies the development and bureaucracy that is attributed to processes of innovation development are embedded as practices in these imaginations. Beyond a focus on manure-based bioeconomic innovations and diffusion that relate to this trajectory, further practices are introduced under sustainability labels that accompany consumption and, in relation to manure, document the sustainability of livestock products in regard to the environmental issues hitherto associated with manure usage. In general, the highlighted practices are labeled science-based. These practices relate to the adaptability of existing structures. Such adaptation means adjustments of the sociomaterial structures of production, such as those driven by the bioeconomic, circular innovations of recycling, which change the sociomaterial architecture of manure application and usage without questioning the general model of livestock production. The manure problem is framed as the surplus of manure originating from general economic developments in recent years, such as globalization and deregulation, that have led to open nutrient cycles. Thus, the problem to be solved is specified by the applicable legal rules (in particular the nitrate directive) that must be followed and the broad interests of multiple stakeholders, such as farmers or the mineral water supply: "But the thing that we also see is, with many of them, especially those that have some connection with livestock, and sometimes it's not so obvious, so also mineral wells, are interested in such solutions. […] So it is now not only necessarily meat or milk production but also there. So there is a broad interest and a broad rethinking to include these things [new forms of production and manure recycling]" (IP 1). In this trajectory, manure is framed as a resource, fertilizer, and recyclable material that has great potential for further use and capital accumulation. The knowledge for these framings is generated in work contexts, namely the experience of the actors and their networks, such as in the search for new development options for one's own company, which can be characterized as intrasectoral.

5.4.4 The transformation trajectory

The transformation trajectory is characterized by the imaginations of a fundamental transformation, a changed human-nature relationship, and challenging of the economic growth paradigm (see Table 5). The practices that are shaped by these imaginations are diverse; they include innovations such as recycling and circular-oriented practices (also organic agriculture) as well as practices that can be attributed to sufficiency, such as changed social consumption practices, cultural changes in values and norms, and political rules and laws that aim to conserve the instrumental and intrinsic values of nature. Cultural change is, for example, attributed to consumers valuing sustainably produced goods: "I think the wish for society is that society basically appreciates the production of sustainable food. That society sees when a farmer now contributes significantly more with respect to public things, i.e., water, promotes clean water, and promotes insects or the like. That society is willing to honor that" (IP 10). These practices thus specify a structural change in agricultural production and consumption to conserve the value of nature (intrinsic and instrumental) against the background of visions such as that of small-scale agriculture: "So in any case, already still small-scale agriculture. […] So, small structures make a living possible [for farmers] and just a slow, but still clearly visible, transformation process to fewer animals, more crop rotations, more diversity in the field, fewer pesticides. […] So in itself, we simply need to look

at the whole thing again and take out some big adjusting screws and with clear changes in laws, clearly come closer to nature" (IP 7). The manure problem frame is integrative and connects different problems, i.e., the current use of manure, environmental issues such as eutrophication, the nitrogen cycle with respect to planetary boundaries, deregulation, the more general globalization of agricultural production, and the societal consumption of livestock products such as meat: "There's the flaw in the system. We eat too much meat. We want cheap meat. […] But factory farming naturally leads to this huge amount of manure. And then we really have a problem. It then becomes waste. Or it is then treated like waste, yes. You simply don't know where to put it" (IP 12). Manure is regarded as a resource and a fertilizer if used correctly, as it can otherwise become an "environmental disaster" (IP 7) or the aforementioned waste (IP 12). The knowledge of this trajectory is diverse and can be characterized as complex, as it is generated by different sources and in different contexts, such as scientific sources, discussion formats with different actors, and societal debate and (interdisciplinary) work contexts.

5.4.5 Distribution of actors among trajectories

The trajectories of preservation, modernization, and transformation represent ideal types of change that ought to happen. In Figure 4, the trajectories are organized in terms of how they change the status quo. The interviewees are attached to this grouping in relation to their individual proximity to the trajectories developed above.

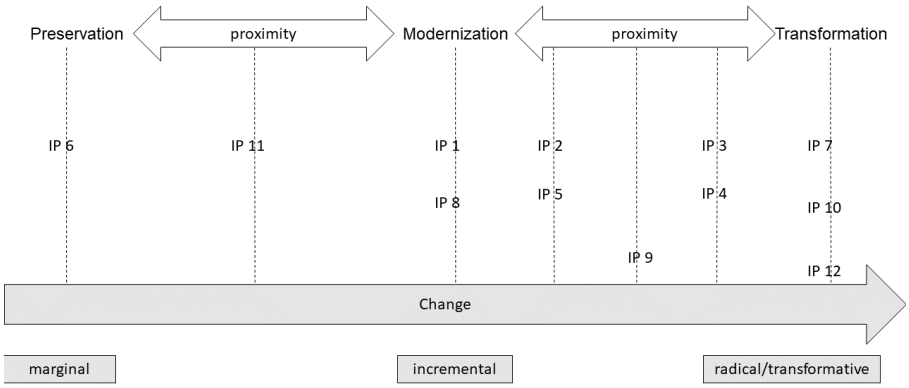

Figure 4: Proximity of interviewees to trajectories (preservation, modernization, transformation) and scope of change.

With respect to proximity, the background and/or motivation of the interviewed actors is relevant to explaining their position. IP 6, who had already developed an innovation that allowed for the reciprocal transport of manure and fodder between different regions of Germany, argued that this innovation had already led to the solution of the issue; thus, the actor intended to maintain the status quo, as legal requirements were being met, and changes would jeopardize the actor's business model (see Table 5). In contrast, IP 7, IP 10, the NGO actors, and IP 12, representing water suppliers (not all actors were directly related to agricultural production), argued for a changed human-nature relationship oriented toward conserving both the instrumental and intrinsic value of nature. These actors highlighted the importance of adjusting every practice and structure to align with this goal and thus also called for transforming and challenging a focus on economic growth; thus, all these actors are attributed to the transformation trajectory. The actors IP 1, IP 2 and IP 5 (innovation actors from the economy), who were all close to the ideal type of modernization, were motivated by the potential for capital accumulation through innovation diffusion (see Table 5) while

at the same time closing nutrient loops; thus, they are examples of so-called green growth imaginations. IP 3 and IP 4, who were innovation actors from scientific fields, could be called hybrids of the modernization and transformation trajectories. Both were motivated to design innovations for ecological reasons (see Table 5). They called for practices of efficiency and sufficiency, but in contrast to the transformation pathway, they did not highlight the importance of regulations and structural change to align with the values of nature. A similar proximity to both the modernization and transformation trajectories is attributed to IP 9, a representative of an organic farming organization. This actor viewed organic farming as a prototype of how nutrients in the form of manure can be used efficiently to benefit both humans and nature. Although this actor specified the need for change, such as in terms of reduced livestock production intensity, the difference rested in the clear focus on organic farming in contrast to the multiple practices of the transformation trajectory. IP 8, who belonged to a farming consultancy, was proximate to the modernization trajectory, as this actor focused his argumentation on the profitability of farming while at the same time viewing innovations as important to enable farming to adjust to environmental issues such as those driven by the manure surplus. IP 11, who represented a farming organization, was a hybrid of the modernization and preservation trajectories. In contrast to IP 6, who represented the preservation trajectory, this actor viewed the current manure surplus as a regional issue and saw potential in using new innovations. However, this emphasis on the preservation of the productivity of agricultural livestock farming separated this actor from the modernization trajectory, as this emphasis implies only marginal change.

5.5 Discussion

The aim of this article was to identify trajectories of "manure futures" in relation to differing imaginations, social practices and sociomaterial structures and their underlying construction, thereby proving the applicability of the sociological conceptual framework of Adloff and Neckel (2019) to a concrete environmental issue. We identified three different trajectories, namely preservation, modernization and transformation, which are shaped by different imaginations of manure futures, leading to different practices and mutually dependent structures. In the following, we discuss our findings in relation to both reflections and implications for theory, and practical implications for the design of a sustainable livestock system, before reflecting on our methodology.

5.5.1 Theoretical reflections and implications for the concept of imaginations

Applying the concept of Adloff and Neckel (2019) to the specific case of manure allowed us to cluster different ideas of how to solve the manure issue in terms of trajectories around the concept of imaginations, practices and structures. However, the interviewed actors (see Figure 4) clearly showed hybrid versions of the trajectories, meaning that these actors embody intersecting trajectories and that a clear, empirical mapping of each actor to one trajectory is not always possible. Adloff and Neckel (2019) have similarly argued that their trajectories could intersect in practical arenas of sustainability discourses. Nevertheless, the identified trajectories and the associated imaginations, practices and structures allow us to conceptually frame the manure discourse and to show which contesting imaginations exist with regard to the design of a sustainable livestock system (see chapter 5.5.2).

The results indicate that the approach of Adloff and Neckel (2019) is applicable to specific environmental issues, discourses and actions, such as those found in the German livestock system.

When comparing our results with the trajectories of Adloff and Neckel (2019), we identified an additional trajectory: preservation. While the authors (ibid.) start from the hypothesis that society is currently characterized by multiple unsustainable practices, a preservation trajectory that specifies imaginations of no change or only marginal change and builds on neglecting the problem of "unsustainability" does not fit this model. We argue that, on the one hand, a preservation trajectory could be a specific case for the agrifood system, as agricultural sectors are described as highly stabilized through political interventions such as subventions and regulations (e.g., Common Agricultural Policy) to secure productivity. Therefore, actors base their expectations and imaginations on relying on these stabilized architectures, as Barnes et al. (2016) found in studying the livestock system. This architecture is complemented by longterm political-economic path dependencies[23] that apply to specific regions and sectors and influence the likelihood and scope of imagined change (e.g., Benoit and Patsias, 2017) as well as by incumbent actors in the socio-technical regime who reproduce rather than transform current practices and structures of the capitalist system (e.g., Friedrich et al., 2021a; van Oers et al., 2021). In addition, specific actors, such as the German "Bauernverband" (farmers' association), exercise hegemonic discourse and cultural power in the German agrifood system (see Heyen and Wolff, 2019). The farmers' association has been lobbying ever since its formation to preserve existing hierarchies and resource distributions in the agrifood system, thereby limiting the possibility of sustainable change. This development aligns with what Reckwitz calls the "order"[24] of social practices that gains a hegemonic character (cf. Reckwitz, 2021: 72 ff.). According to Reckwitz (ibid.), it is highly characteristic of modernity that these orders exist in the first place and are being challenged and changed over time. We argue that this fact is also visible in our case study, in which the current prevailing order— namely the preservation trajectory—is being challenged by the emergence of different orders of social practices, as is evident in the transformation and modernization trajectories. This situation could mean that we are currently witnessing a process of consistency building and "undoing orders" (cf. Reckwitz, 2021) in the German agrifood system. On the other hand, German society is characterized by multiple practices and structures that are not perceived as "unsustainable" by every individual. Thus, several actors neglect problems such as those associated with the denial of climate change (e.g., Walter et al., 2018) and other environmental issues. We argue that this issue may also apply to the case of manure and the preservation trajectory.

In contrast to Adloff and Neckel (2019), we did not identify a control trajectory. We attribute this difference to the specific case of agriculture. Imaginations that are related to the control trajectory specify far-reaching changes in the whole of society and the elements that constitute it. We argue that this trajectory does not appear in our empirical case due to the scope of changes at the level of every societal organization and constitution that it requires. As Germany relies on federal negotiation processes, another possible reason is that some subsystems are excluded from specific discourses. In our view, further empirical research covering other topics in the agrifood system in Germany could reveal this trajectory (see also chapter 5.5.3). Due to the empirical context

[23] These path dependencies exist on different levels of societal organization and are complemented by international and global developments, such as those described through the concept of food regimes; see McMichael (2009).

[24] Orders are being produced through "contingency closure processes" ("doing consistency") that challenge existing orders ("undoing orders") in how social practices are arranged and embodied by humans. Examples of orders include "neoliberalism" or "socialisms" (Reckwitz, 2021: 72ff.).

of our case, we extended the framework of Adloff and Neckel (2019) by adding categories. Based on these considerations and with respect to our empirical data, we identified the framing of problems and the framing of manure as central points for explaining different trajectories, their associated imaginations and how these imaginations shape practices and structures. This approach aligns with Delanty's (2021) critique of the framework of Adloff and Neckel (2019). Delanty (2021) argues that the "relation between actuality, that which exists, and potentiality, needs to be given greater prominence" (ibid.: 7) in the framework. We argue that the problem frame (partially) bridges this gap, as it describes the differing conceptualizations of what is perceived and regarded as the actual problem requiring change. This approach also means that it is not the factual knowledge that constructs imaginations but rather the attributions of meanings by actors, the "normative framings of issues and problematisations" (cf. Longhurst and Chilvers, 2019: 975). In this context, Reckwitz (2002, 2003) argues that "practical knowledge" is the basis for social practices[25] in the theory of praxeology. This author (ibid.) conceptualizes "practical knowledge" as knowledge in terms of interpretive understandings. This approach aligns with our theoretical conceptualizations and empirical findings in that the meanings attributed to actors are crucial for the construction of imaginations. We attribute these meanings to the interpretive understandings of Reckwitz (2002). Our study shows that when an actor does not perceive a problem (see the preservation trajectory), the ability to imagine something different is limited. In contrast, viewing the surplus of manure as just one aspect of unsustainability in the agrifood system means having an integrative/complex problem frame—and thus also imaginations that more fundamentally challenge contemporary practices and structures (see transformation trajectory). The framing of manure aligns with that frame, especially in the context of the routine of practices (cf. Reckwitz, 2002, 2003) becoming visible, e.g., if manure has always been treated as a fertilizer, this routine also becomes visible in future imaginations and accordant practices.

Another aspect that is visible in our empirical results and that we briefly touch upon in the following (see chapter 5.5.2) concerns temporal framings. Some interviewees do not directly relate to imagined futures such that they imagine a reality that is much different from the present. Rather, they rest on experiences and are oriented toward an existing or imagined past. Although interviewees were asked to think about the future, some are more oriented toward the past. This orientation still fits into Adloff and Neckel's (2019) framework, as imaginations can also be oriented toward what has existed and could recover. Thus, imaginations do not necessarily have to adopt utopian or dystopian ideas of what ought or ought not to be; in the end, whatever people imagine regarding the future shapes the social practices they embody. In addition, Reckwitz (2021) argue that late modernity is characterized by temporal hybridization in that societies and their imaginations orient toward different temporal framings, just as different pasts are always accessible through stories, movies, or other historical documents.

5.5.2 Implications for the practice and transformations of the current livestock system

Priebe et al. (2021) argue that it is not factual knowledge that is missing in designing sustainability-oriented transformations in general but rather that past frames limit societal change such that society is trapped and unable "to examine and challenge prevailing values, habits, and ways of thinking" (p. 82). From a psychological perspective, these tendencies can be attributed to aspects of "system justification" on the individual level (e.g., Feygina et al., 2010). These

[25] Social practices, in this respect, include both sociotechnical and economic practices.

tendencies are also visible in our case study (see also chapter 5.5.1). The three identified trajectories and their imaginations, practices and structures do not show new and different ideas of what has been discussed in the public debates of past years. Rather, they present already-existing ideas, such as a fundamental transformation that is often attributed to NGOs or actors from civil society, or the economic-centered perspective of "green growth"; also a technological fix for environmental issues that has prevailed in recent years; these ideas present growth and supply-centered pathways of no or marginal change to the status quo, respectively (e.g., Constance and Moseley, 2018; Friedrich et al., 2021a; Friedrich et al., 2022b; Friedrich et al., 2021b; Longhurst and Chilvers, 2019; Nightingale et al., 2020; Nowack and Hoffmann, 2020; Soetebeer, 2015). They are symbolic of the great importance of discourses and the role of dominant actors in shaping the foci and content of these discourses. In addition, this fact also shows that interviewees use different temporal framings when imagining the future (see also chapter 5.5.1).

Nonetheless, what is visible in our case study, when considering the results of the modified nitrate directive and recent developments in relation to manure after use (Friedrich et al., 2021a), is that bioeconomic ideas are flourishing, thereby following the modernization trajectory (see also Friedrich et al., 2022b). These ideas are strongly intertwined with the motivation of following the nitrate directive. This relationship indicates two things: first, the modification of regulations (in our case, the nitrate directive) can leverage new innovations to be developed and diffused, as argued by the interviewed innovation actors. Second, although different ideas of how to achieve sustainability (in terms of different "manure trajectories") exist, these are not necessarily being negotiated in society, rather, economic actors are performing their imaginations in practice. In our view, this aspect may be related to power imbalances within the current system that may lead to the manifestation of existing (unsustainable) structures and the mental lock-ins of capitalist imaginaries in the livestock system, as we argue elsewhere (Friedrich et al., 2021a; Friedrich et al., 2022b).

However, based on our empirical findings, we contend, with respect to other studies (e.g., Hochschild, 2016; Neckel and Hasenfratz, 2021), that the culture of societies and societal actors with respect to values and norms, emotions, and beliefs describes conflicting goals and imaginations and the associated practices and structures rather than factual knowledge. Our findings on different imagined sustainability trajectories also connect to existing political-economic ideologies of sustainability that are argued to inform decisionmaking on the individual and collective levels of societal organization (e.g., Davidson, 2014). The transformation trajectory is informed by and linked to progressive ideas of social-ecological transformations that must apply to all sectors and dimensions of social life (e.g., Brand and Wissen, 2018), while the modernization trajectory describes imagined technological fixes that will solve problems in the future and are often attributed to neoliberal ideas (e.g., Harvey, 2003).

Our results must also be viewed in relation to the positionality of individuals and collectives in the spectrum of societal interests, as determined through their own economic interests and constraints. For our research, this aspect relates to the differing imaginations of NGO actors and innovation actors, as specified through their different trajectories. NGO actors do not have their own economic constraints in relation to developments in agrifood systems, whereas innovation actors may have invested in specific technologies, thereby developing innovations, resulting in the expectation that past economic investments must now be profitable (for further elaboration, see Friedrich et al., 2022b). Thus, these past investments to some extent "colonize" the present (cf. Beckert, 2018) of these actors and limit their ability to be interested in far-reaching changes, as such

changes would jeopardize their business model. These investments and the necessity of future economic profitability can lead to path dependencies and lock-ins (see Friedrich et al., 2021a; Friedrich et al., 2022b; Klitkou et al., 2015). In particular, farmers are often trapped by their past investments, and agriculture in general is heavily reliant on subventions (Barnes et al., 2016). All these aspects are major barriers to the design of sustainability- oriented transformations in general and with respect to German agrifood systems in particular, as they limit the ability to change.

In our view, different conceptualizations of sustainability are a double-edged sword. On the one hand, as long as these different conceptualizations of what sustainability means and how it can be achieved with social practices and sociomaterial structures exist in the debate on socioenvironmental issues, solving sustainability-related issues could remain difficult, as the differing trajectories, practices and structures are opposed or even antagonistic and could thus lead to concrete conflicts. Such conflicts would present additional barriers (to those discussed above) to the design of a sustainable livestock system. Examples of conflicts arising from contesting imaginations that embed conflicting social practices, which torpedo any conception of sustainability, can be found in various topics associated with sustainability transformations. One such example concerns the goal conflicts in the moderation of sustainable development goals (e.g., Schneider et al., 2019), exemplified by land-use conflicts such as those presented in the "food versus fuel" debate. Sociocultural conflicts between rural and urban regions are especially relevant to our topic, as the former regions are characterized by having the land that is required for change (WBGU, 2020), while the latter are characterized by transformational imaginations about the future with respect to topics such as agriculture or energy transitions (e.g., Friedrich et al., 2021b; Gürtler and Herberg, 2021; Nowack and Hoffmann, 2020). These differences can escalate toward what Gürtler and Herberg (2021) call "moral rifts" that rest in diverging perceptions of justice and that may lead to resistance to change, which again torpedoes any imaginations of sustainability. Against this background, it is thus important to uncover conflicting imaginations to foster societal exchange and discourse that builds the foundation for the co-design of approaches and strategies that solve socioenvironmental issues and moderate different conceptions of sustainability.

On the other hand, it is the very nature of transformation processes that they are leveraged and accompanied by conflicts (e.g., Skrimizea et al., 2020)—or, as we argue above, that these conflicts could present a process of contingency building (cf. Reckwitz, 2021). In addition, theories from sustainability transition literature such as the different transition pathways of Geels and Schot (2007), or the cultural evolution of a sustainable bioeconomy, (e.g., Schlaile et al., 2022) show that different innovations (which can be part of different trajectories) can also complement each other and cumulatively shift existing regimes. This possibility would mean that the different trajectories are a symptom of an ongoing transformation rather than necessarily resulting in concrete (escalatory) conflicts. To leverage sustainability transformations against the background of ongoing global environmental change, these questions must receive further attention from the scholarly community.

5.5.3 Methodological reflections

We have outlined that we did not detect a control trajectory and attributed this lack of detection to the specific case of agrienvironmental discourses. However, other reasons are possible as well. Our sampling strategy, which relied on snowball sampling, could have led to a bias in that governmental and state actors (which Adloff and Neckel, 2019 designate as representatives of the

control trajectory) are excluded from the sample. Other biases could also originate from the sampling strategy, as we built upon problem-centered interviews. Therefore, actors, for example, those who design control practices, which are not necessarily argumentatively tied to the problem of manure surplus, are excluded from our sample. We encourage scholars to conduct further research on sustainability trajectories in the livestock system that quantitatively tests our identified trajectories and discerns whether they point to subsequent conflicts or are drivers of or barriers to change. In addition, future research could further explore conflicting practices as examples of "doing contingency" (Reckwitz, 2021) and apply Adloff and Neckel's (2019) framework to other socioenvironmental contexts to further substantiate the empirics of the theory.

5.6 Conclusions

The aim of this study was to identify different trajectories of manure futures using a case study, thereby empirically proving the applicability of Adloff and Neckel's (2019) conceptual framework and drawing conclusions regarding the development of a sustainable livestock system. Our results show three different trajectories that include opposing imaginations of manure futures: preservation, modernization, and transformation. Thus, our study proves that the conceptual framework of Adloff and Neckel (ibid.) is applicable to specific environmental topics, thereby allowing us to bridge the gap between future imaginations, current social practices and their mutually dependent sociomaterial structures. The empirical nature of our case study enabled us to extend the framework to grasp the construction of specific imaginations. In this respect, we identified the meanings attributed to actors as determining factors for the different trajectories. This category is underrepresented in the original conceptual framework and must therefore be considered in further research. In addition, our results show that the trajectories present ideal types of change that do not exist in reality, rather, the actors show hybrid versions of the identified trajectories.

In terms of practical implications, we found that the different trajectories, including their opposing imaginations, practices and structures, could present a barrier to the design of a sustainable livestock system. As long as differences in imaginations lead to differences in practices and structures, such differences can lead to conflicts. In general, it is the very nature of transformation processes to be accompanied by conflicts. Whether these conflicts are drivers of or barriers to change remains an open question. In our view, it is important to moderate these conflicts as drivers of change. As we have shown, research on imagined futures can enrich this question by answering it in terms of disclosing the content of imaginations of subjects and collectives and how these imaginations shape social practices

6 The role of bioeconomic innovations in livestock transitions[26]

Journal of Agricultural and Environmental Ethics (2021) 34:24
https://doi.org/10.1007/s10806-021-09866-z

ARTICLES

The Potential of Bioeconomic Innovations to Contribute to a Social-Ecological Transformation: A Case Study in the Livestock System

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Accepted: 30 June 2021

Abstract
Environmental crises, which are consequences of resource-intensive lifestyles and are characterized to a large extent by both a changing climate and a loss of biodiversity, stress the urgent need for a global social-ecological transformation of the agro-food system. In this regard, the bioeconomy and bioeconomic innovations have frequently been seen as instrumental in addressing these grand challenges and contributing to more sustainable land use. To date, the question of how much bioeconomic innovations contribute to sustainability objectives remains unanswered. Against this background, we study four bioeconomic innovations using the case study of animal production and manure utilization in relation to their potential contributions to a social-ecological transformation. The analysis is based on the application of analytical categories derived from the literature that assess the normativity of these innovations and their implicit cultural changes. The results show that the innovations examined manifest existing thought styles and the incumbent socio-technical regime rather than contribute to a more fundamental transition. In this respect, we stress the importance of evolving alterative ideas in innovation design, applying more integrative approaches, such as embedding innovation processes into transdisciplinary processes, and developing adaptive and reflective governance approaches. In return, bioeconomic innovations should adjust towards the design mission of a social-ecological transformation and include a multitude of actors to discuss and harmonize contesting imaginaries and ethical concerns.

Keywords Bioeconomy · Social change · Manure · Sustainability · Agriculture · Social sciences · Transdisciplinary

[26] This chapter has been published as Friedrich, Jonathan; Bunker, Ingrid; Uthes, Sandra; Zscheischler, Jana in *Journal of Agricultural and Environmental Ethics* (2021): The Potential of Bioeconomic Innovations to Contribute to a Social-Ecological Transformation: A Case Study in the Livestock System. doi: 10.1007/s10806-021-09866-z

6.1 Introduction

Agricultural landscapes in Europe and around the world are in transition. Climate change, urbanization, digitalization, and increasing societal demands for land and land-based resources drive and accompany these transition processes and will increase land-use competition in the future (Foley et al., 2011; Herrero et al., 2020; Hertel et al., 2013). In addition, many global sustainability challenges related to multiple crises, such as biodiversity loss, nutrient surpluses, soil degradation, greenhouse gas emissions, and environmental justice, are connected to agricultural landuse practices (e.g., Herrero et al., 2020; Temper et al., 2018; Tilman and Clark, 2014; Tscharntke et al., 2012). This specifies the need for a social-ecological transformation (SET) at large.

The bioeconomy and according bioeconomic innovations have frequently been seen as a panacea by policy actors (Giampietro, 2019) in terms of addressing these grand challenges; these factors contribute to more sustainable land use (e.g., Bugge et al., 2016) and have been claimed to be important to at least half of the SDGs (United Nations Sustainable Development Goals) (El-Chichakli et al., 2016). These goals may be achieved through resource efficiency, fuel independence, and by following the contested vision of a green economy (e.g., Hickel and Kallis, 2020; Loiseau et al., 2016) and the contested narratives of decoupling both economic growth from environmental degradation and the technosphere from the biosphere (e.g., Giampietro, 2019; Hickel and Kallis, 2020).

However, the implied additional demand of a bioeconomy for renewable resources may lead to new ethical concerns and moral dilemmas that result from, e.g., an increasing competition for land and natural resources or the intensification of land use (such as through fostering monocultures); in addition, such demand may ultimately produce (new) target conflicts regarding the SDGs (e.g., Hertel et al., 2013) or even create new lock-ins or path dependencies (e.g., Klitkou et al., 2015). In general, the scientific knowledge about the potential risks and uncertainty associated with the complexity of a transition to the bioeconomy remains rather narrow (e.g., Bukkens et al., 2020). A significant example of this complexity is the food versus fuel conflict that resulted in increasing food prices during the so-called Tortilla Crisis in 2007/2008 (e.g., Tomei and Helliwell, 2016); furthermore, bioeconomic policies may even foster land grabbing, which was found to be the case in sub-Saharan Africa (Ashukem, 2020). These risk examples related to food security and global price developments also reveal different vulnerabilities in society that raise new questions of social and environmental justice (Timmermann, 2020; Walker, 2012). In addition, socio-technical innovations and transition trajectories that are at the heart of a bioeconomic transformation may also shift environmental problems from one system to another or from one region to another (van den Bergh et al., 2015). Apart from this, the bioeconomy has been frequently criticized for its neoliberalization of nature at large and for following a "fossil logic" (e.g., Birch et al., 2010).

Against this background, it appears to be of central interest to clarify to what extent the development of a bioeconomy is compatible with the values and imaginaries[27] of a widely postulated SET. Both SET and the bioeconomy imply changes in human-nature relations and

[27] In the following, we refer to "imaginaries" as societally embedded and shared understandings and meanings that govern the way to societally desirable futures. In defining sociotechnical imaginaries, being part of the concept of imaginaries, we follow Jasanoff and Kim (2009: 120), who refer to them as "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects". Jasanoff (2015) extended this definition by also accommodating visions of different groups of stakeholders or collectives in aiming to create a desirable future.

include tacit normative premises that form futures. However, a sustainability-oriented transformation is not granted but rather implies a design mission for a multitude of actors to transform the current agrofood system and the according land-use practices (Jahn et al., 2020). This process also raises numerous ethical questions as precise and normative objectives must be assessed and negotiated both before and after technological design, as "even modest technological improvements create new normative rights and obligations" (Jasanoff, 2016: 266). For a long time, the bioeconomy has been prevailingly considered from a technical-scientific and economic perspective, while little attention has been given to the social and cultural dimensions that reflect the main pillars of sustainability and the social science perspective at large (Sanz-Hernández et al., 2019). This lack of attention has led to the neglect of critically analysing the implicit normativity of the bioeconomy.

Although there is a clear political commitment to fostering a transition toward a bioeconomy on the part of many countries (El-Chichakli et al., 2016), it remains unclear whether bioeconomic approaches foster an SET that addresses the grand sustainability challenges of our time (Brand et al., 2020; Giampietro, 2019).

While Bröring et al. (2020) characterized bioeconomic innovations in regard to their suggested changes at the market level, the aim of this paper is to analyse the potential of currently developed bioeconomic innovations in contributing to SET, with a particular focus on changes at different scales, such as those made regarding the culture and organization of societies. We argue that SET entails changing values and norms in society. To examine the potential of bioeconomic innovations to contribute to SET, we thus apply central categories found in the SET literature to analyse the norms, values, and beliefs that are reflected and materialized in the innovation design of bioeconomic innovation. We exemplarily relate these categories to the German livestock system and, more specifically, to nutrient surpluses in the forms of manure, their complex global entanglements, and manure-based bioeconomic innovation. We discuss the origin of contemporary cultures of bioeconomic innovation design in society and how bioeconomic policies and research on bioeconomic innovation need to be adjusted to foster SET in the German livestock system.

6.1.1 SET to Adress Multiple Crises

Against the backdrop of multiple ecological and social crises and the resulting sustainability challenges, the need for an SET has become increasingly invoked and is largely grounded in topics such as environmental justice or environmental ethics (Hölscher et al., 2018; Temper et al., 2018). Although there is not a single clear definition of the concept, an SET is frequently related to changes made to the complex interactions and interrelations between society and nature and the according social, cultural and ecological interlinkages (Moore et al., 2014). The debate is normatively interlinked with the integrative perspective of the sustainability discourse, and an SET can be seen as an approach that is multidimensional, global, and intersectional and thus transforms not only the economy but also society as a whole (Escobar, 2015; Stirling, 2014; Temper et al., 2018). Both an SET and a transformation towards a bioeconomy imply changes and transitions that are based on normative orientations and visions that mutually interact with norms, values and beliefs, as well as with rules and practices (Moore et al., 2014).

An SET is characterized as being driven by multiple values, norms, and imaginaries, which are often open to discussion. Brand et al. (2020) and Temper et al. (2018) argued that an SET must challenge the roots of contemporary ecological and social crises. In the literature on SETs, it has

also been argued that an SET must integrate the complex relations in adaptive systems and overcome human-nature dualism (Brand and Wissen, 2018), which is often done by using a complex socio-ecological systems approach (e.g., West et al., 2020). To frame contemporary crises, Brand and Wissen (2018) introduced the concept of the imperial mode of living, which integrates the complex global entanglements of capitalist societies. Following this argumentation, an SET is grounded in changing values and practices that move towards a solidarity mode of living (Brand and Wissen, 2018), which the authors (ibid.) considered to be a de-commodification of nature and land, i.e., a "democratization of societal nature relations" (Brand et al., 2020) performed as a bottom-up approach. Social struggles and conflicts are seen as side effects that often strengthen radical change (Brand et al., 2020; Temper et al., 2018) and can accordingly be moderated as drivers of change.

However, as an SET is regarded as a democratic bottom-up approach that involves multiple actors, the normative dimensions of what to preserve ("target knowledge") and how to preserve it ("transformation knowledge") underlie constant negotiation processes and ethical reflections in society (Gorddard et al., 2016; Max-Neef, 2005; O'Brien and Wolf, 2010; Pohl and Hirsch Hadorn, 2008; Wiek, 2007). Changes in values and norms can therefore indicate societal transformation processes (Moore et al., 2014), and changes at the socio-technical regime[28] level (such as cultural and organizational) can be triggered by windows of opportunity and regime-niche interactions in socio-technical transition processes (Geels and Schot, 2007). This also refers to changes in innovation design, as described through the incorporation of novel actors and the challenging of incumbent structures and paradigms (Schlaile et al., 2017; Stirling, 2014).

6.2 Socio-Technical Innovations in the Bioeconomy and the Contribution to SET–Developing Analytical Categories

Innovations are considered a driving force of change and development in modern society. Whether for an SET (e.g., Brand and Wissen, 2018; Bruckmeier and Pires, 2018) or the bioeconomy (e.g, Jander et al., 2020; Strøm-Andersen, 2019), the design of innovations is discussed as having a key role. Beyond this design dimension, innovations can also have analytical and indication dimensions, as they make both social and socio-technical changes observable and therefore studiable.

Innovations and their evolutions follow specific thought styles or so-called sociotechnical imaginaries (Jasanoff, 2015b). Policy strategies, such as the German bioeconomic strategy, function as documented sociotechnical imaginaries of the desired future (Giampietro, 2019). Sociotechnical imaginaries that become explicit in policy documents create implicit societal values and norms and can materialize in innovation. This process also becomes explicit in the characterization of innovation types in the bioeconomy from a market-centred perspective, which ultimately sees innovation as being societally desirable (Bröring et al., 2020).

In general, transformations refer to "radical, non-linear and structural change in complex adaptive systems" (Hölscher et al., 2018: 1) and can be considered "plural, emergent and unruly

[28] The term "socio-technical regime" describes the present stable-dynamic combination of technologies, consumers, industry, and science in terms of activities and governing rules (for more details see Geels, 2002; Geels and Schot 2007).

political re-alignments, involving social and technological innovations" (Stirling, 2014: 1). Thus, not every innovation may be societally desirable and contribute to a transformation.

Socio-technical innovations are also regarded as pivotal for a transformation towards the bioeconomy in Germany (BMEL and BMBF, 2020). We therefore argue that such innovations represent a comprehensive unit of investigation and serve as carriers of meaning for ongoing transformations. In our analysis, we thus focus on bioeconomic socio-technical innovations to study the complex processes of change towards a bioeconomy and to discuss the potential outcome for an SET. We follow the characterization of innovation types by Bröring et al. (2020) to define bioeconomic innovation and differentiate them from the broader topic of sustainability innovations.

We argue that the analysis of values and norms that influence innovation design allows us to determine the likelihood of bioeconomic innovations contributing to an SET. In return, this allows us to critically point out issues and gaps in innovation design and at the policy level of bioeconomic strategies.

Thus, to reflect current bioeconomic innovations and their potential contribution to, as well as their alignment with, a sustainability-oriented transformation, we have extracted the following central categories of an SET that are largely discussed in the literature to perform our analysis. ⌟

6.2.1 Aim of the Innovation

The aim of an innovation reflects an envisaged future on the one hand and the means, instruments and ideas about how to achieve this future on the other hand (Jasanoff, 2015b). In the discourse of transformative sustainability science, these two forms of knowledge are frequently named "target knowledge" and "transformation knowledge" (e.g., Max-Neef, 2005; O'Brien and Wolf, 2010; Pohl and Hirsch Hadorn, 2008; Wiek, 2007). Target knowledge represents normative knowledge and captures the desired goals and the needs and direction for change (know where?). Transformation knowledge incorporates support for the development of strategies for the societal transformation process and concrete action (know how?). This knowledge is also ultimately intertwined with values and norms that lead to specific decisions (Gorddard et al., 2016).

6.2.2 Problem Framing and Solution

The aim of an innovation is grounded in the framing of a certain problem. It can be argued that problem framing anticipates and shapes the solution (i.e., the innovation). Thus, the solution describes the socio-material answer to a perceived problem as the concrete "doing" (cf. Longhurst and Chilvers, 2019) of the actors or actor collective. In discourses on the principles of an SET, it is commonly highlighted that many sustainability problems are highly complex, which points to a societal interest in the problem and an orientation to a "common interest" (Hirsch Hadorn and Jäger, 2008). Often, the concrete definition of these problems is under dispute, shaped by uncertainty and interrelated with differing perceptions among distinct actors and interest groups (Zscheischler et al., 2017). As a consequence, actors (those involved in the innovation process) and their perception of the problem at hand and its origin define this framing. Individual perceptions and definitions of problems are driven by knowledge, societal perceptions and the framing of risks and problems. In the theory of science, these different perspectives on research topics/objectives of research are described by differing ontologies and epistemologies. This also means that societal and individual values and thought styles become reflected and incarnated in the concrete framing of problems and the doing of according solutions (Jasanoff, 2015b; Longhurst and Chilvers, 2019).

6.2.3 Involved Actors

Theoretical considerations on innovation processes consider actor constellations and networks to be essential determinants (e.g., Duygan et al., 2019). As an example, the widely acknowledged multi-level perspective on socio-technical transitions considers "novel actors" who are not part of the existing regime as a prerequisite to design "radical" innovations that challenge incumbent structures and thus provide impulses for sustainable pathways and transformation (Geels and Schot, 2007). In addition, the incorporation of actors with conflicting worldviews, which are expressed in values and norms but also as future visions, can be used as a criterion to show whether the attempt to grasp the complexity of a sustainability problem is disputed over interests, norms and values; thus, societal embeddedness is acknowledged in innovation design (Schlaile et al., 2017). This means that the description and differentiation of the actors involved in the innovation design and their organization are key in identifying the potential of innovation in regard to contributing towards an SET (Longhurst and Chilvers, 2019). We use the differentiation of "incumbent" and "novel actors" proposed by Schlaile et al. (2017) to characterize the actors.

6.2.4 Social Learning

Social learning is defined "as a change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks" (Reed et al., 2010: 6). Following this definition, we argue that transformations entail social learning through the reflective uptake of values and norms in terms of a changed understanding through actors. We therefore characterize the likelihood of stimulating social learning through bioeconomic innovation in regard to the following qualitative categories: limited (not very likely to initiate social learning), moderate (likely to stimulate social learning but limited in spatial extent and intensity of change), and high (likely to initiate deep changes in understanding and behaviour).

6.2.5 Changes in the Socio-Technical Regime

The multi-level-perspective of socio-technical transitions (Geels and Schot, 2007), although it has been criticized and updated since its development (e.g., Geels, 2019), presents a typology of transition pathways towards socio-technical change. We use this typology to estimate future changes in the socio-technical regime (through the uptake of innovation) that relate to values, beliefs, practices, and behaviours and that could foster sustainability. The transition pathways depend on various factors, such as innovation actors, regime-niche interactions, windows of opportunity, the radicalness of the innovation, and the timing and state of the innovation designs, when changes at the landscape level open up windows of opportunity. In general, changes at the regime level that are produced through transition pathways and the diffusion of innovation can inform changes in norms and values among regime actors (Geels and Schot, 2007).

6.2.6 Normativity and Innovation

Innovations and innovation processes are implicitly shaped by and transport normativity, which refers to commonly shared beliefs and imaginaries, hidden convictions, implicit goals and normative orientations (e.g., Jasanoff, 2015b; Schmidt, 2007). The normativity of an innovation is interrelated not only with the values and norms reflected by the underlying problem framing but also with ideas about how the innovation should contribute to solving the problem. It also refers to normative beliefs, discourses, and imaginaries about the role and function of innovations and

innovation processes within society. As an example, modern societies are widely characterized by prevalent techno-optimism -loading innovations with positive associations such as novelty, improvement, societal progress or economic growth, which leads to the perspective of innovations being regarded as per se desirable. In addition to this techno-optimism, there are also more pessimistic connotations associated with innovations that result from an increased perception of risks and ecological damages that have arisen with technological progress. Against this backdrop, the concept of "socially responsible research and innovation" has gained growing attention in recent years (Owen et al., 2012). This concept comprises reflections on the "right impacts" of innovation and considers aspects such as "(ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products" (Schomberg, 2012).

6.2.7 Innovation Paradigm

This category summarizes the other categories based on the characterization of bioeconomic innovation as either following the *conventional* or *dedicated innovation paradigm* (Schlaile et al., 2017). The *conventional paradigm* describes the neoclassical culture of sociotechnical innovation as perpetuating economic growth, efficiency, and system improvement that is performed by either incumbent or dominant actors. In contrast, the *dedicated innovation paradigm* aims to address this norm by including sustainability values in innovation design, focusing on a wider set of actors, acknowledging the wickedness of problems, and incorporating aspects of intra- and intergenerational justice in innovation design.

6.3 Case Study: Livestock Production, Manure Issues and Bioeconomic Innovations

For our analysis, we apply the abovementioned analytical categories to four bioeconomic innovations dealing with manure. The following section first introduces the case of livestock production, briefly describes our approach of applying the analytical categories, presents four selected innovations, and finally shows the results of the analysis.

6.3.1 The Unsustainability of Contemporary Livestock Production

Managing the global nitrogen cycle within planetary boundaries has been specified to be one of the great challenges of our time (Rockström et al., 2009; Steffen et al., 2015). European countries, and more specifically Germany, are characterized by high nutrient surpluses originating from intensive livestock production and inappropriate fertilizer use (Häußermann et al., 2019). Intensive livestock production has various negative impacts on different sustainability dimensions and at different scales. At the local scale, nitrogen surpluses from agriculture can be leached into ground and surface waters, resulting in various negative effects on terrestrial and aquatic ecosystems, including eutrophication, the nitrate pollution of the groundwater and damage to biological diversity (Umweltbundesamt, 2019). Greenhouse gas emissions from livestock production (methane and nitrous oxide) contribute to the global environmental problem of climate change (e.g., Tilman and Clark, 2014). Examples of societal implications are working conditions in the meat processing industry (e.g., Wagner and Hassel, 2016), telecoupled effects such as land-use changes for feed production on other continents that can involve conflicts with indigenous people (e.g., Sauer, 2018), and ethical and animal welfare concerns regarding animal husbandry (e.g., Busse et al., 2019).

6.3.2 Potential Solutions Within the Imaginary of a Circular Bioeconomy

The circular bioeconomy, as proposed by the sociotechnical imaginary of the National Bioeconomy Strategy, is argued to be oriented along natural material cycles and to cover all economic sectors and branches that produce, process, use and trade with renewable resources, such as plants, animals and microorganisms and their products. A particular focus is on residual and waste materials, such as manure, and their cascade use and conversion into value-added products for reuse in agriculture and other sectors (BMEL and BMBF, 2020). Solutions that follow the imaginary of a circular bioeconomy are considered to at least partially close previously open nutrient cycles either farm-internally through cooperation between farms or externally through new value chains alongside perpetuating economic growth (ibid.). We identify four examples of such solutions that can be characterized as bioeconomic innovations based on the definition of such innovations proposed by Bröring et al. (2020), namely, novel manure application techniques (e.g., Darapuneni et al., 2019), crop livestock integration beyond the farm level (e.g., Asai et al., 2018), manure conversion into novel fertilizers (e.g., Pintucci et al., 2017), and manure conversion into new feedstuffs (e.g., Čičková et al., 2015).

Although the abovementioned innovations have been claimed to contribute to a better and circular management of nitrogen, it is unclear whether they contribute to an SET, which we argue is necessary to solve multiple environmental and social crises (cf. Brand et al., 2020; Temper et al., 2018). Thus, we aim to characterize these innovations based on the analytical categories presented in chapter 6.2. We argue that this characterization allows the comparison of the sectoral contribution of a bioeconomy in its current shape to an SET at large by focusing on innovation as an analytical category.

6.3.3 Applying the Analytical Categories to the Case of Animal Production and Manure Utilization

In the following, we exemplarily apply our analytical categories to the case of manure-based bioeconomic innovation. We choose four manure-based innovations that are designed by different actors and imply different approaches based on the characterization of bioeconomic innovations (cf. Bröring et al., 2020). Our results are based on a content analysis of available online documents, homepages, and scientific sources in relation to the categories of our analytical categories (see chapter 6.2). Table 6 gives an overview of the analysed sources.

Table 6: Information sources for considering the normative dimensions of bioeconomic manure-based innovations

Innovation	**Sources**
Novel manure application techniques, i.e., integrating manure with strip-tillage	Darapuneni et al. (2019) Vogelsang (2020)
Manure exportation to other farms and regions	Asai et al. (2018) Agrarhandel Dienstleistungen Nagler (2020) NOM GmbH (2020)
Manure conversion into recycled fertilizer	Pintucci et al. (2017) CORDIS (2016) Frauenhofer IGB (2020) SUEZ (2019)
Bioconversion of manure into new feedstuffs, i.e., insect cultivation in manure	Čičková et al. (2015) EFSA Scientific Committee (2015) van Huis (2019) Hermetia (2020)

6.3.4 Results: Normative Dimensions of Manure-Based Bioeconomic Innovations

An overview of the results can be found in Table 7. In the following, we describe our considerations that led us to these results.

6.3.4.1 Novel Manure Application Techniques: Integrating Manure with Strip-Tillage

Manure storage and application are a major source of N emissions. Novel manure application techniques, such as strip-tillage with root-level liquid manure fertilization, are being increasingly practised and promoted, with the aim of reducing ammonia and nitrous oxide emissions (odour, greenhouse gas) during application and improving N-use efficiency (Darapuneni et al., 2019). The innovation is designed by incumbent actors within the socio-technical regime (agricultural machine manufacturer) that develop new ideas. The problem frame is clearly focused on the application of manure and its field-level consequences in the application process. This can be considered a matter of efficiency for which the solution rests in technologies involving more precise application techniques. This new technique could moderately stimulate social learning, and the reduced odour is a directly perceived positive impact for the local population. Nonetheless, the potential changes in the socio-technical regime remain rather narrow in terms of characterization as a reproduction process (Geels and Schot, 2007), i.e., substituting old technologies with new ones as a way of improving the current system of application. This approach is also rounded in the value of and belief in a technological fix for environmental problems, the increase of efficiency, and the idea that innovation is per se desirable. This means that although innovation prevents nutrient loss and can improve ecological performance, innovation has been designed by incumbent actors and is thus considered to be following the *conventional paradigm* (Schlaile et al., 2017). This means that the neoclassical idea of entrepreneurial innovation materializes in novel manure application techniques through its focus on system improvement and efficiency.

6.3.4.2 Manure Export to Other Farms and Regions

Through novel collaborative arrangements (e.g., Asai et al., 2018) with arable farmers, livestock farmers seek to reduce their nutrient surpluses, particularly since fertilizer regulations have been tightened. The actors involved in this innovation are mainly farmers from different regions who represent incumbent actors, in addition to logistic companies that transport manure from livestock regions to arable regions. This means that the incumbent actors organize themselves in a new format. The problem is framed in the reductionist way such that there is too much manure for too small of an area following the nitrate directive. This means that manure is a matter of spatial distribution, which becomes explicit in the solution of the spatial redistribution of manure. Although new social relations between existing actors could enhance social learning, the contact is mainly shaped by business purposes and is thus limited in regard to stimulating social learning on a broader scale. In addition, the scope of actors remains rather narrow. The innovation itself provides incremental improvements through new relations of existing structures, for which it can be characterized as a "reproduction process" (Geels and Schot, 2007). This also means that innovation represents a pragmatic, economic-oriented way of problem solving (and achieving more sustainable agriculture) that is based on values of efficiency and driven by legal frameworks and the idea that innovation is per se desirable without explicitly considering the potential trade-offs, such as increasing carbon dioxide emissions through transport. Against this background, this innovation follows the conventional paradigm (Schlaile et al., 2017) in terms of being driven by legal frameworks and economic competition in a pragmatic problem-oriented way. Manure Conversion

into Recycling Fertilizers New technological developments (e.g., Pintucci et al., 2017) enable the conversion of manure into recycled fertilizers. Manure is voluminous and therefore difficult to store and transport, and its nutrient content varies depending on the feeding regime of the livestock and the collection and storage systems (potentially high gaseous N losses); thus, manure is less manageable for fertilization compared to mineral fertilizers and it bears a higher risk for emissions and leaching. When it is converted into recycled fertilizers, converted manure arguably becomes more storable and easier to transport, and its on-field application is simpler and better steerable. However, the conversion is also energy intensive; thus, the profitability and ecological footprint depend on the energy source used and the oil price development. Recycling fertilizers can partially serve as a substitute for conventional mineral fertilizers and their contested production/extraction and value chain against the background of ending phosphorus deposits; on the other hand, they integrate formerly superfluous biomass into new value chains. This innovation is currently developed by multiple actors, including scientific projects, and is introduced in the market by firms. These actors, who have a new idea, mainly represent incumbent structures of waste recycling. Problem framing can be characterized as reductionist, as manure is regarded as a matter of recycling/waste in terms of too much manure being located in some regions, which is difficult to store and transport. Thus, the solution to this problem is to revalorize manure. The stimulation of social learning may be regarded as limited, as only a limited set of actors is involved in the design and adoption of the innovation; in addition, the innovation does not present new values and norms that could reflectively be taken up. On the one hand, this approach is grounded in the potential transition pathway that we argue is most likely the "reproduction process" (Geels and Schot, 2007), as the innovation includes incremental improvements, the substitution of mineral fertilizer and the completion of the existing market. On the other hand, this approach builds upon the idea of a technological fix for environmental problems (thereby achieving sustainability) that becomes explicit in the innovation design and is thus influenced by the problem framework and the according imagining of a solution. Furthermore, an imaginary of circularity that has its roots in economics is achieved through the increase of efficiency, the focus on growth and the circularity being imagined as a reintroduction into the market. In this way, innovation is regarded as per se desirable. This also means that the implicit innovation paradigm (Schlaile et al., 2017) of recycling fertilizer can be characterized as conventional (see Table 7). This is explained through supply-side driven developments and incumbent actors, entrepreneurial competition in the innovation design and the implicit assumption that innovation is per se desirable.

6.3.4.3 Bioconversion of Manure into New Feedstuffs: Insect Cultivation on Manure

The cultivation of insects in manure for feed use (e.g., Čičková et al., 2015; van Huis, 2019) presents a circular, bioconversion approach. Insects cultivated in manure can be fed to livestock in return and thus serve as a substitute for fish meal or soy-based fodder. This innovation is currently under development and is being designed in niches by novel actors, thereby representing a new idea. We argue that the problem framing of this innovation is compounded, as two issues associated with livestock production—manure surplus and the fodder topic—are considered together. This means that the problem is framed as a matter of recycling and spatiality, as the insects could be used as fodder locally (even on the same farm). The solution addresses these two aspects of biological recycling and revalorization. This novel approach, which is being designed by novel actors, may thus stimulate social learning in a moderate way, as new actors with differing values and perceptions are coming into contact with incumbent actors. However, the potential of social

learning also rests in the transition pathway and the corresponding changes in the socio-technical regime, which again depend upon the timing of the innovation design and the window of opportunity described through aspects such as legal frameworks. European Union legislation poses a significant hurdle, as neither the feeding of manure to farmed insects nor the feeding of insect-based protein to ruminants, swine and poultry is currently allowed (EFSA Scientific Committee, 2015). These developments suggest that a "transformation pathway" (Geels and Schot, 2007) may be most likely. This normativity follows an imaginary of circularity that is grounded in regionalism (being different from that of recycling fertilizer). This innovation also incarnates values of efficiency and the idea that innovation is per se desirable. This leads to the conclusion that this innovation follows a *conventional paradigm* (Schlaile et al., 2017), as the design is supply-side driven and based on entrepreneurial competition and efficiency.

Table 7: Overview of normativity of four manure-based bioeconomic innovations based on the analytical categories described in chapter 6.2; a comprehensive description of the results can be found in chapter 6.3.4

	Novel manure application techniques; integrating manure with strip-tillage	**Manure exportation to other farm and regions**	**Manure conversion into recycled fertilizer**	**Bioconversion of manure into new feedstuffs, i.e., insect cultivation in manure**
(1) Aim of the innovation	Novel manure application technique; increases N-use efficiency; reduces ecological damages	Collaborative arrangements between crop and livestock farms to manage nutrient surplus; relaxes the area constraints of livestock farms	Overcome the ecological damages associated with overapplication of manure; P and N are valuable nutrients that can be recovered; Conversion into transportable fertilizers to allow beyondregional use	Bioconversion (natural process) of manure through cultivation of insects as protein-rich feed for animals/livestock
(2) Problem framing and solution	"High emissions during application; reduction of odours; wrong distribution of manure"; Matter of efficiency; More precise application technique	Reductionist: "Too much manure for too small of an area"; Matter of spatial distribution; Redistribution of manure	Reductionist: "There is too much manure; it is difficult to transport and store"; Matter of recycling; Revalorization of manure	Compounded: "Too much manure, high demand for protein-rich fodder"; Matter of recycling and spatiality; Biological recycling and revalorization
(3) Involved actors	Incumbent actors with a new idea	Incumbent actors with a new organization	Incumbent actors with a new idea	New actors with new ideas
(4) Social learning	Moderate	Limited	Limited	Moderate
(5) Potential changes in the socio-technical regime	New process; improvement; transition pathway: "reproduction process" of the regime	Incremental improvement; new relations in the existing regime; transition pathway: "reproduction process"	Incremental improvement; substitution and complementing existing market; Transition pathway: "Reproduction process"	Niche innovation that could lead to changes at the regime level, substitution of fodder imports, and spatial regionalization; transition pathway depends on timing and window of opportunity ("transformation pathway" most likely)a
(6) Normativity and innovation	Increase of efficiency; technological fix of environmental problems; innovation is per se desirable	Legal framework that allows a limited manure application per area; actors act in a pragmatic economic-oriented way that increases efficiency; innovation is per se desirable	Technological fix of environmental problem; increases efficiency; innovation is per se desirable; "circular imaginary/economy"	Regionalization; increase of efficiency; innovation is per se desirable; "circular imaginary/economy"
(7) Innovation paradigm	Conventional	Conventional	Conventional	Conventional

[a]Not to get confused: the term transformation used in the "transformation pathway" of Geels and Schot (2007) is different from how it is used in regard to a social-ecological transformation (cf. Brand, 2020; Moore et al., 2014; Temper et al., 2018)

6.4 Discussion

The analysis of four bioeconomic manure-based innovations shows that these innovations follow the values, imaginaries, and beliefs of achieving sustainability through efficiency, a technological fix, entrepreneurial competition, and framing innovation as per se desirable. This can be characterized by following the *conventional innovation paradigm* (Schlaile et al., 2017). As a consequence, we argue that the ability of these innovations in terms of significantly contributing to SET is rather limited, as they do not inherently incarnate changing values and norms. In the following, we will focus our discussion on the origin of the materializing values, norms and beliefs from both society and science. In return, we will discuss solutions in both science and policy in terms of adjusting bioeconomic innovation design in the context of an SET in the complex and globally entangled agro-food system.

6.4.1 Bioeconomic Innovations and Their Potential Towards a SET

6.4.1.1 Manure-Based Innovations Manifest the Existing Thought Styles of Contemporary Societies

Our analysis of four manure-related innovations shows that the existing cultures and imaginaries of sustainability change through entrepreneurial competition and are driven by the growth, efficiency, technological fixing of environmental problems, and framing innovation as per se desirable that materialize in these innovations. Thus, the following question arises: what constitutes the manifestation of these cultures and imaginaries in innovation currently? We mainly identify two determinants, although there may be many more, on which we focus our discussion, namely, the problem and solution frame and techno-optimism.

6.4.1.2 Reductionist Problem Framing as an Example of Manifesting Thought Styles

Based on our analysis and the research of Nightingale et al. (2020), we argue that a major determinant rests in society's perception of the origins, drivers, and complex entanglements of environmental problems. Similar to Nightingale et al.'s (2020) analysis of climate change as being societally framed as a biophysical issue, manure is framed as a matter of distribution, efficiency and recycling. Thus, the solution is considered to be found in redistributing manure through more efficient and new technologies that allow for recycling. This also points to a long discussion in sustainability science and other disciplines on the nature-culture dichotomy and naturehuman dualism, which is also regarded as an inherent characteristic of capitalist societies (e.g., Brand and Wissen, 2018; Fraser and Jaeggi, 2020; Haraway, 2016; West et al., 2020). This means that instead of framing manure as a product of complex human-nature relations and entanglements, manure is framed in the above-described reductionist manner. These complex entanglements are driven by, in a nutshell, production, consumption, industrialization, and globalization patterns in the agrofood system and result in complex, interdependent, and often telecoupled problems, such as land-use change for fodder production, animal welfare, working conditions, the eutrophication of water bodies, and greenhouse gas emissions (e.g., Foley et al., 2011; Herrero et al., 2020; Tilman and Clark, 2014; Tscharntke et al., 2012; Wagner and Hassel, 2016). All these aspects are related to critical issues that require ethical discussions and negotiation processes in the search of a sustainable bioeconomy. In contrast, the solutions that are designed on the basis of the reductionist problem framework thus present a sort of "solutionism" (Morozov, 2013), that is, a technological design

aimed at solving a problem whose complexity is not yet understood (see also Markusson et al., 2017). This is not meant to place blame on innovation actors for their technological inventions and innovative designs but rather to highlight the role of societies and sciences in shaping the understanding of the multiple crises in a reductionist, biophysical way rather than through complex political-economic entanglements (see also Markusson et al., 2017).

6.4.1.3 Prevailing Techno-Optimism is Inherent in Society and Can Lead to Negative Effects for Social-Ecological Systems

In addition, we argue that the analysis of the four bioeconomic innovations points to techno-optimism in society. This does not mean framing technology in a pessimistic way; rather, we argue for a critical turn in society to acknowledge that sociotechnical innovation can of course have benefits for society and the environment but that the belief in techno-optimism does allocate the power to change to technological solutions rather than a combination of socio-technical, cultural and behavioural solutions; this approach supports business-as-usual strategies and, accordingly, the hope of a "deus ex machina" (cf. Rajak, 2020). Techno-optimism also implies overemphasizing the fallacy that humans are able to fully control environmental processes and has been argued to apply to other sectors as well (e.g., Markusson et al., 2017; Pfotenhauer et al., 2019; Rajak, 2020; Strand et al., 2018). This becomes explicit in the neoliberal belief that innovation, which is often associated with technological invention, is per se desirable (see also Schlaile et al., 2017). However, historical developments have shown that socio-technical innovation can lead to lockins in systems that manifest existing structures (e.g., Klitkou et al., 2015), problem shifting to other sectors (e.g., van den Bergh et al., 2015), unintended trade-offs that are uncertain and can play a role in various scales and spatialities through complex relations in the so-called nexus (e.g., Bukkens et al., 2020), or the evergreen rebound effect (e.g., Paul et al., 2019). We argue that framing innovation as per se desirable without critically assessing the potential trade-offs and conflicting values can manifest existing unsustainable practices that are ethically questionable. Giampietro (2019) argued, based on an analysis of global socio-metabolic flows, that tertiary flows (such as manure, or waste in general) depend upon primary energy sources (soil, water, air) and secondary flows (fodder, livestock). This means that manurebased innovations (and bioeconomic innovation in general) could manifest structures of "unsustainable" land use in southern America for fodder production (e.g., Sauer, 2018) and the methane emissions of livestock farms (e.g., Foley et al., 2011), which, if framed as socio-metabolic flows, are the basis for manure-based bioeconomic innovation. In return, this means that the manifestation of thought styles, or a lock-in of capitalist imaginaries, values and norms in society (also policy, as argued by Escobar, 2015), which materialize in socio-technical innovation, has multiple concrete consequences for the sustainability of current social-ecological systems on other scales and could manifest complex unsustainable systems entanglements.

6.4.2 Science Implications: How Can Science Provide Support to Design a Sustainable and Just Bioeconomy?

In accordance with other scholars (e.g., Bukkens et al., 2020; Daedlow et al., 2016; Funtowicz and Ravetz, 1993), we consider the reflection on and adaptation of research processes to be key for leveraging a sustainability transformation. Science is also expected to play a central role in shaping the bioeconomy. This assumption is reflected not only in national bioeconomy strategies, such as those found in in Germany (BMEL and BMBF, 2020), but also in specifying concepts such as ideas

of a "knowledge-based bioeconomy" (Urmetzer et al., 2018). By setting specific research topics in research programmes, research has become an important implementation tool of the bioeconomy. This approach also reveals how these research programmes want to influence bioeconomic innovation processes and how far they align with the aims and processes of an SET. For a long time, a focus on techno-economic knowledge and accordingly rather "reductionist" disciplinary perspectives has been dominant in science agendas (Pfotenhauer et al., 2019; Strand et al., 2018). Even if this techno-optimistic perspective continues to prevail, a recent shift towards more systemic and more integrated approaches could be observed. Currently, inter- and transdisciplinary processes are claimed to be important approaches for a sustainable bioeconomy (BMEL and BMBF, 2020). This is an important and welcome step forward, as it acknowledges that an SET towards a sustainable bioeconomy is a complex, adaptive process in which different and frequently opposite norms and values, interests, world views and target conflicts must be negotiated and harmonized (e.g., Zscheischler and Rogga, 2015). With regard to the design of a socially desirable and ethically acceptable bioeconomy, similar to an SET, there is no general ethical code that is commonly shared by the wider parts of society. Rather, multiple conflicts of interest emerge in evaluating the "proper" use of natural resources with regard to utilitarian and deontological concerns or issues of social justice. For the case of manure, integration thus requires discussing and weighing supposedly antagonistic aspects such as the self-determination of farmers, future generations' right to develop and evolve, animal ethics, or indigenous land rights in Southern America. Transdisciplinary processes are able to grasp these complexities and allow the integration of ontological pluralism, different perspectives, knowledge types and norms and values by involving diverse actors and interest groups (e.g., Scholz, 2011). Only in this way will scientists be able to provide socially robust, wellaccepted and legitimized orientations for a sustainability transformation. In addition, such integrative approaches enhance the social responsibility of research and innovation (Daedlow et al., 2016; Gremmen et al., 2019). The manure example shows that applying such processes is in great need, as current manure-based bioeconomic innovations are designed by incumbent actors who do not represent the heterogeneity of perspectives, positionalities, and knowledges that are necessary to understand these wicked problems (cf. Schlaile et al., 2017).

6.4.2.1 Research and Development Projects Should be Embedded in Larger Transdisciplinary Processes

However, the question of how results from transdisciplinary processes will impact political decisions, bioeconomic research and innovation processes in the future remains unanswered. As long as this issue remains unclarified, the commitment to socially responsible research and transdisciplinary processes may remain a front to appear conscientious. As an example, a comparative study on transdisciplinary research processes has shown that this approach is often misinterpreted by nature scientists as an approach to enhance the acceptability of new technological innovations or is even misused as a kind of "rhetorical mainstreaming" (e.g., Zscheischler et al., 2017). We argue that transdisciplinary processes can help us to better understand and anticipate how and under which conditions a bioeconomic innovation can benefit or harm society. In addition, transdisciplinary processes can stimulate new innovations by codesigning solutions together with societal actors and scientists from different disciplines that might be different from conventional innovations. This would also be aimed towards the dedicated innovation paradigm (Schlaile et al., 2017). Thus, research and development projects should be embedded in these integrative research

processes. However, transdisciplinary processes are time-consuming and require well-trained facilitators, as well as a high degree of flexibility, to meet the high demands with regard to issues of contributive and procedural justice (Timmermann, 2020). It is also challenging to move beyond anthropocentric perspectives and integrate the intrinsic value of non-humans in these processes, such as the environmental concerns related to the overapplication of manure and the according eutrophication of water bodies or the association with soy production for animal fodder.

6.4.2.2 Science has the Obligation and Responsibility to Think of More Radical Solutions

Currently, agriculture in Germany and the EU is associated with many sustainability challenges and is characterized by a strong persistence and lobbyism against SET and the related negotiation processes in society. As an example, Alons (2017) argued that although environmental actors are currently considered in agricultural policy making, this is done to legitimate business-as-usual strategies and not to favour an SET. Many bioeconomic innovations are linked to this nonsustainable system, for example, by looking for new uses for waste and residues from agriculture, as in the case of manure surpluses. We see the risk that many bioeconomic innovations might not only build on unsustainable systems but also contribute to their manifestation. As a consequence, science should use its "freedom" to develop and try out real radical alternative solutions. This development will need more reflexive and integrative research processes that are normatively oriented towards an SET and acknowledge uncertainty in the future (Bukkens et al., 2020). This also means critically analysing political-economic interventions and configurations that are associated with innovation and prevailing techno-optimism in society (Markusson et al., 2017; Pfotenhauer et al., 2019). Additionally, politics should recognize the possibility of transdisciplinary research to stimulate social learning and contribute to social justice in agricultural innovation and decision-making by applying contributive justice concepts and thus further supporting transformative research processes (see also Rogga et al., 2018). Not least, such development will also necessitate the political will to take up the results in a suitable format and move beyond the instrumental value of public participation for the sake of acceptance of decisions (Stilgoe and Guston, 2017).

6.4.3 Policy Implications: How Can Policy-Making Support a Sustainable Bioeconomy?

Politicians depend on democratic elections and operate in distinct time horizons (legislative terms) and thus must take into account and find a balance between multiple interests. Such a setting is generally not particularly suitable for enabling fast and radical changes; rather, it goes along with compromises, second-best solutions, and gradual reforms. However, policy makers can contribute to a social climate in which addressing the realms proposed by Abson et al. (2017)—to re-think our knowledge production and use, to restructure institutions and to reconnect people with nature—becomes possible, thereby setting the framework and incentives (while reducing the disincentives and barriers) for an SET. A policy mix that could be supportive of an SET may include a combination of the integration of different perspectives and positionalities in decision-making, room and support for niche actors (e.g., start-up capital, real laboratories), adequate incentives at the regime level (e.g., through regulations, positive and negative incentives), and macroeconomics and macropolitics that may also influence the landscape level (e.g., alternative national welfare calculation, effective CO_2 pricing). From a *national perspective* on the manure surplus problem, policy makers face a trade-off between allocative (e.g., internalizing negative externalities from stocking rates that are too high) and distributional claims (e.g., mitigating social impacts for

livestock farmers by managing transition times and providing alternative income sources), while also having to ensure stabilization (e.g., avoiding drastic changes to prevent countereffects or radicalisation of society against these politics).

6.4.3.1 Sustainable Governance Needs a Complex Systems Perspective

Addressing the manure surplus problem from an *SET perspective*, however, requires a reframing of the problem and a perspective change towards the entire agro-food system, including local, national and international aspects. Recent developments aim at an integrated policy approach that addresses several domains of the agrofood system (WBAE, 2020), which may also have impacts on the livestock sector and manure surpluses. In this regard, incremental improvements have already been made with regard to reducing production incentives through the reform of the EU's agricultural policy (the abandonment of export subsidies, the introduction of ecoschemes), mandatory animal welfare standards for livestock farms (e.g., piglet castration, space per animal, use of antibiotics), reformed fertilizer regulation with higher demands and sanctions, and research and support for EU protein crops (for substitution of imported animal feed). Further producer-related measures are currently being discussed, such as a maximum livestock density per land area, as are potential high-impact cross-cutting interventions such as effective CO_2 pricing. Consumer-related instruments that have been suggested, for example, by the WBAE (2020), include increasing the value-added tax for meat products (which could result in a further reduction of meat consumption), climate labels for supermarket products (improved information), or mandatory dietary prescriptions for school and kindergarten children. Innovations linking producers and consumers, such as communitysupported agriculture and testing environments for innovation and regulation, such as in transformative research processes (see chapter 6.4.2), need further attention and support. In the sense of Abson et al. (2017), this could both reconnect humans and nature and encourage rethinking with regard to knowledge production.

6.4.3.2 Sustainable Bioeconomy Needs Adaptive and Reflective Governance Approaches

Although the transformation of the agro-food system is perhaps still in an early stage, the above example illustrates how a combination of political instruments allows for the targeting of leverage points at different levels. This approach should be further developed towards integrated systems thinking and following a reflexive governance approach that allows for continuous policy learning and adaptation (Feindt and Weiland, 2018) and acknowledges uncertainty in complex systems (Bukkens et al., 2020). Analogously, systems thinking and reflexive and adaptive governance should also guide the further development of bioeconomy strategies to support SETs. The fact that criticism from non-governmental actors has led to a change in the composition of the German bioeconomy council, the introduction of bioeconomy monitoring, and a widening of the sustainability perspective of new bioeconomy strategy shows that the development and implementation process of the bioeconomy strategy is generally reflexive. However, there are still important needs for further adjustments, as integration may be due to legitimating business-as-usual strategies (Alons, 2017). Currently, the primary responsibility for the bioeconomic strategy is shared between the BMEL and BMBF. Innovation support (e.g., industrial bioeconomy, real laboratories) is granted by the Federal Ministry for Economic Affairs and Energy (BMWi). Other ministries, such as the environment (UBA) and economic cooperation and development (BMZ), play a less central role, but this role should be intensified given the implications of the bioeconomy for different sectors and regional, national and international scales. We also argue for incorporating

the knowledge created by transdisciplinary research processes beyond its instrumental value (see chapter 6.4.2) in regard to the design mission of a social-ecological transformation and the responsibility of policies for societal dialogue and transformation. The uptake of these results and this knowledge also allows us to move towards what has been framed as a dedicated innovation paradigm (Schlaile et al., 2017). This implies acknowledging the wickedness of the problem, which requires multiple actor participation and adaptive governance mechanisms as part of an ethical and responsible approach to an SET. In general, stimulating ethical discourse, including the discussion and consideration of moral dilemmas, on agricultural and bioeconomic innovations and their consequences both within and beyond society is an important step towards producing knowledge concerning how to design a just and sustainable bioeconomy.

6.5 Conclusions

The aim of this article was to identify the contribution of currently developed bioeconomic innovations towards their ability to contribute to an SET. We studied four innovations that aim to reduce nutrient surpluses from intensive livestock production. Based on the argumentation that an SET entails changing values, norms, and imaginaries that are currently present in societies, we developed and applied analytical categories that allowed us to analyse the norms and values that are being both performed and produced in bioeconomic innovation design. The results show that bioeconomic innovations manifest existing dominant thought styles that are based on reductionist problem framing, nature-human dualism, and prevailing techno-optimism. Against this backdrop, science and policy are important actors in both reshaping values and norms and reflecting ethical concerns and principles following the design mission of an SET. We argue that adjusting bioeconomic innovation towards the aims of an SET means highlighting the role of integrative and transformative research approaches that incorporate multiple knowledge and perspectives. In this respect, the role of science in trying out real alternatives as opposed to contemporary cultures of innovation design is important, as politics is trapped between different perspectives. Nevertheless, this needs to be accompanied by the reflective and adaptive governance of systems thinking that acknowledges the complex global entanglements of contemporary livestock production alongside the uncertainty of future transformations and their impacts on sustainability. These approaches can support innovation actors and policy makers in developing socio-technical innovations and strategies to cope with multiple crises. Our results are also applicable to other sectors in relation to bioeconomic approaches and SETs at large.

7 The role of bioeconomic innovation actors in livestock transitions[29]

Sustainable Production and Consumption 30 (2022) 584–595

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Bioeconomic fiction between narrative dynamics and a fixed imaginary: Evidence from India and Germany

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ARTICLE INFO

Article history:
Received 21 July 2021
Revised 15 December 2021
Accepted 23 December 2021
Available online 26 December 2021

Editor: Dr. Lilian Pungas

Keywords:
Imaginations
Capitalism
Sociotechnical change
Transformation
Future visions
Future studies

ABSTRACT

Bioeconomic ideas and visions have received increasing attention from scientists and policy makers to address socioecological challenges. However, the role of imagined futures in the design of bioeconomic innovations and transitions has hitherto been widely neglected. In this study, we therefore explore the role of imaginaries of the future to understand how they shape bioeconomic innovations and transitions. We thereby build on insights from economic sociology and compare two distinct case studies from Germany and India. Based on our results, we inductively develop an analytic model that describes the co-constitution of imaginaries, fictional expectations, narratives, and innovation dynamics. Our results show that narrative dynamics are caused by irritations in the political and discursive landscape; these irritations prompt economic actors to stabilize, adapt, or reject their own bioeconomic conceptions, while the underlying imaginary of a technological fix remains fixed. We discuss this reductionist imaginary and instead plead for an imaginary of a socioecological fix that reintertwines technologies with their underlying societal, cultural, and ecological factors. We conclude that this will support sustainability scholars and policy makers in remaining vigilant against premature mental and institutional lock-ins that could lead to a colonization of the future with severe negative implications for society's ability to mitigate and adapt to global environmental change in the future.

[29] This chapter has been published as Friedrich, Jonathan; Najork, Katharina; Keck, Markus; Zscheischler, Jana in *Sustainable Production and Consumption* (2022): Bioeconomic fiction between narrative dynamics and a fixed imaginary: Evidence from India and Germany. doi: 10.1016/j.spc.2021.12.026

7.1 Introduction

In recent years, the notion of a "bioeconomy" or "biobased economy" has become popular among scientists and policy makers as an innovative economic model for addressing the grand societal challenges that accompany global environmental change (Folke et al., 2021; Giampietro and Funtowicz, 2020). Given the wide spectrum of aims and fields of application accompanied by this notion, some authors even propose that the bioeconomy be perceived as a "panacea" by policy makers for obstacles to ultimately reconciling the effort s to meet the Sustainable Development Goals (SDGs) within the limitations of the planet's life support systems (Giampietro, 2019). As the aim and scope varies, so do definitions of the concept of bioeconomy (Bugge et al., 2016; Hausknost et al., 2017; Vivien et al., 2019). For instance, the European Union (EU) and the organization for Economic Co-operation and Development (OECD) have published bioeconomic strategy papers that have very different goals and include entirely different theoretical approaches. To bring some order to the situation, we refer to Bugge et al. (2016), who identified three major visions of the bioeconomy, namely, the "bio-technology vision", the "bio- resource vision", and the "bio-ecology vision". The "bio-technology vision" aims to create economic growth and jobs through the commercialization of new technologies, while the "bio-resource vision" seeks to combine economic growth and sustainability by converting and upgrading biological resources. The "bio-ecology vision" is ultimately driven by the goal of fostering sustainability, biodiversity, and ecosystem conservation through the development of integrated production systems and high-quality products. According to Hausknost et al. (2017), the "bio-technology vision" emerged first, while the other two visions followed later.[30]

Like other technical and organizational innovations, bioeconomic models are based on specific "imagined futures" (Beckert, 2013, 2018). Imagined futures are basically visions of how the future might look like; they are explicitly or implicitly entailed in scientific studies, reports and strategy papers and help policy makers, producers and consumers develop a more concrete idea of what can be expected or not. The role of imagined futures has thus far been widely neglected in the research on sustainability transitions associated with sociotechnical change (Feola, 2020; Knappe et al., 2019; Longhurst and Chilvers, 2019). Retrospective studies on bioeconomies and sustainability transitions have discussed how the introduction of specific innovations can lead to mental or institutional lock-ins, thus creating path dependencies that are difficult to change afterwards (e.g., Beck et al., 2021; Friedrich et al., 2021a; Graupe, 2020; Trencher et al., 2020; van den Bergh et al., 2015). However, the critical role of imagined futures in the emergence of new path dependencies and a resultant "colonization of the future" (Beckert, 2018) has yet to be accounted for. With this study, we aim to help resolve this gap.

With a specific focus on the notion of bioeconomy, we provide a comparative analysis of two "diverse" (cf. Seawright and Gerring, 2008) case studies from India and Germany. The first case study offers an example of the "bio-resource vision" of the bioeconomy (Bugge et al., 2016) and discusses innovations that aim to solve the manure surplus and the associated issues of the eutrophication of water bodies and the loss of biodiversity in Germany (Friedrich et al., 2021a). The second case study relates to the "bio-technology vision" of the bioeconomy (Bugge et al., 2016)

[30] Please note that further differentiations of the "bioeconomy" have recently been published by Hausknost et al. (2017) and Vivien et al. (2019). However, in their results, these authors do not differ substantially from Bugge et al. (2016); this is why we rely only on the latter.

and discusses the innovation of genetically engineered (GE) cotton that is resistant to Lepidopterans[31] ; the aim of this innovation is to increase production while reducing the need for pesticides in India (Najork et al., 2021). While these two case studies might seem unrelated at first, we argue that it is precisely their differences that allow us to identify exploratory commonalities among different imaginaries underlying the bioeconomic sector. Additionally, the two case studies help identify context-related specificities that involved actors pursue to achieve their ends. For this purpose, the concept of imagined futures (Beckert, 2018) provides the theoretical background, while we focus on narratives of economic actors as an analytical category that is empirically accessible and in which imagined futures are becoming visible. By offering an inductively compiled generalizable model of narrative dynamics, we will show how these narratives, which are used to legitimize specific technologies, alter in response to changes in the discursive level of society. With this aim, we will answer the following research questions:

1. What specific narratives do actors develop to effectively present their bioeconomic innovations to the public?
2. How do actors adjust these narratives to changing conditions and discourses?

7.2 Imagined futures and the bioeconomic transition

In this paper, we argue that an analysis of the ongoing transition toward a bioeconomy needs to consider imagined futures, as these constitute the driving force of capitalism in the form of cognitive resources for identifying new opportunities for capital accumulation (Beckert, 2013, 2018). By outlining possible trajectories for future outcomes, imagined futures, together with fictional expectations and interest-driven narratives, help to bridge much of the prevalent uncertainty in economic decisions and enable relevant actors to navigate in their specific contexts. At the same time, these imaginations of the future shape (bioeconomic) innovation design and guide sociotechnical transitions, thereby causing intended and unintended consequences (Geels, 2020; Jasanoff and Kim, 2009, 2013).

As decision situations in economic contexts in general and in (sociotechnical) innovation processes in particular are fundamentally marked by uncertainty, Beckert (2013, 2018) declares imagined futures to be a crucial precondition for innovation processes (see also Beckert and Bronk, 2019). Since the details and events of the future can never be fully anticipated or calculated, Beckert argues that actors build upon fictions about possible future states to draw conclusions in their decision-making processes. These fictions must be rather broad to allow room for maneuvering and creativity but must be "plausible enough that [they] could become true" (Esposito, 2007: 13). Fundamentally, imagined futures serve to suspend disbelief and equip economic actors with a perpetual capability to overcome paralysis and act purposefully despite omnipresent uncertainty about future events (Beckert, 2013: 226; Beckert and Bronk, 2019: 8). By taking the shape of imaginaries of some future state of the world that is cognitively accessible in the present, these fictions motivate actors to develop innovations that, in turn, continually reproduce the capitalist system (Beckert, 2013).

[31] Lepidopteran insects include butterflies and moths. The most damaging pests in the production of cotton are bollworms, including the pink bollworm (Pectinophora gossypiella), the American bollworm (Helicoverpa armigera), and the spotted bollworm (Earias vittella). Bt cotton provides protection against bollworms and other minor Lepidopterans, such as semiloopers, hairy caterpillars, and leaf-eating caterpillars (Fand et al., 2019).

The mental representations of the imagined future states accessible to actors are referred to by Beckert (2013, 2018) as "fictional expectations." These expectations are fictional in the sense that they represent potential future states as if these states were being realized (Beckert and Bronk, 2019). While these expectations differ from literary fiction in their scope and ramifications, these expectations are likewise anchored in specific narratives (Beckert, 2013; Beckert and Bronk, 2019) that render these expectations tangible to initiators and believers alike, structure their expectations, and create incentives for initiators and believers to act purposefully. Fictional expectations published by state agencies, e.g., can thus be read as signals for economic actors; these signals create an atmosphere of security for investments and for research and development activities (cf. Beckert, 2013). Conversely, such fictional expectations, by guiding innovation processes, help create future states that are hitherto only imagined (Jasanoff and Kim, 2009, 2013, 2015). Therefore, fictional expectations and sociotechnical innovation co-constitute each other –an issue that standard economics has, for a long time, failed to account for (Beckert, 2013; Beckert and Bronk, 2019). Fictional expectations not only accompany the design and diffusion of innovations but also inevitably constitute them by creating the cognitive and imaginative substratum of what could be possible. Conversely, the design of innovations recalibrates fictional expectations in that the resulting new artifacts and knowledge influence the content and shape of fictional expectations. This inevitably also applies to bioeconomic innovations (Bröring et al., 2020; Friedrich et al., 2021a).

Fictional expectations are at the interface of subjective and collective imagination (Beckert, 2018) and are a product of society's imaginaries that have culturally evolved and express normative knowledge of how societies should deal with social or ecological issues (cf. de Witt et al., 2017; Schlaile et al., 2017; Schlaile et al., 2022). While accounting for imaginaries (as social structures at the discursive level) and fictional expectations (as tacit knowledge at the individual level), we add "narratives" as empirically accessible modalities that occupy a middle ground between the former two. Table 8 defines the three aforementioned notions in detail.

In the following, we provide an analysis of the two bioeconomies mentioned above. While the notions of imagined futures and fictional expectations provide the theoretical background of our study, we direct our empirical focus toward the concrete narratives that exist around innovations helping to solve the manure issue in Germany (Friedrich et al., 2021a) and Lepidopteran infestations in Indian cotton fields (Najork et al., 2021). Our aim is to reconstruct the irritations and subsequent dynamics that these narratives are subject to and to understand how these narratives are stabilized and adjusted by the involved actors. Based on our findings, we aim to obtain a deeper understanding of the nature of the very imagined future in which the bioeconomic model is rooted.

Table 8: Imagined futures – key terms, definitions and conceptual scales, as defined by Beckert (2018) .

Term	Definition	Conceptual scale
Imaginary	Mental representation of an envisaged (future) state of the world; this representation motivates actors in their decisions and provides them with guidelines for reaching this state	Discursive level
Narrative	Socially shared and empirically accessible stories, theories or forecasts regarding how the present will be transformed into some imagined (future) state	Middle ground between societal discourses and individual expectations
Fictional expectation	Mental representation of imaginaries; this representation is anchored in economic actors and takes a narrative form, such as a story, theory, or forecast	Actor-oriented level

7.3 Methods and research design

To identify the narratives of bioeconomic innovation actors, we chose to compare two contrasting case studies (see Table 9 for a brief overview of the differences) –one investigating manure-based bioeconomic innovations in Germany (see chapter 7.4.1) and the other examining biotechnological innovations involving genetically engineered organisms (GEOs) in India (see chapter 7.4.2). This comparison follows the logic of "diverse cases" according to Seawright and Gerring (2008); i.e., both cases originate from the same background (i.e., the idea of a bioeconomy) but are based on very different visions (i.e., the "bio-resource vision" and the "bio-technology vision" of the bioeconomy) (Bugge et al., 2016). We would like to mention that diverse cases cannot represent the entire population but can serve to explore or confirm certain aspects of it (Seawright and Gerring, 2008). Our aim was to seek for similar dynamics of narratives among the two case studies that both share despite their content-related differences between these cases (see chapter 7.4.3).

Table 9: Diverse bioeconomic cases of Germany and India.

	A case from Germany (chapter 7.4.1)	**A case from India (chapter 7.4.2)**
Topic	The manure surplus, biodiversity loss issues, and manure-based bioeconomic innovations	Agricultural biotechnology, technological failure, and political regulation
Bioeconomy vision (Bugge et al., 2016)	"bio-resource vision"	"bio-technology vision"
Geography, socioeconomics, culture	Global North, industrialized agriculture, productive economy, and discourses on ecological sustainability and energy transitions (Beck et al., 2021; Friedrich et al., 2021b)	Global South, high share of subsistence agriculture, discourses on food security, population growth, and poverty reduction (Choudhary et al., 2014; Kathage and Qaim, 2012; Najork et al., 2021)
Bioeconomic policy strategies	Guiding principles: (1) the development of innovations by using biological knowledge and (2) the design of a circular economy (CE) based on natural resources; the aim is to help meet the SDGs (BMEL and BMBF, 2020)	Focus on "efficiency, productivity, safety and cost-effectiveness of agriculture, food and nutritional security; affordable health and wellness, environmental safety; clean energy and biofuel; and bio-manufacturing" (Departement of Biotechnology, 2021: 7)

7.3.1 Data acquisition

We conducted 26 qualitative, semistructured interviews with actors in Germany and India; 10 of the interviews were chosen as the empirical base for this study. As this paper focuses on the narratives of economic actors, we limited the interview sample to actors who employed such narratives and excluded other actors. The perspectives of opposing interviewees were purposely excluded from the sample.

Table 10 describes the interviewed actors. In the German case, interviews were conducted to examine contrasting framings of the manure issue and imagined solutions thereto. The interviews included those with actors currently designing bioeconomic innovations and actors from civil society or representatives from farmers' associations who may have opposing perspectives on the issue. In this case, we speak of bioeconomic innovation actors, defined as people or institutions currently developing new innovations related to "substitute products", "new processes", "new

products", or "new behavior" (cf. Bröring et al., 2020). A total of 12 problem-centered interviews were conducted, six of which were included in this study.

In the Indian case study, the interviews helped to map the present political landscape in regard to GEOs in India and disentangle the manifold networks that shape the ongoing negotiations involved in promoting, directing and constraining specific fictional expectations relating thereto. For this purpose, the stances and arguments of the main political actors (i.e., political parties; farmers' associations; and industrial, business, trade, and environmental associations) were documented. In sum, 14 expert interviews were conducted with entrepreneurs, politicians and activists, four of which were ultimately included in this study.

The interviews were conducted in German (for the German case study) and English (for the Indian case study). The German quotes have thus been translated into English. While the two interview guidelines (see supplementary information) are basically tailored to the specific contexts of each case study (see chapters 7.4.1 and 7.4.2), both guidelines share the common focus of bioeconomic innovation, prevalent political discourses on the subject matter, and actors' motivations and expectations in regard to the future of the technologies.

Table 10: Overview of interviewed actors in the two case studies.

IP (interviewed person)	Case study	Actor description
1	Germany	Economic innovation actor, recycling fertilizer
2	Germany	Economic innovation actor, recycling fertilizer
3	Germany	Scientific innovation actor, duckweed cultivation
4	Germany	Scientific innovation actor, recycling fertilizer
5	Germany	Economic innovation actor, recycling fertilizer
6	Germany	Economic innovation actor, transport of manure and fodder
7	India	South Asia Biotechnology center (SABC)
8	India	Farmer representing the Consortium of Indian Farmers Associations (CIFA)
9	India	Company representative from Metahelix Life Sciences under the auspices of the Association of Biotechnology Led Enterprises (ABLE)
10	India	Company representative from DuPont under the auspices of the Association of Biotechnology Led Enterprises (ABLE)

7.3.2 Data analysis

All interviews were recorded and fully transcribed. Data processing was performed by using MAXQDA software. The analysis and coding of interviews followed a combined deductive and inductive approach (Kuckartz, 2014). The first two authors of this article coded the material. We derived our deductive categories from theoretical considerations by Beckert (2018; chapter 7.2), who stresses the relevance of uncertainty, fictional expectations, imaginaries, and narratives for economic decision-making that is directed toward the future (e.g., the design of innovations). We furthermore included the stage of the innovation design and diffusion (roughly guided by the multi-level perspective, cf. Geels and Schot, 2007), possible results of innovation (narrative irritation in

chapter 7.4.3)[32], and actors' innovation distribution networks. Through our analysis, we further added inductively gained categories and examined our data for irritations in technological development, diffusion and adoption processes and, finally, discarded the category of distribution networks. We then used open coding to identify, cluster, and structure different narratives (see RQ 1) about how the interview partners present their technologies to the wider public and which societal issues these narratives are semantically linked to. Furthermore, our empirical material allowed us to identify different dynamics of how these narratives were rejected, stabilized or altered in the face of irritations (see RQ 2 and Figure 5).

7.4 Results

The following two case studies on the surplus of manure in Germany (chapter 7.4.1) and on genetically engineered cotton in India (chapter 7.4.2) show how bioeconomy actors use certain narratives to generate support for their respective innovations. The main emphases of the following sections are both the inductively discovered dynamics of the narratives deployed in the face of irritations and the strategies of the involved actors to stabilize, adapt or reject these narratives (chapter 7.4.3).

7.4.1 Case study 1: manure surplus, biodiversity loss, and bioeconomic innovations

In various regions in Germany, nitrate concentrations in surface water bodies and groundwater exceed the maximum permissible values set by the European Union (50 mg/l; BMEL and BMU, 2020). These high figures are largely attributed to manure surpluses resulting from intensive livestock production. In particular, the infiltration of manure-based nitrate from fields into water bodies raises concerns about the eutrophication of water bodies, the loss of biodiversity and the increase in drinking water costs (Umweltbundesamt, 2019). Approximately 17% of all groundwater assessment sites in Germany register nitrate values above 50 mg/l, while 27% of assessment sites characterized by surrounding agricultural land use register nitrate values that exceed 50 mg/l (BMEL and BMU, 2020). Accordingly, Germany is facing lawsuits from the European Union, and fines of 850,000€ per day for exceeding the specified thresholds are currently discussed (Sundermann et al., 2020).

Against this backdrop, new bioeconomic products for manure management are currently being developed (Friedrich et al., 2021a). These innovations include the cultivation of insects on manure (this innovation could provide a protein-based fodder substitute in livestock production (e.g., Čičková et al., 2015), the cultivation of duckweed on manure (this innovation could be used as a substitute for soy in livestock production (e.g., Stadtlander et al., 2019), and the recycling of manure by using manure as a mineral fertilizer substitute (this innovation could help compensate for the finiteness of rock phosphate (e.g., Pintucci et al., 2017) and strengthen the already existing reciprocal transport of manure and fodder between different livestock-intensive and arable regions in Germany (e.g., Asai et al., 2018). All these innovations fall within the "bio-resource vision" of

[32] We refer to narrative irritations as events or processes that challenge the previously outlined narrative; these events or processes include public discourses, consumer preferences and new scientific results. An exemplary irritation relating to our case studies is the re-occurrence of the target pest (pink bollworm) of the biotechnological innovation (Bt cotton) in our second case. While the new (bio)technology originally promised to defang pests of the bollworm species (Lepidopterans), this narrative is irritated by the pest's renewed occurrence.

the bioeconomy (Bugge et al., 2016), as these innovations relate to the conversion of matter. The German government supports the development of the above mentioned innovations through its bioeconomic strategy (BMEL and BMBF, 2020).

7.4.1.1 Key narratives and the technological fix imaginary

Based on our interviews, we identified five different narratives that are used by involved actors to legitimize their innovations to the public (see Table 11). All of these narratives rest on the imaginary of a technological fix for the underlying issues attributed to the surplus of manure. These narratives relate to two major fields: ecological sustainability and economic potential. Specifically, these narratives include i) "closing the loop" in a circular economy, ii) spatially decoupling agrifood systems, iii) substituting conventional mineral fertilizer, iv) protecting soils and higher yields, and v) unleashing economic potential through the widespread diffusion of innovation (see Table 11). i) The circular economy narrative relates to using technology to close (currently open) regional cycles of matter: "It would be much easier to significantly increase the degree of self-sufficiency […] and then, ideally through a circular economy. […] I imagine that I will be able to spread the liquid manure on the field or bring the liquid manure […] to the duckweed. There are also other ways in which I can increase this circular effect" (IP 3). ii) The narrative of spatially decoupling agrifood systems relates to the end of the area-bound application of manure in livestock-producing regions. Supporters argue that this decoupling will not lead to an intensification of livestock farming: "This means that our concept is a decoupling of areas. This will not lead to an expansion of factory farming because this is no longer possible under current construction laws. […] This means that we can support small and medium-sized farms. We can maintain the basic agricultural structure. […] Yes, let me put it this way: we are back to where we were 150 years ago" (IP 5). iii) The narrative of substituting conventional mineral fertilizer relates to the finiteness of rock phosphate, which can be overcome by using recycled manure instead: "Phosphate is a finite raw material, which we are already seeing today or have seen in recent years, and we are having increasing difficulties processing this raw material because of the many, many impurities. So, the question is, where else can I obtain this raw material?" (IP 1). Relatedly, manure-based fertilizer would also render the energy-intensive Haber-Bosch[33] process unnecessary: "Especially now, from the point of view of CO 2 reduction, we have, for example, been able to recycle nitrogen instead of spending three liters of heating oil per kilogram on transposing nitrogen from the air by using the Haber-Bosch process […] or to completely prevent methanization on agricultural land, including of nitrous oxide" (IP 5). iv) The narrative of protecting soils is related to the use of recycled fertilizer as a carbon carrier that will lead to improved soil health and higher yields: "At the end of the day, we have highly enriched nutrients and carbon carriers. This is one of the issues that is currently being completely overlooked in fertilizer policy, in my view. […] There is actually the issue that they completely neglect the carbon cycle that such soil needs. But it's always just about nutrients and stuff like that. […] You can see that quite clearly in our region. […] The soil structure is gradually changing. […] You can really see this in the yields" (IP 2). v) The narrative of unleashing economic potential through the widespread diffusion of innovations distantly relates to unburdening farmers from the need to pay to dispose of their manure surpluses due to existing legal standards: "So of course it's economically driven" (IP 4).

[33] Haber-Bosch process refers to the synthetization of ammonia out of the atmosphere.

Table 11: Overview of the imaginaries and narratives of innovation actors relevant to manure-based bioeconomic technologies in Germany.

	IP 1	IP 2	IP 3	IP 4	IP 5	IP 6
Type of actor	Company, recycling background	Company, agricultural background	Science	Science	Company, agricultural background	Company, agricultural background
Type of innovation	Recycling fertilizer	Recycling fertilizer	Duckweed cultivation	Recycling fertilizer	Recycling fertilizer	Transporting manure
State of innovation	Development	Development	Development	Finished development	Market entry	Used in market
Imaginaries	Technological fix related to ecological sustainability	Technological fix related to ecological sustainability and economic potential	Technological fix related to ecological sustainability	Technological fix related to ecological sustainability	Technological fix related to ecological sustainability	Technological fix related to ecological sustainability
Narratives	i) closing loops, ii) spatial decoupling	iii) substitution of conventional fertilizer, iv) soil protection and higher yields	i) closing loops	i) closing loops, v) economic potential	i) closing loops, ii) spatial decoupling, iii) substitution of conventional fertilizer	Problem is solved by transporting manure

We categorize all five narratives as relating to a technological fix for the aforementioned manure issue. However, we do so with varying foci based on the different conceptualizations of what is regarded as the actual problem. The first and second narratives address technological fixes for environmental issues, particularly in regard to disturbed biochemical cycles of nutrients; these issues ought to be solved through technological progress. The third narrative also involves the imaginary of a technological fix for environmental issues; however, in this narrative, the environmental issues are specifically related to the energy-intensive production of mineral fertilizer. The fourth narrative concerns a technological fix for environmental and economic issues by arguing for both protecting soil by recycling fertilizer and generating higher yields through more productive agriculture. The fifth narrative ultimately relates to a technological fix for the economic standstill in agriculture; this standstill can be overcome by unleashing the economic potential of manure conversion.

7.4.1.2 Narrative dynamics

As outlined above (see Table 11), all of these manure-based innovations are in different stages of development. Since the innovations from IPs 5 and 6 are already available in the market, these innovations can be used to show the narrative dynamics involved (for more types of narrative dynamics, see chapters 7.4.2 and 7.4.3). We found that both actors use different mechanisms to reproduce and stabilize their narratives over time to be competitive in the market.

IP 5 provides us with two mechanisms that reproduce the narrative (prior to potential irritations), namely, telling economic success stories and building rhetoric coalitions; both mechanisms help the actor address the superiority of the innovation. The success story unfolds as follows: “One of the secrets of our incredible success that we have now [is to] always calculate the quality of the products and whether these can be immediately implemented in the market because we reproduce industrial products one to one as recycled products. That is the crucial difference, and

with it, we have completely captured the entire market because all the others have always gone down this traditional path, typically engineering, but just never released any products of value and then just never achieved sufficient profitability" (IP 5). Building rhetoric coalitions is similarly straightforward: "According to experts from universities and chambers of agriculture/ministries with whom we work very closely, we are now highly recommended. They also highly recommend us because they say, 'This is the best solution that is currently available in the market and it truly works.' That is the decisive point" (IP 5).

IP 6 provides us with a stabilizing mechanism. The actor argues that the reciprocal transport of manure and fodder between regions characterized by intensive livestock production and arable regions allows the manure issue to be solved regionally while meeting the standards of the German nitrate directive. The actor (who developed the innovation of reciprocal transport of manure and fodder) builds on past experiences of success following the nitrate directive to legitimize his or her own innovation and regards the appearance of new innovations as an irritation of his or her own narrative of having solved the manure issue (for more information on irritation, see chapter 7.4.3); IP 6 indicates this view of new innovations as an irritation by devaluing the company's competitors. In response to the question, "So, you are saying that these big industrial manure processing plants [the competitors] are not doing what they should be doing, and they are solving a problem that does not even exist in the end?" (Interviewer) IP 6 said the following: "Right. Which now no longer exists. That would have been a sensible thing to do 15 years ago because the whole logistics chain had not yet been set up. Now it has been built up; now many other biogas plants have been built up and constructed with it, and then you take the basis away from them again, just to operate a large system. That is quite wrong" (IP 6). We see this answer as a way of stabilizing IP 6's own narrative. As such, the planned building of biogas plants translates into an irritation for IP 6 by undermining the favored narrative and elaborated innovation (Figure 5).

7.4.2 Case study 2: agricultural biotechnology, technological failure, and political regulation

Biotechnology is meant to contribute to a "knowledge and innovation driven Bioeconomy,"and its significance as a "tool for national development and well-being of society"is enshrined in the future vision of India's National Biotechnology Development Strategy (Departement of Biotechnology, 2021: 1). According to the Department of Biotechnology's recently published strategy documents, efforts are being made to "create a strong enabling environment to promote the growth of the [biotechnology] sector" (Departement of Biotechnology, 2021: 1); this is a perspective that corresponds to the "bio-technology vision"of bioeconomy (Bugge et al., 2016).

Among the multitude of GE crops researched and developed in India[34] , Bacillus Thuringiensis (Bt) cotton is particularly relevant for our study. Bt crops produce Bt bacterium endotoxins that are lethal to key insects, such as Lepidopterans, which are considered a crucial limiting factor in both cotton and eggplant production (Choudhary et al., 2014; Kathage and Qaim, 2012; Kaviraju et al., 2018). As the first and still only authorized GE crop in the country, Bt cotton (Bollgard I) was introduced to India in 2002, while Bollgard I's successor (Bollgard II) followed in 2006 and is currently used on 94% of the Indian cotton area (Choudhary and Gaur, 2015; International Service for the Acquisition of Agri-Biotech Applications (ISAAA), 2017). While never fully accepted, Bt cotton technology was considered by many to be a silver bullet in the fight against bollworms

[34] For an overview, see Choudhary et al. (2014).

(Choudhary et al., 2014; Kathage and Qaim, 2012). However, the pink bollworm (PBW), the major cotton pest that Bt cotton technology was intended to control, has recently developed resistance to the crop in several Indian states, thus causing plummeting yields and negative socioeconomic effects for farming households (Fand et al., 2019; Mohan Komarlingam, 2020; Naik et al., 2018; Najork et al., 2021; Tabashnik and Carrière, 2019; Tabashnik et al., 2021). The recently developed resistance of PBWs to Bt cotton has been perceived as a major irritation among related innovation actors and has substantially affected the corresponding narratives.

7.4.2.1 Key narratives and the technological fix imaginary

Broadly speaking, all interviewed actors and representatives considered the application of biotechnology in Indian agricultural production to be necessary. Expressed by all four interviewed actors, the superordinate imaginary related to the agricultural biotechnology sector construed biotechnology as a technological fix (IPs 7–10). This imaginary was expressed in the form of various narratives that can be categorized as social benefits, economic potential, and ecological sustainability (IPs 7–10). Specifically, we identified narratives related to i) increased farmer income, ii) workload reduction, and iii) food security in the social benefits dimension; iv) increased yields and v) international competitiveness in the economic potential dimension; and vi) pesticide reduction, and vii) adaptation to climate change in the ecological sustainability dimension (see Table 12).

Table 12: Overview of the imaginaries and narratives of innovation actors relevant to GEOs in India.

	IP 7	IP 8	IP 9	IP 10
Type of actor	SABC South Asia Biotechnology center	CIFA Consortium of Indian Farmers Associations	ABLE (Metahelix Life Sciences) Association of Biotechnology Led Enterprises	ABLE (DU Pont) Association of Biotechnology Led Enterprises
Type of innovation	GE crops (Bt cotton, Bt prinjal)			
State of innovation	Bt cotton: widely used in the market; adoption rate of 94% (International Service for the Acquisition of Agri-Biotech Applications (ISAAA), 2019: 2)			
Imaginaries	Technological fix related to social benefits, economic potential and environmental sustainability	Technological fix related to social benefits, economic potential and environmental sustainability	Technological fix related to economic potential and environmental sustainability	Technological fix related to social benefits and economic potential
Narratives	i) increased farmer income, ii) food security, iv) increased yields, v) international competitiveness, vi) pesticide reduction	ii) workload reduction, iii) food security, vi) pesticide reduction	i) increased farmer income, iv) increased yields, v) international competitiveness, vii) adaptation to climate change	i) increased farmer income, v) international competitiveness

In regard to the social benefits dimension of the involved narratives, all interviewees emphasized the importance of biotechnological innovations for farmers. This emphasis was exemplified by IP 7, who described his interest in research as follows: “As an agricultural scientist, I strongly believe that the technology and seed is very crucial for my farmers in India” (IP 7). In

this context, the narrative of i) increased farmer income was particularly relevant: "And there, technology has a huge role, particularly in increasing incomes" (IP 9; see also IP 10). One interviewee even voiced this expectation aloud, stating that the goal was "doubling farmer income" (IP 7). Moreover, the narrative of ii) workload reduction was mentioned in regard to farmer well-being: "In the villages, it is very, very difficult for them, too. Physical work is [difficult]" (IP 8). Another important aspect related to the social benefits dimension of the technological fix was that of iii) food security (IPs 7–8). The interviewees expected food security to be jeopardized if the use of biotechnology in agriculture was reduced: "Can we stop 10% of cultivation every year? […] What will happen to national food security?" (IP 8); another interviewee stressed the significance of biotechnology for food security against the background of India's population size: "Sooner or later, the government has to look at technology. There's no way that we can run away from development. […] With the kind of population that we have, I think food security is much [more] critical for my country than any other country in the world" (IP 7).

These social benefits depend on narratives related to the economic potential of biotechnology regarding iv) increased yields, as noted by one interviewee: "Our cotton production at the national level actually increased by a factor of three. […] So, I need to look at yield parameters" (IP 7). Another respondent underlined the economic role of biotechnology in India's v) international competitiveness; the respondent argued that productivity had improved in "every parameter" and hence "India was the largest importer of cotton, [and is] today […] the largest exporter of cotton" (IP 9; see also IP 7; IP 10).

Furthermore, a technological fix regarding ecological sustainability was expected (IPs 7–9). Here, the main point was vi) pesticide reduction, which is of particular interest to actors working with food crops, such as Bt brinjal[35] , as voiced by one respondent: "But in India we have half a million brinjal farmers. […] They're still spraying four or five dozen pesticides to get the brinjal crop out to the market; [this] would be about a barrel pesticide residue inside [the crop], which no one wants" (IP 7). Another respondent even specified the potential future trajectory of possible pesticide reductions: "I would consider probably in the next, maybe, 50 years, if genetic technology is adopted, probably the use of pesticides, insecticides and weedicides will come down, maybe 70, 80%" (IP 8). In addition to the expected reduction in pesticide use, positive contributions regarding vii) adaptation to climate change were mentioned: "Water shortages, climate change. All this is going to come in, so you have to modify the crops to suit these conditions" (IP 8). The potential of agricultural biotechnology as one of several solutions was thus emphasized: "Yes, GM crops are not a silver bullet; it is one […] of the potent options for addressing the issues that the agrarian scenario in the country faces. Whether it be challenges from climate change […or the] equitable distribution of development in our country" (IP 9).

7.4.2.2 Narrative dynamics

The aforementioned narratives have encountered irritations, which were found to play a central role in the narrative dynamics, as these irritations ultimately initiated the rejection, stabilization or adaptation of the original narratives. In the Indian case, technological and political irritations were relevant. Our results show that the sector recently faced technological irritations caused by the failure of Bt technology and the reoccurrence of pest infestations. The PBW's evolving resistance

[35] Bt brinjal was developed in India from 2005 onward. However, this crop was put on hold after a moratorium was imposed on the commercialization of the crop by the then environment minister in 2010.

to Bt cotton's built-in pest resistance –originally the crop's raison d'être –forced the actors involved to adapt their narratives. We found that this adaptation involved a rejection and the subsequent adjustment of the original narratives. As an empirical example, PBW infestation has been belittled and reframed as a mere management problem, and the relation of the problem to Bt technology is negated: "We believe that scientifically, it is very easy to manage pink bollworm […] But I don't think pink bollworm per se would have to do anything with Bt technology. […] I think it's a management practice, and I'm sure that by next season we should be able to contain this pink bollworm problem" (IP 7). While the severe damage caused by PBW infestation was originally the main argument for implementing the technology, this narrative is now rejected due to the pest's evolved resistance. Instead, technology failure is reinterpreted as a narrative of technology application failure.

Another rejected and then adapted narrative concerning this technological irritation is that the technology is said to be advanced, and new technological improvements need to be continually authorized for the technology's benefits to be fully realized: "You don't have to use [pink bollworm resistance] to beat down the technology. Technology development is a continuous process. From the very advent of agriculture, things have been moving. Resistant varieties develop, they succumb, then you have a new wave of varieties, […] so it is a continuous process" (IP 9). While the first generation of Bt cotton was originally presented as a silver bullet in the fight against the target pest, now, after the crop's failure, this narrative is being rejected and adapted to a narrative of constant technological development. This narrative adaptation not only explains the failure of the first Bt generation, thereby stabilizing the narrative of its successful implementation, but simultaneously justifies its successors being repeatedly authorized and implemented. Similarly, one interviewee argued that the yield increase, which he had earlier attributed to the introduction of Bt technology, recently stabilized only because new technologies have not been authorized: "The yields have stabilized because Bt is not a yield technology. […] Bt does not increase the yield per se. […] The yield is stabilized only because then new genetics have to come on top of it" (IP 10).

Our results also revealed the possibility of a stabilization of narratives following irritations. For this stabilization, the interview partners referred to past technological innovation successes before the irritation to further consolidate the technological fix imaginary. As Bt technology has now been used in India for almost 20 years, the respondents could draw on their past experiences related to implementing and diffusing biotechnological innovations. Here, the respondents notably referred to past narratives of success while neglecting those of apparent failures: "Why are [the farmers] cultivating this? Obviously, they see the benefit in this, and the downsides, there are relatively fewer" (IP 9). In this regard, the high diffusion and implementation rate of Bt cotton (94%) throughout cotton-growing areas in India (International Service for the Acquisition of Agri-Biotech Applications (ISAAA), 2019: 2) was of particular relevance, as it was argued that this high rate had been achieved because of farmers' preference for the technology: "And today, it is 12 million hectares. And seven million farmers. And who am I to tell my farmers what to do, what not to do? They do it because they like it. They found it to be useful. So, why would I convince my farmers not to use it? […] But I would ask Vandana [Shiva] only one question: Why are there seven million farmers [using it]?" (IP 8). Finally, it was stated that if farmers were unsatisfied, the rates of adoption would have already declined: "they can always discontinue [using it] if it is not working" (IP 7).

Apart from the return of the PBW, political irritations were also mentioned; these included mainly the moratorium imposed on the commercialization of the first GE food crop, named Bt brinjal by the then environment minister, Jairam Ramesh, in 2010 (IP 7; IPs 9–10). One interviewee described the impact of the resulting uncertainties for the biotechnology sector as follows: "In India, I can tell you, until today, we have not been able to do anything because of the moratorium on Bt brinjal. [The] scientific community [is] completely demoralized. Nothing is moving. There is no investment, big investment in this technology. And all that you see today is actually the result of the moratorium" (IP 7; see also IP 9). Thus, "the industry investment in biotechnology [has taken a hit]" (IP 10) due to the moratorium, as was stressed repeatedly (see also IPs 7–9). This description of the demoralization of the entire industry and the lack of investment following the incident shows that the sector's fictional expectations were shaken, and hence no reliable mental representation of the future remained to direct action or investments toward.

All respondents mentioned path dependencies arising from such political decisions (IPs 7–10), as exemplified by the following statements: "I would say that this was the beginning of the slide of the biotech industry in India. Had Bt brinjal [been] commercialized, things would have been much, much better" (IP 10), and "had he [the former Environment Minister] approved Bt brinjal […] you would have seen very different advancement in technology today in India than what we have now. […] You see, since the moratorium began, […] most of the companies withdrew or downsized their R&D facilities in India" (IP 7).

Another political irritation that emerged was the planned governmental price control of Bt cotton seeds: "So, those decisions [about Bt cotton price control] have had further effects. […] Until [the] end of 2015, the industry was suffering because of the unpredictable scenario" (IP 10). As emphasized by all interviewees, these politically induced planning uncertainties had far-reaching effects on research and development (R&D) investments, as these investments, of course, would have to be made before the given innovation could be introduced (IPs 7–10): "For technology development, it's not like you can just come out with a white paper with some point and say that 'here is the technology.' […] It takes time, it takes resources, it takes manpower, it takes intelligence. You need to hire people, […] you need to fill laboratories. And you are liable to the legal structure that you have in the country" (IP 7; see also IPs 8–10). This quote underlines the severity of the irritation after investments have been made.

Ultimately, neither technological nor political irritations prompted a readjustment of the technological fix imaginary. In fact, rather than causing the reevaluation of stakeholders' elementary imaginaries, the irritations were found to have produced narrative dynamics, as they led to the rejection, adaptation or stabilization of the original narratives (see Fig. 1). The stability of the prevailing technological fix imaginary is emphasized by the interviewees' indication of the lack of alternatives to biotechnological solutions in agriculture (IPs 7–10): "Yeah, so I'm one-hundred percent sure that, you know, except for technology, there's no other alternative" (IP 7). In this context, one respondent was hopeful that GE technology "may get delayed, but it will not get denied, because people need it" (IP 9). Thus, in contrast to the dynamic narratives, the original technological fix imaginary remained intact as irritations arose; the imaginary even outlasted the resulting uncertainties.

7.4.3 Synthesizing the case studies: a model of narrative dynamics

Based on our empirical material from the two case studies that present different visions of the bioeconomy (cf. Bugge et al., 2016) in different local contexts, we now develop a generalizable model, depicted in Fig. 1 , that describes the co-constitution of imaginaries, fictional expectations, narratives, and innovation dynamics (this builds up on chapter 7.2; see also Beckert, 2018; Geels, 2020; Jasanoff and Kim, 2009). This model illustrates the contrast of fixed superordinate imaginaries and dynamic narratives by showing how narratives are stabilized, rejected or adapted in response to irritations (Figure 5[4]). In the following, we outline this contrast on the basis of our case studies. An overview of the narratives and imaginaries presented by the two cases is described in Table 11 Table 12.

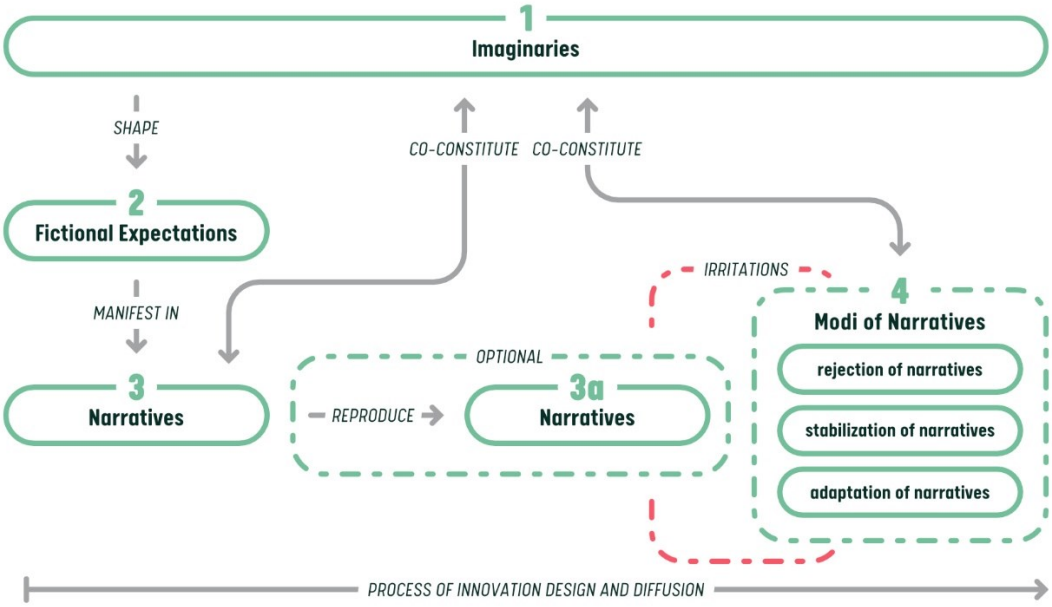

Figure 5: Bioeconomic innovations and involved narrative dynamics.

As our studies show, the narratives enable economic actors to legitimize their technological innovations vis-à-vis the wider public. In this regard, we discovered different dynamics of change in these narratives throughout the innovation design and diffusion.[36] We found that the narrative dynamics were triggered by irritations produced by internal and external incidents or developments that called respective innovations into question. In the German case, the appearance of new technologies that threaten the success of already existing technologies is one such irritation. In the Indian case study, the technological failure of Bt cotton associated with the return of PBWs and the political moratorium on Bt brinjal epitomized these irritative events. We identified three modes of narrative dynamics that actors implement to cope with such irritations: rejection of narratives, stabilization of narratives, and adaptation of narratives (Figure 5 [4]). These dynamics can occur in combined or consecutive forms and are not mutually exclusive. In the following, these dynamics are mapped out in detail. We further found that before irritations, actors use similar strategies which we interpret as a reproduction of their narratives serving to support the same (Figure 5 [3a]).

[36] It is beyond the scope of this article to deeply interrogate the different processes involved in the design and diffusion of innovations across time and space. We point to the substantial body of literature in sociotechnical transition studies that covers these dynamics. In particular, we highlight the research on the multi-level perspective and subsequent related research, such as that on different transition pathways by Geels and Schot (2007), who describe different pathways of sociotechnical change.

An example of the reproduction process (Figure 5 [3a]) is the building of rhetoric coalitions, i.e., referring to experts to provide narratives with an additional degree of credibility. In the German case (see chapter 7.4.1), interviewees referred to scientific experts to amplify their narrative of the success of a specific technology.

The stabilization of narratives (Figure 5 [4]) occurs if economic actors underpin their own narratives with additional information or try to discredit other narratives to make their own more reliable and persuasive. For example, interviewees argue that the high implementation rate of Bt cotton in India (see chapter 7.4.2) can be seen as proof of the technology's success despite the irritation caused by the return of PBWs.

A rejection of narratives (Figure 5 [4]) takes place if economic actors discard a specific narrative that they had formerly used to legitimize their technological innovation. In this case, these actors turned to adapted or completely different narratives, which may have existed before the irritation or may be created anew. For example, the failure of Bt cotton and the evolving resistance of the target pest forced the relevant actors to drop their original narrative of the first generation of Bt cotton technology being a cure for the PBW problem and instead reinterpret the situation as one of continuous technological development (see chapter 7.4.2).

The adaptation of narratives (Figure 5 [4]) means that involved actors add or remove specific aspects of the story and change the way they legitimize their technological innovation. This dynamic is found in the Indian case (see chapter 7.4.2), where the failure of the Bt cotton technology forced involved actors to argue that the return of the pest was a mere management problem not attributable to the technology as such.

In addition to revealing these narrative dynamics, the two case studies bring to the fore a single superordinate imaginary that stays unchanged over time, and that is one of a technological fix (for further discussion on this aspect, see chapter 7.5.2). Notably, this imaginary is not shaken, even in situations marked by severe internal (e.g., technological) or external (e.g., political or economic) irritations (see chapter 7.4.2.2). Rather than revising their entire imaginary and thereby questioning their internalized logics, the interviewees adapted or rejected isolated narratives and adjusted them to avoid criticism to ultimately maintain their belief in technology.

7.5 Discussion

In this article, we investigated different narratives that bioeconomy actors used to legitimize certain technologies and examined how these narratives relate to changing conditions and discourses. We applied the economic sociology of Beckert (2013, 2018) to bioeconomies and showed that interview partners in both case studies followed the imaginary of a "technological fix" to solve social, environmental or economic challenges (see also Birch, 2019; Birch et al., 2010). The "technological fix" imaginary itself remained static over time as a prevailing idea of progress and development (cf. Harvey, 2003, 2007; Markusson et al., 2017) despite the occurrence of manifold irritations. Our results therefore reveal a sharp contrast to the more dynamic narratives used by bioeconomic innovation actors to legitimize their technologies (see Figure 5). These narrative dynamics allow the relevant actors to avoid the dismissal of their single superordinate imaginary. Our inductively received model of narrative dynamics (Figure 5) contributes to the existing theory of imagined futures in that the model describes these futures (in the form of empirically accessible narratives) on the micro level, thereby contributing to the overarching topic of normative dimensions of sustainability transformations (e.g., Schlaile et al., 2017). In the

following, we first discuss these results in relation to the duality of the fixed imaginary of a technological fix and the dynamic narratives, and we come up with a plea for escaping fixed imaginaries in an attempt to "decolonize" the future through integrated systems thinking.

7.5.1 Narrative dynamics and a fixed imaginary

The results of our case studies show that the narratives of bioeconomic actors are related to the specific problems and societal discourses in each country. Thus, the technological fix imaginary is realized in different forms and manifestations (see chapters 7.4.1 and 7.4.2). In the German case, technology was meant to solve environmental issues and create economic potential. This was described by using narratives of closing loops, decoupling, using substitutes for the energy-intensive production of fertilizer, increasing yields, and promoting the economic potential of cost avoidance for those willing to adopt the innovation. Socioeconomic narratives appeared to be less relevant than in the Indian case. In fact, in the latter, socioeconomic narratives were found to rather co-constitute the technological fix imaginary, e.g., in narratives of food security, increased yields and income, and the reduction of farmers' workload, while in Germany, public discourses are centered on questions of ecologic sustainability, especially in relation to energy transitions (Beck et al., 2021; Friedrich et al., 2021b); in India, emphasis is placed on how to erase food insecurity and end poverty (Beck et al., 2021; Choudhary et al., 2014; Kathage and Qaim, 2012).

However, although the focus of the narratives differs, our results show that the imaginary of a technological fix underlies all mentioned narratives. While this imaginary stays unchallenged over time, the narratives are dynamically used to defend the idea of a technological fix against all odds (see chapter 7.4.3 and Figure 5). As the imaginary of a technological fix forms the basic roots of neoliberalism (Harvey, 2003, 2005, 2007; Markusson et al., 2017; McLaren and Markusson, 2020), its fixation has historically grown and is meanwhile deeply inscribed in society (e.g., Nightingale et al., 2020). It is therefore little wonder that this imaginary is highly resilient, thus posing ever more difficulties for any attempt to change it. The narrative dynamics discussed here both constitute and are constituted by the technological fix imaginaries, as these dynamics continually feed the imaginaries with new ideas and argumentations regarding how to effectively legitimize the respective technological innovation. Likewise, the fixed imaginary continually yields new adapted narratives and relativizes failing innovations caused by external factors.

7.5.2 Overcoming the imaginary of a technological fix: toward integrated systems thinking

In the neoliberal order, problems of public concern are often recast as nonpolitical issues to be solved by technological solutions instead of through changes in socioeconomic relations or culture (Roy, 2011; Scott, 2011); this has been described as technological fetishism (cf. Harvey, 2003). Morozov (2013) extends this by adding "solutionism", which refers to technological design and innovation that aims to solve problems whose complexity is not fully understood. We argue that similar tendencies apply to our case studies, as bioeconomic technologies attempt to solve highly complex social and environmental problems reductionistically by excluding societal aspects, such as human decision making, thereby possibly overlooking unintended side effects, which are difficult to solve once a certain development path has been taken (see also Friedrich et al., 2021a).

Escaping the imaginary of technological fixes is thus difficult, as it is rooted deeply in neoliberal ideas of growth and development and helps reproduce the neoliberal order (Birch, 2019; Birch et al., 2010). However, what can then be done to potentially overcome this imaginary? In our

view, we first need to acknowledge the role of imaginaries in principle, as without them, society would be unable to make new social or technological developments (Ziegler, 2019). Castoriadis (1990) argues that imaginaries, specifically social imaginaries, constitute society as such through shared understandings and meanings; therefore, without social imaginaries, social life would simply be impossible. Thus, imaginaries that materialize in new technologies should not be viewed as negative per se. However, what is needed is an imaginary that is characterized by its own limitations. We can think of a technological fix of a technological issue; but as shown in our study, it is reductionist and may even be risky to rely entirely on a technological fix of societal issues by neglecting the underlying social, cultural and ecological aspects that produce these issues. Against this background, what is needed to grasp the complexity of socioecological problems is to develop an imaginary of a socioecological fix, meaning an imaginary that reintertwines the aforementioned idea of a technological fix with its underlying societal, cultural, and ecological factors. This also means attending to the complexity of wicked problems (in contrast to the "simple" narrative of neoliberalism; cf. Waddock, 2021). We therefore want to stress scientific concepts that indicate possible ways for future thinking. These approaches include, among others, philosophical debates on the ethics of invention (e.g., Jasanoff, 2016), responsible research and innovation (e.g., Owen et al., 2012), dedicated innovation systems (e.g., Schlaile et al., 2017), and adaptive governance methods (e.g., Bohle et al., 2009; Cleaver and Whaley, 2018; Kovacic and Di Felice, 2019). These concepts can help develop short-term strategies for adaptive and dynamic sociotechnological development. We therefore see the necessity of developing these approaches further in exchange with and for society.

As a long-term solution, we argue that societies need open discursive spaces that allow for societal exchange and debate, thereby building the ground for developing new imaginaries that can materialize in or produce new social and/or technological innovations. In our view, transdisciplinary science projects (e.g., Zscheischler and Rogga, 2015) that acknowledge the complexity of problems and the uncertainty of the future and include a broad range of stakeholders, thus coproducing knowledge and being able to influence the imaginaries of society and science, can provide such discursive spaces. Therefore, these projects provide opportunities to discuss wishes, expectations, and, thus, imaginaries of desirable futures (see, e.g., Pereira et al., 2018). In the words of Beck et al. (2021: 149), this would also mean "attend[ing] better to diversities of visions, actors and commitments that are present when one looks beyond dominant reductive and linear framings. Doing this reduces the risk that visions of transformative change close down, rather than expand, the range of pathways and the diversity of actors and their visions contributing to them." A practical example of how such discursive spaces in society could look like, very close to the transformation toward a bioeconomy, has been demonstrated by Kimpeler et al. (2018), who discussed different bioeconomic scenarios (imagined futures) during participatory workshops with interested societal actors. The results of the workshops show the importance of engaging with society in discussing (desirable) imagined futures, as this acknowledges the diversity of perspectives and knowledge in creating a sustainable bioeconomy. However, in our view, this could even be extended toward open imaginative and discursive spaces (following the idea of transdisciplinary science) that would not just discuss existing ideas (and scenarios) but rather would aim toward creating entirely new imaginaries with society and for society.

7.5.3 Limitations of the research: reflections on methods and research design

We chose an exploratory research design to examine the diverse (cf. Seawright and Gerring, 2008) and contrasting bioeconomic cases of Germany and India; this design allowed us to inductively develop a model of how bioeconomic actors legitimize their technologies by means of narratives that are adjusted over time. We contributed to the study of imagined futures (Beckert, 2018) by showing that the content of narratives is context related (see Table 9; see chapter 7.5.1 for a brief discussion on this aspect), while actors apply a similar set of strategies to stabilize, reject or adapt their narratives (see chapter 7.4.3). Particularly, the discrepancies resulting from the different backgrounds of the two cases (one case is in the Global North, and the other is in the Global South) and their contrasting visions of the bioeconomy (cf. Bugge et al., 2016) allowed for conferrable findings that we consider transferable to other regions.

While we presented two contrasting cases to allow us to identify commonalities among the broad range of bioeconomies, we see further need to prove our resultant model of narrative dynamics through complementary research, such as through an analysis of cases from other regions and other bioeconomic contexts and visions (cf. Bugge et al., 2016). Moreover, a comparison of different national bioeconomic strategies promises fruitful insights at the international level. Additionally, the manifold kinds of uncertainty (i.e., risk, ambiguity, uncertainty, and ignorance) can be addressed in more detail in further research (cf. Stirling, 2010).

Altogether, our approach should be seen as a starting point of how to empirically access bioeconomic futures among the interviewed actors. Thus, the above-stated limitations also relate to the very nature of exploratory, inductive, qualitative research approaches that are focused on in-depth descriptions of new phenomena or on applying theory to practical examples. We encourage scholars to place much more emphasis on the role of imagined futures and fictional expectations relevant to sustainability science to uncover how prevalent uncertainties are managed and to see how and what futures are imagined to overcome these uncertainties. In our view, this is very relevant knowledge that can inform the management of not only bioeconomic but also sustainability transitions more broadly.

7.6 Conclusion

The aim of this article was to shed light on the imaginaries that shape bioeconomic innovation design and the co-constituted narratives employed by actors to legitimize technological innovations in the public. We found that these narratives inform different dynamics that can be triggered by irritations on discursive or political levels. Based on empirical material from two case studies on the bioeconomy in Germany and India, our research reveals a duality of both the highly resilient and mostly context-independent imaginary of a technological fix and highly dynamic, context-specific narratives. Against this background, we inductively developed a model that combines the notions of imaginaries, fictional expectations and narrative dynamics to serve as a guideline for future research.

We have argued that the imaginary of a technological fix is rooted in the logic of neoliberalism and is therefore deeply inscribed in society. As a result of this inscription, path dependencies may arise, provoked by mental lock-ins that culminate in a “colonization” of the future and that deem societal issues to be solved by technical solutions. We criticize such a reductionist perspective and propose the elaboration of a socioecological imaginary that limits technology to solving technical

problems while accounting for societal and ecological issues to be solved by societal and ecological means. We therefore end by encouraging sustainability scholars to create open spaces for debate in transdisciplinary research projects that serve to jointly imagine futures and to develop solutions that can be dynamically adapted to ever-changing circumstances.

8 The role of farmers as incumbents in livestock transitions[37]

8.1 Abstract

Livestock farmers, as incumbents, face pressures to transition toward sustainability. We study these actors' role in this process, particularly their in/ability to contribute to endogenous institutional change. Our study entails an interview-based single case study with farmers based on institutional theory. We find that the only likely form of endogenous change is partaking, as incumbents predominantly rely on routine and sensemaking agency. They externalize the locale of change to other actors whom they expect to change framework conditions. However, we also find contrasting examples that may drive institutional change in livestock farming. We discuss incumbents' ambivalent role and embedded agency in these change process. Here, strategic agency and the ability to imagine are important aspects for self-determined change. We recommend regional policy-makers and change agents to work with farmers to create alternative imaginations for livestock farming that have the destructive and affective power to disrupt existing practices and structures.

8.2 Introduction

In the literature on sustainability transitions, the role of incumbents has attracted increasing attention in recent years. In theories of transitions, incumbents are defined as actors resistant to change (e.g., Geels et al., 2016) who are in charge of power and can be afraid of losing control (Gürtler and Herberg, 2021). Initially, incumbents were defined as actors who reproduce existing practices and maintain the status quo, favoring only incremental changes (Hockerts and Wüstenhagen, 2010). This definition was used as a contrasting example in regard to niche innovation actors favoring radical innovations and influencing the emergence of transition pathways. Later, this dichotomy was questioned (Geels et al., 2016). Rather, it has been suggested that these actors maintain an ambivalent position or have multiple positions during transitions. Incumbent actors are equipped with the resources and discursive positions needed to simultaneously drive transitions, e.g., by allowing sociotechnical innovations to diffuse while, on the other side, enabling cognitive lock-ins and technological path dependencies to arise, thereby ultimately hindering transitions (e.g., Ampe et al., 2021; Galeano Galvan et al., 2020; Geels et al., 2016; Lee and Hess, 2019; Runhaar et al., 2020; Simoens et al., 2022; Turnheim and Sovacool, 2020; van Oers et al., 2021). In general, incumbents comprise a heterogeneous group of actors from within and outside existing regimes who can have multiple roles in transitions that may change over time, e.g., from early resistance to change to driving change in a later stage (Turnheim and Sovacool, 2020). The different roles of incumbents in both supporting and hindering transitions have appeared in empirical observations. Examples from energy transitions describe how grid operators in the Dutch energy transition play multiple roles at the same time, maintaining existing practices by discouraging alternatives while performing institutional work on disruption and creation, thereby supporting decentralized energy transitions (Galeano Galvan et al., 2020). In contrast, research on

[37] This chapter refers to an *earlier version* of the *accepted article* Friedrich, Jonathan; Faust, Heiko; Zscheischler, Jana. Incumbents' in/ability to drive endogenous sustainability transitions in livestock farming: Lessons from Rotenburg (Germany) in *Environmental Innovation and Societal Transitions.*

transport sectors in Scandinavia shows that incumbents continue to impede electrical vehicle diffusion via locked in institutional settings (Kotilainen et al., 2019). An example from the Australian water sector describes how incumbent utilities are managing the existing water supply and have difficulties engaging with niches and potential restructurings (Quezada et al., 2016). In agriculture, incumbents have used their power and resources to hinder transitions, such as in the case of the battery phase-out of hen battery cages in the Netherlands (van Oers et al., 2021), or have exploited their discursive power to shape grazing practices as sustainable and able to exist without losing power (Runhaar et al., 2020). These studies therefore show not only the ambivalent yet predominantly hindering roles of incumbents but also the potential that rests in the power and resources these actors have concerning transitions toward sustainability.

While many previous studies on incumbents in sustainability transitions have focused on energy, transport and water transitions (e.g., Galeano Galvan et al., 2020; Geels et al., 2016; Kotilainen et al., 2019; Lee and Hess, 2019; Lockwood et al., 2017; Quezada et al., 2016), the role of incumbents in agriculture has only recently received attention (Runhaar et al., 2020; van Oers et al., 2021). Agriculture and, more precisely, livestock farming constitutes an important object for studying sustainability transitions, as it is characterized by a multitude of ongoing sustainability issues and the subsequent normative need to transition. Livestock farming is responsible for environmental degradation, such as the eutrophication of water bodies and whole landscapes, methane emissions that drive climate change, and high shares of land use for fodder production (e.g., Steffen et al., 2015; Sundermann et al., 2020; Tilman and Clark, 2014). Against this background, actors from civil society and an increasingly broad public are calling for sustainable changes including dietary change, reduced livestock numbers and an area-bounded livestock system. Some innovation actors are also developing new technologies that aim to contribute to solving some of the above issues (Friedrich et al., 2021a).

From a sustainability-oriented perspective, the current land-decoupled livestock system needs to undergo a transition. We understand transitioning as a change in the configuration of the sociotechnical regime of livestock farming, particularly the institutions (e.g., practices, culture, technologies) that characterize this system, following Fuenfschilling and Truffer (2014, 2016)[38]. As agriculture and, in particular, livestock farming systems in many European countries can be described as an organizational field with a high degree of institutionalization[39] characterized by routine practices, norms, values, and political subventions that create very stable semiotic and extrasemiotic structures, the question of how transitions can unfold in such an environment is of crucial importance for understanding and creating sustainability-oriented change processes.

Accordingly, we conceptualize livestock farmers as incumbents (see also Runhaar et al., 2020) that are established actors within the current regime and may have a "disposition to change" (Turnheim and Sovacool, 2020). Together with other actors along the value chain, they are relationally embedded in regime structures, maintaining the status quo and stabilizing the system (e.g., Burton and Farstad, 2020; Maes and van Passel, 2017; Runhaar et al., 2020; Stuhr et al., 2021; Sutherland et al., 2012; van Oers et al., 2021). These stable and persisting mechanisms in agriculture

[38] We want to note that sustainability as such is a deeply normative and ambiguous concept. This means that any restructuring of the regime may not necessarily lead to a sustainable outcome: This clearly depends upon what actors refer to as sustainable.

[39] We regard the system to have a high degree of institutionalization, as it is characterized by routines in practices, values, and norms. See Zucker (1977) and Dorado (2005).

result from the field's complex and entangled systems, which are dependent on the input of materials and energy as well as the processing of agricultural products and societal consumption. These stabilizing processes take place at different levels of societal organization. At the individual level, stabilizing mechanisms have been demonstrated via financial commitments, based on entrepreneurial decisions that "colonize" the future and consequently reduce the scope of action for innovation and change (Beckert, 2013, 2016; Friedrich et al., 2022b), akin to credits and sunk costs. The current financial pressures in agriculture, e.g., high investment costs and long planning horizons, can result in limited financial capabilities to change. At the collective level, stable structures in agriculture are maintained through both cultural and discursive aspects, such as the reproduction of existing imaginations about the future that include cultural aspects (Friedrich et al., 2022a), potentially as a result of discursive hegemons[40] (Heyen and Wolff, 2019), which can, by consequence, lead to cognitive, mental, or discursive lock-ins in sociotechnical regimes (e.g., Simoens et al., 2022) and may inhibit transitions.

In this paper, our aim is to study the in/ability[41] of incumbents in these stable regime structures to contribute to endogenous sustainability changes. We use the term endogenous to characterize change originating from actors within the system, following Runhaar et al. (2020). This stands in contrast to any exogenous change from outside the system (e.g., disasters, discourses, policies, actors from other organizational fields). We employ an institutional and agentic perspective (see section 8.3; Beckert, 1999; Dorado, 2005; Emirbayer and Mische, 1998; Zietsma and Lawrence, 2010) and start by defining the current livestock system in Germany as an organizational field with a high degree of institutionalization, following our above elaborations on the stabilizing mechanisms in livestock farming. From this perspective, farmers are both incumbents and institutional workers who constitute the structure of this system through material-semiotic elements and are shaped by it. Following Lawrence et al. (2011: 52), we define institutional work as "the practices of individual and collective actors aimed at creating, maintaining, and disrupting institutions." In accordance with this institutional perspective, we argue that transitions (reconfigurations of the sociotechnical regime, cf. Fuenfschilling and Truffer, 2014), occur through institutional changes that result from a combination of the type of agency an actor can employ, an actor`s ability to mobilize resources, and perceived opportunity in the organizational field (Dorado, 2005). Hence, we operationalize the aim of our study by asking the following research question:

- What different profiles of endogenous institutional change can be found among incumbents in livestock farming?

To analyze the role of farmers, as incumbents, in driving such changes, we reveal what challenges and perceived uncertainties farmers are currently experiencing and what solutions they propose. Challenges, uncertainties and how actors deal with these are important descriptors of change in institutional theories (Beckert, 1999; Dorado, 2005) and with respect individual agency (e.g., Stuhr et al., 2021).

[40] By discursive hegemon, we refer to the hegemonic position of specific actors in discourse. With respect to farming, an example is the farming organization "Bauernverband," which we regard as an organization that has gained hegemony with respect to structuring and shaping discourses on the future of farming.

[41] With "in/ability," as a term, we want to highlight the ambivalent and paradoxical situation of the actors and the gray area between the binary dualism of ability and inability.

We first describe our theoretical foundations for analysis based on institutional theory. Next, we introduce our methodological approach and case study of the German livestock system and provide empirical examples of potential endogenous institutional change. We then discuss our findings using the general role of incumbents in transitions and explore how farmers can be empowered for self-determined sustainability-oriented changes in agriculture before we close the study by drawing our conclusions.

8.3 Conceptualizing institutional change in livestock farming from an agentic perspective

To examine the (in)ability of livestock farmers to engage in endogenous change, we apply the concept of institutional change from institutional theory. In this context, institutional changes are regarded as changes in organizational fields and conceptualized through the interplay of institutionalized social structures and the agency of social actors, both individual and collective (Battilana, 2006; Beckert, 1999; Dorado, 2005; Emirbayer and Mische, 1998; Zietsma and Lawrence, 2010).

Dorado (2005) describes institutional change as dependent on the *agency* of social actors, *resource mobilization,* and the perception of the respective *organizational field* (see also Beckert, 1999). Dorado (2005) identifies these three elements as "the will and creativity to change" (agency), "the process of change" (resource mobilization) and "the locale of change" (organizational field) (ibid.: 406; Table 13). Depending on the specifications and interplay of "agency," "resource mobilization" and "organizational field," three different profiles of institutional change can arise, namely, *institutional entrepreneurship*, *partaking,* and *convening* (Table 13).

Building on Dorado's (2005) approach, we complement the extant institutional approaches in research on sustainability transitions (e.g., Fuenfschilling and Truffer, 2014, 2016; Galeano Galvan et al., 2020; Löhr et al., 2022). In contrast to the frequently applied institutional logics perspective in examining the "deep structures" of regimes in terms of their culture and the relevance for changes (Fuenfschilling and Truffer, 2014) that extends from structures, the approach of Dorado (2005) has an agentic focus. It centers on individual actors, as embedded in these structures. By adopting the latter, we thus complement existing theory on sustainability transitions and highlight the ambivalent and embedded role of individuals in reconfiguring existing regimes. In the agentic focus of Dorado (2005), the role of individual social actors, as embedded in social structures to drive institutional changes, is highly related to their agency (Emirbayer and Mische, 1998), their perception of the organizational field, and their ability to lever resources (see Table 13). Hence, we place exemplary yet special emphasis on conceptualizing agency in the following and point to Dorado (2005) for a more in-depth conceptualization of the two other aspects. Agency is conceptualized by Emirbayer and Mische (1998: 970) as "the temporally constructed engagement by actors of different structural environments—the temporal–relational contexts of action." This focus[42] leads to three forms of

[42] These different temporal foci align with those of Emirbayer and Mische (1998), who state that "our central contribution is to begin to reconceptualize human agency as a temporally embedded process of social engagement, informed by the past (in its habitual aspect), but also oriented toward the future (as a capacity to imagine alternative possibilities) and toward the present (as a capacity to contextualize past habits and future projects within the contingencies of the moment)" (ibid.: 963).

agency: *routine agency*[43], *sensemaking*[44] *agency* and *strategic*[45] *agency* (Dorado, 2005; Emirbayer and Mische, 1998), which are not independent and can interact, complement or overlap in specific situations. They are characterized by the dominance of one temporal orientation at a time (routine agency: past; sensemaking agency: present; strategic agency: future). This temporal focus adds an additional dimension to the characterization of institutional change in the sustainability transition literature, as it highlights the experiences, perceptions, and imaginations of individuals in restructuring sociotechnical regimes and shaping transitions. In our livestock setting, routine agency may appear when farmers rely on past experiences and habitualized routines and values, which Friedrich et al. (2022a) have called the "preservation" of the status quo. Sensemaking agency relates to situations of uncertainty (e.g., legislative changes, market pressure) that lead farmers to make sense thereof by, e.g., protesting against new nitrate legislation. In this situation, strong normative judgments become visible. Strategic agency therefore relates to imaginations and a general, future-oriented focus; examples may be found among farmers that semiotically contrast and challenge existing values and practices with imaginations that shape their extrasemiotic doing, i.e., they forge new paths with regard to retail or business models.

Table 13: Profiles of institutional change according to Dorado (2005). The profiles all have an agentic focus, which means that they start from the actors and their perception. All profiles of institutional change depend upon the combination of agency, organizational field and resource mobilization.

Profiles of institutional change	**Resource mobilization**	**Agency**	**Perception of organizational field**
Entrepreneurship	Leverage	Strategic	Opportunity opaque
			Opportunity transparent
			Opportunity hazy
Partaking	Accumulate	Routine	Opportunity opaque
			Opportunity transparent
			Opportunity hazy
		Sensemaking	Opportunity transparent
			Opportunity hazy
		Strategic	Opportunity transparent
Conveners	Convening	Strategic	Opportunity hazy

Hence, we operationalize the aim of our research by studying the potential profiles of endogenous institutional change brought forward by incumbents. We regard the resulting three profiles of institutional change (Table 13; Dorado, 2005) as the potential options for the endogenous changes driven by farmers in livestock transitions. The focal combination of features (Table 13) shows the multiplicity and ambivalence of trajectories of institutional change that may characterize livestock system transitions, depending on the relational embedding of incumbents within regime structures (Battilana, 2006). Hence, incumbents, both individuals and collectives, as social actors, are always performing institutional work—whether intended or not (Lawrence et al., 2011). Whether actors' work leads to institutional changes or maintains the status quo thus depends on a combination of agency, resource mobilization, and their perception of the organizational field (Dorado, 2005; Lawrence et al., 2011).

[43] The theoretical roots of routine or habitual agency follow those of Giddens (1984).
[44] The theoretical roots of sensemaking were developed by Weick (1995).
[45] Strategic agency relates to a conceptualization by DiMaggio (1988).

8.4 Methods

In this study, we focus on incumbents in livestock system transitions to draw conclusions on their in/ability to contribute to endogenous sustainability changes. We empirically operationalize this focus by centering on the challenges and uncertainties that agricultural incumbents, namely, livestock actors, experience and the solutions to these challenges that they propose. We define perceived uncertainties as subject to these actors' perception and social position (Battilana, 2006), dependent on the factors that the latter perceive to be current challenges. By unraveling how these perceived uncertainties in the organizational field are processed in a cognitive–discursive manner, we are able to draw conclusions on the agency the actors can employ (while unpacking their dominant temporal focus) and where these actors position the locale of change. The concept locale of change therefore enables us to obtain a picture of the resource mobilization in and perception of the organizational field (Dorado, 2005). Moreover, the dominating temporal patterns actors follow when processing challenges and uncertainties reveal the type of agency they can employ: sensemaking, routine, or strategic (Dorado, 2005; Emirbayer and Mische, 1998)).

Our study follows an iterative process involving these theoretical considerations (section 8.3) and empirical observations. Our empirical approach is based on 16 problem-centered, semistructured interviews (Table 14). These interviews were conducted with a range of livestock farmers, farming representatives, and extension services personnel in Rotenburg (Wümme), Germany (section 8.5.1). The topics of the interviews centered on the current challenges for livestock farmers, how they deal with them, and what solutions they propose. Our approach followed the methodology of problem-centered interviews (Witzel, 2000). Problem-centered interviews are used for theory generation, characterized by their focus on societally relevant topics that regard actors as experts in their practices (Witzel, 2000). In the following sections, we first briefly describe our case study selection (8.4.1) and then detail our data collection and processing (8.4.2 and 8.4.3).

8.4.1 Case study selection

Our case study region is Rotenburg (Wümme), located in lower Saxony in northwestern Germany. We chose this region because it constitutes a pragmatic case that allows us to "highlight [the] more general characteristics of the societies in question" (Flyvbjerg, 2006: 232), i.e., livestock farming in Germany. Rotenburg (Wümme) represents a typical rural region in northwestern Germany that is dominated by intensive livestock production and lower soil quality than other German regions. We choose this region because it contrasts with other regions in Northwest Germany, especially around the city of Vechta; the latter represent extreme cases dominated by intensive livestock farming, which is known for its agri-tech cluster (Tamásy, 2013)[46].

8.4.2 Data collection

The aim of our collection of interviews was to obtain a comprehensive picture of livestock farming in our case study region. We defined livestock farmers and actors who are very close to livestock farming (such as representatives and extension services personnel) as our sample. Our sampling of interview partners followed a snowball sampling approach (Reed et al., 2009; Rubin,

[46] In 2010, Rotenburg had 1.4 livestock units per hectare of agricultural land use while the administrative regions Cloppenburg or Vechta had more than 2.5 livestock units per hectare of agricultural land use (LWK Niedersachsen 2015).

2021); we started the interviews with a first actor with existing, long-standing contacts and well connected in the region and aware of the topic of livestock farming as a key actor. We conducted an initial scoping talk with this actor[47], who provided us with contacts for other actors, from whom we then derived further contacts. We asked the interviewees about actors who have different views on problems and solutions or who are opening new paths to obtain a comprehensive picture of the current situation and discourse on livestock farming in the region. While we aimed to interview actors in the Rotenburg (Wümme) region, we also included two actors from outside its administrative boundaries, as the relevant social boundaries do not necessarily match the administrative boundaries. Our data collection took place between January and February 2022, the interview durations were between 39 minutes and 116 minutes, the interviews were conducted in German, and all quotes were translated to English by the authors. Due to the ongoing COVID-19 pandemic, we avoided personal meetings and conducted telephone and software-based interviews. We stopped our data collection when content saturation was reached (Rubin, 2021; Saunders et al., 2018). Content saturation was defined through the recurring arguments in the interviews. Although we built our empirical approach on snowball sampling and the social contacts we obtained during data collection, we experienced difficulties contacting farmers who had recently given up their farms and were facing severe emotional situations, such as frustration and anger; they were not open to scientific contact. Thus, their perspective may be lacking in this study.

Table 14: Overview of interviewed actors

IP	Main function/relation to livestock farming
1	Commodity cooperative related to livestock inputs
2	Pig farm
3	Pig farm currently transitioning to organic
4	Pig farm
5	Earlier pig farm, yet new business model
6	Pig farm
7	Pig farm
8	Extension service with regard to plant fertilization
9	Pig farm
10	Cattle breeding
11	Machinery ring supplying livestock farming
12	Cow farm (milk)
13	Cow farm (milk), organic
14	Cattle breeding
15	Pig farm
16	Cow farm (milk)

8.4.3 Data analysis

All our interviews were recorded and fully transcribed. MAXQDA software was used for further processing. We analyzed our interview data following Kuckartz's (2014) qualitative content analysis guide and employed a deductive–inductive approach by taking into account our theoretical elaborations, which also guided us in developing our guiding questions. For our analysis, we followed the seven-step guide to "thematic qualitative text analysis" (Kuckartz, 2014). Thus, after the initial text work, we deductively coded our material based on our a priori theoretical considerations (section 8.3; see Kuckartz, 2014). In the next step, we refined our category system

[47] This actor did not participate in the interviews and was only used to derive contacts of livestock farmers in the region.

by adding inductive subcategories and additional categories, which we derived directly from the material. We then coded all material with this coding system (Kuckartz, 2014). Table 15 describes our coding system, including our subcategories and exemplary quotes derived from the interviews to describe the codes.

Table 15: Coding system including deductive codes and (inductive) subcodes; each category is described with an exemplary quote from the interviews.

Deductive code	Inductive subcode	Exemplary quotes and codes
Challenges	Economic challenges	Economic challenge with respect to price situations in agriculture: "A price situation currently exists in German agriculture. There has not been such a crisis in the last 20, 30 years" (IP 2).
	Governance challenges	Governance challenge in relation to German building law: "In some cases, it is not even possible to convert stables into open-air runs, because the building law does not allow it. And then there are emission guidelines that prevent you from opening the walls. Otherwise, many more farmers would do that, I think. Or I know. And the building code prevents that. That is also counterproductive" (IP 3).
	Discursive challenges	Discursive challenge, acceptance of society: "A recurring challenge is the acceptance in society, [...] which we face and which we do not see negatively now. The only negative aspect [..] is that many people in the population do not accept the job we do" (IP 16).
	Specific agricultural challenges	African Swine Fever, as a specific agricultural challenge: "And first and foremost the African swine fever" (IP 2).
	Other	Other challenges, e.g., related to sociotechnical change and digitalization: "[…] more technology. I often see young farmers using their phones to control their biogas plant. Control their pigsty, control their cowshed" (IP 1).
Uncertainty		Uncertainty because of multiple challenges and "nervous exhaustion": "My father and my grandfather, they worked themselves to death physically. They broke their backs. Their knees were broken. […] Nowadays, I see it more as us farmers working ourselves to nervous exhaustion" (IP 15).
Cognitive processing	Routine	Routine agency, as waiting: "At the moment it's really the case that we tend to wait and see, that we clearly modernize somewhere, but we don't take any really big steps" (IP 9).
	Sensemaking	Sensemaking of political changes with regards to new moor strategy: "Let's take the moor strategy here in our region. In our region there are these moors. And if that goes according to political will in this region, there is no more agriculture. Because there is [...] no more cow husbandry possible, if all this is wetted again. For our region and other regions [...] that is the end of agriculture. And that is a huge problem" (IP 2).
	Strategic	Strategic agency, as forging new paths: "Because I have many colleagues […] who do not manage to go on vacation, […] have broken relationships […], I just realized, if you have such a real hamster wheel, then you have to have a permanent employee. And, when you always add it all up like that, I have the feeling that you actually don't have anything more in your pocket. you just want to distinguish yourself from other farmers due to how great you are […]" (IP 5).
	Routine-sensemaking	Routine-sensemaking, as being overwhelmed with the challenges and continuing routines: "For me, though, I don't know where to go at the moment. So I'm a bit perspective-less in this regard.

		[...] And that's why, for me, it's all about keeping the branches of the business going at the moment. To generate the operating income. And to wait and see" (IP 15).
	Sensemaking-strategic	Sensemaking-strategic example of an actor who invested in a better run for pigs but received no support from downstream firms, such as Aldi: "[…] Aldi, for example, issued a press release half a year ago stating that they also want to have this husbandry level in seven years. And, we had also invested in it already a year ago in the free range for pigs [...]. But, then, there was no marketer who had received one with open names. Oh, finally, you are there with your outlet pigs? [...] I would like to build an outlet, I would like to market those also. You look for a contractor who tells you, yes first build the stable and then we can see further. [...] So you go into full risk with your animal husbandry when you build a run. And you don't really know yet what will come out" (IP 4).
	Sensemaking-exit	Sensemaking-exit, as farmers who are leaving livestock farming due to the amount of challenges: "[Interviewer:] And how do the farmers in your region deal with this situation? [Interviewee:] "That some get out of production. [Interviewer:] Do you know any farms? [Interviewee:] Yes" (IP 11).
Solutions/ discursive processing	Governance	Governance, as support from politics: "In any case, much more support from politics [...]" (IP 6).
	Appreciation	Appreciation of farming: "I wish to get fair treatment. [...] generally, from the people here, from the fellow citizens, who then simply see what you do. And just see, what you're already doing" (IP 10).
	Consumers and society	Consumers as important factor: "The biggest factor is the consumer. They must be prepared to pay more. The state cannot absorb everything that the consumer demands and does not pay" (IP 2).
	Food retailers and value chain	Food retailers and value chain actors, such as butchers and slaughterhouses: "That we have guaranteed prices [from food retailers], I would prefer surcharges that we get on top of the unification price. [...] I negotiate with a butcher because of my outlet pigs. It is quite difficult and we negotiate what I get on top of it." (IP 4).
	other	Other solutions, such as being more critical of fellow farmers: "I do not know. Difficult. Difficult, difficult. I don't know. I don't have a solution at the moment. So you don't do that you-. You actually have to be much more critical of your professional colleagues. That is, I think-" (IP 7).

8.5 Results

In the following section, we first provide some basic descriptions (section 8.5.1) of the case study in Rotenburg (Wümme) before we describe the challenges that livestock farmers and actors are currently facing and the uncertainties these reveal (section 8.5.2). Second, we describe how the cognitive–discursive processing of these uncertainties indicates these actors' type of agency, perception of the organizational field, and ability to mobilize resources, thereby revealing two profiles of potential institutional change (section 8.5.3).

8.5.1 Case study description: Livestock farming in Rotenburg (Wümme)

For our qualitative approach, we chose the case of intensive livestock farming in Rotenburg (Wümme), Germany. In general, livestock farming in Germany is currently facing strong pressures within agri-food systems, which specify the needs for change: In addition to the environmental pressures resulting from climate change and exceeding planetary thresholds (Steffen et al., 2015), livestock systems face additional pressures, such as new legal requirements (e.g., EU nitrate directive), shrinking demand due to consumption changes and import bans from China due to African Swine Fever, ethical discussions on animal welfare, and rising energy prices, which have produced their own set of added pressures. While bioeconomic strategies are being discussed as potential solutions in scientific and political debates on some of these challenges, e.g., manure surplus (Friedrich et al., 2021a), the systems themselves are characterized by structures with a high degree of institutionalization[48] and actors who maintain the status quo (Burton and Farstad, 2020; Friedrich et al., 2022a; Heyen and Wolff, 2019; Maes and van Passel, 2017; Sutherland et al., 2012) and experience low agency (Stuhr et al., 2021). This adds to the regional economic path dependencies in German livestock-intense regions via the economic share of livestock farming in regional value creation or a lack of alternative productive land use opportunities due to low soil yield, which are additional stabilizing mechanisms (Franz et al., 2018; Franz and Schumacher, 2020; Tamásy, 2013), as are the rare potential for regional distribution and the high pressure on alternatives, in contrast to existing farming practices (Tamásy, 2013).

In northwestern Germany, among its intensive livestock regions, Rotenburg (Wümme) is one of the regions in which these phenomena are visible. This region is characterized by groundwater values exceeding 50 mg/l nitrate (BMEL and BMU, 2020) that are subject to a pressure to change to fulfil new EU nitrate directives (Sundermann et al., 2020). The region of Rotenburg (Wümme) can be viewed as a typical rural region in lower Saxony that lies between the metropoles of Bremen and Hamburg. It is characterized by intensive livestock farming and 70% agricultural land use (LBEG and LWK Niedersachsen, 2019). In recent decades, agricultural farms in Rotenburg (and Germany) have faced a period of ongoing restructuring and concentration (Nowack et al., 2019). In Rotenburg, this led to a reduction in farms of more than 60% and an increase in farm size on average from ca. 20 ha to almost 70 ha per farm between 1979 and 2010 (LWK Niedersachsen, 2015).

8.5.2 Challenges for livestock farmers and perceived uncertainties

Livestock farmers in the Rotenburg region indicated that they are currently experiencing a multitude of different challenges. We therefore coded our material with the following subcategories: economic challenges, discursive challenges, governance challenges, agricultural

[48] See Footnote 39.

challenges, and other challenges (Table 15). Economic challenges relate to prices, market pressures, or investment planning horizons: "*When we make investments, especially in animal husbandry, these are [...] usually for 20 years. And, the time or the planning security is not given at all*" (IP 6). Discursive challenges relate to the perceived pressures that result from changed societal discourses and values, e.g., *"[...] normal citizens, I do not want to say, but, like, the nonagricultural fellow citizens, they think simply differently in my eyes nowadays about agriculture than in the past*" (IP 10). These discursive challenges are experienced as pressures resulting from negative media reports and local discussions on the topic of livestock farming. Challenges that relate to the governance of livestock systems originate from legislative pressures, such as the new nitrate directive, or with respect to permits for new construction projects. Agricultural challenges are related to the need for workers or geographical factors, such as those in relation to soil. Finally, more general challenges are evident in growing pressures or sociotechnical changes, resulting in continuous adaptation requirements. Although our interviewees had different backgrounds (Table 14), governance challenges were mentioned by all of them (Table 15).

As a result, we found that the current situation is perceived to be uncertain, demonstrated by the multiplicity of challenges and factors that are not under the control of many interviewees. Some interviewees even referred directly to the term "uncertainty" in describing the situation, i.e., as IP 2 puts it, "*The uncertainty in agriculture is there. It's huge. [...] The political risk is currently very high for many farmers. And, there is a price situation in German agriculture at the moment. There has not been such a crisis in the last 20 or 30 years.*" This uncertainty, the interviewees argue—which relates to their challenges being mainly a matter of governance—is a result of politics: "*The biggest challenge at the moment is actually political uncertainty*" (IP 12). However, economic uncertainty is also currently being experienced due to price and market fluctuations, as outlined by IP 2. We therefore suggest that their experienced uncertainty indicates that these actors currently perceive their organizational field as rather opportunity hazy (Dorado, 2005).

8.5.3 Forms of potential endogenous institutional change in German livestock farming

As the following two subsections outline, actors process challenges and uncertainties in different cognitive–discursive ways. These ways reveal the agency actors can employ, how they perceive the organizational field, and how they are able to leverage resources. While there are obviously nuanced differences among the interviewees, we have found and describe below the dominant form of partaking as an endogenous institutional change. In addition, we contrast this form with those of actors who are actively disrupting institutions and practices and who differ in terms of their type of agency and where they position the locale of change. Our considerations of cognitive processing are based on the categorization of agency by Emirbayer and Mische (1998) and Dorado (2005) as (1) routine, (2) sensemaking, or (3) strategic; discursive processing relates to the proposed solutions by the interviewees, which we inductively coded with additional subcategories and relate to the locale of change (cf. Dorado, 2005).

8.5.3.1 Institutional change as partaking

Cognitive processing, revealing routine and sensemaking agency

In addressing the challenges and perceived uncertainties described in section 8.5.2, the interviewees' answers show different dominating temporal foci that reveal routine agency, sensemaking agency, and combinations thereof (see Table 15). We identify a temporal focus on the present and a normative orientation toward beliefs in sensemaking agency. One example of this is

IP 7's view on the nitrate directive. In this example, the dominant temporal focus is on the present, and the actor makes sense of the uncertainty derived from this situation. The actor explains his doubts in the accuracy of nitrate measuring points and the law that is built on these: "[…] *I also doubt the measuring points [of nitrate][49]. [...] The area around the village where I come from, somewhere within 20 kilometers, there is a well that is not in a good condition. Then, we'll take the village in with us. Our place. And, that is all arbitrariness and not thought through to the end at all*" (IP 7). Another orientation toward beliefs is evident in the view of IP 12 on higher animal welfare standards: "*Just imagine, in the supermarket, there are these typical surveys—yes, yes, I'm for more animal welfare—and, afterward, they buy the cheapest discount meat from Aldi for fifty cents a hundred gram package. That is still the reality"* (IP 12). Here, the actor offers a normative explanation of why higher animal welfare does not make sense, in the actor's view, based on a critique of consumers' choices. Another example of sensemaking is provided by IP 12, who describes the current mood in agriculture as frustrated (normative judgment) in addition to revealing a clear temporal focus on the present and a potential exit from livestock production: "*[…] the mood in agriculture at the moment is not very good […]. And, I also say, where farm transfers are imminent, and when I think of the pig fattening in the current price situation, there is also the one or the other that now says 'okay, I close the store. […] So, I close the farm gate*'" (IP 12).

We also observed some actors who maintain temporal frames that are oriented to the past and/or perform habitual practices that indicate the dominance of routine agency. This mainly relates to these actors' continuation of what they have done before because of a perceived uncertainty that impedes decision-making, as outlined by IP 9: "*Yes, at the moment, it's really the case that we tend to wait and see, that we clearly modernize somewhere, but we don't take any really big steps*" (IP 9). Modernization in this example thus relates to short-term decisions, such as *"investments that pay off in one year*" (IP 9).

In addition to the dominating forms of sensemaking and routine, we found forms of agency that can be viewed as combined forms of routine and sensemaking, revealing both normative beliefs and routines: "*I am ready [to change]. I am, as I said, 48. I also have a healthy business. I am also ready to change something. But, at this pace, I simply can't. And, if you have the feeling that you're powerless in the face of change and simply can't keep up with the pace, then you're better off leaving it alone. That's my attitude toward it" (*IP 6). Here, we observe an instance of sensemaking via a temporal focus on the present that is combined with a maintenance of routines, leading to a lack of change, as the actor suggests that they cannot cope with the "pace" of change.

Discursive processing revealing the externalization of the locale of change

When asking our interviewees about the solutions they propose for their current challenges, what we call discursive processing, we found that our actors externalize the locale of change. This indicates a resource mobilization of accumulation, as actors are not individually able to mobilize the resources necessary for institutional change and thus perceive the organizational field to be rather opportunity hazy. We find indications of these aspects among the inductive subcodes of our

[49] In the context of the new nitrate directive, measuring points are used to assess whether a region exceeds the 50 mg/l of nitrate in the groundwater or not. This regulates the manure application on fields for farms. There is continuing discussion of the accuracy of these measuring points for indicating nitrate values in the groundwater in relation to manure application on the field. This discussion is mainly driven by farmers and farming organizations that question both the reliability of instruments to measure nitrate values as well as the locale of these measuring sites.

material (see Table 15), as interviewees suggested that actors other than themselves are those who need to change or provide assistance to enable cumulative change. These inductively coded actors include food retailing and other value chain actors, consumers and society, and governance actors. Hence, the interviewees argue that these actor groups may also be combined to provide solutions to current challenges, thereby underlining the aspect of governance: "*Yes, so, politically, we have to have absolute security somewhere. But, we also need to get the retail trade on board. [...] And, there has to be some kind of concept that gives us political security but also gives us the retail trade security to still be able to exist in the future*" (IP 4). This actor-related proposal for solutions is combined with the experiences of a lack of appreciation among all these actor groups, as outlined in the following example: "*For years, we have only been badmouthed [...]. And, right now, we are not getting anywhere near what we should be getting for the products. We have to invest heavily to get to stage three or four of pig farming*[50]*. I have the feeling that we're always being taken for a ride […]*" (IP 6).

In summary, the results of our interviews show that endogenous institutional change is likely to appear in the form of partaking (Dorado, 2005). The dominant temporal focus of the actors remains on the past and present, as routine and sensemaking agency, in processing challenges and uncertainties. This analysis shows that actors externalize the locale of change, demonstrating these actors' dependency on strategies of resource accumulation and their perception of the organizational field as opportunity hazy. Hence, institutional changes will only happen occasionally and through the cumulative resources and practices of autonomous actors in this organizational field.

8.5.3.2 Contrasting partaking

Cognitive processing, revealing strategic agency

As an example of the future-dominated processing of uncertainties that we have coded and attribute to strategic agency (see Table 15), IP 5 described how strategic development and new business ideas had emerged from experiences: "*[...] I have many colleagues […] who do not manage to go on vacation, […] have broken relationships […]. I just realized, if you have such a real hamster wheel, then you have to have a permanent employee. And, when you always add it all up like that, I have the feeling that you actually don't have anything more in your pocket. You just want to distinguish yourself from other farmers due to how great you are. […]*" (IP 5). This example shows how the actor processes challenges via a future orientation that is based on his own experiences. This future orientation leads the actor to exit from livestock farming and to develop a new business idea. Another example of strategic agency entails the design of alternative value chains that have made IP 14 independent of other actors, thereby reducing uncertainties and changing the configuration of structural economic dependencies: *"So, everything, we produce ourselves; I have managed in the past year to market myself, whether when breeding animals or for direct marketing*" (IP 14). In this way, the challenges perceived by the other actors, which have led them to experience an uncertain situation, no longer apply to IP 14.

In addition, we found a hybrid of sensemaking and strategic agency. Here, a future-oriented decision clearly results in uncertainty, as outlined by IP 4: *"[…] Aldi, for example, issued a press release half a year ago stating that they also want to have this husbandry level in seven years. And,*

[50] These stages relate to the husbandry of animals and ethical standards of animal husbandry. The higher the number is, the higher the standards with respect to space per animal and free-range farming.

we had also invested in it already a year ago in the free range for pigs [...]. But, then, there was no marketer who had received one with open names. Oh, finally, you are there with your outlet pigs?" (IP 4). The uncertainty results from decisions and leads the actor to question the process and governance of change. This reveals a combination of strategic and sensemaking, as the future orientation of a decision results in a focus on the present due to the uncertainty derived from that future orientation.

Discursive processing, revealing the internalization of the locale of change

When asking our interviewees about the solutions that they propose for their challenges, we found actors who discursively internalize solutions, i.e., position themselves as the locale of change, thereby indicating their ability to leverage resources and identify opportunities in the organizational field (see Table 3). IP 5 described this internalization as a contrast, as being fixed in structures that do not allow one to change or the ability to think in a strategic way: "*[...] I'm sorry to say that some of them [people in agriculture] are so entrenched in their structures that there's only one way to go, the way you learned at school. You have to grow or give way. […] I think very few farmers are entrepreneurs. So, they may not even calculate it to the end because they think something is great. But, [they] just do it that way*" (IP 5). We also found an instance of how this internalization functions to relate to staying informed and keeping track of new developments; as mentioned by IP 10: "*I think what's important is that you just, well, stay on the ball—that you just always keep yourself—[...], top informed; that is, actually, in my eyes, the most important thing.*" These examples therefore show how the interviewees do not refer to other actors with respect to challenges but rather focus on themselves (internalize the locale of change). Such discursive internalization of the locale of change is also combined with their nonexperience of a lack of appreciation by consumers and media coverage; concerning these examples of the externalization of the locale of change (section 8.5.3.1), IP 5 and IP 14 did not address these during their interviews.

In sum, we found that two interviewees mainly process the current situation differently, via a focus on the future and an internalization of the locale of change. This contrasts with the partaking activities in section 8.5.3.1, as it may disrupt existing institutions and practices. In general, however, few examples in our data offer forms that contrast with partaking.

8.6 Discussion

In this article, we have studied the role of farmers, as incumbents, in contributing to endogenous sustainability transitions in livestock farming. We have used the case of Rotenburg (Wuemme), Germany, and theoretically embedded our results by building on institutional theory with an agentic focus (Beckert, 1999; Dorado, 2005; Lawrence et al., 2011). We have found that livestock farmers are experiencing a range of novel challenges and uncertainties concerning, e.g., governance, economic situations, and discourses on the sustainability of livestock farming. As a consequence, they process these challenges and uncertainties using dominating forms of habitualized routines and an orientation toward belief systems based on routine and sensemaking agency (Dorado, 2005; Emirbayer and Mische, 1998). We have also found that our interviewees discursively externalize the locale of change to other actors. These aspects, then, reveal that partaking is the most likely form of endogenous institutional change, if any. Institutional change, therefore, will only occur occasionally, incrementally, and as a consequence of cumulative yet autonomous actors and practices. Our interviewees' situations are exemplary of the paradox of

embedded agency, which is dependent on other actors and their interplay in social structures (Battilana and D'Aunno, 2010; Emirbayer and Mische, 1998; Lawrence et al., 2011). Nevertheless, we have also found some actors who are future oriented, employ strategic agency to enable them to leverage resources, and who perceive the organizational field to be rather transparent. These actors are currently disrupting existing values and practices and may be important for endogenous institutional change. In the following section, we discuss these findings with regard to the general in/ability of incumbents in agriculture to contribute to change and the importance of imagination for alleviating political-economic consequences. We then briefly reflect on the methodological limitations of this study.

8.6.1 Between boundary work and embedded agency: Livestock incumbents and endogenous changes

The results of our case study show that if endogenous institutional change is to take place, it will likely occur as "partaking" in the livestock system. The focus on the past and present, i.e., the routine and sensemaking agency in the cognitive processing of perceived uncertainties and challenges, indicates this profile of change, as does the perception of the organizational field to be opportunity opaque or hazy (Dorado, 2005). Transitions in livestock farming that are driven by this type of institutional change will likely be incremental reconfigurations of the values and practices that emerge from the cumulative practices of autonomous actors. Hence, farmers, as incumbents, primarily continue their habitualized practices, orient themselves toward beliefs, and externalize the locale of change to others (e.g., governance actors) whom they expect to change the framework conditions.

Although we have found two cases that disrupt existing practices, the dominance of the maintenance and continuation of existing practices stands in contrast to the empirically demonstrated roles of incumbents in energy transitions (e.g., Galeano Galvan et al., 2020). In this sector, a heterogeneous set of incumbents (Turnheim and Sovacool, 2020) both maintains and disrupts institutions through, e.g., the maintenance of the status quo and adoption of new practices that mark incumbents' ambivalent positions (Galeano Galvan et al., 2020; Lee and Hess, 2019; Löhr et al., 2022). In regard to livestock farming, this ambivalence does not appear in our case study; rather, there is a predominant focus on maintenance. This aligns with the cases of Quezada et al. (2016) on water transitions and Kotilainen et al. (2019) on transport transitions in terms of describing incumbents, rather, as hinderers in transitions at this stage. It also aligns with the findings of Runhaar et al. (2020) and van Oers et al. (2021), who have both found that farmers lobby for existing practices to delay cultural and practical change. In our view, this reflects how the maintenance and preservation of the status quo comprises the dominating temporal focus, in combination with the discursive hegemons that structure agricultural discourses and culture and make endogenous changes unlikely (e.g., Friedrich et al., 2022a; Heyen and Wolff, 2019; Maes and van Passel, 2017; Sutherland et al., 2012). Our study supports these findings. We attribute the reasons for this mainly to the specific characteristics of livestock farming, especially its long planning horizons and investment periods and entanglements of farmers, values, and input chains, which lead to path dependencies, e.g., intensification (e.g., Burton and Farstad, 2020; Maes and van Passel, 2017). Additional reasons for the differences among incumbents' roles in agriculture and transitions in other sectors may also be found in the varying levels of political support for agricultural transitions and energy transitions in Germany (Heyen and Wolff, 2019), in the stages

thereof (e.g., in a later transition stage, incumbents may benefit and thus support transitions; Turnheim and Sovacool, 2020), in the differences in property relations and their relevance for sustainability transitions (Grenzdörffer et al., 2022), and in the importance of geographical aspects in agriculture, such as poor soils that are upgraded through manure application, as economically viable land use alternatives are often difficult to develop for these marginal agricultural sites. An example of the absent political support for livestock transitions can be found in the study of Stuhr et al. (2021), which shows that pig farmers perceive their agency in coping with nitrogen policies as low due to ever-changing political regulations and missing exchanges with actors outside their region and context.

While our case demonstrates how these aspects shape the perceptions of livestock farmers maintaining the status quo, we also want to highlight the "deep structures" (Fuenfschilling and Truffer, 2014), in terms of an institutional logic of growth in livestock farming, which we attribute to incumbents maintaining the status quo. Livestock farming in Germany and in Rotenburg have undergone decades of restructuring, in terms of reducing the number of farms, while increasing farm sizes by both allocated land and number of animals (see section 8.5.1, Nowack et al., 2019). The farmers we have interviewed have long been the profiteers of this process: For them, the last decades have been an era of growth. Now that the culture of "growth," the historically institutionalized logic of livestock farming, is being questioned by legislative changes such as the new nitrate directive and media discourse, the incumbents struggle to escape their cultural conditioning and, consequently, defend these positions.

While the actors who are currently disrupting existing practices in our case may become institutional entrepreneurs[51] (Dorado, 2005), we have not found any indications of convening (Dorado, 2005) as a profile of institutional change. We attribute this to competition in agriculture, not least that for land, which renders interactor cooperation for institutional change unlikely. However, it is exactly this interactor cooperation among actors who work in different organizational fields that produces "change agents" in transitions, as outlined by Strambach and Pflitsch (2020) and Bünger and Schiller (2022). In our view, then, it is of urgent importance for transitions in German livestock farming to unfold, for interactor cooperation to evolve, and for knowledge exchange to take place (Bünger and Schiller, 2022), given that actors working in different organizational fields[52] have been found to potentially drive both cultural and practical change. As the case of Strambach and Pflitsch (2020) shows, this is not an easy and quick process but one that can take years and requires continuous institutional work among change agents or intermediaries and support from governance to change structural conditionings.

Moreover, we have purposely neglected actors along the value chain or in overlapping organizational fields, such as consumers, retailers, processors, or governance actors, in our sample. However, institutional change more generally can also be leveraged by new actors entering the

[51] With institutional entrepreneur, we do not imagine "hyper-muscular agents" (Fuenfschilling and Truffer, 2016). Rather, with the term institutional entrepreneur, we follow Dorado (2005) to avoid complicating our results and relate it to the actors who are merely responsible for institutional innovation (Zietsma and Lawrence 2010). This, of course, also take into account their embedded (and entangled) positions within the structures of the existing regime.

[52] We want to note that the "Borchert commission" initiative and especially the process to develop the "Recommendations of the Competence Network Farm Animal Husbandry" may have an important effect on the shaping of actors who work in different organizational fields, as the initiative brought together actors from disparate fields (e.g., farming, food processing, retail).

organizational field (Gurses and Ozcan, 2015), by the boundary work[53] of exogenous actors (Zietsma and Lawrence, 2010), and by the coconstitutional relationship of technologies and institutions (e.g., Fuenfschilling and Truffer, 2016). Institutional change is thus highly dependent on social positioning and embedded agency (Battilana, 2006). Reflecting upon these aspects regarding livestock farming in Germany, we are clearly in the middle of an institutional change that is not mainly driven endogenously (e.g., by farmers) but, more likely, by exogenous forces. With reference to Zietsma and Lawrence (2010) and a perspective on boundary work and practice work, our case offers a snapshot of the process of institutional change and conflict. The dominant form of sensemaking and routine agency among livestock farmers in our case can therefore be attributed to boundary bolstering and the defense of institutionalized practices (Zietsma and Lawrence, 2010). This relates to farmers who defend their values and practices by devaluating critiques from NGOs or media reporting, as we found in our case. On the other hand, the actors in our example who exert strategic agency and disrupt existing practices while creating new ones challenge the institution from within. This is a common aspect of institutional innovation, which is also described by Zietsma and Lawrence (2010). By widening the focus to encompass exogenous actors outside the organizational field, one can detect how NGOs and civil society are performing both boundary and practice work that challenges the existing practices and structures of livestock farming. One example of this relates to protests by NGOs and civil society, e.g., those that state they "we are fed up" in Germany with, among others, industrialized livestock farming (Nowack and Hoffmann, 2020). In response, livestock farmers are protesting, a form of practice work that defends their institutionalized practices and values. Examples are found in the recent protest of "Land Schafft Verbindung"[54] in Germany against new nitrate directives and in farming protests in the Netherlands against new environmental legislation (Holligan, 2022). These legislative changes, such as the new nitrate directive in Germany, can be interpreted as a result of the process of boundary and practice work between exogenous and endogenous actors in regard to livestock farming; they shift and create new boundaries of how livestock farming is practiced.

Although exogenous actors are performing boundary and practice work and may ultimately provoke changes or exert pressures to change, we argue that the institutional changes in agriculture remain highly dependent on incumbents. Here, aspects of ownership, property, and historic accumulation of farms and land, knowledge and values, as well as its high entrance costs, make it difficult for new actors to enter organizational fields in agriculture. We therefore suggest that incumbents are and will be important actors in institutional changes and sustainability transitions in livestock farming. However, the question of how transitions could be governed with respect to the participation of incumbents remains. Hence, we use the next section to briefly discuss the potential for self-determined changes and the experience of a sense of self in relation to change.

8.6.2 Governing transitions in livestock farming: The role of imagination in self-determined change

The role of livestock farmers in transitions is contested and under dispute. If livestock numbers are to be reduced, as called for by NGOs and as a potential consequence of legislative changes, the

[53] With boundary work we refer to Zietsma and Lawrence (2011: 194), who define this as "actors' efforts to establish, expand, reinforce, or undermine boundaries."

[54] Translated to English, this means "land creates connection." This organization was created in 2019 as a response to legislative changes and to farmers who felt unrepresented in the conventional lobby organizations of farming. See https://landschafftverbindung.org/.

question of rural farming identities and the political economy of this (partial) phase-out process with regard to aspects of both experienced justice and social conflict is of high relevance. Currently, we suggest observing livestock farmers lobbying against transitions in an attempt to preserve the status quo (Friedrich et al., 2022a) and to prolong phase-out processes to avoid negative economic revenues and make the process "manageable" (van Oers et al., 2021). McDowall (2022) argues that economic diversification can reduce the negative regional political-economic consequences of the phase-out processes in specific industries or regions. We add to this argument by highlighting the role of self-determined changes (a sense of perceived agency) in the softening of transition processes that imply a (partial) phase-out of specific practices. In our view, livestock farming will only meet the planetary boundaries (Steffen et al., 2015) and reduce environmental degradation once livestock numbers are reduced and/or an area-bounded livestock system is introduced. This would definitely entail a (partial) phase-out for some livestock farms and/or a reorientation toward new business models. We argue that in a reconfiguration of livestock farming, which such a transition would imply, it is of great relevance that livestock farmers experience agency[55]. This will help alleviate potential negative political-economic consequences in terms of social conflict, rural identities and livelihoods. Our study has demonstrated the important role of strategic agency and individual farmers' general ability to imagine real alternatives in this process. If transitions in livestock farming are to happen—e.g., reduced livestock numbers, more sustainable practices, or farm diversification—such changes will always be shaped by the imaginations of the future (Adloff and Neckel, 2019) that represent new and alternative practices for both livestock production and farmers. In our view, this aspect has thus far been overlooked in the governance of agricultural and livestock transitions. Hence, while imaginations of the future are of course inspired and shaped through past experiences, coproduced through science and society, they must disrupt and discontinue habitualized routines and beliefs to challenge institutionalized practices and embed institutional changes.

We see great potential for filling this gap among the regional policy-makers and change agents (see also Bünger and Schiller, 2022) working with livestock farmers to cocreate imaginations of potential future possibilities and how to achieve these, thereby integrating different organizational fields. We have no potential blueprint for how to govern or design such a process; however, ideas concerning the anticipatory governance of sustainability transformations (e.g., Muiderman et al., 2022) may be of relevance in building imaginative capacities among livestock farmers, akin to transformative research approaches, e.g., in real-world laboratories (e.g., Bergmann et al., 2021). As our research shows, an individual's lack of the ability to imagine and anticipate the future will ultimately result in his or her continuation of habitualized routines. It is thus of high relevance to open the future through new ideas of sustainable livestock farming and/or alternative agricultural practices. We argue that a continuous transition in the livestock system in terms of an ongoing sociotechnical reconfiguration and decreasing number of livestock can be shaped by endogenous actors if they are supported in their practices and capacity to imagine real alternatives for their farms, their identities and their (rural) culture. Only in this way will just transitions in livestock farming be assured and negative political-economic consequences reduced.

[55] We also want to note that livestock farming is characterized by multiple externalizations, such as socioecological issues, on local and global levels. By observing how they undermine and often neglect the consequences of their farming practices and the lifestyles they have built upon these, we also see the risk that these farmers will only experience the agency to preserve instead of the agency to alter practices.

8.6.3 Methodological limitations

Our research has focused on the endogenous perspectives of incumbents in livestock transitions. Similar to every empirical study, it has a number of limitations. We therefore note the necessity for future research to complement our understanding of incumbents and to add examples of both endogenous and exogenous sustainability transitions in agriculture to illustrate a more comprehensive picture of the role of incumbents and their relational embedding in agriculture. This topic relates to other geographies, other types of farming, and other approaches to institutional work and change; it could also comprise research that focuses on new actors entering agricultural organizational fields and their role in shaping transitions.

8.7 Conclusion

In this paper, we have explored the in/ability of incumbents to contribute to endogenous livestock transitions in Germany. Our results show that if endogenous change is to take place, it likely occurs as "partaking" (incremental changes through cumulative yet autonomous actors and practices), as the focal actors dominantly and cognitively process challenges and uncertainties through routine and sensemaking agency while discursively externalizing the locale of change to other actors. We have also identified actors who are currently disrupting existing practices by following strategic patterns and internalizing the locale of change. These actors may be potential institutional entrepreneurs or innovators. Thus, while endogenous changes will most likely occur incrementally, as accumulations of multiple actors and actions, exogenous actors are currently and mainly driving reconfigurations of both the culture and practice of livestock farming through both boundary and practice work. While our empirical results are an ex negativo answer to the question of the ability of incumbents to drive endogenous sustainability transitions, they have also highlighted the role of imagination in the experience of self-determined change among livestock farmers. In our view, then, we need spaces in which we can support farmers in imagining real alternatives to their businesses and how to reach these alternatives, places to equip farmers with experienced agency and to alleviate the political-economic consequences of the partial phase-out of livestock farming. Rural change agents and political leaders should take this into account. Indeed, only through a consideration of these aspects will livestock incumbents be impelled to participate in sustainability transitions, will conflicts be anticipated early, will a just livestock transition be ensured, and will environmental degradation be reduced.

9 Synthesis and Discussion

Throughout the chapters of this dissertation, the overarching aim has been to examine the case of livestock farming in Germany in its different facets and to analyze the mechanisms, actors, and processes of how sustainability transitions in this system can be driven or leveraged, and how they might unfold with respect to innovation, incumbents, and imagined futures. I started from the observation that livestock farming currently faces numerous issues with regard to sustainability (such as those relating to eutrophication of water bodies on a local scale and aspects of climate change at the global level) and faces legislative and discursive pressures to change. Simultaneously, bioeconomic innovations are being developed that may contribute toward a sustainability-oriented transformation (see Figure 1). This setting opens up the possibility, so went my research hypothesis, to observe transitions in the making. My aim of understanding transitions in livestock farming fed into four overarching research questions (see chapter 1.1) that I have approached in an integrative way by means of four in-depth qualitative case studies: (1) a focus on different trajectories of livestock farming and their underlying imaginations of "manure futures" (Friedrich et al., 2022a, see chapter 5), (2) the capacity of innovations to contribute to a sustainable livestock system as part of the approach of a sustainable bioeconomy (Friedrich et al., 2021a, see chapter 6), (3) imaginaries that shape bioeconomic actors and their innovation design (Friedrich et al., 2022b, see chapter 7), and (4) the role of farmers as incumbents and their in/ability to perform institutional change and drive endogenous sustainability transitions (Friedrich et al., 2023, *unpublished manuscript*, see chapter 8).

Building on multiple in-depth case studies with different actors, I have demonstrated the importance of future-oriented approaches to the study of socio-environmental issues and sustainability transitions more generally. My research argues for the relevance of treating the future not as an object of projection but rather as a social arena and an open-ended space characterized by conflicting meanings, diverse ontologies, and constructed via contesting problem frames. Individual and subjective yet socially shared and embedded imagined futures shape extra-semiotic practices of social actors and embed, accompany, and drive reconfigurations of societal sub-systems such as livestock farming. Hence, imagined futures represent important explanatory dimensions for sustainability transitions and for devising solutions to socio-environmental issues.

In my research, I found different and contradictory trajectories with regard to potential futures of livestock farming, namely preservation, transformation, and modernization. Bioeconomic innovations that are being discussed as a solution to manure surpluses follow imaginaries of technological fixes that risk stabilizing unsustainable mechanisms in agriculture. They are at odds with reconfigurations of the system toward sustainability because these innovations tend to reproduce existing values and norms. I further argue that farmers as incumbents are embedded in institutionalized regime structures. The ability of these actors to drive change is rather limited as they externalize the locale of change onto other actors whom they expect to change frameworks. I regard both the ways in which innovations are designed and how incumbents reproduce rather than alter regime structures as indications for a general absence of the capacity to imagine alternatives beyond technological fixes and a maintenance of the status quo. I have argued that this phenomenon currently hinders real transitions as reconfigurations in livestock farming from unfolding and will

make radical change relatively unlikely (Friedrich et al., 2021a; Friedrich et al., 2022a, 2023, *unpublished manuscript*; Friedrich et al., 2022b).

In the following, I will provide an in-depth elaboration and synthesis of my empirical findings and insights into transition processes in German livestock farming (chapter 9.1) before discussing theoretical and conceptual contributions (chapter 9.2), and methodological reflections (chapter 9.3). I close by sketching future research avenues (chapter 9.4) and drawing some general conclusions (chapter 9.5).

9.1 Synthesizing main empirical findings and contributions

My aim in this dissertation was to depict the mechanisms and actors through which transitions in livestock farming in Germany are unfolding. I operationalized this aim via four research questions and a particular focus on innovations, incumbents, and imagined futures. In chapter 2, conceptualized transitions as reconfigurations of the orders of social practices (Adloff and Neckel, 2019) or as reconfigurations of the socio-technical regime. Changes in the sociotechnical system refer to the adoption of new technologies and changes in the regime's culture and in particular in the values and norms that are reconfigured in transitions (Fuenfschilling and Truffer, 2014). I have outlined that I treat reconfigurations as embedded and shaped by imaginations of the future and imaginaries as models of how to transition toward these envisioned stages (see also Adloff and Neckel, 2019; Beck et al., 2021; Beckert, 2016; Hajer and Pelzer, 2018; Jasanoff and Kim, 2015). In the following, I want to synthesize the main empirical findings and contributions of my dissertation to the question of how to transition in German livestock farming and regarding the bioeconomy as a political and scientific project.

9.1.1 Empirical findings with regard to transitions in livestock farming

My research suggests that there are different approaches and imaginations of how (not) to transition in livestock farming, namely (i) a preservation of the status quo that does not reflect any substantive changes, (ii) a modernization based on the idea of substitution and efficiency, and the vision of (iii) a transformation that imagines small-scale agriculture and more systemic changes (Friedrich et al., 2022a). These idealized trajectories for livestock farming reflect broader conceptions of agriculture depicted in the manure/slurry discourse (Artner-Nehls and Uthes, 2023), and contextualized in the "fertilizer–waste continuum" (Gesing, 2023), thereby revealing contesting imaginations of the future with regard to sustainability more generally (Adloff and Neckel, 2019). The transformation trajectory relates to ongoing debates around small-scale agriculture in Germany, evident in the protest movement "we are fed up" (Busch et al., 2022; Nowack and Hoffmann, 2020), while the modernization trajectory refers to socio-technical innovations and their capacity to achieve more sustainable outcomes by following principles of efficiency or substitution, such as those evident in bioeconomic approaches that are part of bio-resource or bio-technology visions (Bröring et al., 2020; Bugge et al., 2016). The preservation trajectory describes forces of inertia in reproducing the habitualized practices and livestock actors that are change-averse due to their fear of losing power and positions (see also Runhaar et al., 2020; van Oers et al., 2021). In transition studies, these different conceptions are often attributed to the relationships and positions that actors have or take (see Fischer and Newig, 2016) when it comes to change and the object of change (in

this case livestock farming). I also attribute this to differences in cultural repertoires[56] (cf. Swidler, 1986; Tilly, 1993) which these actors are able to draw from in their actions, that again are informed by their position in society (and partly influenced by social categories of class, gender, and race, cf. Johnston et al., 2011) and the experiences and social contacts these actors have in relation to this position and which form the bases for their cultural repertoires. The different trajectories also suggest that livestock farming is a social arena in which contesting ideals of transformation and the mentalities, practices, and cultures of these transformations become empirically apprehensible (e.g., Adloff and Neckel, 2019; Eversberg and Fritz, 2022).

I regard the different trajectories of livestock farming as an indication that a reconfiguration of the system is taking place at the moment. By viewing this transition process through the X-curve framework of Loorbach et al. (2017) and Hebinck et al. (2022), I argue that one can witness that livestock transitions have currently not reached the middle point yet at which major reconfigurations could take place. The empirical phenomena that I have researched, and in particular the role that innovations have, the resistance to change that characterizes farmers, and the incremental changes that are currently occurring, indicate a position prior to the messy and chaotic middle point. In particular, this means that some actors in livestock farming may be forced to (partially) phase out, that innovations (in this case of a bioeconomic character, cf. Friedrich et al., 2021a; Friedrich et al., 2022b) are currently being devised that may diffuse further and potentially reconfigure the actor–technology relationships of the existing regime. At the same time, this observation points out that a destabilizing of the existing regime and its values is an emergent and ongoing process, evident in the boundary defense[57] of farmers (Friedrich et al., 2023, *unpublished manuscript*). The phase of "emergence" in which new structures become visible (Hebinck et al., 2022) has yet to be reached because actors tend to defend their routines and have not yet widely adopted new practices and values that may form new structures. Nevertheless, my research on farmers as incumbents (see Friedrich et al., 2023, *unpublished manuscript*, chapter 8), bioeconomic innovations (Friedrich et al., 2021a, see chapter 6), and innovation actors (Friedrich et al., 2022b, see chapter 7) suggests that change is happening and that livestock farming is in an emergent stage of transition. This change in terms of a reconfiguration is largely driven by exogenous forces that have a semiotic relationship with livestock farming. Since bioeconomic innovations are currently driven by business-as-usual assumptions, their capacity to lead to a reconfiguration of the existing regime beyond actor–technology relationships is rather limited.

One reason is the embedded position that farmers ascribe to themselves. Because of this, they are only able to perform habitualized practices and make sense of uncertain situations by relying on routine and sensemaking agency (see also Stuhr et al., 2021 for the case of perceived agency of farmers concerning nitrogen policies) while at the same time they externalize in their discourse the locale of change onto other actors[58] whom they expect to change conditions (Friedrich et al., 2023,

[56] I take cultural repertoires to refer to the practices, ideas, and values which individuals are able to draw from in their day-to-day practices, see Swidler (1986).

[57] By boundary defense, I refer to Zietsma and Lawrence (2010), who describe the work of actors in defending the boundaries of their system and the historically institutionalized practices and values of this system. Boundary defense is one type of boundary work, see footnote 59.

[58] Some meat producers may externalize the locale of change onto other actors by accepting the neoliberal ideology of "consumer sovereignty": the idea that consumers are independent and free in their food-related consumption decisions and practices. For details and reflections on how the imagined "consumer sovereignty" unfolds in practice, see Baumann et al. (2023).

unpublished manuscript). This is evidence of "partaking" as the most likely type of institutional change driven by endogenous actors (Dorado, 2005). This means that livestock farmers as incumbents are largely permeated by the imagination of preservation, the culture of maintenance, and reproduction of existing cultural structures and mechanisms (Burton and Farstad, 2020; Friedrich et al., 2022a, 2023, *unpublished manuscript*; Maes and van Passel, 2017; Runhaar et al., 2020; van Oers et al., 2021), which are historically institutionalized and inscribed in practices by the logic of "grow or die" in Germany (Nowack et al., 2019). Hence, their ability to effect changes in the institutionalized livestock system is quite limited (for further discussion of this aspect, see chapter 8). Livestock farmers and their institutionalized culture and practices describe one aspect of the interplay of different factors that perpetuate historically institutionalized path dependencies in agri-food systems (Conti et al., 2021).

Transitions, in terms of cultural and socio-technical reconfigurations, are at the moment mainly driven by exogenous actors such as NGOs, and driven by the result of innovative development, e.g., within the paradigm of a sustainable bioeconomy. Exogenous actors such as NGOs or civil society bodies mainly have semiotic relationships with livestock farming and only rarely material-semiotic ones, as farmers have. I argue this to be a reason that allows the former to envision more radical imagined futures of sustainability in contrast to that which currently exists (Adloff and Neckel, 2019; Friedrich et al., 2022a). When taking an institutional perspective on change in organizational fields by Zietsma and Lawrence (2010), it becomes clear how the boundary and practice work[59] of NGO actors and civil society bodies in terms of their imaginations of the future of manure use has influenced the ongoing process of a reconfiguring of the organizational field of livestock farming. Their work has changed values concerning manure and accordingly resulted in new legislative regulations with regard to nitrogen (Vogeler et al., 2021; Vogeler et al., 2019). The lobbying for more rigorous environmental protection from NGOs and the Green Party against the "agrarian coalition" of the CDU, FDP, and farmers (Vogeler et al., 2021) should therefore be seen as a successful intervention to implement EU law with regard to reducing nitrogen in water bodies in Germany. These new legal stipulations, which regulate the application of manure on fields and its leaching into water bodies, have implications for farmers' day-to-day practices (Stuhr et al., 2021). The new fertilizer ordinance demands high compliance costs and hence it is argued that this runs the risk that farmers will not follow the new regulations (Kuhn et al., 2019). The active delaying of the implementation of new environmental law with regard to nitrogen build-ups and manure application by the "agrarian coalition" of CDU, FDP, and farmers is one reason for the difficulties and compliance costs as well as for the experience of lack of agency that many farmers feel (Stuhr et al., 2021; Vogeler et al., 2021). Consequently, this has led farmers to protest against the new fertilizer ordinance in Germany by forming the relatively new coalition of "Land Schafft Verbindung".[60] This presents a form of boundary bolstering[61] (Zietsma and Lawrence, 2010) in which farmers defend their institutionalized values and practices for the sake of preserving the status

[59] Zietsma and Lawrence (2010: 194) define boundary work as "actors' efforts to establish, expand, reinforce, or undermine boundaries." The authors (ibid.: 190) define boundary practices as "actors' efforts to affect the recognition and acceptance of sets of routines, rather than their simply engaging in those routines."

[60] "Land Schafft Verbindung" is a German farmers' organization, established in 2019 as a response to legislative changes and to farmers' perceptions of being unheard by the German "Bauernverband", the more well-established farmers' organization. In English, the name would mean "land creates connection."

[61] Boundary bolstering describes the efforts of actors in defending system boundaries such as institutionalized values and practices. Boundary defense is one type of boundary work, see footnote 59.

quo, thereby contrasting with the transformation or modernization trajectories (Friedrich et al., 2022a). The above-described phenomenon is an example of the process of reconfiguration that livestock farming is currently witnessing, and one which is mainly driven by exogenous forces leading to a defense of the historically institutionalized practices and system by endogenous forces. The reconfiguration is emergent and ongoing because the "messy" and chaotic middle point within transition processes (Loorbach et al., 2017) has not yet been reached, and a new dynamic-stable configuration has yet to arise.

9.1.2 Empirical findings with regard to the bioeconomy

Another prospect arising from this reconfiguration process in terms of how manure is viewed and treated relates to the design of bioeconomic innovations that process manure for the sake of duckweed cultivation, the production of NPK fertilizer, or the breeding of insects (e.g., Čičková et al., 2015; Pintucci et al., 2017; Stadtlander et al., 2019). In my empirical research, interviewees mentioned manure surpluses and the new nitrate directive as providing an incentive to develop manure-based bioeconomic innovations (Friedrich et al., 2021a; Friedrich et al., 2022b). While this acknowledges some of the economic effects of livestock farming, i.e., that manure has become a risk product for industrialized livestock production in that it jeopardizes the current intensive-production pathways (Franz and Schumacher, 2020), it also neglects various sustainability-relevant aspects of livestock farming (emissions, odor, telecoupled effects). I have argued that this presents a reductionist problem framing by neglecting the globally entangled and locally embedded aspects of livestock farming that produce multiple socio-environmental concerns of livestock farming (Friedrich et al., 2021a; Friedrich et al., 2022b). Consequently, I found manure-based bioeconomic innovations to follow classical innovation paradigms (Friedrich et al., 2021a; Schlaile et al., 2017) which are shaped by imaginaries of technological fixes for socio-environmental problems (Friedrich et al., 2022b; Nightingale et al., 2020). Hence, these innovations describe a capitalist product within the coupled imperative of growth and development; a product of continuous capitalist self-renewal through creativity and growth that terminates in the production of new socio-technologies for capital accumulation (Marx, 1872; Reckwitz, 2012; Schumpeter and Kurz, 2020).

By following the classical innovation paradigm and the imaginary of a technological fix, bioeconomic innovations relating to manure processing risk perpetuating unsustainable modes of production as their designers do not question the globally telecoupled effects of livestock production. In particular, this refers to primary and secondary socio-metabolic flows (Giampietro, 2019). In the case of livestock farming, primary flows are the production of fodder that threatens the land rights of indigenous people in e.g., South America (Sauer, 2018) and secondary flows refer to the general farming of animals with regard to climate change emissions (Tilman and Clark, 2014). Bioeconomic innovations are based on tertiary flows and, in this case, on manure. Tertiary flows presuppose primary and secondary flows (Giampietro, 2019) and hence manifest and reproduce their unsustainability in terms both of threats to indigenous land rights and of continuous greenhouse gas emissions that drive climate change. Hence, bioeconomic innovations tend to promise incremental improvements to the local socio-technical regime of livestock farming while their ability to effect more systemic changes for globally linked and diffusing regimes (e.g., Fuenfschilling and Binz, 2018; Miörner et al., 2022a) is limited. The complexity of socio-metabolic flows (Giampietro, 2019) and globally diffusing regimes (Fuenfschilling and Binz, 2018; Miörner

et al., 2022a) hinders bioeconomic innovations from altering the constitution of socio-environmental issues at the water–energy–food nexus (Franz et al., 2018).

Manure-based bioeconomic innovations offer a lens through which to view the bioeconomic project. These innovations have been triggered by, among other factors, the new fertilizer ordinance following the EU nitrate directive as part of the German bioeconomy strategy (BMEL and BMBF, 2020) and its local consequences for intensive livestock production. The low ability of these innovations to drive sustainability-related transitions in livestock farming also point to some broader questions and reflections regarding the bioeconomy as a scientific and political project: first, my research points to the need to continuously and critically evaluate the project of a sustainable bioeconomy concerning its capacity to alter social orders so as not to be seen ultimately as a failed project (Lühmann and Vogelpohl, 2023). Second, the political project has been argued to be unable to offer new innovation policies (Bogner and Dahlke, 2022) with regard to livestock farming evident in the incorporation of the fertilizer ordinance as bioeconomic policy. Hence, the ability of its innovations to present new kinds of innovatory design and to operate within dedicated innovation paradigms (Schlaile et al., 2017) that may effect sustainability-oriented transitions is limited, as my research on bioeconomic innovations underlines.

Thus, although bioeconomic strategy papers emphasize their contributions to sustainability, the real-world practices betray "business as usual" (Lühmann, 2020) thinking. Bioeconomic innovations relating to manure processing underline this diagnosis by reproducing imaginaries of technological fixes and infinite growth that are attributed to the bioeconomy. In my view, this emphasizes the concerns that bioeconomic approaches in their current aggregates represent business-as-usual assumptions rather than transformative concepts that could stimulate sustainability-oriented transformations (Birch, 2019; Eversberg et al., 2022; Eversberg et al., 2023; Friedrich et al., 2021a; Friedrich et al., 2022b; Giampietro, 2023; Lühmann and Vogelpohl, 2023). Bioeconomic innovations, as a product of these policy strategies and as a scientific concept, therefore risk reproducing and perpetuating existing issues rather than offering solutions. By following imaginaries of technological fixes and by neglecting the socio-cultural embedding and generating of socio-environmental issues, their capacity to drive sustainability-oriented transitions is limited. Hence, bioeconomic innovations and transitions, as I have elaborated elsewhere,[62] threaten to result in further polarization in rural areas where much of the natural resources for bioeconomic development are found (Friedrich et al., 2023).

9.1.3 The risk of semiotic path dependencies

I have argued that bioeconomic innovations, as new technologies that are being adopted by farmers and other actors of the existing regime, reconfigure the relationship between actors and technologies (Fuenfschilling and Truffer, 2016) in livestock farming. However, as these innovations reproduce existing approaches and conceptions of transitions through technological fixes being entangled with imaginaries of infinite growth, they are not shaped by values that could radically alter the structures of the existing regime (Friedrich et al., 2021a). This suggests that, while they change the relationship between technologies and actors, i.e., how animal farming is practiced, the underlying cultural structures are not altered. Indeed, I argue that bioeconomic innovations are

[62] This article is not part of the dissertation but emerged out of the research. It combines insights derived from different case studies in Europe to draw conclusions concerning the impact of bioeconomies on rural practices and people.

a product of society's "technological fetishism" (Harvey, 2003) in addressing problems detached from their socio-cultural embedding and constitution. By engaging in a reductionist problem framing, bioeconomic innovations relating to manure processing fail to treat socio-environmental issues of livestock farming as wicked problems (Duckett et al., 2016) that require dynamic, adaptive, and context-specific solutions. This not only presents a risk to maintaining the unsustainability of primary and secondary socio-metabolic flows (Giampietro, 2019). Rather, bioeconomic innovations and especially their semiotic constitution in terms of narratives and the imaginary of a technological fix (Friedrich et al., 2022b) threaten to "colonize the future" (Beckert, 2016) with unknown impacts for future generations. By presenting the semiotic incentive for investments, narratives of bioeconomic innovations (Friedrich et al., 2022b) risk resulting in semiotic path dependencies – i.e. on a cognitive level at the individual, actor level and, on a discursive level, on the collective level of societal discourse (e.g., Simoens et al., 2022). These semiotic path dependencies may ultimately result in extra-semiotic path dependencies such as those arising from sunken costs or triggered by material inscription and lock-ins of specific technologies or infrastructures (Conti et al., 2021), as well as the concentration of capital in "socioecological fixes" (Ekers and Prudham, 2017, 2018) that result in the contours of today's agricultural landscapes. These inscriptions, lock-ins, and fixes reduce the future "action space" for individuals and groups, thereby "colonizing" both semiotic and extra-semiotic aspects of future social lives and generations.

The potential outcomes of such developments and path dependencies are visible in research on Bt cotton in India and the political and economic consequences of technological failure for the sustainability of rural farming livelihoods (see chapter 7; Friedrich et al., 2022b; Najork et al., 2022; Najork et al., 2021). Here, the imaginary of a technological fix that shapes bioeconomic innovations like Bt cotton remains fixed in situations of severe irritations (such as regarding questions of the obsolescence and longevity of the technology). Actors only adapt the narratives that present their technologies to the wider public (Friedrich et al., 2022b). The issues of poverty and debt for rural farmers and their livelihoods, which are a consequence of the socio-biological obsolescence of the Bt technology, are neglected and reinterpreted as a management and cultivation problem for farmers to face (Najork et al., 2022; Najork et al., 2021). The narrative adaptation, instead of a questioning of the longevity of the technology and its socioeconomic consequences, exemplifies the risk that semiotic path dependencies relating to the idea of technological fixes. When it comes to livestock farming, these semiotic path dependencies risk perpetuating socio-environmental issues. Hence, it is of great importance to develop adaptive governance mechanisms for innovations and to be able to adapt innovations to ever changing environments and discourses instead of just adapting narratives. This would be a valuable contribution to the sustainability of socio-ecological systems such as those related to livestock farming.

9.2 Conceptual reflections and contributions

In this dissertation, I have studied the various aspects of livestock transition. I have used different yet complementary theoretical approaches to the study of imagined futures, innovation, and incumbents. The commonality of these approaches lies in their future-orientation with regard to explaining transitions. This includes the framework of futures of sustainability (Adloff and Neckel, 2019), imagined futures and fictional expectations (Beckert, 2016), sociotechnical imaginaries (Jasanoff and Kim, 2009, 2015), and institutional change and agency (Dorado, 2005;

Emirbayer and Mische, 1998). By this combination, my research yielded new insights into the role that imagined futures and imaginaries elucidate concerning sustainability transitions and institutional change. This focus led to a range of theoretical contributions and reflections, which I want to point out in the following concerning scholarship on sustainability transitions.

In my focus on imagined futures, innovation, and incumbents in sustainability transitions, I took a semiosis-oriented approach to the study of change and transformation. This approach allows me to draw attention to the role that imaginaries of the future, discourses, and narratives play concerning change. It also points to the role that (dominant) models of transitions (e.g., that of technological fixes) have with respect to transitions and innovation design. The empirical nature of my research topic in a focus on spatially and temporally explicit phenomena (see also Schlüter et al., 2022) meant that different theoretical angles were needed from which to view the research problem. In the following, I want to elaborate on my theoretical contributions before I draw some reflections for the study of agricultural sustainability transitions.

9.2.1 The need for transdisciplinary approaches

In my dissertation, I first argued for the importance of the role of imagined futures in shaping and accompanying sustainability transitions and innovative development in general. My research suggests that imagined futures (e.g., Adloff and Neckel, 2019; Beckert, 2016; Jasanoff and Kim, 2009) are important explanatory dimensions for contested perceptions not only on a societal level but on the level of context-specific solutions to specific socio-environmental issues like the problem of manure surpluses and eutrophication of water bodies (Friedrich et al., 2022a). In addition, a focus on imagined futures allows me to draw attention to how fixed imaginaries, such as those of technological fixes (Markusson et al., 2017; Nightingale et al., 2020), visible in a "fetishization of technology" (Harvey, 2003), are inscribed in society as a model of how to achieve transitions to both socio-ecological sustainability and growth.

On the individual level, innovation-related narratives, i.e., how actors present their technologies to the public, are dependent on context and discourse while these models of technological fixes remain entrenched (Friedrich et al., 2022b). This is an example of how uncertainties about future developments with regard to technologies and the complexities that these bring are often (unintentionally) neglected on a micro level for actors to be able to act purposefully, with the upshot that dominant imaginaries are reproduced (see also Beckert, 2016; Jasanoff and Kim, 2015). With this finding, my research underlines the importance of more diverse approaches to the study of innovation and change, such as those of co-design and transdisciplinary or transformative approaches (e.g., Bergmann et al., 2021; Busse et al., 2023; Lang et al., 2012).

As an example, transdisciplinary research, through its focus on three types of knowledge – namely system knowledge, target knowledge, and transformation knowledge (Pohl and Hirsch Hadorn, 2008) – promises robust orientations for actors in their change processes. Currently, the understanding of problems (system knowledge) and solutions (target and transformation knowledge) by actors is different although arguably informed by neoliberal conceptions of transformations through technological fixes (Friedrich et al., 2022b; Markusson et al., 2017; Nightingale et al., 2020). Transdisciplinary research fosters approaches that debate dominant models of transition and transformation with actors in the process of change and may help them to come up with new ideas. My research underlines the importance of developing theoretical accounts, models, and imaginaries of transitions that are context-specific and which incorporate the tacit

knowledge of stakeholders. This allows for a challenging of dominant and linear conceptions of transition as well as a critique of the work of laboratories and epistemic cultures (Knorr-Cetina, 1999) through which these are reproduced.

I argue that, without such context-specific approaches, the capacity of innovations to address problems remains low because their designers are often concerned with reductionist rather than complex interpretations of problems, and they hence depoliticize wicked problems by being governed by primarily business-as-usual ideas. Hence, my contribution lies in underscoring the importance of transdisciplinary research approaches that allow scope for discussing different perspectives on solutions to socio-environmental issues, allowing researchers to – at least partially – grasp the uncertainties, complexities, ambiguities, and normativity inherent in these issues by conceptualizing them as wicked problems, and providing a general openness and context-specificity when it comes to addressing these problems (Brown et al., 2010; Duckett et al., 2016; Pohl and Hirsch Hadorn, 2008). With this focus, transdisciplinary research and co-design approaches allow for treating the future as an ontologically versatile entity rather than a fixed object that can be approached via linear, often deterministic and mechanistic, interpretations and conceptions such as the depoliticized notion of technological fixes.

9.2.2 Problem frames and imagined futures

Alongside the value of transdisciplinary research and the co-design of innovations, findings from my research underscore theoretical arguments about the importance of a scholarly focus on the construction of futures and imaginaries concerning sustainability transitions and in particular the politics of making and unmaking of futures (Beckert, 2016; Jasanoff and Kim, 2015; Knappe et al., 2019). Hajer and Pelzer (2018) have argued that this should be a major concern in that "sustainability transitions scholarship tends to see constructions of the future (visions, scenarios, predictions etc.) as *explanans* (that what explains) while constructions of the future are rarely seen as *explanandum* (that what should be explained)" (ibid.: 222). My research underlines this. While I have not directly focused on the construction of futures in terms of the laboratories, cultures, and practices (Knorr-Cetina, 1999) through which these futures are negotiated and constructed, my research suggests that the problem frame through which socio-environmental issues are regarded is an important factor for the construction of imagined futures. The problem frame, i.e., the conception of what should ideally change, explains contesting imaginations of manure futures in my research into different trajectories for a sustainable livestock system (Friedrich et al., 2022a, 2023, *unpublished manuscript*). The problem frame bridges the gap between the present (what exists) and the future (what ought to be), thereby being shaped through the past, through knowledge and the experiences of individuals embedded in social structures (Adloff and Neckel, 2019; Delanty, 2021; Priebe et al., 2021). Imagined futures therefore are not just an imaginative conception of the future, they are also inextricably tied to the present and what exists. They provide a diagnosis of the present as much as an imagining of the future.

Hence, on the one hand, this evidences the importance of the diagnosis of problems as a descriptor of change, while it also points to the importance of understanding these problems as wicked and as shaped by subjective and normative conceptions of individual actors (Duckett et al., 2016). On the other hand, my research on incumbents in chapter 8 underlines the relevance of the subjective perception of problems and solutions for individuals to experience agency (see also Stuhr et al., 2021) and to feel able to effect institutional change (Friedrich et al., 2023, *unpublished*

manuscript). Simultaneously, my research on contesting imaginations of manure futures (Friedrich et al., 2022a) suggests that a more complex problem frame relates to a more transformational conception of change, while a reductionist problem frame aligns with a preservation-based conception of (no) change.

My research also suggests that actors with a semiotic relation to, though without direct economic interests in, livestock farming (such as NGOs) can have more complex problem frames. Farmers and innovation actors that have both a semiotic and extra-semiotic (semiotic-material) relation with livestock farming, including economic interests, tend to view certain issues through reductionist problem frames. I argue that this reveals that actors with extra-semiotic relationships seem to need to experience a problem as manageable, and hence often in a reductionist way, to be able to experience agency for addressing this problem (Friedrich et al., 2023, *unpublished manuscript*). If farmers view problems as complex, they often do not feel a sense of agency for addressing this problem (Friedrich et al., 2023, *unpublished manuscript*). Hence, instead of experiencing ontological insecurity because of the lack of agency in altering complex problems, they rely on reductionist frames to be able to act purposefully.

Consequently, the conception of problems, being shaped by the position of individuals as embedded in social structures, the cultural repertoire (Swidler, 1986) that is informed by this position and which they can draw from in their actions, and their semiotic and extra-semiotic relations with the problem, explains to large extent the futures that actors seem able to imagine for a problem. To reiterate, problems need to be perceived as manageable by individuals for them to experience agency. These findings link to the work of scholars who focus on individuals' perceptions of climate change (denial) and how this is related to their experiences of agency. Hochschild (2016) and Norgaard (2006) argue that, if climate change is perceived as something beyond our control that individuals do not experience agency for, these social actors may deny the very existence of these issues so as not to experience ontological insecurity. Similar tendencies are at work in my research: because farmers do not (or do not want to) experience agency and stewardship/responsibility for socio-environmental issues and for transitions in livestock farming, these actors need to conceptualize the issues of livestock farming as beyond their control. In this way, they view and treat issues and possible solutions in livestock farming as mainly a matter of governance and the responsibility of other actors, and hence externalize the locale of change onto other actors whom they expect to change current conditions (Friedrich et al., 2023, *unpublished manuscript*). To be able to act purposefully despite not experiencing agency, these actors tend to deny the very existence of problems like climate change (Norgaard, 2006) or, in the case of livestock farming, they are skeptical about the results from measuring sites for nitrogen and the sustainability-related issues of manure surpluses (Friedrich et al., 2022a, 2023, *unpublished manuscript*). In these situations, actors seem to experience ontological security by relying on normative beliefs and sensemaking agency by means of which they interpret the uncertain and complex situation they find themselves in (Dorado, 2005; Emirbayer and Mische, 1998; Friedrich et al., 2023 *unpublished manuscript*).

I argue that this also points to the psychological phenomenon of systems justification (Feygina et al., 2010), in that the existing systems – both semiotic in terms of culture and extra-semiotic in terms of material infrastructures – become continually justified. In a moment or situation of (perceived as severe) uncertainty and complexity such as being provoked by the need to change in livestock farming, this justification is based on sensemaking agency (Dorado, 2005; Emirbayer

and Mische, 1998) and normative beliefs. This can result in a denial of specific phenomena that may have contributed to the perceived uncertainty and complexity (Feygina et al., 2010). I attribute this especially to actors with material-semiotic relationships with livestock farming, like farmers. This phenomenon underlines the importance of experiencing problems as being within one's own control to be able to act purposefully. Hence, imaginations of the future are ultimately constructed as a consequence of the relations that actors have with problems these imaginations relate to, and by the need to experience agency for solving these problems.

The material-semiotic relationships that actors have can prevent radically different imaginations from emerging, because these actors would need to question the system that exists and the one they have emotional ties to. For sustainability transitions to occur, this indicates how individual social actors like farmers can be helped to see problems as complex, how their capacity to imagine can be enhanced so that they are able to conceive of transformative solutions that reconfigure existing regimes, and that they experience agency for these changes as they do so. In chapter 9.4, I lay out some research avenues that aim to address this.

9.2.3 Experiencing agency for endogenous institutional changes

I want to draw attention to another aspect that my dissertation has revealed about the study of sustainability transitions. In chapter 8, I studied the in/ability of incumbents to drive institutional change in livestock farming (Friedrich et al., 2023, *unpublished manuscript*). In doing so, I conceptualized institutional change by drawing on the work of Dorado (2005) concerning the interplay between agency, resource mobilization, and perception of the organizational field. This focus allowed me to emphasize the role of individual social actors in processes of change and their embedded agency. It complements existing theories of institutional change in sustainability transitions scholarship that have followed a more structural perspective on institutional change via the approach of institutional logics (Fuenfschilling and Truffer, 2014, 2016; Runhaar et al., 2020). With my focus, I highlight how individuals are a product of structural phenomena with respect to culture, and the norms and values individuals' embody. However, I also foreground the agency of these actors, being dependent on their dominant focuses on the past, the present, or the future (Emirbayer and Mische, 1998) with regard to leveraging change.

This has two implications: first, I set out how agency is a relevant factor in the study of incumbents in sustainability transitions (see also Duygan et al., 2019; Galeano Galvan et al., 2020). These actors have the resources and positions to effect change (Steen and Weaver, 2017; Turnheim and Sovacool, 2020). A focus on their perceived agency in driving endogenous sustainability transitions and how these actors can gain support in their experiencing of agency, I argue, is an important aspect in the search for strategies to accelerate transitions (Markard et al., 2020). In my view, especially in persistent systems like agriculture, which are characterized by property relations (Grenzdörffer et al., 2022) that partly determine those actors that are in a position to change – because they have the resources and land to do so – this focus is inevitably important for driving and accelerating transition.

Second, studying the kind of agency that farmers experience, and the temporal patterns associated with it, highlights how the capacity to imagine (Hajer and Versteeg, 2019) relates to institutional change in persistent systems. My findings reveal that the capacity to imagine and to accordingly be able to experience strategic agency (Dorado, 2005; Emirbayer and Mische, 1998), is an important determinant of institutional change in persistent systems. This underlines the

argument of Hajer and Versteeg (2019) that, without the capacity to imagine, the ability to transition is limited. Incumbents especially are in an ambivalent situation: the persistent nature of the culture of the existing regime that permeates incumbents as established actors within this regime limits their capacity to imagine, while the limited capacity to imagine constrains the capacity for change in this persistent culture. This underlines the importance both of actors that work in different organizational fields and of knowledge flows between different organizational fields when it comes to effecting change (Bünger and Schiller, 2022; Strambach and Pflitsch, 2020). These actors that operate in different organizational fields can accordingly stimulate both exchange and knowledge flows and lead to cultural changes that may result in an enhanced capacity to imagine. The consequence could be imaginations of the future that can shape practices and models of transitions toward sustainability instead of a maintaining of the status quo. In theories of sustainability transitions and economic geography, these actors are often conceptualized as change agents (e.g., Grillitsch and Sotarauta, 2020) or as intermediaries (e.g., Bünger and Schiller, 2022). My research underlines that without such actors, cultural exchange in persistent systems is limited (Friedrich et al., 2023, *unpublished manuscript*). This exchange is needed for enhancing the capacity to imagine (Hajer and Versteeg, 2019) and to drive institutional changes and sustainability transitions in a particular organizational field.

The above-mentioned transdisciplinary research approaches (see chapter 9.2.1) provide opportunities for cultural exchange beyond existing organizational fields. These approaches integrate the knowledge and experiences of a range of stakeholders that come from different organizational fields such as agriculture, policy, and NGOs. So transdisciplinary approaches may provide the theoretical spirit for transitions in persistent systems and new approaches to the design and implementation of innovations.

9.3 Methodological reflections and limitations

Along my methodological path, I followed a multiple in-depth qualitative case-study approach, whereby I combined insights from different empirical contexts to study transitions in livestock farming. The case studies complement each other in their focus on different empirical facets of livestock farming and transitions: while the first case study gives an overview of how different imaginations of manure futures are currently being discussed among actors (Friedrich et al., 2022a), the second case study describes the capacity of manure-based bioeconomic innovations to contribute to reconfigurations in the system (Friedrich et al., 2021a). The third case study, employing a comparative yet diverse case-study approach (Seawright and Gerring, 2008), examines how imaginaries of technological fixes shape the narratives of bioeconomic actors depending on local contexts (Friedrich et al., 2022b). The fourth case-study approach involves farmers and investigates their in/ability to drive institutional changes in livestock farming (Friedrich et al., 2023, *unpublished manuscript*).

These approaches complement each other in that they treat the empirical object of livestock farming and currently unfolding transitions from different yet complementary theoretical perspectives. I arrived at these particular case studies through an iterative and inductive process of investigation and engagement with the empirical context. I started with the observation that livestock farming is characterized by multiple socio-environmental issues and the pressure to change. At the same time, bioeconomic innovations are being developed that may contribute to a sustainability-oriented transformation in this sector (see Figure 1). Hence, the current situation may

provide a setting in which transitions can unfold. By investigating these topics through three case studies (Friedrich et al., 2021a; Friedrich et al., 2022a; Friedrich et al., 2022b), I arrived at a focus on the role of farmers as incumbents and their role in driving (or not driving) transitions (Friedrich et al., 2023, *unpublished manuscript*). In the following, I will first discuss how my versatile theoretical approach suits the nature of sustainability-related topics and inductive qualitative research before I reflect on limitations regarding research designs of qualitative case study approaches such as those applied in my dissertation.

I have used and operationalized theoretical versatile and context-specific focuses in the complementary case studies of my dissertation. These suit the spatially explicit and time-specific nature of sustainability-related issues that need to be approached from different theoretical and methodological angles appropriate to these contexts (Schlüter et al., 2022). This is also the nature of complementary, inductive qualitative research: while I started with a focus on contesting imaginations of manure futures (Friedrich et al., 2022a) and the potential of bioeconomic innovations to contribute to a sustainability-oriented transition of livestock farming (Friedrich et al., 2021a), I arrived at a focus on farmers as incumbents and their ability or otherwise to drive changes. This was stimulated by the process of conducting empirical research on this topic and through continuous engagement with the empirically examinable reality. This process led me to realize that livestock transitions are currently taking place, driven by exogenous events like the spread of African swine fever and policy interventions such as the new fertilizer ordinance. Against this background, I aimed to understand the potentials and limitations for change in livestock farming. While I already had some insights into the potential with my focus on bioeconomic innovations, I also wanted to understand the motives of farmers in lobbying for the preservation of the status quo (Friedrich et al., 2022a). This resulted in my fourth case study and the role of farmers as incumbents in driving institutional change (Friedrich et al., 2023, *unpublished manuscript*).

In my view, this process of deriving empirical results that accordingly guide the next research question is the heart of qualitative research. Qualitative research is based on the rationale of a general openness to the empirical material and context and hence allows for the adaptation of the research design and methods to the specific object under study (e.g., Agee, 2009; Creswell, 2013; Rubin, 2021). This also underlines the importance of being theoretically versatile in empirical research in sustainability science (Schlüter et al., 2022). Because of the importance of temporally and spatially explicit phenomena, research designs must be adaptive to empirical realities by including exploratory aspects.

Qualitative case-study approaches are often argued to have limitations in generalizing and transferring the results to other contexts and societies in question. This also results in a questioning of qualitative research approaches using small samples (Rubin, 2021). I argue that social phenomena that relate to sustainability transitions can be especially well researched through qualitative methods as they provide an in-depth understanding of the contexts and processes that characterize these phenomena. In contrast to other research designs, qualitative case studies are key to providing these in-depth insights and elaborations (Flyvbjerg, 2006). In addition, qualitative case studies provide researchers with the ability to adapt their approaches to the empirical reality as outlined above (see also Agee, 2009 with respect to the adapting of qualitative research questions to empirically examinable phenomena).

My research has generated in-depth insights about the topic of sustainability transitions in German livestock farming and the particular focuses on innovation, incumbents, and imagined

futures. Hence, my research could be used as a basis for additional and complementary research approaches such as quantitative techniques that target the distribution of the researched phenomena, or qualitative, workshop-based approaches that foster discussion about the contesting "problem framings" through co-designing ways of addressing these problems (e.g., Busse et al., 2023). Thus, my research provides an initial step in a more comprehensive understanding of transitions in German livestock farming that allows other researchers to build on this work.

It is useful to combine methodological approaches to studying empirical phenomena by means of mixed-methods approaches or triangulation of, e.g., theoretical perspectives, data, and empirical approaches (e.g., Flick, 2017). Triangulation of data and methods promises to generate valid orientations in terms of how phenomena unfold. When I started my dissertation research, I had the idea to carry out qualitative, interview-based research as a basis for designing an approach inspired by transdisciplinary research (e.g., Lang et al., 2012; Luks and Siebenhüner, 2007; Zscheischler and Rogga, 2015). This would have allowed me to triangulate the data received from case-study approaches via workshops that include stakeholders in livestock farming, that may bring up new research problems and understandings of the wicked problems relating to livestock farming (Duckett et al., 2016). Hence, my case studies would have been pre-studies for the design of a transdisciplinary process. Due to Covid-19 restrictions and resulting time constraints, it was unfortunately not possible to design such a process and to triangulate the data derived from the case studies as part of a transdisciplinary process. It is a limitation of my research that triangulating of data and methods was not conducted. This is also an example of how research designs in practice are constrained in terms of time, opportunities, funding, and of course the recent pandemic.

In my research approach, I took a social constructivist approach to knowledge and the social. Hence, for me, the in-depth analysis of actors' "meanings" regarding livestock farming based on qualitative, problem-centered interviews (Witzel, 2000), allowed me to interpret their actions in this context. Whatever they perceive as relevant informs their doings and is hence an appropriate object of study (Berger and Luckmann, 1966). If I had approached the issues from another epistemological angle, such as through critical realism or poststructuralism, other actors and methods may have come into play. I argue that, from a social constructivist perspective, my research designs based on qualitative interviews and document analysis are adequate to explain the social phenomena that I researched. I aimed to examine different meanings of sustainability and transitions in livestock farming, so what actors perceive in this regard elucidates this knowledge.

I want to note that my semiotic approach, being focused on meaning systems and perceptions of actors, only reveals indications of the extra-semiotic aspects of these perceptions rather than generating specific insights. My research approach has limitations concerning the description of extra-semiotic consequences of specific perceptions and meanings in terms of infrastructural realities and their material/physical manifestations in technologies. It is an important avenue for further research to focus on how the semiotic space in terms of perceptions and meanings relates to the extra-semiotic space in livestock farming.

In the process of this dissertation and researching the topic of sustainability transitions in German livestock farming, I realized that poststructuralist thought that incorporates power aspects and asymmetries regarding dominant meaning systems, discourses, and hegemonic imaginaries might have given my research an additional nuance. While I have not followed this epistemology in my empirical approaches, I have drawn from these approaches in the discussion sections of my empirical articles (see chapter 5 to chapter 8) by highlighting the processes, structures, discourses,

and power asymmetries that characterize the politics of making and unmaking futures (Knappe et al., 2019) and that lead certain futures to become hegemonic while others are sidelined (Kovacic et al., 2020). It would be a promising research avenue to examine the mechanisms by which futures are opened up and others closed off. Following these ideas would enable a design of methodological approaches and toolkits that investigate the building and reproducing of hegemonic imaginaries, the laboratories, institutes and cultures where these are generated (Knorr-Cetina, 1999), and the politics and power relations that underlie this (Hendriks and Friedrich, 2023, *unpublished manuscript*). I make some more detailed remarks on this possible research avenue in chapter 9.4.3.

9.4 Outlook and future research avenues

In the previous chapters 9.1 to 9.3), I discussed and synthesized the empirical and theoretical contributions that informed my research, and I briefly reflected on my methodological approach. In these chapters, I also touched upon some avenues for future research. I will now go into more detail about four research avenues that I see as some of the most promising. Some preliminary conclusions and necessity for future research with regard to the effects of bioeconomies in rural regions in Europe, that I have contributed to in my focus on bioeconomic and manure-based innovations, are specified in Friedrich et al. (2023, *forthcoming*)[63] and hence not outlined here. In the following, I focus on research avenues for sustainability transitions in livestock farming and the role of imagined futures in the scholarship of sustainability transitions. I will lay out how my research draws attention to questions of researching reconfigurations in action (see chapter 9.4.1), downstream actors in livestock systems (see chapter 9.4.2), the construction of futures in sustainability transitions (see chapter 9.4.3), and the aspect of experiencing agency in the light of a phasing-out of some agricultural industries (chapter 9.4.4).

9.4.1 Researching reconfigurations in action

In my dissertation, I elucidated that transitions in German livestock farming are currently taking place and that these are mainly driven by exogenous rather than endogenous actors (Friedrich et al., 2022a, 2023, *unpublished manuscript*). While I have looked at these transitions by focusing on innovation, incumbents, and imagined futures, I did not concentrate particularly on how these transitions are occurring in terms of a reconfiguration of the existing socio-technical regime of livestock farming. While I argue that contesting imaginations of "manure futures" (Friedrich et al., 2022a) and bioeconomic innovations (Friedrich et al., 2021a; Friedrich et al., 2022b) are driving this reconfiguration, I am unsure of the possible implications of these developments. To gain a better (and more comprehensive) understanding of the actors, concepts, and technologies through which reconfigurations take place in livestock farming, I see great potential in employing an STCA (socio-technical configuration analysis, cf. Heiberg et al., 2022; Miörner et al., 2022b) for the specific case of livestock farming. The STCA as a method has recently been developed to enable an analysis of transition-related dynamics by focusing on the roles of concepts, actors, and their temporal changes in institutionalized socio-technical systems (Miörner et al., 2022b). The use of this method with regard to sustainability transitions in German livestock farming could allow researchers to trace the development of regime reconfigurations, elucidate the actors driving these reconfigurations, and the concepts that inform these reconfigurations. This is not only an important

[63] As mentioned in footnote 62, this article does not belong to the dissertation although it emerged out of the research I conducted.

research avenue for a detailed description of the reconfiguration processes in livestock farming, it can also help paint a clearer picture of how and to what extent bioeconomic innovations and approaches play a role in livestock farming regarding reconfigurations of the existing regime. Hence, such a focus will also prove useful for assessing the semiotic impacts of political strategy papers (such as the German bioeconomy strategy paper) on regimes such as livestock farming.

In addition, I see great potential in such a research approach in its capacity to complement research on (bioeconomic) innovation narratives and their dynamics (Friedrich et al., 2022b). An STCA offers the possibility of researching narratives of specific technologies in taking into account dynamics beyond the actor level, such as discourses. In this way, the STCA approach may help to further elucidate the discursive dynamics that underlie changes in the semiotic sphere of livestock farming. The research I carried out for this dissertation can help to calibrate and elucidate the meanings that underline different concepts and especially their use over time. As an example, sustainability as a concept may be found to diffuse into certain socio-technical regimes. While this can highlight how the regime reconfigures the "logics" by means of which it functions, the meaning of sustainability is contested and ambiguous, and it may be difficult to assess whether this will genuinely lead to a reconfiguring of the existing regime or whether it continues to be governed by business-as-usual mindsets masquerading as sustainable ones. Researching actors' different perceptions of sustainability via interviews, or using some of the approaches followed in this dissertation, can thus help to calibrate the results of an STCA and to elucidate the dynamics that drive changes in meanings rather than remaining on the descriptive surface.

9.4.2 Downstream actors in livestock systems

In the previous chapter, I set out how issues around reconfiguration in livestock farming may be interpreted using an STCA approach. Another focus that may add to the understanding of transitions in livestock farming relates to actors that I have purposefully neglected in my research thus far. This especially applies to downstream actors such as the meat processing industry or food retailers that can have relevance for a more comprehensive understanding of transition dynamics and especially with regard to path dependencies arising from lock-ins in livestock systems. Hence, I see great potential in focusing on these actors in future research. Firstly, this relates to gaining a more nuanced and comprehensive understanding of the heterogeneity of incumbents (Turnheim and Sovacool, 2020) both in terms of actors as well as of technologies and/or infrastructures regarding transitions in livestock systems and how these may be challenged and changed accordingly. This could further contribute to a more comprehensive understanding of path dependencies in agri-food systems (Conti et al., 2021), in terms of incumbencies (Turnheim and Sovacool, 2020), or arising from different kinds of lock-in (see e.g., Simoens et al., 2022 for a typology of discursive lock-ins).

Secondly, the downstream focus should not stop at the corporate scale but could be expanded to encompass the roles of workers and trade unions in the meat processing sector and slaughterhouses as potential agents of sustainability transitions (Barca, 2012; Brand, 2020; Friedrich et al., 2021b; Moilanen and Alasoini, 2023; Räthzel and Uzzell, 2011). These actors experience and embody social injustices of livestock farming in their day-to-day work and may be relevant actors for integrating social and ecological means in the transition toward a sustainable livestock system. Their tacit knowledge and lived experiences thus offer an important area of study. I have argued (in another article) that such a focus and perspective would be useful for arriving at a clearer picture of socio-ecological injustices and transformations in livestock farming more

generally (Friedrich et al., 2021b). The notion of working-class environmentalism (Barca, 2012; Bell, 2020), as I argued in Friedrich et al. (2021b), may prove helpful in addressing current problems in livestock systems, and in particular slaughterhouses, and looking at ways to alleviate these at the science–policy interface. A focus on workers could illuminate the roles these actors play in sustainability transitions, a focus that has so far not been commonly applied (Moilanen and Alasoini, 2023).

9.4.3 The construction of futures in sustainability transitions

In my research, I argue that it is important to understand how imagined futures shape practices of the present (Adloff and Neckel, 2019) and that they therefore constitute a key aspect of sustainability transitions. These imaginations are contested and characterized by conflicting meanings (Friedrich et al., 2022a) and multiple ontologies, such as in the case of manure (e.g., Gesing, 2023). Currently, these perspectives are not all valued equally concerning their relevance for solving wicked problems. This can result in cognitive path dependencies and a "colonization" of the future (Beckert, 2016) as I have argued (Friedrich et al., 2022b). To open up the future again, to allow space for maneuver and adaptation to altered environments, I argue that it is important to better understand how futures are currently constructed and produced (see also Hajer and Pelzer, 2018).

In my view, dominant approaches when it comes to transitions currently risk to "empty" the future (Hendriks and Friedrich, 2023, *unpublished manuscript*). Opening up the future will imply a deeper understanding and challenging of dominant and hegemonic modes of "future making". Conducting research on the construction and production of futures, and the political and power dynamics that enable some possible futures to diffuse and to become hegemonic and institutionalized in political strategy papers and sociotechnical imaginaries while others are neglected, is an important research avenue (Hendriks and Friedrich, 2023, *unpublished manuscript*). Such a focus would allow for an opening up of the future, pluralizing it by letting counterhegemonic imaginaries diffuse. Such a lens would be relevant for the study of sustainability issues and sustainability transitions: my research has pointed to the risks of being permeated by a preservation of the status quo (Friedrich et al., 2022a, 2023, *unpublished manuscript*) and which arise from the fallacy of attributing agency to technology as a tool for "solving" socio-environmental issues independent of their socio-ecological and socio-cultural contexts (Friedrich et al., 2022b; Najork et al., 2022). Accordingly, I see great potential for future research to engage with the construction of imagined futures, e.g., via a focus on the epistemic practices and cultures, as well as the laboratories and institutes, by means of which these are (re)produced (Knorr-Cetina, 1999). This may also relate to a scientific gatekeeping that privileges certain genders, or English-speaking readers and authors, for instance (see e.g., Müller, 2021; Schurr et al., 2020 with regard to geography-influenced knowledge production) that currently reproduces dominant models of transitions. Ideally, these kinds of research focus could enable a more effective challenging of power dynamics and a critique of dominant social actors in transitions by contributing to more equitable and sustainable futures.

9.4.4 Experiencing agency in the process of change

As a final research avenue I see as emerging from my research, I now elaborate on the political and economic aspects of phasing-out (McDowall, 2022) in livestock farming systems (see also van Oers et al., 2021), with a particular focus on actors' (such as livestock farmers') experiencing of agency or non-agency when it comes to moderating unjust experiences and social conflict that may

hinder transitions. In my view, it is clear that, taking into account the goal of staying within planetary boundaries (Steffen et al., 2015), it is impossible to continue with the current livestock numbers per area in Germany. Hence, livestock numbers will need to be reduced, e.g., by applying an area-bound livestock system.

I regard it as an important focus how livestock farmers and other downstream actors perceive agency in this process (Friedrich et al., 2023, *unpublished manuscript*). If these actors do not experience agency or only low agency, there is a risk that they may actively hinder change processes and/or that this could lead to newly emerging social conflict lines being drawn up by these actors' perceiving of the process as unfair. It is thus key that these actors experience agency in this process, agency to change something, and to actively participate in the process of transitioning. For this purpose, I regard two factors as crucial. First, it would be valuable to design research approaches by which individual social actors, such as livestock farmers, can be encouraged to view problems as complex and to imagine ways of reconfiguring existing regimes toward more sustainable outcomes. At the moment these actors seem to be entrenched in imagining solutions for problems that are framed in a reductionist way and which downplay the complex and "wicked" nature of these problems. Transdisciplinary or co-design approaches, as well as real-world laboratory research (e.g., Bergmann et al., 2021; Busse et al., 2023; Geus et al., 2023; Hirsch Hadorn and Jäger, 2008; Pohl and Hirsch Hadorn, 2008; Zscheischler and Rogga, 2015) is a potential alternative way to support livestock actors in imagining solutions for complex and wicked problems without resulting in ontological insecurity because of the complexity of problems. Through the integration of perspectives, culture, knowledge, and experiences of different actors, these approaches integrate knowledge and stimulate cultural exchange and social learning. Such processes could enhance these actors' capacity to imagine and to be able to employ agency in the process of change. In this way, these approaches may prove helpful in supporting actors in their individual transitioning toward (potentially) new business models. Secondly, it is vital to examine those governance models that steer and monitor transition processes and that help farmers to navigate transition, and which organizational actors could support the latter in their decision-making and capacity to imagine. This is an important research avenue that can help regional policymakers and change agents to design and navigate transition processes that are accepted by e.g., farmers because the latter would then be more likely to experience agency during the process of change. Approaches from economic geography such as the "trinity of change agency" (Grillitsch and Sotarauta, 2020) may provide useful background for those wishing to develop place- and context-specific governance mechanisms that could facilitate sustainability transitions in specific sectors like agriculture and in particular livestock farming.

9.5 Conclusion

My dissertation aimed at understanding transition mechanisms, actors, and processes in German livestock farming. I operationalized this aim via a focus on innovations, incumbents, and imagined futures. I have unraveled how contesting imaginations of manure futures shape different trajectories of a sustainable livestock system, depicted the role of bioeconomic innovations and actors developing these in the context of transitions in livestock farming, and focused on how farmers as incumbents can drive endogenous sustainability transitions. Based on a multiple case-study approach, my research reveals that transitions, in terms of a reconfiguration of livestock farming, are indeed happening in Germany. Currently, these reconfigurations are driven by

exogenous actors such as NGOs, external shocks, and the adoption of bioeconomic innovations that alter both the semiotic and actor–technology relationships in livestock farming. Endogenous actors, such as farmers, experience low agency when it comes to changing existing structures and practices of livestock farming and hence many prefer to maintain the status quo. My research also suggests that bioeconomic innovations are shaped by imaginaries of technological fixes and are based on reductionist problem framing. Hence, their capacity to drive genuine sustainability-oriented transitions in livestock farming is limited. On the contrary, in being shaped through imaginaries of technological fixes, these innovations risk "colonizing the future" through cognitive lock-ins and semiotic path dependencies on an individual and societal level, with unknown consequences for the sustainability of socio-ecological systems and the livelihoods of future generations. My findings regarding bioeconomic innovations also point to the limited potential of the political project of a sustainable bioeconomy in driving changes in social orders and practices and to the risk of this project remaining trapped in business-as-usual conceptions.

My theoretical account of imagined futures elucidated how the study of imagined futures can enrich scholarship on sustainability transitions in describing the contestation of the future, how the capacity to imagine is relevant for navigating transitions, and how transitions more generally are driven and accompanied by conceptions of the future. My research argues that imagined futures are always a diagnosis of the present, and are often based on specific conceptions and framings of problems that construct and are in turn constructed by these.

While transitions in livestock farming are occurring, the current shape of these transitions in terms of a superficial change of actor–technology configurations carries the risk of semiotic and material-semiotic lock-ins and path dependencies. These lock-ins and path dependencies threaten to close off future possibilities by reducing actors' scope of action. I close this dissertation by advocating for a reflexive engagement with imagined futures in livestock farming through transdisciplinary research projects and by a focus on the processes through which imagined futures are enacted and (re)produced. Transdisciplinary or co-design-inspired approaches can help to challenge dominant models of sustainability-oriented change and support individual actors in developing the capacity to imagine in livestock farming. By means of these approaches, socio-environmental issues of livestock farming can be treated as wicked problems, and the uncertainties, complexities, and ambiguities of imagined futures and current developments can be included. By incorporating the views of different actors with multiple backgrounds and normative orientations, these approaches enable social learning and knowledge flows that could challenge persistent cultures in livestock farming. In addition, these approaches can support people in honing their capacity to imagine, which may shape the experience of agency in the process of change, by providing the semiotic spirit for navigating transitions.

Lastly, the processes, contexts, and structures through which imagined futures are currently enacted and (re)produced should receive increasing scientific attention and reflection. Because imagined futures are as much envisioned as they are a diagnosis of the present, the power asymmetries and hegemonies that characterize our present are informing their shape. To open up the future, to make space for, and to create the semiotic spirit for genuine, just and sustainable change, these power mechanisms and historically institutionalized structures of unsustainability and unlimited growth must be continuously challenged.

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11 Annex

In the following, the guiding questions that I have used in my empirical research are attached. Annex I and II relate to interviews that I have conducted for chapter 5 and 7, while Annex III refers to the guiding questions used in the case study in chapter 8.

Annex I: Guiding questions innovation actors

Einführung in das Interview

Erzählfluss stimulieren und langsames „Kennen lernen".

Erzählen Sie mir etwas über sich. Wie kamen Sie in dieses Unternehmen?

Was macht Ihre Arbeit aus?

Welche persönliche Identifikation haben Sie mit dem Unternehmen?

Wichtige Fragen

Diese Fragen sollten alle – wenn möglich – von der Interviewpartner:in beantwortet werden.

Leitfrage/Stimuli/Erzählaufforderung		
Erzählen Sie mal: Sie stellen ja die Innovation [Name der Innovation] her. Wie funktioniert denn die Technik, die sich hinter dieser Innovation verbirgt?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Technische Verfahren und Details des Produktionsprozesses • Subjektive Wahrnehmung von Vor- und Nachteilen	• Und dann? • Können Sie das genauer beschreiben?	• Was daran ist originell? • Was würden Sie als Innovation in dieser Hinsicht bezeichnen? • Welche Vorteile bietet diese Praktik gegenüber der bisherigen? [ggfls. Nachteile]

Leitfrage/Stimuli/Erzählaufforderung		
Erzählen Sie mal, wie kam Ihr Unternehmen auf die Idee des [Gülle-Recycling/Gülle-Nachverwertung/XX]?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Motivation • Idee für die konkrete Innovation • Erzählung der Innovationsentwicklung • Wichtige Ereignisse	• Können Sie das spezifizieren? • Welche anderen Einflüsse gab es?	• Welche Motivation und welcher Anreiz unterliegen dieser Entwicklung seitens Ihres Unternehmens? • Woher bezieht Ihr Unternehmen das Wissen über zukunftsfähige Ideen? • *Wie identifizieren Sie generell betriebliche Fokusse Ihrer Arbeit?*

Leitfrage/Stimuli/Erzählaufforderung		
Wenn Sie mal generell über Gülle nachdenken… Was ist Gülle für Sie? Bzw. das Unternehmen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Rohstoff vs. Abfall • Ideologie vs. Geschäftspraktiken	• Fällt Ihnen sonst noch was ein?	• Was sehen Sie in Gülle?

Leitfrage/Stimuli/Erzählaufforderung		
Erzählen Sie mal: Ist Ihnen die Begrifflichkeit der „Bioökonomie“ schon einmal unter gekommen? [Ja] In welchem Kontext?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Definition(en) falls möglich • Kontextualisierung des Begriffs „Bioökonomie“	• Welche Bereiche beinhaltet das? • Fällt Ihnen sonst noch was ein?	• Wie denken Sie über bioökonomische Maßnahmen? • Welche Veränderungen sehen Sie darin? • *Welche Zusammenhänge gibt es zwischen der Arbeit Ihres Unternehmens und der Begrifflichkeit?* • *Gibt es einen Zusammenhang zwischen Ihrer Innovation und der Strategie der Bundesregierung zur Förderung von bioökonomischen Innovationen?*

Leitfrage/Stimuli/Erzählaufforderung		
Gegenwärtig gibt es einen starken öffentlichen Diskurs in Bezug auf Nachhaltigkeit und die Produktion von Lebensmitteln. Welche Herausforderungen sehen Sie in Bezug darauf?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Problemframes • Lösungsansätze • Integration der Innovation	• Können Sie das Problem spezifizieren? • Und sonst?	• Welche Probleme liegen den Herausforderungen zugrunde? • Welche Lösungsansätze sehen Sie in dieser Beziehung? • Wie interagiert Ihre Innovation mit den Herausforderungen?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir nun von den Problemen und Herausforderungen übergehen zu vermeintlichen Wünschen: Wenn Sie sich die Zukunft vorstellen: Welche Wünsche haben Sie diesbezüglich? [generell]		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Erst generell, dann spezifischer Fokus auf Lebensmittelernährungssystem • Persönliche Ansicht der interviewten Person • Gesellschaft der Zukunft • Lebensmittelernährungssystem der Zukunft	• Und in Bezug auf das Zusammenleben? • Wie äußert sich das für Sie konkret?	• Welche Art von Gesellschaft wünschen Sie sich bzw. sollen wir werden? • Welches Lebensmittelernährungssystem wünschen Sie sich? • Kennen Sie Beispiele, welche die von Ihnen angesprochenen Praktiken gegenwärtig schon umsetzen? • *Welche Art von Menschen werden wir, wenn wir die von Ihnen entwickelte Technologie verwenden?*

Leitfrage/Stimuli/Erzählaufforderung		
Gibt es konkrete Beispiele [etwa Berichte, Zeitungsartikel, Diskussionen, etc.], worauf diese Vorstellungen aufbauen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Epistemische Basis/Einflüsse	• Was noch?	• Woran orientieren Sie sich? • Welche Berichte, Dokumente, Erzählungen, Diskurse bilden die Basis?

Leitfrage/Stimuli/Erzählaufforderung		
Und wenn wir jetzt mal an die Kommunikation denken? Wo und wie kommunizieren Sie diese Ideen und Ihre Innovation?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Aspekte der Produktkommunikation • Aspekte der Kommunikation von Zukunftsvorstellungen (epistemischer Output)	• Wo noch? • Gibt es außerdem noch Kanäle?	• Wie kommunizieren Sie diese innerhalb des Unternehmens? • Wie kommunizieren Sie diese nach außen? • Welche Zielgruppe adressiert Ihre Kommunikation?

Leitfrage/Stimuli/Erzählaufforderung		
Wie sind Sei denn in Ihrem Unternehmen organisiert? Welche Organisationsstruktur haben Sie?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Form der kollektiven Struktur des Unternehmens • Unternehmenskultur	• Wie äußert sich dies? • Können Sie das an einem Beispiel erläutern?	• Wie hat sich die Organisationsstruktur in den letzten Jahren entwickelt? • Gibt es eine konkrete Unternehmenskultur, die sich darin wiederspiegelt?

Optionale Fragen

Werden nur gestellt, wenn der Akteur noch Zeit und Lust hat, sich weiter mit der Thematik auseinander zu setzen.

Leitfrage/Stimuli/Erzählaufforderung		
In Bezug auf gegenwärtige Nachhaltigkeitsdiskussionen im Lebensmittelernährungssystem stellen wir Wissenschaftler_innen fest, dass es eine Vielzahl von Akteuren mit unterschiedlichen Ansichten, Werten und Normen gibt. Welche Erfahrungen haben Sie in dieser Hinsicht gemacht? Finden Sie hierbei etwas besonders erwähnenswert?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Unterschiedliche Werte und Normen	• Wie äußert sich der Unterschied konkret? • Können Sie das an einem Beispiel erläutern?	• Welche Unterschiede wurden sichtbar?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir nun noch auf eine andere Weise auf Ihre Innovation schauen: Welche (zukünftigen) Marktchancen rechnen Sie Ihrem Produkt aus? [ggfls. Innovation schon am Markt – dann auf weitere Diffusion und Adoption eingehen]		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Subjektives Marktpotenzial der Innovation • Ggfls. Situationsveränderung durch Covid-19	• Worin gründet sich Ihre Annahme?	• Haben Sie diesbezüglich Marktforschung betrieben? • Inwiefern konkurrieren Sie mit anderen Innovationen? • Wer ist die Zielgruppe dieser Innovation?

Schluss

Gibt es etwas, was Sie noch loswerden möchten? Etwas das Ihnen im Gespräch zu kurz kam?

Vielen Dank, dass Sie sich die Zeit für dieses Interview genommen haben! Wir behandeln Ihre Informationen äußerst vertraulich und anonym.

Ich bitte Sie nun noch, die vorliegende Datenschutzerklärung zu unterschreiben. Damit erklären Sie sich für die Nutzung der Aufzeichnung für wissenschaftliche Zwecke einverstanden. Sie können diese Erklärung, wie schon zu Eingang des Interviews erwähnt, jederzeit widerrufen.

Aus Interesse hätte ich noch zwei Fragen:

- Wie war das Interview für Sie?
- Warum haben Sie sich entschlossen, am Interview teilzunehmen?
- Ich bin weiterhin auf der Suche nach Akteuren, mit denen ich diese Interviews führe. Wenn Sie mir 3 Akteure vorschlagen müssten, die sich auch mit dieser Thematik beschäftigen und welche Sie als wichtig erachten – welche wären das?

Annex II: Guiding questions regime actors

Einführung in das Interview

Erzählen Sie mir etwas über sich. Wie kamen Sie in diese NGO/Behörde/etc.?

Was macht Ihre Arbeit aus?

Welche persönliche Identifikation haben Sie mit Ihrer Arbeit?

In welchem Kontext taucht Gülle in Ihrer Arbeit auf?

Wichtige Fragen

Leitfrage/Stimuli/Erzählaufforderung		
Wenn Sie mal generell über Gülle nachdenken… Was ist Gülle für Sie? Bzw. das Unternehmen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Rohstoff vs. Abfall • Ideologie vs. Geschäftspraktiken	• Fällt Ihnen sonst noch was ein? •	• Was sehen Sie in Gülle?

Leitfrage/Stimuli/Erzählaufforderung		
Erzählen Sie mal: Ist Ihnen die Begrifflichkeit der „Bioökonomie“ schon einmal unter gekommen? [Ja] In welchem Kontext?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Normative Definition • Subjektive Definition	• Welche Bereiche beinhaltet das? • Fällt Ihnen sonst noch was ein?	• Welche Zusammenhänge gibt es zwischen der Arbeit Ihrer Behörde/NGO/Unternehmen und der Begrifflichkeit? • Wie denken Sie über bioökonomische Maßnahmen? • Welche Veränderungen sehen Sie darin?

Leitfrage/Stimuli/Erzählaufforderung		
Gegenwärtig gibt es einen starken öffentlichen Diskurs in Bezug auf eine nachhaltige Transformation des Lebensmittelernährungssystems. Welche Herausforderungen sehen Sie in Bezug auf das gegenwärtige Lebensmittelernährungssystem?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Problemframes • Lösungsansätze	• Können Sie das Problem spezifizieren? • Und sonst?	• Welche Probleme liegen den Herausforderungen zugrunde? • Welche Lösungsansätze sehen Sie in dieser Beziehung? • Kennen Sie Beispiele für konkrete Lösungsansätze?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir nun von den Problemen und Herausforderungen übergehen zu vermeintlichen Wünschen: Wenn Sie sich die Zukunft vorstellen: Welche Wünsche haben Sie diesbezüglich? [generell]		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Erst generell, dann spezifischer Fokus auf Lebensmittelernährungssystem • Persönliche Ansicht der interviewten Person • Gesellschaft der Zukunft • Lebensmittelernährungssystem der Zukunft	• Und in Bezug auf das Zusammenleben? • Wie äußert sich das für Sie konkret?	• Welche Art von Gesellschaft wünschen Sie sich? • Welche Art von Gesellschaft sollen wir werden? • Welches Lebensmittelernährungssystem wünschen Sie sich? • Kennen Sie Beispiele, welche die von Ihnen angesprochenen Praktiken gegenwärtig schon umsetzen?

Leitfrage/Stimuli/Erzählaufforderung		
Gibt es konkrete Beispiele [etwa Berichte, Zeitungsartikel, Diskussionen, etc.], worauf diese Vorstellungen aufbauen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Epistemische Basis/Einflüsse	• Was noch?	• Woran orientieren Sie sich? • Welche Berichte, Dokumente, Erzählungen, Diskurse bilden die Basis?

Leitfrage/Stimuli/Erzählaufforderung		
Welche konkreten Maßnahmen [Kampagnen, Gesetze, etc.] treffen Sie, um Ihre Visionen umzusetzen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Konkretes Engagement des Akteurs für die Umsetzung der Visionen	• Können Sie ein Beispiel nennen? •	•

Leitfrage/Stimuli/Erzählaufforderung		
Und wenn wir jetzt mal an die Kommunikation denken? Wo und wie kommunizieren Sie diese Ideen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Aspekte der Kommunikation von Zukunftsvorstellungen (epistemischer Output)	• Wo noch? • Gibt es außerdem noch Kanäle?	• Wie kommunizieren Sie diese innerhalb Ihrer Behörde/NGO/Unternehmen? • Wie kommunizieren Sie diese nach außen? • Welche Zielgruppe adressiert Ihre Kommunikation?

Leitfrage/Stimuli/Erzählaufforderung		
Wie sind Sei denn in Ihrer [Behörde, NGO, Unternehmen] organisiert? Welche Organisationsstruktur haben Sie?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Form der kollektiven Struktur des Unternehmens • Unternehmenskultur	• Wie äußert sich dies? • Können Sie das an einem Beispiel erläutern?	• Wie hat sich die Organisationsstruktur in den letzten Jahren entwickelt? • Gibt es eine konkrete Unternehmenskultur, die sich darin wiederspiegelt?

Optionale Fragen

Leitfrage/Stimuli/Erzählaufforderung		
Ich habe mich in den letzten Wochen auch mit einigen anderen Akteuren getroffen. Diese haben mir von den folgenden Innovationen erzählt. Was halten Sie von der Innovation XYZ? Können wir dadurch die von Ihnen beschriebenen Probleme lösen? Kommt diese Innovation Ihrer Vision des Lebensmittelernährungssystems nahe?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Subjektive Einschätzung zu 3 Innovationen • Adoption und Diffusion der Innovation	• Welche Vorteile würde das bieten? • Welche Nachteile würde das bieten?	• Denken Sie, dass diese Innovation das Potenzial hat, die bestehenden Probleme zu lösen? • Gibt es noch Innovationen, die ich nicht genannt habe, die Sie aber besonders erwähnenswert finden?

Leitfrage/Stimuli/Erzählaufforderung		
In Bezug auf gegenwärtige Nachhaltigkeitsdiskussionen im Lebensmittelernährungssystem stellen wir Wissenschaftler_innen fest, dass es eine Vielzahl von Akteuren mit unterschiedlichen Ansichten, Werten und Normen gibt. Welche Erfahrungen haben Sie in dieser Hinsicht gemacht? Finden Sie hierbei etwas besonders erwähnenswert?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Unterschiedliche Werte und Normen	• Wie äußert sich der Konflikt konkret? • Können Sie das an einem Beispiel erläutern?	• Welche Unterschiede wurden sichtbar? •

Schluss

Gibt es etwas, was Sie noch loswerden möchten? Etwas das Ihnen im Gespräch zu kurz kam?

Vielen Dank, dass Sie sich die Zeit für dieses Interview genommen haben! Wir behandeln Ihre Informationen äußerst vertraulich und anonym.

Ich bitte Sie nun noch, die vorliegende Datenschutzerklärung zu unterschreiben. Damit erklären Sie sich für die Nutzung der Aufzeichnung für wissenschaftliche Zwecke einverstanden. Sie können diese Erklärung, wie schon zu Eingang des Interviews erwähnt, jederzeit widerrufen.

Aus Interesse hätte ich noch zwei Fragen:

- Wie war das Interview für Sie?
- Warum haben Sie sich entschlossen, am Interview teilzunehmen?

- Ich bin weiterhin auf der Suche nach Akteuren, mit denen ich diese Interviews führe. Wenn Sie mir 3 Akteure vorschlagen müssten, die sich auch mit dieser Thematik beschäftigen und welche Sie als wichtig erachten – welche wären das?

Annex III: Guiding questions incumbents

Einleitung

(je nach IP frei gestalten, Beispielfragen im folgenden):

Wie geht es Ihnen heute?

Wo kommen Sie gerade her?

….

Dann Überleitung zu landwirtschaftlichen Fragen mit spezifischem Fokus auf den Hof. Dadurch auch noch „entspanntes" Kennenlernen möglich.

Thematisch-spezifischer Teil des Interviews

Leitfrage/Stimuli/Erzählaufforderung		
Können Sie mir ein bisschen was über Ihren Betrieb / Hof erzählen? Was bauen Sie an? Was wird hier produziert? **Alternative**: *In welchem Bezug stehen Sie beruflich zur Landwirtschaft und Viehhaltung?*		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Charakteristika des Hofs • Größe, Anbaumethoden / Produktionsausrichtung des Betriebs (Ackerbau, Viehhaltung, gemischt, etc.), Beschäftigte •	• Gibt es noch mehr? • War das schon immer so?	• Was wird hier produziert? • Wie viele Tiere haben Sie? • Haben Sie Unterstützung?/ Wer hilft hier auf dem Hof?

Leitfrage/Stimuli/Erzählaufforderung		
Wie sind sie in die Landwirtschaft gekommen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Narrativer Teil des Interviews: Geschichte des IPs • Geschichte des Hofs • Motivation, in der Landwirtschaft zu arbeiten • Zukunft des Hofs (Nachfolge)	• Und dann? • War das schon immer so?	• Was war Ihre Motivation, in der Landwirtschaft zu arbeiten? • War das schon immer ein [XX]-Mast-Betrieb? • Wer hat den Hof vor Ihnen besessen? • Wie lange besitzen Sie den Hof schon? • Wissen sie schon, wer Ihren Hof übernehmen wird?

Leitfrage/Stimuli/Erzählaufforderung		
Mit welchen **aktuellen** Herausforderungen müssen Sie auf Ihrem Hof gerade umgehen? **Alternative**: Mit welchen aktuellen Herausforderungen müssen Höfe in Ihrer Region gerade umgehen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• „Hot" Topics des Hofs • **Unterschied zur Viehhaltung und Landwirtschaft** • Probleme, Ursachen •	• Was fällt Ihnen sonst noch ein? • War das schon immer so? •	• Wie gehen Sie damit um? • *Wie geht es anderen Landwirten in Ihrer Region?* • Was ist Ihrer Meinung nach die Ursache?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir jetzt mal konkret auf die Tierhaltung schauen: Welche **aktuellen** Herausforderungen sehen Sie für die Tierhaltung im Generellen momentan?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• „Hot" Topics des Tierhaltung • **Unterschied zum Hof und Landwirtschaft** • Probleme • Schweinepest? Ökonomische Zwänge? Hofaufgabe? Umstellen auf Bio? • Anmerkung: nach Gülle fragen, wenn dies nicht erwähnt wird: Warum haben Sie das nicht erwähnt?	• Was fällt Ihnen sonst noch ein? • War das schon immer so?	• Wie gehen Sie damit um? • Was ist dafür die Ursache? • Wie ist es in Bezug auf Umwelthemen? • Ggfls.: Sie haben nicht über die Gülle/Nitrat-Problematik gesprochen, gibt es dafür einen Grund?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir jetzt mal auf die Region schauen: Welche Herausforderungen sehen Sie in Bezug auf die Region Rotenburg im Allgemeinen in Bezug zur Landwirtschaft? [*und ggfls. auch darüber hinaus*]		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• **Unterschied zu Herausforderungen auf Hof-Ebene** • Ländliche Entwicklung LK Rotenburg • Probleme der Region	• Können Sie das ausführen? • Fällt ihnen sonst noch was ein?	• Gibt es so etwas wie Konflikte? • Und in Bezug auf die ländliche Entwicklung im generellen? • Woran liegt das?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn sie die Region Rotenburg beschreiben müssten: Wie würden Sie das tun? Was ist charakteristisch/einmalig an dieser Region? Auch in Bezug zur Tierhaltung?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Narrationen und (ggfls.) Identität der Region • Auch im Hinblick auf Landwirtschaft und Tierhaltung	• Können Sie das ausführen? • Fällt ihnen sonst noch was ein? •	• Was zeichnet Ihre Region aus? • Wofür ist sie bekannt? • Gibt es Geschichten die das beschreiben? • Gibt es so etwas wie eine lokale Identität? • Wie ist ihr persönlicher Bezug zur Region?

Leitfrage/Stimuli/Erzählaufforderung		
Nun haben wir viel über Herausforderungen gesprochen. Welche Lösungen sehen Sie in Bezug auf diese Herausforderungen? *[Themen: Region, Tierhaltung, Hof]*		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Lösungen der oben genannten Herausforderungen (Hof, Tierhaltung, Region) • Beispiele, Pioniere, Sicht auf diese Beispiele • Nachhaltige Tierhaltung • evtl. nach bioökonomischen Innovationen fragen: Warum wurden Sie nicht erwähnt	• Fällt Ihnen sonst noch was ein?	• Kennen Sie ein konkretes Beispiel, wo das schon umgesetzt wird? • Gibt es in Ihrer Region so etwas wie Pioniere, die das schon umsetzen? • Wie ist Ihre Sicht auf diese Akteure? • Was sind Ihrer Ansicht nach die größten Hemmnisse, weshalb dies noch nicht (im größeren Maßstab) umgesetzt wird? • *Wie stellen Sie sich eine nachhaltige Tierhaltung vor?* • Was ist mit Innovationen?

Leitfrage/Stimuli/Erzählaufforderung		
Was sind Ihrer Meinung nach die Maßnahmen, die ergriffen werden müssten, um die von Ihnen angesprochenen Lösungen umzusetzen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Maßnahmen für die Lösungen der Probleme • Ggfls. politisch, ökonomisch, sozial, kulturell	• Können Sie das ausführen? • Fällt ihnen sonst noch was ein?	• Welche Rolle spielt dabei die Region und ihre lokalen Gegebenheiten? • Welche Neuerungen müsste es dafür geben? • Was sind wichtige Schritte, die man gehen müsste?

Leitfrage/Stimuli/Erzählaufforderung		
Was sind Ihrer Meinung nach die Akteure, die für die Herausforderungen und Lösungen eine zentrale Rolle spielen? [*Aufgliederung: Betroffene, Verursacher, Regulatoren*]		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Zentrale Akteure für die Herausforderungen • Akteure als Personen oder Institutionen • Sicht von IP • Ggfls. Konflikte? • Bauernverband?	• Was fällt Ihnen sonst noch ein? • War das schon immer so? •	• Wer ist betroffen? • Wer ist Verursacher? • Wer reguliert das? • Können Sie das an einem Beispiel ausführen? • Wie ist ihre Beziehung zu diesen Akteuren? • Gab es in dieser Hinsicht schon Konflikte, die sie nennenswert finden?

Leitfrage/Stimuli/Erzählaufforderung		
Wenn wir jetzt mal von konkreten Lösungen übergehen zu abstrakteren Fragen in Bezug auf **zukünftige** Herausforderungen und potenziellen Lösungen: Welche Zukünfte sind Ihrer Meinung nach für die Tierhaltung denkbar? [*Können Sie sich eine andere Zukunft für Ihre Region und die Tierhaltung vorstellen?*] Was würden Sie sich wünschen?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Womit „rechnet" IP vs. was wünscht sich IP • Zukunft der Tierhaltung • Zukünftige Herausforderungen, Lösungen, und Wünsche	• Und weiter? • Können Sie das ausführen?	• Wovon gehen Sie in dieser Hinsicht aus? • Was würden Sie sich wünschen? • Und in Bezug auf Umwelthemen? • Und in Bezug auf den Konsum von tierischen Produkten seitens der Bevölkerung?

Leitfrage/Stimuli/Erzählaufforderung		
[Provokativ]: Es wird im Zusammenhang mit aktuellen und zukünftigen Herausforderungen von der Notwendigkeit einer Transformation in der Landwirtschaft/Gesellschaft/Region gesprochen. Wie sehe Sie das Thema Transformation? [*in der Tierhaltung, in der Gesellschaft, in der Region*]?		
Inhaltliche Aspekte	**Aufrechterhaltungsfragen**	**Nachfragen**
• Provokativ auf das Wort Transformation eingehen • Sicht auf das Wort und die damit verbundenen Bedeutung	• Und weiter? • Können Sie das ausführen?	• Wie sollte diese aussehen? • Was wären die wichtigsten Stellschrauben? • Wer sind wichtige Akteure in dieser Hinsicht? • Was müsste sich dafür ändern? • Braucht es eine Transformation?

Optionale Fragen

(sind nicht perfekt ausformuliert und im besten Fall schon oben beantwortet):

Konkrete Bezugnahme auf das Güllethema

Was ist Gülle für Sie? Was stellt Ihrer Meinung nach das Gülle-Problem dar?

Umwelthemen im generellen:

Was denken Sie in Bezug auf Umweltthemen, wie den Klimawandel oder die Rückkehr des Wolfes?

Re-Regionalisierung:

Im Gespräch mit anderen Landwirt*innen ist uns aufgefallen, dass das Thema Re-Regionalisierung (Anbau und Distribution vor Ort) diskutiert wird. Inwiefern stellt dies für Sie eine mögliche Lösung der gegenwärtigen Herausforderungen dar?

Ende des Interviews

Danke:

Vielen Dank, dass Sie sich die Zeit für dieses Interview genommen haben! Wir behandeln Ihre Informationen äußerst vertraulich und anonym.

Datenschutz:

Ich bitte Sie nun noch, die vorliegende Datenschutzerklärung zu unterschreiben. Damit erklären Sie sich für die Nutzung der Aufzeichnung für wissenschaftliche Zwecke einverstanden. Sie können diese Erklärung, wie schon zu Eingang des Interviews erwähnt, jederzeit widerrufen.

Weitere Akteure:

Ich bin weiterhin auf der Suche nach Akteuren, mit denen ich diese Interviews führe. Wenn Sie mir 3 Akteure vorschlagen müssten, welche Sie als wichtig erachten – welche wären das?

Könnten Sie mir auch die Kontakte dieser Akteure vermitteln?