Unlocking Controversies in the European Circular Bioeconomy Transition

Jan R. Starke

Propositions

1. Policymakers currently undervalue the innovative potential of controversies in sustainability transitions.
   (this thesis)

2. Better listeners deal more productively with controversies.
   (this thesis)

3. Social scientists have the responsibility to complicate the early stages of technology development.

4. It should be forbidden to use public funding to develop privately exploitable patents.

5. Tackling polarization requires becoming friends with someone you fundamentally disagree with.

6. The most important contemporary challenge is to prevent humanity from colonizing other planets.

Propositions belonging to the thesis, entitled

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Thesis

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To my strong sister.

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Chapter I

Introduction

AgRefine is a Marie Skłodowska-Curie International Training Network with the primary goal of training 15 'PhD students to become the bioeconomy leaders of tomorrow with the necessary skills and knowledge to […] position Europe as the global leader in developing an agri-bioeconomy industry based on advanced biorefinery technologies' (CORDIS, 2023)*. The opening AgRefine training week took place in September 2021 in Vienna. The training week was the first live meeting with my PhD colleagues, after having collaborated online for 1.5 years. Following the strict winter lockdown, it was finally possible to meet colleagues for the first time in person. During that training week, two-dimensional video call frames became real people and training network colleagues became friends.*

Within the AgRefine network, my job as a social scientist in an otherwise highly techno-economic project was to work on the governance dimension of 'next-generation agri-biorefinery technology' (AgRefine, 2020)*. I got in touch with such technology when we visited a frontrunner biogas installation during that training week in Austria. A staff member of the biogas plant explained all the fascinating details of the installation. I learned that the state-of-the-art, highly efficient biogas plant was upgraded for biomethane purification and therefore ready for direct gas grid injection. The typical digester smell was barely noticeable and the installation was as tidy as it can get. According to the project developer's website (which I leave anonymous for discretion), the installation used renewable raw materials as well as organic residues from the food industry as feedstocks for its anaerobic digestion process. In addition to the produced biomethane, the remaining digestate could be used as a renewable fertilizer in agriculture. Professionally designed signs pointed out the sustainability mission of the installation: green power, in harmony with nature.*

The visit was around lunch time and the digester was also just about to get lunch. Looking around, I noticed that the digester had quite an exquisite appetite. In addition to collected grass and other bio-based waste, pallets of a famous brand of Austrian waffles piled up in the cargo area in front of the installation. Next to it stood pallets of jackfruit, harvested in Thailand, canned, shipped around the globe, advertised, stored, retailed, showcased, and expired – by only a couple of days… I got the impression that we as a society are not able to avoid that high-value food products are treated like waste and downcycled to biomethane. What is more, many policymakers and scientists call this the forerunner approach towards circularity and sustainability. That was the moment when I truly realized that besides technical hurdles, the underlying challenge in AgRefine's objective of developing 'an agri-bioeconomy industry based on advanced biorefinery technologies' is a societal and political one. I became interested in the controversial aspects of biorefining.

Fast-forward one year. An interview partner was driving me through Northern Tipperary in rural Ireland. The velvet-green landscape was only occasionally dotted by scattered houses and farms. Finally, we reached the goal of our journey: a vast, empty area with some

seemingly tumble-down office buildings and a fence around it. This was the site of the former Lisheen zinc and lead mine, where nowadays the Irish Bioeconomy Foundation is based. As a close collaboration of businesses, the county administration, as well as various universities and research institutes, the foundation is set up as a so-called Triple Helix cluster, which brings together actors from industry, government, and academia. The cluster aims to rehabilitate the former mining site into a green energy and bioeconomy campus.

During the ride, I explained to my interview partner that I was doing research on controversies. 'We don't have any controversies here', I remember him saying. Other projects next door indeed sparked lawsuits and protests, he explained, but he was not aware of any conflict around the planned National Bioeconomy Campus in Lisheen.

This triggered my curiosity: While seemingly uncontested in Lisheen, I knew that at least the energetic use of bio-resources was highly contested elsewhere. For instance, activists protested against biomass co-firing in the former Drax coal plant in England (BBC, 2021) *and in the Dutch town of Diemen* (Het Parool, 2022)*. In the Netherlands, local protests surfaced against smelly animal slurry digesters in rural areas, such as North-Brabant and Friesland* (Eindhovens Dagblad, 2022; Omrop Fryslân, 2017). *Biogas production and resulting monocultures of energy crops like maize and rapeseed were controversial in Germany not so long ago* (Pestalozzi et al., 2019). *'Food versus fuel?' is a long-standing question in distributing bio-based resources to either the food system or the bioenergy sector* (Muscat et al., 2020; Tomei & Helliwell, 2016). *I asked myself if this apparent lack of controversy in Lisheen was purely due to project characteristics, such as the remote location of the mining site or the early planning stage of the project. I could not imagine, though, that in Lisheen, project developers have found a project setup that is unanimously embraced as desirable by all affected stakeholders. Was it rather the case that more fundamental, controversial aspects in comparable contexts, which apparently have not (yet) been surfaced at this location, are simply not heard or set aside as irrelevant by project developers?*

Back in office, I scrutinized if this attempt of 'letting sleeping dogs lie' is really a promising way of dealing with this form of societal input. While reading the literature on large-scale socio-technical change processes, such as developing 'an agri-bioeconomy industry', I realized that controversies evolve at different 'speeds' and continuously resurface during such a long-term sustainability transition. How do project developers then manage to shield their projects on the ground from highly contentious discussions in other settings? Why do controversies remain ignored or at least unnoticed by local project developers and policymakers, but then burst out again in times of high public attention? Are controversies indeed something that should be avoided? Or could this form of conflict even 'unlock' more sustainable and circular – but currently overlooked – options? And how, then, can

controversies be dealt with more productively by the various stakeholders involved in sustainability transitions?

1.1. The governance challenge: Controversies in bioeconomy governance

Humanity currently lives on a diminishing stock of fossil resources, such as mineral oil and gas. Using these fossil resources generates greenhouse gas emissions that cause climate change (IPCC, 2023). To tackle the pressing sustainability challenge of being dependent on fossil resources, policymakers and scholars around the globe, but particularly in the European Union (EU), push for the development of a **bioeconomy** (Dietz et al., 2018; European Commission, 2018; Meyer, 2017). A bioeconomy aims to substitute fossil resources by bio-based ones, for instance crops, wood, and algae, for the production of widely used products, including fuels, plastics, chemicals, pharmaceuticals, cosmetics, fertilizers, food and feed products, as well as energy (McCormick & Kautto, 2013).

In the EU, a future bioeconomy has been envisioned by the European Commission in a Bioeconomy Strategy (European Commission, 2012). The original strategy was updated after a public consultation process (European Commission, 2018) and translated into multiple national and sub-national bioeconomy strategies (Dietz et al., 2018; Meyer, 2017). In the current strategy, EU bioeconomy policymakers underline that to 'be successful, the European bioeconomy needs to have *sustainability* and *circularity* at its heart' (European Commission, 2018, p. 4, highlighting added). This implies that a bioeconomy is not sustainable or circular by definition. Therefore, the concept of the **circular bioeconomy** integrates the bioeconomy concept with circularity principles, such as the (re-) utilization of waste and side streams in industrial processes and reducing the demand for energy and materials in production and consumption (D'Amato, Veijonaho, et al., 2020; Salvador et al., 2022). According to the European Commission, such a sustainable and circular bioeconomy 'will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity' (European Commission, 2018, p. 4).

In the EU Bioeconomy Strategy, the European Commission describes developing a bioeconomy as an economic opportunity for rural and peripherical regions. Triple Helix clusters of industry, local governments, and academia (such as the network that I encountered in Lisheen) form collaborations that aim to accelerate regional bioeconomies in these rural areas (Kircher et al., 2018; Rowan & Casey, 2021). To advance this form of bio-based production, many policymakers and scholars regard **biorefineries** as a key technology. Biorefineries are understood as integrated factories to produce multiple, valuable products from bio-based resources (Cherubini, 2010). The mentioned Austrian biogas digester falls under this definition, as well as large-scale factories to produce biofuels, biochemicals, or bioplastics.

Despite being pushed for by policymakers, bioeconomy scholars and critical observers question the sustainability and circularity of pursuing a bioeconomy. Although the bioeconomy literature is traditionally predominantly characterized by technical and economic scholarly attention (Pfau et al., 2014), a branch of social science contributions has steadily developed. This branch elaborated a more nuanced perspective on the bioeconomy as envisioned by EU policymakers. In particular, critics in academia and civil society scrutinize how transformative the envisioned bioeconomy is with regards to its sustainability and circularity ambitions (Eversberg, Koch, et al., 2023; Giuntoli et al., 2023; Kleinschmit et al., 2017; Ramcilovic-Suominen, 2022; Ramcilovic-Suominen & Pülzl, 2018; Riemann et al., 2022). In this sense, scholars put question marks on the assumed carbon neutrality of bio-based production (Giampietro, 2019; Zabaniotou, 2018) and underline possible negative environmental and social trade-offs, for instance for our food system, biodiversity, and sustainable land use (Kleinschmit et al., 2017). In addition to the bioeconomy concept itself, biorefinery installations can face more localized societal contestations (Palmeros Parada et al., 2018, 2020). Controversial issues could be, for instance, space availability and permitting, energy demand, water availability and water quality deterioration, increasing traffic volumes in the vicinity of the installation, or environmental nuisances, such as odour and noise emissions.

What is more, bioeconomy controversies already go on quite some time in the academic literature and bioeconomy policymaking, without being resolved (Mukhtarov et al., 2017; Vivien et al., 2019; Vogelpohl & Töller, 2021). Most prominently, the 'food versus fuel' debate surfaced at the beginning of the century, highlighting negative impacts of biofuel production on sustainable land use, food security, and global justice (Fast, 2009; Tomei & Helliwell, 2016). While shifting the raw material base for bio-based production from so-called first-generation food crops to second-generation non-food bio-resources, such as wood and grass, controversies around the sustainability of this endeavour have never been resolved (Eversberg, Koch, et al., 2023).

Shifting industrial production from a linear system based on fossil resources towards a more circular and bio-based one therefore constitutes a wicked problem, where today's solutions cause tomorrow's problems (Termeer & Dewulf, 2019; Termeer & Metze, 2019). Although the bioeconomy nowadays entails many different technologies and forms of biomass use, essentially the same concerns remain unresolved. In fact, underlying concerns around the sustainability of biomass production, its use in divergent products, and more fundamental questions around overconsumption as well as intra- and intergenerational justice are still highly topical today (Hamilton & Ramcilovic-Suominen, 2023; Ramcilovic-Suominen, 2022; Ramcilovic-Suominen et al., 2022). In wicked problem situations, both problem definitions and solution approaches are contested (Rittel & Webber, 1973). Since no solution can solve the problem in a conclusive way, only 'good enough' approaches

can be aimed for (Rittel & Webber, 1973, p. 163). Long-term controversies about what solution is good enough are thence an inherent element of such problems (Termeer & Kessener, 2007). However, as visualized in the preluding anecdotes and found by means of the literature review presented in Chapter 2, actors working within the bioeconomy struggle to deal with these controversies beyond unfruitful approaches of avoidance.

Having outlined the societal problem of interest for this dissertation, I continue this introduction by carving out the academic knowledge gap that this dissertation aims to address and presenting some key concepts applied throughout this dissertation (Section 1.2). To fill the identified knowledge gap, I formulate a main research question and three sub-questions (Section 1.3). Next, I shortly introduce my research approach and applied methods of data collection and analysis (Section 1.4). The introduction closes with an outline of the dissertation (Section 1.5).

1.2. Knowledge gap and key concepts

Despite emerging scholarly interest in the role of politics and conflicts, the bioeconomy literature struggles to understand intractable controversies and consequently fails to provide ways of how to deal with them. As will be elaborated in more detail in Chapter 2, the predominantly techno-economic bioeconomy literature omits explanations of why controversies resurface again and again, despite resolution approaches. Such resolution approaches include ever more complex impact assessments or approaches to model sustainable supply chains and the optimal location of production sites. These approaches aim to 'design out' contested elements of novel innovations and thereby 'engineer' societal acceptance, but remain unfruitful in addressing underlying controversies.

In addition to the general techno-economic bioeconomy literature, the evolving bioeconomy *governance* literature also struggles to provide answers on more productive ways to deal with controversies. On the one hand, this branch of literature investigates bioeconomy *policy* documents, such as national or regional strategies (e.g., Dietz et al., 2018; Haarich et al., 2022; Meyer, 2017; Rojas-Jimenez, 2021). On the other hand, a discursive section of the bioeconomy governance literature analyses what actors promote what positions in bioeconomy *politics* (e.g., Eversberg & Fritz, 2022; Giurca, 2020; Giurca & Metz, 2018; Mijailoff & Burns, 2023; Ramcilovic-Suominen, 2022; Riemann et al., 2022; Vogelpohl, 2021). The former approach omits explanations on how policies differ or change over time in reaction to novel problem definitions and solution approaches. The latter approach often remains generic about argumentative changes of identified actor coalitions over time (see Leipold, 2021 for a notable exception). Both the policy and the politics approaches in the bioeconomy governance literature therefore struggle to understand the role of particularly intractable controversies in bioeconomy policymaking. Such an understanding is required, though, to find more productive ways of dealing with these

controversies. It is therefore paramount to explore how bioeconomy governance actors in policymaking, research and innovation, businesses, or other parts of society can deal with controversies in the circular bioeconomy transition more productively.

To substantiate how this knowledge gap is addressed conceptually in this dissertation, I first outline the role of controversies in sustainability transitions. I then shortly explain my understanding of controversies as framing conflicts. This conceptualization will be further elaborated in Chapter 2.

1.2.1. Controversies in sustainability transitions

To understand how controversies continuously evolve throughout the change process of developing a circular bioeconomy, I elaborate a sustainability transitions perspective that better accounts for possible controversies that may surface throughout the transition process. I will further substantiate this conceptualization in Chapter 2.

According to the established sustainability transitions perspective, a transition is a structural, long-term shift of embedded social and technical systems (Geels, 2002, 2005; Rip & Kemp, 1998). To address sustainability challenges, such as the harmful use of fossil resources, transition scholars have developed the concept of a **sustainability transition**, which connects transitions thinking to societal grand challenges, for instance climate change, biodiversity loss, or developing a circular society (Geels, 2010; Loorbach et al., 2017; Smith et al., 2010). Due to the required large-scale and systematic changes in tackling societal grand challenges, these sustainability transitions are highly conflictual processes. This perspective is generally suitable for the analysis of controversial aspects of developing a bioeconomy, because technological innovations, such as novel biorefinery technologies, are regarded as central in societal change processes, which is in line with the content-related demarcation of my research project.

However, scholars have pointed out that until recently, the transitions literature has widely failed to foreground the political dimension of these change processes (Avelino, 2017; Cuppen et al., 2019). Accordingly, sustainability transition scholars have called for a better focus on the role of conflicts in sustainability transitions (Meadowcroft, 2009; Proka et al., 2018). Since then, politics and power have formed emerging topics in the sustainability transitions literature (Avelino, 2021; Hölscher et al., 2019; Köhler et al., 2019). However, the role of value-based conflicts – such as controversies – in sustainability transitions has received only marginal explicit attention (see Cuppen et al., 2019 for an exception).

To contextualize controversies in sustainability transitions, I locate entry points in the widely applied Multi-Level Perspective (Geels, 2002, 2005, 2020), where controversies affect the transition process. These adaptations will be further elaborated in Chapter

2. According to the Multi-Level Perspective, transitions unfold by interactions between three different levels of a transition process, namely the macro-level landscape, the meso-level regime, and micro-level niches. In my perspective, these levels entail controversy **loci**, which are settings within an unfolding sustainability transition with specific actors, framings, and communication rules.

On the *macro level*, so-called landscape developments occur, including 'cultural changes, demographic trends, [and] broad political changes' (Geels, 2002, p. 1262). Controversies on the macro-level locus particularly regard the landscape development of 'broad political changes', such as shifts in the strategic vision of supra-national bioeconomy politics. A further relevant landscape development for this dissertation is the depletion of fossil resources as well as related climate impacts and the resulting demand for renewable alternatives. Controversies surface around what this ongoing depletion implies, thus if and how political action is required.

On the *meso level*, socio-technical regimes operate (Geels, 2005). These regimes are dynamically stable configurations of infrastructure, technology, markets, sectoral policy, knowledge, industrial networks, and connected meanings (Geels, 2002, p. 1263). In this dissertation, I focus on controversies around the de- and reconfiguration of regimes. Currently, the dominant linear, fossil-based system of producing energy and materials shifts towards a new, circular, and bio-based regime. Controversies in this locus could concern for instance the distribution of roles between incumbent and novel actors in new regime constellations.

On the *micro level*, both technological and social innovations, which have the potential to disrupt current regime practices, are developed in niches, protected from regime logics (Avelino & Wittmayer, 2016; Geels, 2002). Examples are an ecovillage community, experimenting with novel, bio-based and circular systems to become autarkic, or a bio-refinery pilot installation to produce an innovative bioplastic to substitute fossil-based plastics. Controversies in this locus could for example thematize what innovations tackle the landscape pressure adequately and therefore deserve a place in the novel regime configuration.

As will be further elaborated throughout the dissertation, interrelations and cross-dependencies between these different loci underlie the analytical separation of macro, meso, and micro levels. In Chapter 6, I will further reflect upon the values and shortcomings of this analytical lens.

1.2.2. Understanding controversies as framing conflicts

To properly understand what controversies are and why this form of conflict is particularly intractable in sustainability transitions, I build on the broader public administration literature on policy controversies. Based on this literature, I explain the more positive perspective on controversies applied in this dissertation. In particular, this perspective entails that controversies can have the productive potential of surfacing marginalized concerns and consequently disrupting biases that result from dominant ways of thinking and doing.

Controversies are a particularly intractable and therefore long-term form of conflict. According to a traditional definition, **conflicts** occur whenever actors have the idea that their activities are incompatible with each other (Deutsch, 1973). As stressed in this definition, activities do not actually have to be incompatible, but ideas of their incompatibility suffice to ignite conflict. For instance, two (or more) actors might think that they need the same scarce resources to perform their activities (Pruitt et al., 2004). For societal conflicts in political settings, the Policy Conflict Framework is a widely adopted heuristic. This framework specifically focuses on conflicts about policies and provides a longitudinal perspective by specifying that an episode of conflict about policies shapes and is shaped by the policy setting, which, in turn, is affected by the outputs and outcomes of the conflict episode (Weible & Heikkila, 2017).

However, an alternative perspective on conflicts stresses that cognitive divergences in problem definitions underlie conflicts over interests (Schön & Rein, 1994). According to this adopted perspective on controversies, actors not only have conflicting interests, but differ in their perception of what situation is problematic and in what way. While actor A might describe a situation as problematic, actor B sees no problem at all. Divergent problem definitions usually imply different solutions as suitable to solve defined problems. As a result, **policy controversies**[1] emerge, which are understood as situations in which actors 'see issues, policies, and policy situations in different and conflicting ways that embody different systems of belief and related prescriptions for action' (Schön & Rein, 1994, p. xviii). In contrast to mere disagreements about what solution is most suitable to tackle a given problem, controversies cannot be resolved by producing more facts (Schön & Rein, 1994). What is more, new fact knowledge can even add new 'fuel to the fire' of a controversy (Metze, 2018b). Well-meant intentions to resolve controversies by producing more fact knowledge can therefore 'backfire' and contribute to conflict escalation (Wolf & Van Dooren, 2021). Hence, controversies are **intractable** to technocratic resolution approaches that aim to find an objective solution to solve the conflict (Schön & Rein, 1994). This perspective is more suitable for the goals of this dissertation, because established approaches in bioeconomy thinking of generating new fact knowledge to address conflicts

1 For the sake of readability, I will refer to policy controversies simply as controversies in the remainder. Whenever I refer to a controversy, I therefore mean an intractable framing conflict that deals with policies.

might be suitable to resolve disagreements about facts. However, in the bioeconomy governance literature, knowledge lacks precisely in dealing with more fundamental, value-based issues, which the adopted perspective on controversies foregrounds.

In this dissertation, I understand controversies as framing conflicts, to underline the agency of actors in (re-)shaping controversies throughout a transition process. According to this understanding, actors sponsor conflicting frames in controversies to highlight different facts. For instance, while one actor might describe the bioeconomy as an opportunity to substitute fossil resources by bio-based ones (which is true and can be substantiated by fact knowledge), another actor might highlight that a bioeconomy adds to a further commercialization of nature (which is also true and can be substantiated by different fact knowledge). As actors continuously (re-)construct these frames, using the verb **framing** instead of the noun frame is more accurate (Van Hulst & Yanow, 2016).

In controversies, actors frame by using storylines as cognitive short hands to communicate complex sets of assumptions, knowledge and information, underlying beliefs, and values (Hajer & Versteeg, 2005). Instead of predominantly strategically applied rhetoric devices (cf. Entman, 1993), I understand framing as primarily articulating a cognitive understanding. As such, to frame means to foreground a **discourse**, which is a 'specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities' (Hajer, 1995, p. 44).

Actors, including political decisionmakers, form groups around shared storylines about a situation at stake. I refer to groups of actors that frame an issue by means of coherent storylines that are congruent with a shared discourse as **discourse coalitions**. This is broadly in line with the seminal definition that a discourse coalition is 'a group of actors that, *in the context of an identifiable set of practices*, shares the usage of a particular set of story lines over a particular period of time', with practices understood as 'embedded routines and mutually understood rules and norms that provide coherence to social life' (Hajer, 2006, p. 70, original highlighting). However, in my understanding, I put conflicting articulated framings, rather than other practices, central in the identification of opposing discourse coalitions. This conceptualization will be further elaborated in Chapter 3. In a nutshell, I conceptualize **controversies in sustainability transitions** as *evolving framing conflicts between groups of actors that continuously reshape divergent discourses (discourse coalitions)*.

Analysing discourses and discourse coalitions is relevant for policymaking, because dominant ideas become institutionalized in policymaking (Fischer, 2003; Hajer, 1995). Simply put, policymakers are more likely to embrace ideas that they feel are more broadly

shared within society. The framing of a dominant discourse coalition is therefore more likely to be translated into the problem definitions and connected solution approaches that underlie novel policies. A particularly problematic situation in these ideational struggles is the **discursive lock-in**, which is a situation, where a particular framing is so dominant that alternative perspectives are overlooked or neglected (Metze, 2018a; Simoens et al., 2022). This is problematic for policymaking, because innovative solutions are not even considered. In these situations, debates become closed down to solutions that remain near to status quo practices (Stirling, 2008). As I aim to show in Chapters 4 and 5, controversies can be productive in surfacing divergent and marginalized framings, which helps 'unlocking' such discursive lock-ins.

This indicates that conflicts can have not only negative, but also positive effects on societal change processes, such as sustainability transitions. According to the conflict resolution literature, unconstructive conflicts escalate from the level of content to the level of processes and ultimately deteriorate interpersonal relations (Kriesberg & Dayton, 2017). Constructive conflicts, by contrast, can stimulate learning by surfacing alternative problem definitions and innovative solutions (Cuppen, 2012; Ligtvoet et al., 2016). In this dissertation, I apply the labels of **productive** and **unproductive** (Dorren & Wolf, 2023) to connect positive or negative impacts of controversies not only to group and conflict dynamics, but to the transition process. In accordance with the outlined framing perspective, I understand productive controversies as bringing the transition process forward by stimulating reflection and learning, whereas unproductive controversies paralyze transitions in stalemates of enduring conflict or exclusion of important stakeholders, which leaves underlying controversies smouldering.

1.3. Research questions

How controversies continuously evolve throughout the circular bioeconomy transition and how to deal with these evolving controversies productively remains both under-conceptualized and empirically under-explored in the bioeconomy (governance) literature. To address this knowledge gap, the main research question of this dissertation is: *How can evolving controversies be dealt with productively in the European transition towards a sustainable and circular bioeconomy?* With this question, I address a two-fold research objective. On the one hand, this dissertation aims to increase the academic understanding of how controversies evolve throughout the different loci of a sustainability transition. On the other hand, this dissertation aims to explore how actors can deal with these controversies productively in bioeconomy governance. These actors are stakeholders working on the circular bioeconomy transition in various roles, for instance in policymaking on different scales, businesses, or research, innovation, and development. In this dissertation, stakeholders are understood as actors with a stake in further developing some form of circular bioeconomy.

To address the overall research question, I structure my research around three sub-questions (SQ). The first SQ aims to develop a more suitable conceptual understanding of the role of controversies in the EU bioeconomy transition. The second SQ foregrounds the agency of actors in the continuous resurfacing of controversies throughout a sustainability transition by exploring evolutions of discourse coalitions. By means of the last SQ, I aim to empirically explore how stakeholders in different loci of the transition process can deal productively with these intractable controversies. Figure 1.1 sketches an overview of the relationships between the SQs and how they are addressed in the subsequent chapters of this dissertation.

SQ 1. How do controversies evolve throughout a sustainability transition?

This SQ serves to construct the conceptual framework of this dissertation. The conceptualization is based on the observation that currently, bioeconomy research is characterized by a predominant engineering perspective of regarding conflicts as a 'design fault' in bioeconomy innovation. According to this perspective, negative trade-offs stem from badly designed technological innovations. Consequently, by 'fixing' the trade-offs of innovations, conflicts can be 'designed out' and societal acceptance can be 'engineered'.

In contrast, a framing conflicts perspective from the social sciences branch of bioeconomy literature highlights the intractability of societal conflicts. As a consequence of conflicting values and interests, actors pursue conflicting transition pathways. Researchers can map these different perspectives. However, it remains underexplored how these perspectives change over time, which results in opening up new problem definitions and innovative solution approaches.

Therefore, I propose a novel understanding of controversies in the circular bioeconomy transition around three interrelated conceptual building blocks: (1) Controversies surface at various entry points throughout the transition process and therefore (re-)appear in different loci that include divergent involved actors and frames; (2) across the different loci, discourse coalitions adjust their storylines over time and therefore continuously (re)construct discourses at play, which leads to novel opportunities to open up discussions, when shifting from locus to locus; (3) unproductive evolutions of controversies can hamper transition processes, but productive ones can also bring the transition process forward. The first SQ aims to explore a conceptual answer, which is empirically substantiated throughout the dissertation by analysing controversies in micro, meso, and macro loci of the transition process.

SQ 2. How do discourse coalitions evolve throughout a sustainability transition?

To understand how stakeholders can deal more productively with controversies, we first require a better understanding of the agency of actors in shaping how controversies evolve. For this end, my second SQ engages with the second conceptual building block. This building block suggests that like-minded actors align in discourse coalitions across the different loci.

These groups of actors evolve over time because actors continuously reshape underlying discourses by adjustments in their use of storylines. These actor-storyline dynamics continuously revive controversies, what enhances the intractability of controversies in transition processes. With this SQ, I contribute to filling the knowledge gap in the discursive bioeconomy governance literature that whereas this literature made important steps in carving out what controversies characterize bioeconomy policymaking in Europe, it remains nebulous how these framing conflicts have come about and how they can change.

SQ 3. How can controversies be dealt with productively in sustainability transitions?

By means of this final SQ, I further develop the third conceptual building block on a more productive role of controversies in sustainability transitions. With this SQ, I aim to illuminate how controversies affect the course of sustainability transitions, how stakeholders on the different levels of a transition deal with this intractable form of conflict, and how controversies can productively feed into the transition process.

This SQ will be answered in two parts. First, I take the meso level as a point of departure and ask how controversies are dealt with in Triple Helix (regime) projects that aim to move the bioeconomy transition forward. Second, I take micro-level controversies as a point of departure, namely within my own training network, the EU-funded AgRefine project on next-generation biorefinery technology to advance the bioeconomy transition. In a collaborative process, together with my AgRefine PhD colleagues, we commonly reflect on how we have learnt from each other, from involved partner organizations, and from the broader, uninvolved public.

1.4. Methodology

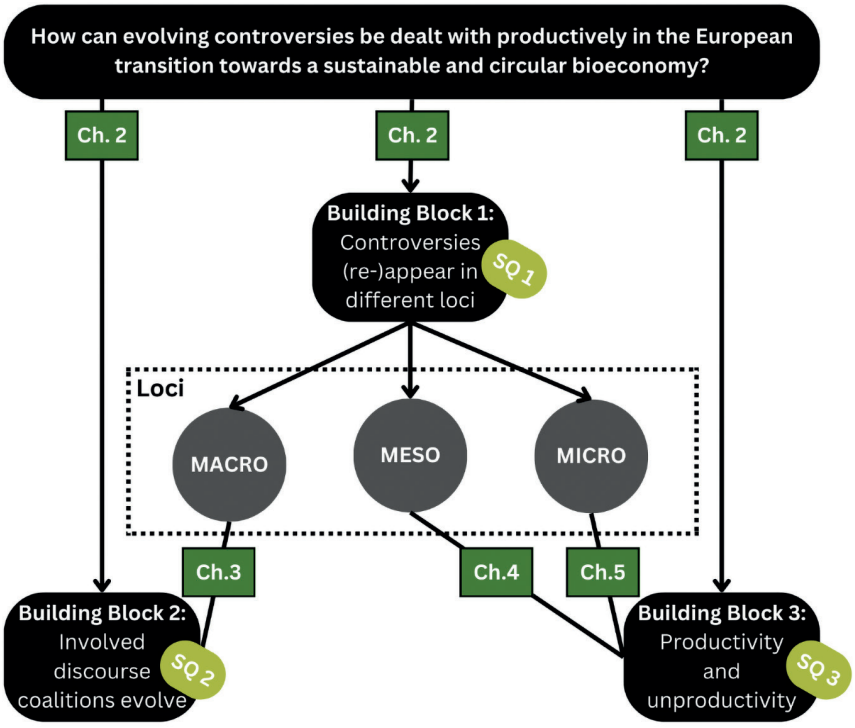

Figure 1.1 *Addressed relationships between the main research question and three sub-questions (SQ) in the subsequent chapters (Ch.).*

1.4.1. Exploratory research design

Due to the nascent character of the study of controversies in the bioeconomy transition, this dissertation takes an exploratory approach. Such an approach is suitable for research fields, where little or no systematic scientific knowledge is built up (Kumar, 2019). In my case, little is known about how controversies evolve throughout the circular bioeconomy transition. This is because the study of bioeconomy governance is a growing, multidisciplinary, and dispersed field of research (Böcher et al., 2020; Eversberg, Holz, et al., 2023; Golembiewski et al., 2015). Bioeconomy research stretches from technical contributions about novel biomass processing technologies, systematic life cycle assessments to evaluate the sustainability of new technologies and business models, economic analyses of bioeconomy potentials and supply systems, to social sciences contributions on bioeconomy governance (Böcher et al., 2020; D'Amato et al., 2019; Muizniece et al., 2020; Pfau et al., 2014). However, as outlined above, the scholarly focus has not been on the role of conflicts in the transition towards a bioeconomy so far and even less is known about

the role of controversies as a particularly intractable form of conflict. Broadly accepted theories, models, and research agendas are absent.

As part of this exploratory approach, in Chapter 2, I further develop the novel conceptualization on the role of controversies in the EU bioeconomy transition, which was briefly explained above. I then empirically substantiate this conceptualization in the subsequent chapters. Chapter 3 provides a high-level overview analysis of controversies in the macro-level locus of social media discussions on the future of the bioeconomy in Europe. Chapter 4 zooms in on the meso-level locus by exploring three situations, where novel regime constellations are developed. This casing will be further explained and justified in that chapter. Chapter 5 explores the micro-level locus, based on the case that is most accessible for me to achieve the required richness of data, namely my own AgRefine research and innovation training network.

In addition to their empirical contributions, Chapters 3 through 5 each also contribute to theory development by means of an abductive reasoning approach, building on the interplay of broader theoretical knowledge and empirical observations (Yanow & Schwartz-Shea, 2015). These conceptual contributions are specified in each individual chapter and brought together in Chapter 6.

1.4.2. Interpretive research approach

To analyse controversies in different loci throughout this dissertation, I contribute to diverse literatures and conceptual lenses. Chapter 2 applies and further develops sustainability transitions thinking to contextualize controversies in the EU bioeconomy transition process. To elaborate the conceptual building blocks, I furthermore draw on discourse theory as well as literature on conflict resolution and constructive conflicts. Chapter 3 builds on the literature on (dynamic) discourse coalitions. Chapter 4 contributes to the Triple Helix model and draws from organizational learning literature. Chapter 5 is connected to the literature on Responsible Research and Innovation. These diverse strands of literature have different and partly conflicting ontological assumptions. However, a common connector, which I apply throughout, is the framing literature. In particular, I follow a cognitive and relational understanding of framing, in contrast to a merely rhetorical one (Dewulf et al., 2009; Fischer, 2003; Hajer, 1995; Metze & Dodge, 2016; Schön & Rein, 1994; Van Hulst & Yanow, 2016). Due to the multiplicity of applied lenses, I continue by clarifying the underlying assumptions that unify the application of conceptual lenses with partly divergent ontological points of departure.

For the study of intractable controversies in sustainability transitions that aim to address wicked problems, it is central to analyse the language-in-use applied by involved actors. In these framing conflicts, actors understand the issue at hand in incongruent and therefore

conflicting ways (Schön & Rein, 1994). Actors communicate their divergent understandings of the situation of interest by means of language, both verbally and in written texts (Hajer, 1995; Hajer & Versteeg, 2005). This communicated framing foregrounds conflicting understandings of the problem at hand and implied solution approaches (Fischer, 2003). The language-in-use makes the underlying controversy analysable (Hajer, 2006). Moreover, common sets of vocabulary and storylines are shared across the different loci of a sustainability transition. By analysing the language-in-use, it becomes possible to investigate the 'like-mindedness' of different actors involved in discussions on different loci. To identify conflicting interpretations in controversies, it is therefore paramount to take language and the communicated meaning as a point of departure.

Consequently, I follow an interpretivist research approach in this dissertation. According to this approach, people interpret incoming information in a process of meaning-making (Yanow & Schwartz-Shea, 2015). This means that actors interpret the same objectively true information in different ways. This 'made' meaning can be congruent or conflicting, implying that parallel knowledge about the same 'stuff' can exist at the same time. Interpretivists strive to analyse resulting webs of meaning, continuously generated by actors who communicate by means of language in a relational manner (Simmons & Smith, 2021). These webs of meaning form our inter-subjective knowledge about the world. Analysing this web of meaning usually requires deep forms of inquiry and qualitative methods that produce thick descriptions (Yanow & Schwartz-Shea, 2015). However, this does not constitute an exclusivity of qualitative methods. As I will show in Chapter 3, also quantitative methods, such as network analysis, can be helpful in disentangling webs of meaning. These more quantitative methods help me to maintain an overview, while more qualitative approaches enable me to achieve the required depth in analysing the formed web of meaning.

1.4.3. Data collection and analysis

Following from this positioning, I apply diverse methods of data collection and analysis throughout this dissertation. Table 1.1 contains an overview of applied methods per chapter. Chapter 2 deals with the first SQ and is conceptual in nature, building on a review of the standing literature. Chapter 3, treating SQ 2, takes a relatively quantitative point of departure to data collection and analysis, because I conduct a network analysis in a large-N setting. However, I give the method a more qualitative twist, allowing for a contextualization of resulting network graphs. Chapter 4, treating SQ 3, uses a qualitative approach in a small-N setting and is based on a qualitative content analysis of interview transcripts, newspaper articles, as well as policy and planning documents. Chapter 5, also addressing SQ 3, applies an interdisciplinary action research method of reflective co-generation.

Table 1.1 *Overview of research design, methods, and publication status per chapter.*

Chapter	Research design	Material	Data analysis method	Publication status
2	Conceptualization based on reviewing existing literature on conflicts and controversies about the (circular) bioeconomy transition	Peer-reviewed and grey literature on bioeconomy conflicts	Literature review	*Published as:* Starke, J.R., Metze, T.A.P., Candel, J.J.L., Termeer, C.J.A.M: Conceptualizing controversies in the EU circular bioeconomy transition. *Ambio* 51, 2079–2090 (2022). https://doi.org/10.1007/s13280-022-01730-2
3	Qualitative discourse network analysis of the content of tweets, based on an inductively developed coding scheme, informed by expert interviews	Overview expert interviews *(N = 7)* and tweets about the future of the bioeconomy in Europe *(N = 9,983)*	Discourse network analysis	*Published as:* Starke, J.R., Metze, T.A.P., Candel, J.J.L., Dewulf, A.R.P.J., Termeer, C.J.A.M: 'Green future' versus 'Planetary boundaries'? Evolving online discourse coalitions in European bioeconomy conflicts. *Journal of Cleaner Production* 425, 139058 (2023). https://doi.org/10.1016/j.jclepro.2023.139058
4	Development of a novel conceptualization of hearing, listening, and learning capabilities, empirically anchored by a framing analysis of three different cases of Triple Helix clusters working on bioeconomy transitions	In-depth interviews *(N = 23)*; policy and planning documents *(N = 24)*; newspaper articles *(N = 938)*	Qualitative content analysis	*Accepted for publication* as: Starke, J.R., Metze, T.A.P., Candel, J.J.L., Termeer, C.J.A.M: Hearing, listening, and learning: How bioeconomy Triple Helix clusters deal with uninvited societal input. *Sustainability Science* (2024).
5	Collaborative reflection process with AgRefine peers on key learning outcomes and processes throughout the project	Questionnaire *(14 responses)*; in-depth interviews *(N = 10)*; group reflection workshop *(8 participants)*	Learning history	*Single-authored chapter of this dissertation*

1.5. Outline of the dissertation

Chapter 2 presents a novel conceptualization of the role of controversies in the European bioeconomy transition, which functions as the conceptual framework of this dissertation. The framework introduces three conceptual building blocks. The three subsequent chapters take the different loci introduced as first building block as a point of departure. Chapter 3 further develops the second conceptual building block, discourse coalition dynamics. The third conceptual building block, controversy (un)productivity, is applied and further refined in Chapters 4 and 5.

Chapter 3 builds on the second conceptual building block from the conceptual framework and takes the macro-level locus as a point of departure. In this chapter, I map landscape evolutions of controversies in an online setting on the future of the European bioeconomy. By identifying changes of discourse coalitions and dynamics in the use of storylines that tie these coalitions together, I identify how discourses change over time and open up entry points for reviewed problem definitions and innovative solutions.

To sharpen the third conceptual building block, **Chapter 4** introduces a conceptualization of organizational hearing, listening, and learning capabilities to deal with controversies more productively. This chapter takes the meso-level locus as a point of departure. Triple Helix clusters of industry, local governments, and the academic sector are regarded as regime endeavours to advance the bioeconomy transition. To engage more productively with controversies, I argue that these collaborations need to become better in hearing, listening to, and learning from uninvited societal input.

Chapter 5 also applies the third conceptual building block but takes the micro-level locus as a point of departure. In this chapter, I analyse how we (PhD researchers in the AgRefine training network on next-generation biorefinery technology) have managed (but also failed) to learn from controversies by dealing with input from the different publics that are affected by the research and innovation network. By means of a collaborative learning history, developed together with my AgRefine PhD colleagues, we reflect on how we as researchers have learned from each other, from involved societal partner organisations, and the broader, uninvolved public.

Chapter 6 synthesizes the insights from the individual chapters and provides an answer to the overarching research question. I position the findings of the individual chapters within the broader literature and also reflect on limitations. Based on this, I formulate recommendations for further research as well as for bioeconomy stakeholders to 'unlock' the innovative potential of controversies.


2

Chapter 2

Conceptualizing controversies in the European circular bioeconomy transition

Abstract

The transition towards a circular bioeconomy (CBE) in the European Union is not without contestation. In particular, research has highlighted potential trade-offs of the large-scale production of bio-resources, for instance with environmental quality goals. To date, however, it remains underexplored in the CBE literature how controversies develop throughout a transition process. To address this gap, this chapter explores where controversies are situated in a transition, how they change throughout, and how they influence the transition process. First, we suggest that controversies can be situated on and between different system layers within a transition. Second, we offer an explanation of how controversies evolve, as actors confirm, integrate, disintegrate, and polarize underlying storylines. Third, these controversies can have both productive and unproductive outcomes while they unfold throughout a transition. We illustrate this understanding with the example of biorefineries as CBE key technology and discuss a research agenda on controversies in sustainability transitions.

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2.1. Introduction

Shifting towards a circular bioeconomy (CBE) is cherished widely within the European Union (EU) and beyond as an answer to current challenges, such as the depletion of fossil resources, climate change, and the environmental impact of human production and consumption (D'Amato, Bartkowski, et al., 2020; European Commission, 2018; Meyer, 2017; Priefer et al., 2017). The road towards a CBE constitutes an ongoing shift from the current – predominantly linear – extract-use-dispose logic of production based on fossil resources, towards an envisioned circular system, based on sustainably sourced renewable resources such as plants, fungi, and algae (Bugge et al., 2016; Kirchherr et al., 2017; McCormick & Kautto, 2013). We understand this change process as a sustainability transition, i.e. a large-scale societal shift from a normatively undesired (unsustainable) state towards a desired (sustainable) one (Köhler et al., 2019; Loorbach et al., 2017; Markard et al., 2012).

Despite high expectations for the CBE, previous research has recognized that the CBE transition is not without contestation. The large-scale production of bio-resources as industrial feedstock can entail trade-offs, for example regarding biodiversity conservation, environmental quality, and resulting human welfare (Buchmann-Duck & Beazley, 2020; Gawel et al., 2019). Pursuing a CBE based on economic growth and increased production of bio-resources is criticized for not addressing problems of unsustainability, for example the question of whether some humans consume more than our planet can sustain (Vivien et al., 2019). Furthermore, conflicts have arisen about land available for uses that compete with bio-resource production, for instance food production, biodiversity conservation, or recreation (Muscat et al., 2020). As bio-resources are scarce, their distribution as feedstock for different purposes (for example, the production of materials versus the production of electricity or warmth) is conflict laden (Meyer, 2017). In addition to conflicts about the distribution of available bio-resources, conflicts also arise about where to locate production sites such as large biorefineries (Serrano-Hernandez & Faulin, 2019). Biorefineries are a key technology in the CBE transition because they convert bio-based resources into materials such as chemicals, plastics, or feed products (Cherubini, 2010). Controversies around biorefineries serve to illustrate our conceptual arguments. Examples of controversies in the CBE transition with relevance for biorefineries include food-feed-fuel (Muscat et al., 2020), green growth versus degrowth (D'Alessandro et al., 2020), globalization versus regionalization (Priefer et al., 2017, pp. 12–13), or techno-optimism versus techno-scepticism (Arancibia, 2013; McCormick & Kautto, 2013).

Policy controversies (in short: controversies) are a particularly intractable form of conflict. 'A *conflict* exists whenever *incompatible* activities occur' (Deutsch, 1973, p. 10 original highlighting). Importantly, activities do not actually need to be incompatible; ideas about their incompatibility are sufficient to incite conflict (Deutsch, 1973). Controversies are

situations in which involved actors 'see issues, policies, and policy situations in different and conflicting ways that embody different systems of belief and related prescriptions for action' (Schön & Rein, 1994, p. xviii). These 'underlying structures of belief, perception, and appreciation' (Schön & Rein, 1994, p. 23) are called frames. Consequently, we use the term *conflict* when referring to incompatibilities between actors in a broad sense, and the term *controversy* when referring to intractable framing conflicts. Controversies are particularly relevant in the EU CBE transition, as both of the concepts forming the transition's goal, *circularity* and *bioeconomy*, are contested (Bauer, 2018; Bugge et al., 2016; Kirchherr et al., 2017) and thus prone to conflicting interpretations.

As we will show in Section 2.2, it remains underexplored how controversies change throughout the CBE transition and how they influence the transition process. We differentiate two overarching perspectives on conflict in the state-of-the-art CBE literature: i) *conflict as design fault*, which approaches controversies as an optimization problem that needs to be resolved, and ii) a *framing conflicts* perspective, which acknowledges that controversies are an inherent element of the CBE transition and identifies actor groups around conflicting frames. We, however, show that the former struggles to explain why controversies reappear during a transition process despite resolution approaches, whereas in the latter, it remains unclear how these frames change dynamically throughout a transition. In this contribution, we therefore aim to advance the understanding of how controversies develop throughout the transition towards a CBE in the EU. Moreover, we propose conceptual entry points with the ambition to further explore how these developments of controversies influence the transition process.

We argue that current perspectives on controversies in the CBE transition could be advanced in three regards. First, we situate controversies within the transition process. We point out that actors move controversies through different loci on and between multiple system layers: micro, meso, and macro (Section 2.3). Second, we problematize how controversies change throughout a transition. Groups of actors involved in these controversies continuously change the storylines they tell to communicate their understanding of what is problematic and how these problems should be solved (Section 2.4). Third, we highlight the outcomes of controversy changes on the transition process. Controversies can indeed develop in unproductive ways and paralyze the transition. However, productive changes of controversies can add to a more reflexive, innovative, and democratic form of CBE transition (Section 2.5). Subsequently, we discuss the implications of our conceptual work for both researchers and practitioners and sketch a research agenda on controversies in sustainability transitions (Section 2.6).

2.2. Current perspectives on conflict in the circular bioeconomy literature

Despite acknowledging the relevance of conflict, the ways in which controversies develop as well as their outcomes on an unfolding transition process remain largely underexplored in the state-of-the-art literature on the CBE. For the discussion of the literature in this section, we searched Scopus and Google Scholar for publications (peer-reviewed and grey literature) that use the terms "*bio-based economy", "*biobased economy", "*bioeconomy", "circular economy", or "biorefin*" in their title, keywords, or abstract. We selected publications based on the number of citations, while also including recent publications, and for containing the terms "conflict*", "controvers*", or "accepta*". All references were checked for additional relevant publications. Subsequently, we synthesized the literature into two overarching perspectives on the role of conflicts and controversies in the CBE transition: a perspective on conflict as a design fault of novel technologies and supply chains and a perspective focusing on framing conflicts to (de) legitimize transition pathways and visions.

The two perspectives differ in their ontological positions. Authors adopting the perspective of conflict as design fault regard conflict as an objective problem to be solved to advance the CBE transition. Knowledge is understood as a tool to solve conflicts. In contrast, the framing conflicts perspective underlines that conflicts are socially constructed and an inherent element of transitions, which cannot be solved for good. Scholars adhering to this perspective highlight that actors frame knowledge divergently or may draw on different sources of knowledge. Knowledge can therefore also be a source of conflict (Metze, 2018b). In this chapter, we contribute to both perspectives by contextualizing controversies as an intractable type of conflict in the transition process and conceptualize how such controversies change throughout a transition.

2.2.1. Conflict as design fault

Particularly in techno-economic contributions, conflict is understood as a negative societal effect resulting from an incongruence of interests between actors, which can and should be resolved. In the CBE literature, techno-economic analyses are frequently carried out to identify the societal effects of key technologies in the CBE transition (e.g., Kokkinos et al., 2018; Serrano-Hernandez & Faulin, 2019; Vyhmeister et al., 2018; Zetterholm et al., 2020).

Novel biorefinery designs compete on scarce bio-resources for the production of materials with other purposes, such as bio-resources for animal feed or energy production (Muscat et al., 2020). These distributional conflicts are assumed to be overcome by tools such as supply chain optimization (Zandi Atashbar et al., 2018) and appropriate production site planning (Santibañez-Aguilar et al., 2014). Considering biorefinery supply chains as an optimization problem assumes that negative social and economic impacts can be

prevented by selecting cost-efficient designs and plant locations. For example, Serrano-Hernandez and Faulin (2019) establish a calculation method for the optimal location of a large-scale biorefinery in Northern Spain. They propose a location strategy based on feedstock purchase, transport, and storage to pinpoint a cost-optimal location for a new biorefinery (Serrano-Hernandez & Faulin, 2019, pp. 89–90). The authors claim that, based on this generated knowledge, 'decision makers could take advance in next negotiation processes with farmers' (Serrano-Hernandez & Faulin, 2019, p. 91). It is thus assumed that a rational positioning decision mitigates conflicts with local farmers and helps create societal acceptance of new installations.

In this perspective, conflicts stem from unintended, negative sustainability impacts of novel technologies that diminish societal acceptance. For example, Souza et al. (2018) recognize that different biorefinery set-ups for producing biofuels from sugarcane in Brazil lead to different impacts on society, for instance varying levels of job creation and different numbers of accidents. Also Yao and Tang (2013, p. 1707) conclude that 'improved acceptance and conscientious understanding among the public' need to accompany the development of new renewable chemicals and polymers. Furthermore, Moretto et al. (2020, p. 5) regard societal acceptance in addition to legislative barriers as obstacles for products from an urban waste biorefinery in Italy and suspect consumer values such as 'green self-identity' and 'awareness of recycling' as factors affecting the acceptance of bio-based products. Consequently, analysts sometimes regard conflicts as bad news, impeding societal acceptance and transition support (e.g., Arancibia, 2013; Gawel et al., 2019; Peck et al., 2009). However, controversies can also be beneficial by stimulating decision makers to learn from different perspectives and thus achieve a more reflexive form of CBE transition (Cuppen, 2018; Metze, 2018b).

Conflicts arising from the lack of technology acceptance are then implicitly assumed to be prevented by design choices based on advanced lifecycle assessments. For example, Sillero et al. (2021) compare six process design routes to valorize almond shells in terms of their overall environmental impacts. The explicit goal is to identify 'the most suitable one for large-scale valorisation' (Sillero et al., 2021, p. 749). According to this view, engineers can thus *out-design* conflicts by a smart appreciation and subsequent limitation or elimination of negative impacts.

Although such assessments are certainly useful for estimating and comparing impacts of different process designs ex ante, understanding conflicts solely as a design fault or optimization problem struggles to grasp the complexities of policy controversies, though. This is because conflict is regarded as a *static* barrier that needs to be overcome to engineer technology acceptance. However, controversies are *dynamic*, popping up again and again during a transition (Yuana et al., 2020). What is more, controversies are particu-

larly intractable to resolution approaches such as providing information about rational benefits or negotiation (Hisschemöller & Hoppe, 1995; Schön & Rein, 1994; Van Eeten, 1999). Conflicting actors use this form of fact knowledge to increase the credibility of their previously established arguments (Metze, 2017; Wolf & Van Dooren, 2021), thus use fact knowledge politically. Hence, controversies cannot be overcome by generating objective fact knowledge, for instance in the form of impact assessments.

Moreover, the cost-optimal location planning of large, new installations is not always the most accepted and thus least controversial choice, given that the local population could introduce new concerns and problem understandings that have not been considered before. The local population might perceive the costs to them (e.g., facility-related traffic, emissions, land use) as disproportionately high compared to the benefits for the broader region (e.g., employment, progress in the CBE transition) and thus engage in a not-in-my-backyard argumentation (see Hisschemöller & Hoppe, 1995). Scholars and engineers should therefore be careful in assuming that an objective calculation of cost-efficient positioning strategies for biorefinery facilities or out-designing aspects that experts regard as controversial translates directly into local acceptance. Positioning a biorefinery is not purely a cost-rational act based on objective calculations, but also political. Controversies rather need to be understood in the context of broader transition processes. However, it seems as yet unclear how controversies are contextualized in a transition, thus where and why controversies continue to arise again and again in transition processes.

2.2.2. Framing conflicts

Contributions applying a *framing conflicts* perspective not only regard conflicts as interest incongruencies, but also clarify that conflicts are rooted in different framings of both the problem and proposed solutions. Empirically, in transitions, problem definitions and connected solutions are often formulated in policy transition visions and pathways. The transition *vision* is the goal of the transition process, for example a CBE as outlined in the EU Bioeconomy Strategy. In addition to conflicts about what the CBE vision should entail, conflicts arise on the right way to get there, thus on competing ideas about *pathways* to achieve the vision (cf. Geels & Schot, 2007). Examples of pathway elements in the CBE transition include the form of technology to use, how to consider sustainability trade-offs, or in what way stakeholders should participate in vision definition and pathway selection (Priefer et al., 2017).

In this line of reasoning, visions and pathways on how to achieve a bioeconomy are framing conflicts in which particular problem perceptions and solutions are legitimized or delegitimized by different groups of actors. These loosely connected networks of actors promote conflicting storylines to organize political support. Storylines are socially constructed communicative devices to ‘condense large amounts of factual information

intermixed with the normative assumptions and value orientations that assign meaning to them' (Fischer 2003, 87).[2] Social scientists in the CBE literature have focused on identifying these conflicting storylines and the actor groups advocating them (e.g., Bauer, 2018; Giurca, 2020; Peltomaa, 2018; Sanz-Hernández et al., 2020; Simoens & Leipold, 2021).

For example, Peltomaa (2018) identifies five storylines in an analysis of Finnish newspaper articles on the bioeconomy during the periods 2010–2011 and 2015–2016: a biotechnology-centred bioeconomy, a resource-centred bioeconomy, an agroecological bioeconomy, bioeconomy as skilfulness, and a climate-change-centred bioeconomy. The storylines are reproduced by different actor groups. For instance, whereas dominant storylines seem to be advocated by industrial actors, experts, and politicians, the agroecology storyline is voiced by 'farmers, citizens, or activists' (Peltomaa, 2018, p. 10). Although Peltomaa (2018, p. 12) acknowledges in his discussion that storylines 'are not stable but change over time', the study's focus was to identify stable storylines and advocating groups of actors. The precise mechanisms and actor motivations leading to changes of these groups had to remain a black box.

This perspective acknowledges the intractability of controversies in the CBE transition by stressing that controversial aspects are defined differently by different actors. However, *changes* of controversies throughout a transition process are underexplored (see Leipold, 2021 for a notable exception on EU circularity policies). Although we acknowledge the relative stability of actor groups, we add to this perspective by explicitly conceptualizing how and why storylines and associated actor groups change over time, particularly in long-term controversies, and what this means for the overall transition process. In controversies, new actors enter the group, others leave, the underlying storyline is continuously re-defined, and new groups develop. We therefore propose to highlight the dynamics of these discursive conflicts by regarding underlying storylines as continuously evolving. In this sense, we first situate controversies in the transition process, then explain how controversies develop due to changes in underlying storylines, and finally reflect on the outcomes of changing controversies on the overall transition process.

2.3. Situating controversies in the transition process

To assess how controversies develop throughout a transition, we first situate controversies within the transition process. We argue that controversies arise in different forms on and between different system layers during a transition. The much-used multi-level perspective (MLP) on transition processes (Geels, 2002, 2005, 2019) distinguishes three system layers: micro, meso, and macro. According to this understanding, transitions advance thanks to interactions of micro-level niches, meso-level regimes, and the macro-level landscape.

2 Some authors use the concept of storylines, while others refer to narratives. For the sake of conceptual coherence, we do not differentiate between storylines and narratives and uniformly use the concept of storylines.

In our case, *macro-level* pressure (the – perceived – need for fossil-free alternatives for depleting fossil resources) in combination with alternative options from *micro-level* niches (novel biorefineries) lead to a change from a fossil-based *meso-level* regime (linear, fossil-based production) towards a new regime (CBE). In line with this understanding, we distinguish loci for CBE transition controversies on and between micro, meso, and macro levels, Figure 2.1. Controversies are contextualized in these *loci*, which are *specific locations in a transition process with particular involved (groups of) actors, frames, and communication rules*.

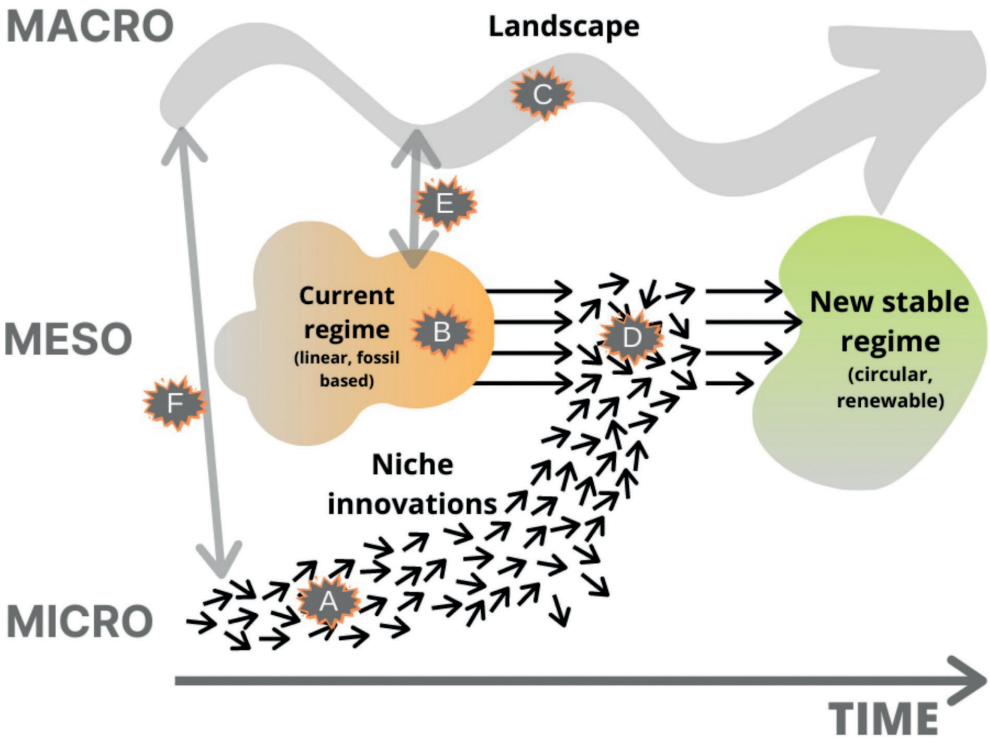

Figure 2.1 *Loci of transition controversies on and between different system layers. After Geels, 2002, 2005; Loorbach et al., 2017; Van Der Minne et al., 2021.*

The micro-level locus (A in Figure 2.1) hosts controversies in small-scale, detailed, and exclusive settings, for example expert discussions on novel biorefinery set-ups. Involved actors are 'outsiders and entrepreneurs [...] "below the surface" of incumbent regime actors' (Geels, 2011, p. 498). Examples include a group of independent scientists working on a novel biorefinery design or an off-grid, self-sustaining community thinking about new ways of utilizing organic waste. Micro-level controversies concern alternative, regime-challenging ways of thinking, doing, and organizing (Van Der Minne et al., 2021). Involved frames can be divergent from one another but commonly deviate from state-of-the-art

frames. An example of a micro-level controversy is a discussion between two expert groups working on alternative biorefinery designs: decentralized, small-scale biorefineries versus centralized, large-scale integrated biorefineries.

The meso-level locus (B in Figure 2.1) hosts controversies in the bureaucratic setting of current rules and infrastructure. One example is the permit process to locate a new biorefinery. Meso-level controversies concern the dominant way of thinking, doing, and organizing (Van Der Minne et al., 2021) and gradual adaptations of the status quo. Involved actors can be (departments of) companies in fossil sectors and their industry organizations (Geels, 2004), (units of) ministries (Verbong & Geels, 2007), municipal civil servants, or administrators of established infrastructures such as the gas grid. The set of involved actors is thus rather limited, actors are well-established, have high stakes, and are connected to the dominant set of frames. Regime controversies concern the distribution of resources and how to gradually adapt to pressures from both landscape and niches. Hence, these controversies can entail, for instance, the radicality as well as the technical or economic feasibility of such adaptations.

The macro-level locus (C in Figure 2.1) concerns landscape developments, which are 'cultural changes, demographic trends, [and] broad political changes' (Geels, 2002, p. 1262), among other long-term trends. In the CBE transition, macro-level developments include, for instance, diminishing fossil resources and the resulting demand for fossil-free alternatives. Macro-level controversies concern interpreting the need for action stemming from these landscape developments. One example is the shaping of the EU Bioeconomy Strategy. When controversies surface on the macro-level, not only are direct stakeholders involved, but also the broader public becomes engaged in these discussions. Involved sets of actors and frames are therefore wide and divergent.

The different configurations of actors and associated frames present *across* these loci are of particular interest for controversies. For example, whereas engineers might develop a new biorefinery design on the micro level, policymakers craft strategic decisions on the future of the CBE in the EU on the macro level, and the installation ultimately has to be located in a municipality, concerning the meso level. As the loci are interlinked, controversies can also be located between the different system layers. Most prominently, micro-meso controversies (D in Figure 2.1) are controversies between niche innovators and regime incumbents (e.g., Hess, 2014; Leipprand & Flachsland, 2018). Regime actors typically highlight current hindering regulations or high costs, whereas innovators argue that their innovations are a better way to handle landscape pressure. For example, a controversy could develop between an innovative micro-level expert team proposing a biorefinery using genetically engineered algae as feedstock and facing meso-level regime regulations impeding the use of this feedstock. Such controversies could result in a

delegitimization and consequently a destabilization of the current regime (Bosman et al., 2014). Macro-meso controversies (E in Figure 2.1) concern incongruencies between the need to adapt the regime because of landscape pressure and regime lock-ins impeding this adaptation. Regime actors, for example, might favour small adaptations (e.g., blending biofuels from the novel algae-based biorefinery into conventional fuels), whereas the landscape pressure might require more radical actions (e.g., banning internal combustion engines and thus requiring a different product from the biorefinery). Macro-micro controversies (F in Figure 2.1) arise from incongruencies between micro-level innovations and macro-level pressures. For instance, a macro-level EU strategy could point out the risks of using genetically engineered algae and strive to use sustainably sourced wood as a feedstock, whereas micro-level engineers might assess the risks as insignificant compared to the economic and technical benefits of using genetically engineered algae.

Controversies might be more visible in some loci than in others at different junctures. For example, the algae controversy could be salient between micro- and macro-level actors in the design phase of a biorefinery and pop up later in the form of meso- and macro-level citizen concerns about locating the new facility. As a result, controversies are intractable because actors move them through the different system layers and controversies thus reappear in different loci.

2.4. Changes of controversies due to dynamic storylines

While controversies move through the different loci within a transition process, actors adjust underlying storylines, resulting in controversy changes. Actors involved in controversies do not act in isolation, but rather form groups around similar storylines. For example, Leipold (2021) argues that current circular economy storylines in the EU are shaped by a joint coalition of business- and environment-oriented parts of the European Commission. Controversies evolve within a transition process due to interactions between actor groups and storylines. This means that involved actor groups adjust underlying storylines throughout the transition process. As a result, actor groups may grow, shrink, merge, or fall apart.

We conceptualize these actor groups as *dynamic discourse coalitions* (Metze & Dodge, 2016) around common storylines, which involved actors reproduce and shape. Discourse coalitions are 'defined as the ensemble of (1) a set of story-lines; (2) the actors who utter these story-lines; and (3) the practices in which this discursive activity is based' (Hajer, 1995, p. 65). Discourse coalitions gather around shared storylines in congruence with underlying discourses (Hajer, 1995). A discourse is 'a specific ensemble of ideas, concepts, and categorizations that is produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities' (Hajer, 1995,

p. 60). Discourse coalitions sponsor a shared interpretation of a social reality, which they continuously reinvent and thus also shape (Fischer, 2003).

Coalition building can be both strategic and unintentional. Actors are not always conscious of the frames that they apply and can unintentionally form discourse coalitions with actors applying similar frames. However, by reflection, actors can become aware of the frames channelling their thinking and learn to adjust them, i.e. to reframe (Schön & Rein, 1994). Actors in different discourse coalitions frame knowledge and experiences divergently because they make sense of new information and select, name, and categorize aspects strategically to build their storylines (Van Hulst & Yanow, 2016). Actors therefore have agency in framing, meaning that they can highlight selective aspects of reality strategically. Hence, actors use storylines to legitimize a particular vision as well as pathways with connected tools, strategies, and interventions to achieve this vision (cf. Bauer, 2018; Fischer, 2003; Hajer, 1995). For example, a challenging coalition can successfully delegitimize dominant regime storylines, contributing towards regime destabilization (Bosman et al., 2014).

Storylines and surrounding discourse coalitions develop throughout the transition process. More specifically, discourse coalitions change over time through processes of *confirmation* (strengthening of a storyline), *integration* (connection of storylines), *disintegration* (contestation of a storyline within the discourse coalition itself), and *polarization* (reconfirming the differences in competing discourse coalitions' storylines) (Metze & Dodge, 2016, p. 4). Hence, storylines are not designed once and then remain stable throughout the transition period; rather, actors continuously reproduce storylines and produce new ones. Because of changes in storylines, the surrounding discourse coalitions are also in constant flux: New actors join the coalition along the transition process, others leave it.

Figure 2.2 illustrates processes whereby dynamic discourse coalitions shift over time. First, a discourse coalition can *confirm* its underlying storylines. For instance, a coalition around policymakers, scientists, and companies, which favours large-scale, central biorefineries, produces new scientific reports that underlines their storyline that this form of biorefinery is indeed the most cost-efficient, economically feasible, and thus desirable form. As a result, the coalition can grow, for example in number, resources, or the persuasiveness of their storylines.

Second, two separate discourse coalitions can *integrate* their storylines and merge. For example, coalition A reproduces the storyline that non-food (e.g., lignocellulosic) feedstock biorefineries are more accepted than biorefineries using food crops. Coalition B promotes the storyline that supply structures with a central, large-scale biorefinery

are more feasible than supply structures with decentralized, small-scale biorefineries. Integrating these storylines, coalition AB sponsors the storyline that a central biorefinery using lignocellulosic feedstocks is the most feasible and accepted design.

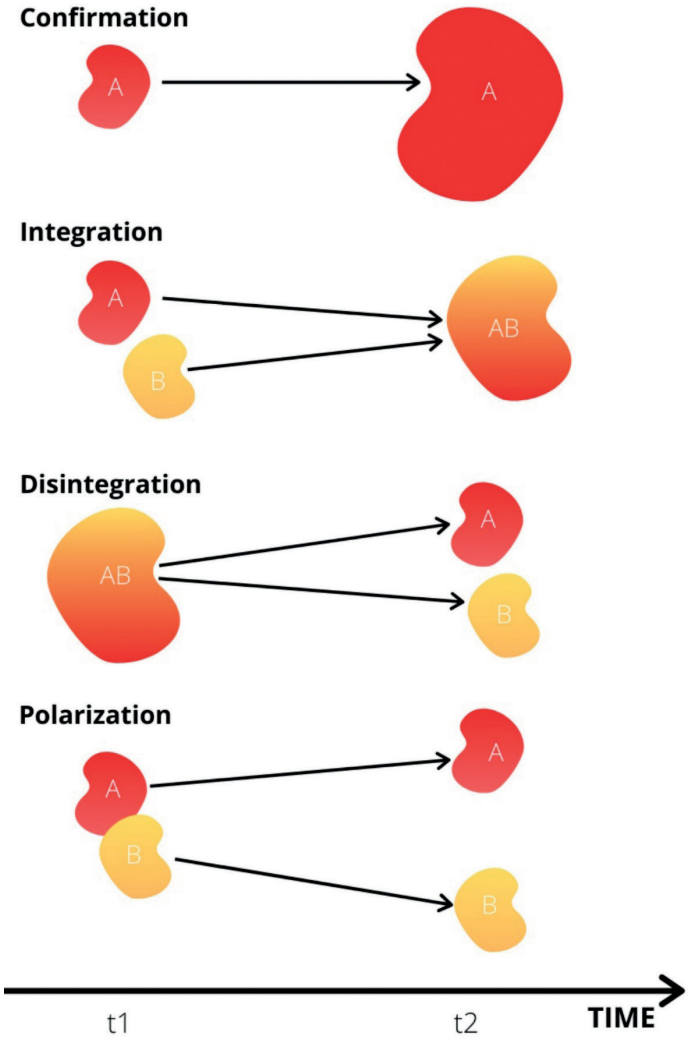

Figure 2.2 *Four possible shifts in dynamic discourse coalitions over time.*

Third, discourse coalitions can *disintegrate* over time. For example, coalition AB later splits into two coalitions, coalition A promoting marine feedstocks and coalition B promoting forest-based ones.

Fourth, actors can work to *polarize* discourse coalitions. In our example, the two initially close and even overlapping discourse coalitions A and B depart from one another. Coalition A (promoting algae) starts to make moral claims in public discussions about coalition B (promoting wood), arguing that using wood contributes to the destruction of forests and is therefore morally inferior. Polarization in controversies can even result in misinformation and undermining scientific evidence because involved actors instrumentalize new knowledge to legitimize a preferred transition pathway or to support the status quo. Competing coalitions interpret new knowledge so that it corresponds with their established frames. Each discourse coalition therefore creates its own interpretation of new evidence. Instead of providing an objective solution, new evidence can thus also lead to new controversies on how to interpret this new fact knowledge, hence generating new polarization (Metze, 2018b).

2.5. Unproductive and productive outcomes of controversies

Controversies evolve during the transition process in both unproductive and productive ways. These developments affect the inter-personal relationships of actors shaping both transition vision and pathways in dynamic discourse coalitions, while the transition process develops. Therefore, we propose criteria on how to differentiate unproductive and productive evolutions of controversies while they unfold in a transition process.

On the one hand, controversies can evolve in an unproductive way. Actors can escalate a conflict from a substantial level (disagreement on content, for example on the question of what is the biorefinery set-up with the least CO_2 emissions) to a procedural level (who defines what is counted as CO_2 emissions?) and further to the level of interpersonal relations (accusations of polishing CO_2 assessments) (cf. Wolf & Van Dooren, 2021). This form of escalation leads to an increase of distrust between conflicting actors (Wolf & Van Dooren, 2021). Increasing distrust can then lead to a deterioration of relations (cf. Deutsch, 2014), resulting in conflicting actors viewing 'themselves as moral and their opponents as immoral and unreasonable' (Kriesberg & Dayton, 2017, p. 158). This can permanently damage inter-personal relationships and is thus likely to jeopardize future intents to rebuild trust and reinstall collaboration (Wu & Laws, 2003). Another sign of a controversy becoming unproductive is when key actors manage to actively exclude actors with a different perspective from decision-making processes. Moreover, actors talking past each other without regarding the arguments of their adversaries is an unproductive form of controversy (cf. Van Eeten, 1999). Importantly, this is not a stepwise development. For instance, a deterioration of relations does not always precede the exclusion of others. Moreover, the different examples are not necessary ordered hierarchically in order of their magnitude. For example, talking past each other is not necessarily a more intense evolution than the exclusion of others.

On the other hand, controversies are not always bad news. Controversies can evolve in productive ways, meaning that they improve the CBE transition process. Controversies can stimulate learning (cf. Cuppen, 2018; Metze, 2018b) and thus obtain innovative potential. Actors engaged in transition processes generate knowledge of many kinds, for example new, alternative options to handle macro-level pressure to act and new empirical experience of the micro-level approaches that do or do not work. In addition to technological innovations, such as biorefineries, these can also be social innovations, for instance novel transformative storylines (cf. Avelino et al., 2019; Wittmayer et al., 2019). Actors can also learn by reflecting on their frames and adjust them, if necessary (Schön & Rein, 1994). This form of frame innovation can contribute new perspectives to intractable controversies, shake them up, and thus help overcome stalemates. Moreover, new actors become aware of one another during the course of a transition, meet one another, begin to collaborate, and become connected. Controversies can thus bring together previously unconnected actors in new groups with new resources and new power relations. Hence, productive controversies can add to new dynamics. Moreover, controversies can motivate actors to voice legitimate concerns, which have been previously overlooked. These additions of also emotional and value-based aspects increase the knowledge base for decision-making in the transition process. Furthermore, having experienced successful collaborations despite their different perspectives, actors can develop increasing trust in each other, what is in turn a fruitful ground for new collaborations (Kriesberg & Dayton, 2017).

2.6. Discussion and research agenda

Controversies in the CBE transition cannot be out-designed. We have provided conceptual steps towards understanding how these controversies change during a transition and how controversies shape a transition process. This understanding provides opportunities for both analysts and practitioners in the environmental sciences in at least three regards. Based on these opportunities, we suggest a multidisciplinary research agenda on the changes of controversies in sustainability transitions.

First, understanding transition controversies as potentially productive and exploring criteria for such beneficial evolutions of controversies in a transition process provides a basis for policymakers to guide controversies towards more productive forms. Corresponding interventions include exploring all relevant dimensions of key innovations such as biorefineries, in particular value concerns in addition to technical and economic aspects. In this way, policymakers can encourage exchanges between different perspectives to foster learning and mitigate unproductive evolutions of controversies. In practical terms, such interventions would stimulate deliberations on transition visions and pathways, the design of technical and social innovations, but also to reflect on the necessity of particular technologies to achieve the goals of the overall transition. Importantly, ill-designed interventions to manage conflicts can lead to more distrust (Wolf & Van Dooren, 2021)

and thus give rise to unproductive forms of controversy. Future work thus needs to be done on the careful design and testing of governance interventions to achieve more productive forms of controversy.

Second, our conceptualization provides a more context-sensitive understanding of CBE transition politics. This is in line with a call for a more contextualized appreciation of transition conflicts (Avelino, 2021) as well as to better regard societal conflicts on the road towards a CBE (Vogelpohl & Töller, 2021). Tracing back the development of current coalition constellations and underlying storylines creates a more complete picture of controversies in the CBE transition. This temporal contextualization provides analysts with a lens to assess how controversies have developed, what controversial aspects of the CBE transition have surfaced before and could reappear in the future. Put practically, an analysis of shifting discourse coalitions provides insight into *how* ideas (storylines binding discourse coalitions together) change in a transition process, where these ideational changes affect policymaking (shifting legitimization of transition vision and pathways), and how this translates into changes in micro-level innovations and policies. Deeper, actor-level examinations could focus on *why* actors adjust their ideas, what strategies they pursue, and the capacities of actors to institutionalize their ideas. A next step would be to empirically connect the different dimensions of our conceptual advances: what dynamics of discourse coalitions shifting through the different loci explain whether a controversy evolves in unproductive or productive ways? Moreover, future empirical research could apply our conceptualization to identify different controversies and their dynamics in other sustainability transitions. We have illustrated our conceptual advances by examples from the literature on biorefineries in the EU CBE transition. Other contexts might yield further or different controversy aspects. Therefore, the conceptualization should also be applied in different contexts, for example in neighbouring energy, food, or water management transitions. Moreover, we suggest applying the conceptualization on different scales, from the international level to nations, regions, municipalities, or organizations.

Third, conceptualizing controversies as inherent element of a transition contributes to a better understanding of the role of emotions and values in conflicts. These aspects should not be neglected in techno-economic assessments and the design of technical innovations in the context of transition processes. This is also highlighted in discussions on responsible research and innovation (cf. von Schomberg, 2013). Understanding changes of controversies in the context of a transition helps to illuminate the discursive dimension of responsible research and innovation, as is recently called for (Jakobsen et al., 2019). A good example of the inclusion of value-based aspects in technology design is to co-design biorefinery technologies in value sensitive design processes (Palmeros Parada et al., 2020). Analysing value-based aspects could be key in finding out why some controversies are gridlocked or smoulder under the surface only to pop up repeatedly during a transi-

tion. Seemingly logical and rational design choices (for example the chosen feedstock, which was most suitable in technical assessments) could become controversial later on in the municipality where the installation is envisioned to be located. Future research could design methods to integrate meso- and macro-level concerns already in micro-level design steps. A practical example could be to let stakeholders craft design principles for a novel biorefinery design.

In summary, conceptualizing the changes of controversies in the CBE transition is a first step towards designing governance interventions to stimulate productive forms of controversy. This is a fruitful way towards a more democratic, inclusive, and responsible form of CBE transition.

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3

Chapter 3

Evolving discourse coalitions in online controversies

Abstract

The European Commission is pursuing a circular bioeconomy to tackle pressing sustainability challenges, such as climate change and fossil dependency. Previous bioeconomy policy studies demonstrated the existence of competing bioeconomy discourses in the European Union. However, it remains nebulous how such discursive conflicts emerge and change, particularly in online settings. In this chapter, we provide a more in-depth analysis of how argumentative changes of actors alter the network of online dynamic discourse coalitions. We base our findings on interviews and a qualitative discourse network analysis of 9,983 tweets about European Union bioeconomy policies from the period 2008–2021. Our results indicate that initially, expert debates centred around storylines on bioeconomy advantages. After the 2012 Bioeconomy Strategy, the debate diversified with the entry of new actors and storylines. Two discourse coalitions, 'Green future' and 'Planetary boundaries', emerged around conflicting storyline clusters. In the aftermath of the 2018 Bioeconomy Strategy update, the debate simplified into core argumentations of few, highly conflicting storylines, leading to a polarization of the two discourse coalitions. Storyline hijacking further added to polarization and conflict. Understanding the evolution of online dynamic discourse coalitions provides new opportunities for practitioners to open up discourses towards storylines from other parts of the discourse network. This can help to prevent locking-in the limited range of solutions in congruence with the dominant 'Green future' discourse.

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3.1. Introduction

Policymakers in the European Union (EU) have pursued a circular bioeconomy (CBE) to address pressing sustainability challenges, such as climate change and the dependency on fossil resources (European Commission, 2018; Kardung et al., 2021; Temmes & Peck, 2019). A bioeconomy is 'an economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources, such as plant and animal sources' (McCormick & Kautto, 2013, p. 2590). The CBE concept connects the bioeconomy with circularity principles, such as waste minimalization and the prolongment of the value retention of products (cf. D'Amato et al., 2017). In the European Union, moving towards a *sustainable* and *circular* bioeconomy is cherished for marrying economic benefits (e.g., limiting the dependency on fossil raw materials, providing new markets for EU-based businesses, and maintaining the EU's global competitiveness) with ecological ones (e.g., climate neutrality and limiting waste) (European Commission, 2018; Meyer, 2017; Priefer et al., 2017).

Critics, however, stress that realizing a CBE may further increase the demand for bio-based resources (e.g., crops, wood, or algae), at the detriment of already overused ecosystems (Kleinschmit et al., 2017; Riemann et al., 2022). Since sustainably sourced bio-based resources are not abundant, different uses (most prominently, food, materials, and energy) may compete for resources, such as land, water, capital, and labour (Muscat et al., 2020). While these concerns might be addressed by establishing a use hierarchy (Muscat et al., 2021) and limiting the resource base for industrial production to waste streams, more fundamental questions remain. These fundamental questions centre around the sustainability and circularity of bio-based production. For instance, it is doubted whether energetic uses of biomass actually reduce greenhouse gas emissions (Korhonen et al., 2018; Zabaniotou, 2018). Moreover, a CBE as envisioned by EU policymakers may solidify problematic power relations by focusing on value-added products in the formal market, while disregarding informal practices, such as food self-provisioning (Pungas, 2023). Biophysical constraints limit the scale of a CBE, because an absolute decoupling of value generation and resource consumption is thermodynamically impossible (Giampietro, 2019; Vivien et al., 2019). Focusing on substituting the raw material base from fossil- to bio-based without addressing the demand side therefore contributes to manifesting unsustainable scales of consumption in some parts of the globe and resulting global justice issues (Ramcilovic-Suominen & Pülzl, 2018).

Social scientists studying bioeconomy and circularity debates have analysed how different actor groups argumentatively promote conflicting bioeconomy or circularity discourses and associated courses of action (e.g., Bugge et al., 2016; Dieken & Venghaus, 2020; Giurca & Metz, 2018; Kleinschmit et al., 2017; Leipold, 2021; Meyer, 2017; Ramcilovic-Suominen & Pülzl, 2018; Riemann et al., 2022; Vogelpohl, 2021). Central topics in these

discursive struggles are the expected sustainability of bio-based resources and the roles of technological versus other forms of innovation in the transition towards a CBE (Priefer et al., 2017). Scholars have shown that the dominant discourse in EU bioeconomy policy-making argues that technological innovation enables a substitution of fossil raw materials by bio-based resources to maintain current consumption levels; an alternative discourse highlights that the CBE is limited by planetary boundaries, with the consequence that other transition pathways need to be explored (Pungas, 2023; Ramcilovic-Suominen et al., 2022; Ramcilovic-Suominen & Pülzl, 2018; Riemann et al., 2022).

Previous CBE research has successfully identified competing discourses and surrounding actor coalitions in EU bioeconomy politics, but the analytical focus was less on how these discourses came into being and how they might change. The broader literature on discursive change, however, suggests that both the constellation of discourse coalitions and the stories they tell may evolve over time, calling for a specific analytical focus on such discursive dynamics on the level of individual actors (e.g., Metze & Dodge, 2016; Starke et al., 2022; Yuana et al., 2020). Moreover, previous CBE studies have largely focused on academic debates or the policy process, drawing on academic literature (Bugge et al., 2016; Vogelpohl, 2021), survey data (Giurca & Metz, 2018), or policy documents (Kleinschmit et al., 2017; Meyer, 2017; Ramcilovic-Suominen & Pülzl, 2018), occasionally combined with stakeholder interviews (Leipold, 2021; Riemann et al., 2022). Research into the larger public debate, for instance in online settings, is still in its infancy. Therefore, the research gap is that it remains unclear what discursive dynamics, on the level of individual actors, underlie the emergence of the two competing discourses in EU bioeconomy policymaking in online settings. We address this gap by posing the research question: *How have discourse coalitions evolved in online EU bioeconomy debates?* In this study, we are particularly interested in the role of social media platforms, as these have become an important arena for public debates (Marres, 2015; Stevens, 2020; Teixera Rabello et al., 2021). 𝕏, the social media platform formerly known as Twitter, constitutes such a public arena that is widely used by both interested citizens and official organizations (cf. Gu et al., 2016; Stevens, 2020).

We approach our research question by advancing the conceptualization of discourse coalitions as dynamic and emerging both off- and online. Discourse coalitions do not only change because new actors embrace already existing discourses. Rather, actors add and alter storylines and thereby change the discourses themselves. In this chapter, we further conceptualize and empirically study how such argumentative changes reshape connections between actors around shared discourses. Our contribution is that we specify how argumentative changes of individual actors continuously alter the network structure of their discourse coalitions. Understanding how this network of discourse coalitions changes is relevant because dominant understandings become institutionalized

in policies and regulations (Fischer, 2003; Hajer, 1995), ultimately shaping the actions of societal actors. Closing down ideas in policy debates to dominant understandings (Stirling, 2008) holds the danger of generating discursive lock-ins, which are situations where one understanding is so dominant that policymakers do not take into consideration innovations stemming from another discourse (Metze, 2018a; Simoens et al., 2022; Simoens & Leipold, 2021). Such a situation limits the search for innovative policy approaches (Brown & Dillard, 2015). For instance, a focus on technological innovation for stimulating the valorisation of bio-resources might impede social innovations to reduce the demand for materials and energy (Vivien et al., 2019).

We base our results on the qualitative analysis of the content of 9,983 tweets on EU bioeconomy debates in the period 2008–2021, spanning the elaboration of current EU bioeconomy policies. We identified changes in discourse coalitions by conducting a discourse network analysis (DNA) (Leifeld, 2013, 2017; Leifeld & Haunss, 2012). DNA is currently predominantly used to map advocacy coalitions around the shared agreement or disagreement on policy instruments (Leifeld et al., 2022). We contribute to further broadening the DNA application range towards tracking evolutions of discourse coalitions by redefining concept nodes as storyline nodes and omitting the dis-/agreement qualifier. Our adaptations avoid the 'bipolarization by design' problem (Leifeld, 2017, p. 5) when using DNA to track discourse coalitions.

The paper proceeds by providing a theoretical background on discourse theory, highlighting the currently rather static understanding of discourse coalitions in previous social sciences contributions to the CBE literature. Based on this, we present a more dynamic understanding, drawing on the literature on discursive dynamics. After outlining our material and methods and clarifying our methodological adaptations, we present our results. This paper ends with a discussion of our findings, including implications for bioeconomy policymaking.

3.2. Theoretical background

Identifying discursive changes in online debates over time requires a more dynamic understanding of discourse coalitions. In this section, we first provide a background on discourse theory. Second, we synthesize how previous social science contributions to the CBE literature have so far approached discursive changes in a rather static manner. Third, we build on the discursive change literature to arrive at a more dynamic understanding.

3.2.1. Discourses and discourse coalitions

Previous social science contributions to the CBE literature have identified competing discourses on the bioeconomy in the EU (e.g., Kleinschmit et al., 2017; Ramcilovic-Suominen et al., 2022; Ramcilovic-Suominen & Pülzl, 2018; Vogelpohl, 2021). In this

study, we follow Hajer (1995, p. 44) in defining *discourses* 'as a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities'.

Actors do not act in isolation, but form groups around shared discourses, so-called *discourse coalitions*. Discourse coalitions are 'the ensemble of (1) a set of story-lines [as communicated representations of discourses]; (2) the actors who utter these story-lines; and (3) the practices in which this discursive activity is based' (Hajer, 1995, p. 65). A storyline is a 'generative sort of narrative that allows actors to draw upon various discursive categories to give meaning to specific physical or social phenomena' (Hajer, 1995, p. 56). In contrast to advocacy coalitions, in which actors form coalitions around shared interests (Sabatier & Jenkins-Smith, 1993), a discourse coalition is formed around implicitly or explicitly shared storylines. Hence, in understanding how policies change, the discourse coalition conceptualization emphasizes the role of discursive changes, rather than changes in actors and institutions (Fischer, 2003). Discursive changes institutionalize into policymaking because policymakers regard some problem definitions and policy options as suitable in accordance with their discursive categories, while disregarding others (Hajer, 1995). Changing these discursive categories results in a different array of regarded problem definitions and solutions.

A related, but somewhat different concept is the *discourse network*. A discourse network is a 'cross-sectional clustering of actors around similar statements' (Leifeld, 2017, p. 5). Such statements are utterances of actors with reference to an idea (Leifeld, 2017). While a discourse coalition describes groups around shared ideas, the discourse network refers to the entirety of discourses and actors present in a debate, clustered according to their congruence. Hence, different discourse coalitions can be part of the discourse network. Moreover, discourse networks differ from discourse coalitions because actor practices and congruent ideas, which are not uttered, are not considered as part of the discourse network.

3.2.2. Understandings of discourse coalitions in the circular bioeconomy literature

Despite valuable insights into existing bioeconomy discourses, previous CBE studies have predominantly approached discourse coalitions as rather static groups around stable storylines. For example, Vogelpohl (2021) studied transnational sustainability certification schemes for biomass. He identified a discourse coalition of industry and national state actors opposing these schemes. However, the study did not aim to provide insights into changes in this discourse coalition. Giurca and Metz (2018) conducted a network analysis of actors around similar visions of the wood-based bioeconomy in Germany, similarly as Mijailoff and Burns (2023) for Argentina and Uruguay. Findings concern a particular

moment in time, with the development of the network falling outside the scope of both studies. Riemann et al. (2022) analysed the argumentation of non-governmental organizations (NGOs), identifying a static narrative of a fixed group. Dieken and Venghaus (2020) identified changes of what actors refer to the visions identified by Bugge et al. (2016), while adaptations of these visions over time are not regarded. Consequently, the analytical focus so far lies on changes in what actors align with what discourse on what moment in time and to a lesser extent on changes in the discourses themselves.

As a notable exception, Leipold (2021) identified a 'change coalition' (p. 5) around environmental actors promoting radical waste reduction policies and a 'status quo coalition' (ibid.) around industry actors opposing these policies. Later, the European Commission worked towards bringing actors together in a 'joint coalition' (p. 6) that strived to *redefine* the initial storyline. While providing an analysis of discursive changes in circularity policies, the study did not focus on bioeconomy policies. Moreover, it remained outside that study's scope how actors within one discourse coalition alter storylines and how this affects the composition of their discourse coalition.

3.2.3. Towards a more dynamic understanding of discourse coalitions

To move beyond current static understandings, discourse coalitions need to be approached as inherently dynamic, paying attention to how actors continuously work on shaping their storylines (Metze & Dodge, 2016; Starke et al., 2022). Over time, actors strengthen storylines, for example by gathering new empirical material to underline the validity of a narrative (confirmation), establishing new connections between storylines (integration), contesting storylines (disintegration), and reconfirming differences between different storylines (polarization) (Metze & Dodge, 2016, p. 4).

We build on this understanding by further specifying how individual actors continuously reshape their discourse coalitions through storyline adaptations. Termeer (1993) identified different patterns of how network configurations of actors change when involved actors adjust their definitions of social reality. This implies that actions of individual actors can lead to shifts in the relational network of their groups. Actors evolve their argumentation over time. These storyline adaptations result in shifts in both the internal composition and the relational network structure of discourse coalitions. Due to storyline adaptations, other actors may start contesting the adapted storyline and ultimately 'leave' a discourse coalition, start a new one, or 'join' another one. Consequently, discourse coalitions can shrink, grow, solidify, merge, fall apart, disappear, or (re)appear over time.

3.3. Material and methods

We analysed how the discourse network evolved on 𝕏 between August 2008 and June 2021. This time period entails the elaboration of the first EU Bioeconomy Strategy in

2012 and its update in 2018. For our analysis, we adapted an established approach to identify discourse networks, discourse network analysis (Leifeld, 2013; Leifeld & Haunss, 2012). We combined this discourse network identification with an interpretive analysis of the content of tweets spread through the discourse network, based on an inductively constructed coding scheme. An extensive research protocol is provided as Supplementary Material A.2.

3.3.1. Data set construction

To identify the online discourse network, we created a data set of tweets by applying the search string *(biomass OR bioeconomy) AND ('European Union' OR EU)*. By choosing these key words, the data set focuses on bioeconomy and biomass debates, with less emphasis on neighbouring debates (such as circularity or air pollution). The initial data set consisted of *N = 39,930* tweets.

We reduced the data set by selecting the most impactful tweets. On 𝕏, users can like, retweet, or quote-retweet content to show their appreciation, comment their dissent, and further disseminate tweets to their own followers. For selecting the most impactful tweets, we ranked them from the highest to lowest total number of retweets, likes, and quote-retweets per tweet, with the highest ranking to be considered most impactful. We set a threshold of 25 per cent most impactful tweets per year to be included in the analysis. This reduced the data set to manageable proportions *(N = 9,983)* for a manual, in-depth qualitative analysis. These tweets form the analysed network for this study. We maintained the time stamp of every tweet to allow for a longitudinal analysis.

3.3.2. Adaptations of the discourse network analysis method

Some adaptations of the DNA method were needed to allow for a more dynamic analysis of evolving discourse coalitions. In DNA, two types of nodes are used: actor and concept nodes (Leifeld, 2013). Actor nodes represent actors in a data set, in our case user accounts. Concept nodes represent arguments or ideas in a debate (Leifeld, 2017). These nodes are connected by edges, which can be visualized as links in a network graph. Edges can be qualified as either an agreement or disagreement relationship between an actor and a concept node. This qualifier introduces a binary variable into the data set: clusters of actors form around either the agreement or disagreement on a set of concepts. For this specific study, we adapted the DNA in two ways.

As a first adaptation, we redefined concept nodes into storyline nodes (cf. Kukkonen et al., 2021). While concept nodes in DNA usually refer to ideas in a broader sense, in our adaptation, storyline nodes stand for an opinionated, generic narrative, highlighting particular aspects of social reality.

A second adaptation is that we only used agreement qualifiers and no disagreements. Hence, all actor-storyline connections were coded as agreement. We did so for a conceptual and a methodological reason. Conceptually, actors in discourse coalitions rather deploy alternative storylines instead of solely disagreeing with a storyline. Methodologically, omitting the dis-/agreement qualifier avoids the 'bipolarization by design' problem (Leifeld, 2017, p. 5), describing a design-induced trend towards bipolar network structures in using DNA to identify discourse coalitions. A bipolar network structure displays two discourse coalitions, based on either agreement or disagreement of actors on a set of policy instruments in line with their endorsed discourse. Omitting the dis-/agreement qualifier allows for the identification of complex structures of multiple discourse coalitions, highlighting various storyline combinations.

3.3.3. Interpretive analysis to establish storyline nodes

To establish storyline nodes, we performed a manual interpretive analysis of the storylines that are used in EU bioeconomy debates. To this end, we first constructed an initial list of controversial aspects in bioeconomy debates and connected storylines highlighted by the existing literature (e.g., Leipold, 2021; Ramcilovic-Suominen & Pülzl, 2018; Temmes & Peck, 2019; Vogelpohl, 2021) and eight experts from the European Commission, environmental non-governmental organizations (NGOs), and industry associations, who we interviewed between June and September 2021. We used this list as an initial coding scheme for storyline nodes.

We then took samples from our data set to iteratively adapt the initial coding scheme. To this end, the first author performed two training rounds of coding in the Discourse Network Analyzer software (Leifeld et al., 2019) on randomly selected quarters of the data set. After each round, we refined the coding scheme. Questionable cases and coding scheme adjustments were discussed among the team of authors to establish a common set of storylines and to enhance coding reliability. Examples of storylines coded for are 'Green growth' (a CBE is an environmentally friendly way to maintain or increase economic growth), 'Sustainability criteria' (certification schemes or guarantees of origin are needed to ensure the sustainable harvesting of bio-resources), and 'Deforestation overseas' (increased demand for bio-resources in the EU leads to deforestation elsewhere). Supplementary Material A.1 includes the final list of storylines and their definitions.

3.3.4. Analysis of discourse coalition dynamics in three time periods

To analyse dynamics of discourse coalitions over time, we split the data set into three time periods according to changes in EU bioeconomy policies, see Figure 3.1. Period 1 spans from the first available tweet on 13 August 2008 until the publication of the first EU Bioeconomy Strategy on 13 February 2012. Period 2 ranges until the publication of the

strategy's update on 10 October 2018. Period 3 runs until the last included tweet from 30 June 2021.

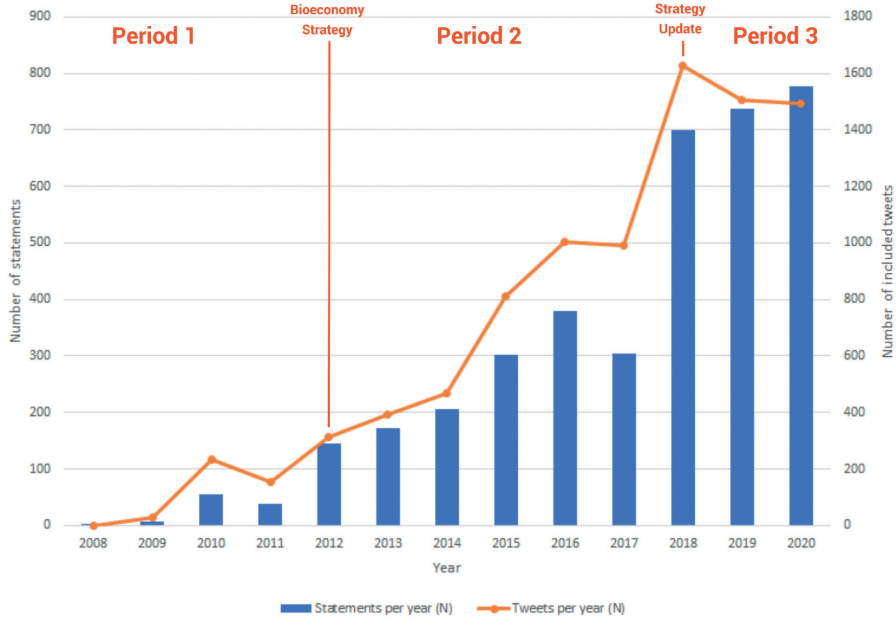

Figure 3.1 *Number of tweets and statements per year in three study periods.*

For each of the three periods, we extracted two types of networks: actor and storyline congruence networks. In *actor congruence networks*, actor nodes are connected by an edge if accounts deploy statements with reference to a common storyline. In resulting network graphs, edge weight indicates the number of statements with shared storylines between actors (Leifeld et al., 2019, p. 9). These networks visualize the (unintentionally) formed groups of actors around congruent storylines. In this analysis, we regard actor clusters around a coherent combination of storylines as discourse coalitions. We also extracted *storyline congruence networks* (cf. Kukkonen et al., 2021; Leifeld, 2017), in which we checked what storylines are commonly referred to by actors. We present storyline congruence network graphs as Supplementary Material A.3.

3.4. Results

Discursive dynamics and changing compositions of online discourse coalitions over time are presented over three time periods, corresponding with EU bioeconomy policy changes.

3.4.1. Period 1 (2008–2012): Expert debate highlighting different positive bioeconomy effects

Period 1 spans from the start of available tweets in August 2008 until the publication of the first EU Bioeconomy Strategy in February 2012. This strategy sketched a 'knowledge-based bioeconomy' (European Commission, 2012, p. 18). Bioeconomy advantages were seen in benefits for economic growth and rural development, while greening primary production and lowering the dependency on fossil raw materials.

In the first period, we observe a multifocal debate, with multiple actor clusters interpreting the topic slightly differently. Specific discourses are not visible, yet. A central 'Green future' cluster involved industry actors, experts from the European Commission, and journalists, see Figure 3.2. According to this cluster, bio-technological innovation would decouple economic growth from environmental impacts. Actors of this cluster were tightly connected to the 'Sustainability criteria' cluster, which broadly endorsed the storylines of 'Green future' but specified the need for sustainability criteria for bio-resources.

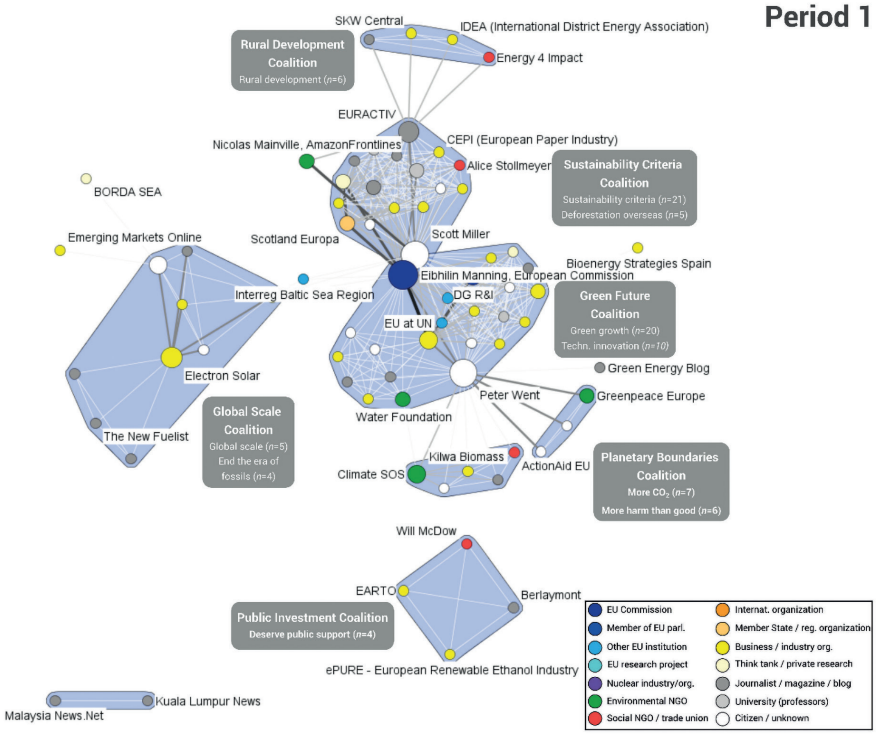

Figure 3.2 *Actor congruence network for period 1.*
Nodes represent actors, their colours indicate different actor categories. Selected node labels are displayed. Node size is proportional to the frequency of statements the actor made. Edge weight indicates the strength of congruence, with the highest 5% visualized in black, 5-20% in dark grey and below that in light grey. Light blue group nodes show Girvan-Newman clusters of the highest hierarchy level. Grey curved boxes display cluster labels, storylines characterizing the cluster and the total number of utterances of these storylines.

Around these central clusters, several smaller clusters nuanced this 'Green future' narrative, for example by adding the element of a particular opportunity for peripheral regions ('Rural development' cluster). A 'Planetary boundaries' cluster of NGOs and citizen accounts pointed out that not every form of biomass use was CO_2-neutral. Moreover, they criticized the role of genetic engineering as a bioeconomy enabler.

3.4.2. Period 2 (2012–2018): Diversification and formation of a counter-coalition

Period 2 consists of the period between the Bioeconomy Strategy and its update in October 2018. A participation process preceded this update, in which the European Commission invited interested persons and organizations to submit position papers. In the updated strategy, the bioeconomy concept was explicitly married with the concepts of sustainability and circularity.

After the publication of the 2012 Bioeconomy Strategy, the discourse network diversified. While industry actors, university professors, environmental NGOs, and some European Commission experts participated in period 1, new discussants in period 2 included members of the European Parliament, member state organizations, journalists, and other citizens.

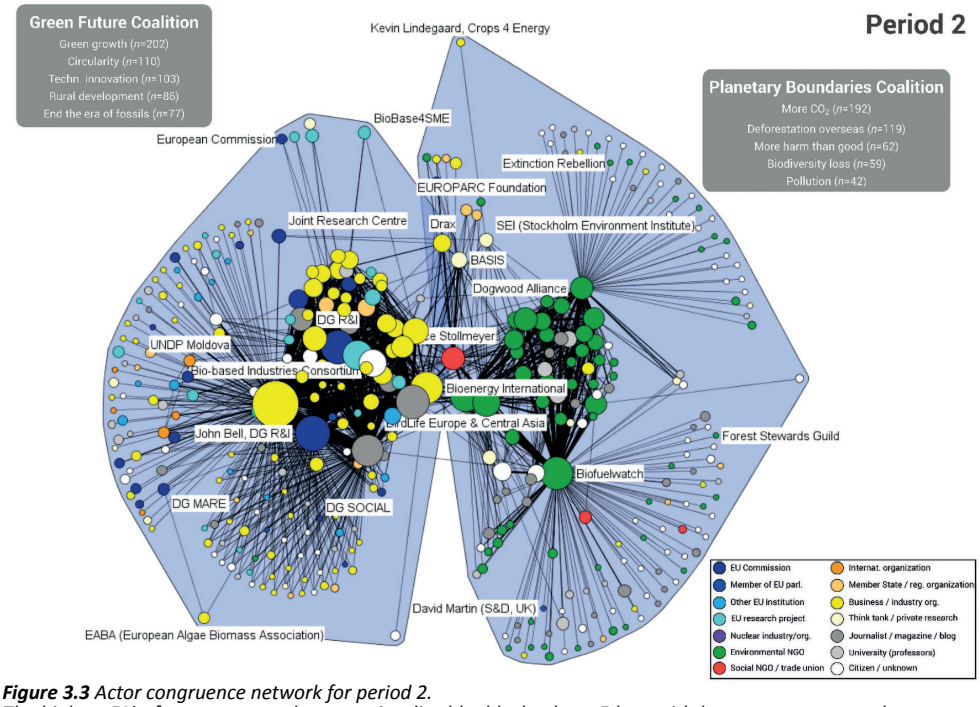

Figure 3.3 *Actor congruence network for period 2.*
The highest 5% of congruence values are visualized by black edges. Edges with lower congruence values are not displayed, nor are isolates.

Parallel to the diversification, the network constellation became more bipolar, see Figure 3.3. Instead of several connected clusters that broadly share the same discourse, two main discourse coalitions emerged in period 2. First, a 'Green future' coalition of industry and European Commission actors integrated storylines that were shared by separate clusters in period 1. This coalition considered a global, large-scale bioeconomy, enabled by technological innovation, as inherently circular due to the use of renewable resources. Second, a 'Planetary boundaries' coalition, mostly consisting of environmental NGOs, criticized the vision of a bioeconomy set out in the 2012 strategy. For instance, this coalition questioned the assumed carbon-neutrality of bio-resources due to the long time period until emitted carbon is bound back. A bioeconomy would make things worse by further contributing to deforestation and biodiversity loss.

3.4.3. Period 3 (2018–2021): Simplification and increasing polarization

Period 3 ranges from the strategy's update until the end of the data set in June 2021. In this period, the European Green Deal was published, which further stressed sustainability principles in developing the bioeconomy, for instance highlighting reforestation (European Commission, 2019, p. 13) and rural development (p. 23). The Fit-for-55 package to deliver the Green Deal's climate ambitions does not entail the term bioeconomy, but calls for a 'green, competitive, inclusive, circular economy' (European Commission, 2021, p. 12).

After the Bioeconomy Strategy's update, storyline clusters simplified. Most statements of both discourse coalitions concerned the simplified question of whether or not the bioeconomy *in general* functions to mitigate climate change by binding more carbon than it emits, regardless of whether energy or more durable products are produced. The 'Green future' coalition now focused on storylines to underline that developing a bioeconomy would be necessary to achieve policy goals, such as global climate commitments or the EU Green Deal. The 'Planetary boundaries' coalition stopped broadly uttering the consolidating 'Not all biomass is CO_2-neutral' storyline and focused on more fundamental concerns. A bioeconomy would mean more harm than good by adding more CO_2 and other pollutants due to additional production, transport, and harvesting as well as endangering biodiversity by stimulating deforestation.

Congruent to this simplification, the discourse network further polarized into a bipolar structure, see Figure 3.4. While actors in the overlap of the two coalitions were still present in period 2, the overlap nearly vanished in period 3.

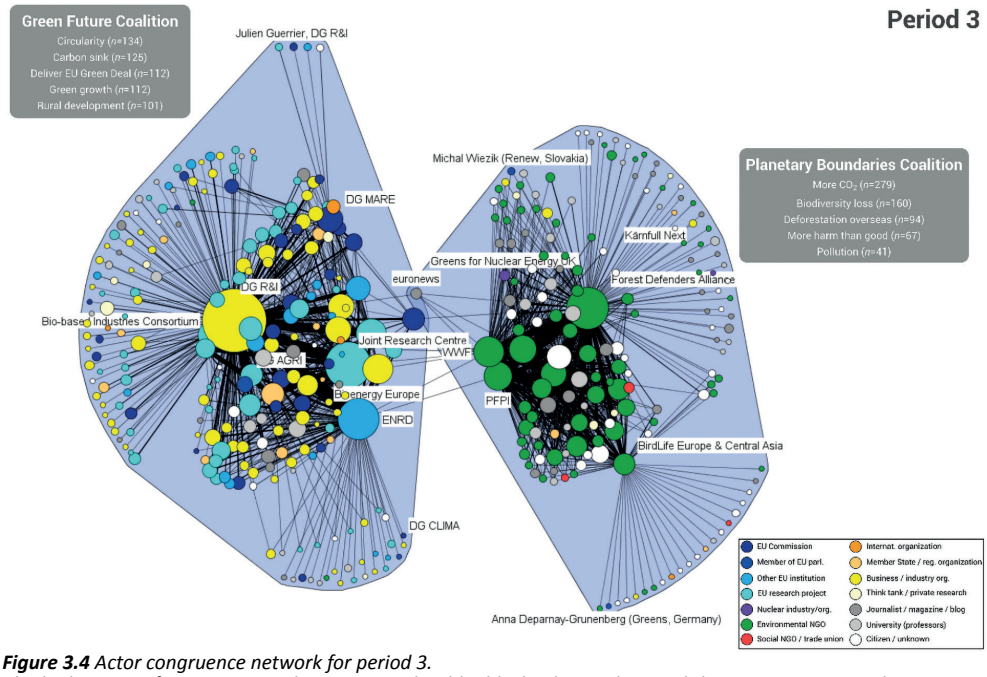

Figure 3.4 *Actor congruence network for period 3.*
The highest 5% of congruence values are visualized by black edges. Edges with lower congruence values are not displayed, nor are isolates.

Compared to period 2, many EU-funded research projects joined the 'Green future' coalition. Projects, for instance Bloom or Schoolnet, integrated the storylines 'Education', 'Public awareness', and 'Democratization' into a common narrative. According to this narrative, a bioeconomy would be fostered by empowering the younger generation to discuss the future of the bioeconomy as well as informing the public about how a bioeconomy benefits society.

3.5. Discussion and concluding remarks

This chapter started with the aim of developing a better understanding of discourse coalition dynamics in online EU bioeconomy debates. While our findings confirm the general divide between an ecomodernist and an ecological discourse coalition in bioeconomy politics, as recently identified in Europe (Ramcilovic-Suominen et al., 2022) and South America (Mijailoff & Burns, 2023), our contribution is that we point out the dynamics underpinning the emergence of these two coalitions online. Initially, primarily experts participated in the online debate, which *diversified* towards the broader public after the adoption of the 2012 EU Bioeconomy Strategy. This diversification involved the entry of new actors and storylines into the discourse network. Besides the emergence of new storylines brought in by new actors, debates also *simplified* into two main argumentations. On the one side, the 'Green future' coalition argued that a bioeconomy

was a necessity to achieve climate goals and EU Green Deal objectives. On the other side, the 'Planetary boundaries' coalition scrutinized the assumed carbon neutrality and highlighted environmental trade-offs. The diversification towards the broader public and the simplification of storyline clusters contributed towards an increasing *polarization* of the debate, resulting in a bipolar discourse network with tight internal links and few connections between the coalitions.

This sequence of dynamics at the level of the discourse network is grounded in storyline adaptations by individual actors, which Metze and Dodge (2016) identified as storyline integration, disintegration, confirmation, and polarization. While the debate diversified, established actors confirmed storylines, resulting in the growth of actor clusters and tighter links within a corresponding storyline cluster. For example, in period 2, the congruence between the 'Circularity' and 'Green growth' storylines in the 'Green future' cluster increased compared to period 1. Actors worked towards a simplification of the debate by disintegrating storylines of another discourse coalition and integrating complex storylines into a simple core argumentation. As a result of this simplification, debates centred around few, highly conflicting storylines. Nuanced and consolidating storylines shifted towards the periphery of the discourse network. This loss of nuance risks simplifying bioeconomy debates into black-and-white clashes on the energetic use of biomass, possibly constraining deliberations on less straightforward trade-offs, such as lock-ins, but also consolidating options, such as use hierarchies.

In addition to the dynamics proposed by Metze and Dodge (2016), we suggest storyline hijacking as an additional dynamic leading to polarization and conflict escalation. Hijacking means integrating a storyline from another discourse coalition, but redefining it to match one's own interpretation of reality (cf. Vivien et al., 2019). For example, the 'Green future' coalition seems to have hijacked storylines such as 'Circularity'. While environmental organizations initially stressed that a bioeconomy *is not* inherently circular, 'Green future' actors claimed that a bioeconomy *is* inherently circular, because it uses renewable resources. As a result of storyline hijacking, actors have different interpretations in mind when referring to the same storyline. Conflict smoulders in this.

While proving useful to track storyline dynamics over time, our study also has limitations. Notably, the analysed debate on 𝕏 is only part of the public debate (Stevens, 2020). DNA studies traditionally rely on newspaper articles (e.g., Kukkonen et al., 2021; Leifeld, 2013; Mijailoff & Burns, 2023). However, we find that tweets are particularly useful for DNA because tweets are coherent and short. Actors selectively highlight aspects that they find most important. Moreover, tweets can univocally be connected to one actor by the user handle and have a time stamp. Using different textual data might result in the identifica-

tion of different discourse coalitions. Therefore, it cannot be inferred that the same coalitions would also appear in different settings, for instance in public consultation processes.

Moreover, our analysis does not allow for conclusions about how balanced the online debate is, because we regarded uttered storylines as equally valid, thus independent of their scientific substantiation. To mitigate a false balance bias in our interpretation, we grounded our analysis in standing literature and interviews with experts from different perspectives.

Our findings have implications for the literature on EU bioeconomy policymaking. In particular, results indicate the starting institutionalization of a discursive lock-in towards the 'Green future' understanding. If powerful decisionmakers gather on one side of the discourse network and alternative discourse coalitions are excluded from this idea-policy channel, then policymakers face a bias in the range of considered policy options (Metze, 2018a; Simoens et al., 2022; Simoens & Leipold, 2021). This discursive lock-in of the 'Green future' discourse has started to institutionalize, because EU-funded research projects gather exclusively in the 'Green future' discourse coalition. EU-funded research projects thereby perpetuate the dominant discourse, which limits the disruptive potential of innovation to techno-economic solutions. This is problematic, because the range of regarded policy solutions and envisaged futures (Ahola-Launonen & Kurki, 2022) becomes biased towards the ones congruent with the 'Green future' discourse. Future research can further explore how this bias in considered problem definitions and solutions becomes legislation and how this affects the development of bioeconomy projects on the ground.

At the same time, our results are in line with findings that argumentations within one discourse coalition are not as unified and stable as the discursive divide suggests (Eckert, 2021). In fact, we show that actors continuously adapt their storylines. Discourses are therefore evolving and changeable. To unlock the current discursive lock-in, recent bioeconomy policy research has suggested more inclusive, participatory approaches in governing the bioeconomy, for example in crafting regional bioeconomy strategies (Szarka et al., 2023). Our findings suggest that this focus on inclusivity in bioeconomy governance needs to be accompanied by a focus on the plurality of involved knowledge systems and fundamental perspectives (see also Gebara et al., 2023). Future work remains to design models of participatory bioeconomy governance that not only foster inclusivity, but also plurality.

In addition, our findings have governance implications. First, our findings imply that a further politicization of debates on the future of the bioeconomy is required to surface the biases in problem definitions and connected solutions that result from the discursive congruence of EU decisionmakers and EU-funded research projects with industrial ac-

tors. In funding decisions and policymaking, the danger smoulders of exclusively aligning research and policies with techno-economic perspectives, which are congruent with the 'Green future' discourse. This could contribute to a further decline of the disruptive character of research and innovation (see Park et al., 2023) and failing to deliver the bioeconomy's transformative ambition by a perpetuation of unsustainable business practices (Eversberg, Holz, et al., 2023; Lühmann & Vogelpohl, 2023), To surface these value conflicts, it is necessary to politicize currently rather technical bioeconomy debates (Eversberg, Koch, et al., 2023). Policymakers and stakeholders engaging in the debate can work on this in both offline and online settings.

Second, our longitudinal analysis enables understanding at what moments and due to what argumentative changes the debate closed down, which also allows for the identification of entry points to open up the debate again. Regarding these moments as intervention points enables more adaptive governance by avoiding locking-in problem definitions and solutions congruent with one particular – and changing – discourse. Practitioners can work towards opening up the debate by including storylines from different parts of the discourse network. For instance, the Joint Research Centre published a report on alternative bioeconomy visions, which also highlights problem definitions congruent with the 'Planetary boundaries' discourse (Giuntoli et al., 2023). This helps in avoiding a bias towards problem definitions and solution approaches in congruence with the 'Green future' discourse in bioeconomy policymaking.

Third, policymakers should embrace the innovative potential of conflicts to surface currently disregarded problem definitions and policy options. This implies that conflict and polarization are not necessarily bad news (Cuppen, 2012). Unlocking the innovative potential of conflicts requires stepping out of one's own discursive bubble and seeking discussions with critics, even if this sparks disagreement (Van Eeten, 1999). A practical example is the 'Beyond Growth' conference in May 2023, organized by members of the European Parliament and also featuring critical voices of current EU policies. This includes establishing and maintaining relationships with stakeholders from other parts of the discourse network, which might form blind spots for policymakers tightly aligned with another part of the discourse network. Our findings imply that discourses and connected coalitions continuously change. Stakeholder identification and relationship forming must therefore be continuous processes (Cuppen, 2018; Wehling, 2012).

Taken together, a bioeconomy with sustainability and circularity at its heart requires considering problem definitions and solution approaches beyond the current bias towards dominant 'Green future' interpretations, which are only one side of the discourse network. In order to achieve this, policymakers, researchers, and other practitioners need to

work towards opening up bioeconomy debates to ideas from other parts of the discourse network.

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4

Chapter 4

How bioeconomy Triple Helix clusters deal with controversies

Abstract

Policymakers in the European Union embrace collaborations of businesses, governments, and academia to develop a sustainable and circular bioeconomy. These so-called Triple Helix clusters aim to stimulate innovation and learning. However, Triple Helix collaborators also face conflicting perspectives on the desirability and directionality of the bioeconomy transition, either within a cluster or with societal actors affected by a cluster's innovations. While previous Triple Helix research focussed on how to broaden the cluster collaboration towards a more inclusive range of actors to handle such contestations, we study how cluster partners deal with uninvited input from societal actors that do not form part of a cluster. We conceptualize this input as societal back talk and distinguish organizational hearing, listening, and learning capabilities to explore how back talk contributes to innovation in three bioeconomy clusters in the Netherlands, Germany, and Ireland. Our qualitative case study analysis is based on interview transcripts, newspaper articles, and policy and planning documents. Results indicate that collaborating partners generally do not hear uninvited back talk that fundamentally challenges their tacit beliefs, because partners focus on informing the public about what they consider techno-economic benefits of their projects. As a consequence, collaborators become 'insiders', what hinders listening to divergent problem definitions and alternative solutions of 'outsiders'. Learning from uninvited back talk is therefore restricted to minor adjustments. To avoid innovative solutions remaining unexplored as a result of this discursive lock-in, Triple Helix collaborators must engage in hearing and listening to critical societal actors by establishing a reflective, two-directional dialogue.

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4.1. Introduction

Policymakers in the European Union (EU) and beyond cherish the transition towards a sustainable and circular bioeconomy as a promising answer to tackle pressing sustainability challenges, such as climate change and the (geopolitical) dependency on fossil resources (Dietz et al., 2018; European Commission, 2018; Meyer, 2017; Priefer et al., 2017). A bioeconomy is an economy based on bio-based resources, including crops, wood, agricultural residues, or algae, for the production of both energy and materials (McCormick & Kautto, 2013), for example biogas and other fuels, bioplastics, biochemicals, fertilizers, cosmetics, and pharmaceuticals. Specifically in the EU, policymakers aim to advance this bioeconomy transition by fostering industrial modernization and technological innovation (Ahola-Launonen & Kurki, 2022; European Commission, 2018, 2022; Ramcilovic-Suominen & Pülzl, 2018).

However, despite high hopes of policymakers that this form of bioeconomy transition may contribute to tackling the dependency on fossil raw materials and mitigating climate change, bioeconomy governance scholars have pointed out that developing the envisioned bioeconomy is also subject to societal contestations (Kleinschmit et al., 2017; Riemann et al., 2022; Starke et al., 2022). Concerns include how further stimulating the large-scale production of bio-based products can have detrimental effects on biodiversity, environmental quality, and food security (Giampietro, 2023; Pungas, 2023; Richardson, 2012; Vivien et al., 2019).

Addressing such complex and contested sustainability challenges as the bioeconomy transition entails connecting different forms of knowledge (for instance, scientific knowledge and the contextualized knowledge of practitioners) in innovation projects that aim to advance the tasked societal mission (Bogner & Dahlke, 2022; Scholz, 2020). One prominent instrument to address sustainability challenges by means of collaborative innovation processes is the so-called Triple Helix (TH) model (Cai & Etzkowitz, 2020; Scalia et al., 2018). TH clusters are collaborations between the three helices of academia, industry, and government that produce specialized knowledge to gain competitive advantages for a particular region (Etzkowitz & Leydesdorff, 1995, 2000; Shearmur, 2011). These clusters aim to spark innovation by bringing together actors with fundamentally different perspectives (Scholz, 2020). More precisely, by connecting actors that uphold divergent knowledge systems, TH clusters are believed to stimulate innovative ideas and practices due to mutual learning (Leydesdorff & Etzkowitz, 1998; Murillo-Luna & Hernández-Trasobares, 2023). This is particularly relevant for the European bioeconomy transition because of the multitude of possible combinations of raw materials, production processes, and products of industrial endeavours falling under the bioeconomy umbrella (McCormick & Kautto, 2013; Vogelpohl et al., 2022). Because of the resulting multiplicity of involved perspectives, TH clusters are prone to face contestations on what a desirable bioeconomy is and how to

achieve one. Due to the complexity and interconnectedness of the bioeconomy transition across governance scales (Ahola-Launonen & Kurki, 2022; Wohlfahrt et al., 2019), this input might not only be localized towards the concrete projects that TH clusters aim to develop, but also concern the directionality of the bioeconomy transition more generally. On the one hand, such contestations – but also laudatory or indifferent input – can stem from societal partners that are invited to offer feedback by being included in the cluster. On the other hand, uninvolved actors of the broader public might provide *uninvited* input, adding even more divergent perspectives (Carayannis & Campbell, 2009; Cuppen, 2018; Maciejczak, 2009; Wehling, 2012). This input could stem from protests, public debates in newspapers or on social media, or talks between citizens in various informal settings.

Research on the innovation potential of TH clusters has so far focussed on the collaboration process *within* clusters (e.g., Gustafsson & Jarvenpaa, 2018; Maciejczak, 2009; Murillo-Luna & Hernández-Trasobares, 2023). Various scholars have therefore called for a better acknowledgement of the perspectives of societal actors that do not form part of TH collaborations (Casale Mashiah et al., 2023; Compagnucci et al., 2021; Diepenmaat et al., 2020; Grundel & Dahlström, 2016; McAdam & Debackere, 2018; Miller et al., 2018). Despite these scholarly calls for better regarding societal input in helix collaborations, research into *how* TH cluster organizations deal with uninvited societal input is still in its infancy.

In this chapter, we address this knowledge gap by *exploring how collaborating actors within bioeconomy Triple Helix clusters deal with uninvited input stemming from societal actors that do not form part of a cluster*. Identifying how TH collaborators deal with societal input is relevant because this input scrutinizes how bioeconomy projects align with the overall societal mission of developing a bioeconomy that 'needs to have sustainability and circularity at its heart' (European Commission, 2018, p. 4). Previous bioeconomy governance studies have pointed out the existence of conflicting perspectives on the desirability and directionality of the bioeconomy transition (Bugge et al., 2016; Eversberg, Holz, et al., 2023; Giuntoli et al., 2023; Kleinschmit et al., 2017; Ramcilovic-Suominen & Pülzl, 2018; Riemann et al., 2022; Vivien et al., 2019), mapped resulting discursive conflicts between actor groups (e.g., Giurca & Metz, 2018; Mijailoff & Burns, 2023), and traced their development (Leipold, 2021; Starke et al., 2023). Local decisionmakers working on the bioeconomy transition on the ground take over, translate, and localize these higher-level discourses in their projects, for instance in industrial bioeconomy clusters (Wilde & Hermans, 2021). However, it remains nebulous how decisionmakers on the various levels of the bioeconomy transition can deal with these discursive conflicts productively (Cuppen, 2018; Starke et al., 2022). With this chapter, we aim to contribute to this ongoing debate in the bioeconomy governance literature by studying the political process of what societal input is taken up and how other input is left neglected by decisionmakers

in TH collaborations that aim to bring the bioeconomy transition forward. By doing so, we foreground the politics in the development of techno-economic innovation projects. These insights can help decisionmakers to avoid that costly solutions and biased problem definitions are locked-in, which might be rejected by societal actors as unfit to address pressing sustainability and circularity challenges (Simoens et al., 2022; Stirling, 2008). What is more, dealing effectively with societal input creates opportunities for out-of-the-box thinking to identify trade-offs, but also innovative solutions, which are currently overlooked by cluster partners. Moreover, critical observers could use these insights to identify and scrutinize blind spots and biases in local bioeconomy projects.

To explore how TH cluster collaborators deal with uninvited societal input, we first conceptualize processes and preconditions of organizational hearing, listening, and learning capabilities. We build upon organizational learning literature that provides generic answers on what these capabilities consist of but is less sophisticated about how TH clusters apply them. We therefore sharpen and empirically anchor the conceptualization by applying it to three major bioeconomy TH collaborations in different EU member states: *Chemport Europe* in the Northern Netherlands, *Bioeconomy e.V.*[3] in Saxony-Anhalt (Germany), and the *Irish Bioeconomy Foundation*, located in Tipperary (Ireland). We base our results on an interpretative analysis of interviews, contextualized by newspaper articles as well as policy and planning documents.

4.2. Societal actors in Triple Helix conceptualizations

Scholars have criticized TH clusters for being too exclusive towards societal actors (Diepenmaat et al., 2020). This is because TH clusters are set up to fulfil societal missions towards sustainability and take into account interests above and beyond their own organization (Gerritsen, 2019; Scalia et al., 2018). In TH clusters, however, these societal missions are – at best – only indirectly represented, in the cluster's mission and for example by governments or universities. This results 'in a higher risk of a narrow value creation process, with negative costs to society and natural eco-systems' (Diepenmaat et al., 2020, p. 2).

TH scholars have conceptually addressed these exclusivity concerns by proposing new forms of collaboration: N-tuple helix extensions and TH twins. Advocates of *N-tuple helix extensions* call for broadening the range of actors and connected perspectives engaged in collaborations. TH clusters are embedded in society which, in turn, is inseparable from the natural environment and therefore bound to biophysical characteristics of the region as well as planetary boundaries (Carayannis et al., 2012; Van Bueren et al., 2023). To include according perspectives, Carayannis and Campbell (2009, p. 201) proposed to add

3 The abbreviation e.V. stands for *eingetragener Verein*, a German legal denomination for a registered non-profit association.

'the perspective of the media-based and culture-based public' as a fourth helix, thereby extending the model towards a Quadruple Helix. In another extension, Carayannis and Campbell (2010) and Carayannis et al. (2012) further developed the model towards a Quintuple Helix by adding the natural environment as a fifth helix. In fact, the model might be extended even further, into an '*N*-tuple of helices' (Leydesdorff, 2012, p. 25). By adding additional helices, particularly by inviting societal actors to become part of the collaboration, innovation processes are assumed to better align with societal perspectives and facilitate transformative change (Grundel & Dahlström, 2016).

Etzkowitz and colleagues proposed the concept of *TH twins* as a different way of coping with exclusivity concerns (Cai & Etzkowitz, 2020). A TH twin is a University-Government-Public collaboration mirroring original TH clusters with a specific focus on realizing sustainability goals (Etzkowitz & Zhou, 2006; Gebhardt et al., 2022; Zhou & Etzkowitz, 2021). Twinning the original TH should foster innovation that is not purely justified on economic merits and therefore assumed to better align with societal demands (Zhou & Etzkowitz, 2021).

These forementioned conceptual and organizational advances both aim at inviting societal actors to become part of the collaboration. However, dealing with this form of *invited* input does not suffice in addressing input from societal actors that are not part of the collaboration (Cuppen, 2018; Grundel & Dahlström, 2016). Scholars have therefore reflected on questions such as who should partake and have influence in TH collaborations, what to do with possible knowledge imbalances, or how to avoid the 'incorporation and co-optation [of the participation process] by powerful political and scientific institutions or economic actors' (Wehling, 2012, p. 55). One proposition to counter knowledge imbalances is to develop a continuous learning approach, rather than organizing (a series of) singular moments of invited participation (Wehling, 2012). Continuous learning could take place along the societal opinion formation process, in which actors change positions over time when encountered with new information and opinions (Cuppen, 2018). TH clusters that aim to adhere to societal ambitions can learn from these developing opinions, interests, ideas, and values without making all actors part of the collaboration or organizing public participation processes. TH clusters can adapt and learn by listening to this *uninvited* societal input.

4.3. 'Dealing with' uninvited societal input

In this chapter, we conceptualize such uninvited societal input as *back talk*. The notion of back talk stems from design rationality thinking and describes a form of direct reaction towards new realities created by policy designers in action (Korsmeyer et al., 2022; Schön, 1983; Schön & Rein, 1994). Back talk consists of the 'messages sent back to policy designers that surprise them by violating their taken-for-granted assumptions' (Schön & Rein, 1994,

p. 123). This back talk exceeds feedback, because it fosters reflection-in-action on beliefs that underlie design decisions (Kuitenbrouwer, 2018; Yanow, 2009). TH cluster partners function as policy designers in developing business models and organizational policies. Societal actors, through media and other outlets, may bring in perspectives, knowledge, ideas, and values that critically scrutinize or even conflict with the perspectives held by the TH cluster. For example, societal actors may question the resource harvesting, production process, or product properties and uses of bio-based products developed by TH cluster collaborations. Moreover, back talk scrutinizes taken-for-granted assumptions, including the fundamental logics and value considerations underlying bio-based production (Metze et al., 2017).

To conceptualize how collaborating actors within a TH cluster deal with back talk, we draw on organizational learning literature, which has a long tradition in explaining how organizations learn. According to this literature, organizations reflectively *learn* by effectively *hearing* and *listening* to societal input (Jacobs & Coghlan, 2005; Pahl-Wostl, 2009). Organizations necessarily do so selectively, because people cognitively filter incoming information and interpret it according to underlying belief systems, so-called frames (Schön & Rein, 1994). Hearing, listening, and learning are capabilities. A capability is an organization's ability to observe ill-defined and contested problems and to act accordingly (Termeer et al., 2015).

More specifically, ***hearing*** is an organization's capability to detect societal back talk. For an individual, hearing is 'the physiological detection of auditory stimuli' (Yip & Fisher, 2022, p. 660), while for organizations, hearing is the detection of diffuse input from outside the organization's boundaries. Organizations can increase their hearing capability by expanding their network (Gieske et al., 2016; Lahtinen, 2013).

Listening is an organization's capability to constitute relationships with societal actors for intersubjective meaning generation (Jacobs & Coghlan, 2005). While a multitude of definitions of listening in organizational contexts exist, a common denominator is that listening 'is an interpersonal communication process that involves a *listener* receiving messages from a *speaker*' as well as 'responses that signal comprehension' (Yip & Fisher, 2022, p. 657, original highlighting). Whereas hearing is a precondition for listening by the detection of input, listening exceeds hearing because it involves the generation of meaning of this input between persons (Jacobs & Coghlan, 2005; Van Quaquebeke & Felps, 2018). Feedbacks in this sequence are possible, as listening to societal back talk can result in identifying blind spots concerning which actors are currently not being heard and a consequent network extension. Meaningful listening reaches the depth of fundamental values and tacit belief systems (Jacobs & Coghlan, 2005). Particularly valuable for organizations is listening to actors that sponsor divergent frames, which

enables exchanging perspectives across the boundaries of one's own cognitive frame (Schön & Rein, 1994).

Learning is an organization's capability for reflection and adaptation, if necessary (cf. Belle, 2016; Presbitero et al., 2017). Learning can be achieved in different depths. First-loop learning describes adaptations within current logics; second-loop learning describes adaptations of underlying logics themselves (Argyris & Schön, 1978). Third-loop learning means working towards adapting the context, which shapes underlying logics (Gerritsen, 2019; Hargrove, 2008; Pahl-Wostl, 2009). Learning experiences need to be stored in an organizational memory to not be forgotten when personnel within an organization shifts (Argyris & Schön, 1978). In an interorganizational context, listening is a precondition for learning, because knowledge needs to be transferred beyond organizational boundaries. Learning must therefore include the ability to share knowledge across different groups (cf. Presbitero et al., 2017). Also in this sequence, a feedback is possible, since organizations can learn to improve their hearing and listening capabilities.

Table 4.1 contains an overview of the three capabilities, their key *processes* (what organizations do), and *preconditions* (what enables organizations to do).

Table 4.1 *Key processes and preconditions of organizational hearing, listening, and learning capabilities.*

Capability	Processes	Preconditions
Hearing	Detection of back talk	• Network outside of cluster boundaries
Listening	Interpersonal generation of meaning	• Hearing • Meaningful relationships with actors beyond the cluster organization
Learning	Reflection and implementation of required adaptations	• Listening • Ability to share knowledge across and beyond organizational boundaries • Organizational memory

4.4. Materials and methods

To empirically anchor the outlined conceptualization, we empirically explored processes and preconditions of hearing, listening, and learning from societal back talk by bioeconomy TH clusters. We did so in three different cases of TH clusters (see Table 4.2) that all had some form of media exposure. In all clusters, actors from industry, local government, and research collaborated on the transition from fossil to bio-based industries in the EU. The selected cases concern three TH clusters facilitating three different forms of bioeconomy projects in three different EU member states that operate in three different stages of

development at the time of writing: (1) a transition towards green chemistry around multiple bio-based raw materials on Chemistry Park Delfzijl (the Netherlands) with several operating industrial installations; (2) a large-scale factory to produce bio-based chemicals (a so-called biorefinery) in a former petrochemical region in Leuna (Germany), which is planned to operate in the near future; and (3) a knowledge-based bioeconomy and renewable energy hub hosting several pilot installations for organic waste treatment and dairy by-product refining on a former mining site in Lisheen (Ireland) in the early stages of development with no operations on industrial scale taking place. This diversity allowed us to study the content of back talk that arises for projects across a range of raw materials, process technologies, and products as well as in different development phases, and how TH clusters with different degrees of institutionalization deal with this back talk. This will help to contextualize the different processes and preconditions for hearing, listening, and learning.

Table 4.2 *Overview of case characteristics.*

Cluster organization	**Involved actors**	**Connected bioeconomy project(s)**	**Operational phase**
Chemport Europe *(Northern Netherlands)*	*Industry:* Enterprises in the food, materials, chemicals, waste management, and energy sectors *Government:* Provincial administrations *Academia:* Five connected universities and universities of applied sciences	Chemistry parks; waste management projects; R&D facilities; knowledge campus	Established, expanding
Bioeconomy e.V. *(Saxony-Anhalt, Germany)*	*Industry:* Chemistry enterprises plus suppliers *Government:* Saxony-Anhalt state administration *Academia:* Three connected universities and universities of applied sciences; various private research institutes	Chemistry parks	Expanding; biorefinery about to become operational
Irish Bioeconomy Foundation *(Tipperary, Ireland)*	*Industry:* Enterprises in the food, biotechnology, and renewable energy sectors *Government:* County administration *Academia:* Nine connected universities, universities of applied sciences, and research institutes	Rehabilitation of a mining area by developing a renewable energy and bioeconomy hub	Conceptual, initial

We gathered three types of data (interviews, newspaper articles, and policy and planning documents) for different purposes. We conducted 23 in-depth *interviews* (Weiss, 1995) to understand how the bioeconomy projects have been developed in the different regions and how clusters deal with back talk. Accordingly, interviews centred around the development processes of the respective cluster and connected bioeconomy projects, relationships with societal actors, as well as the content of societal input. Supplementary Material B.1 contains an overview of interview partners. As the focus of this study is on TH organizations, we focused the interviews on the cluster organizations' management boards.

To identify the content of societal back talk, we also interviewed local actors that were not a collaborating partner in the TH cluster. In addition, we collected *newspaper articles* from the Nexis Uni data base. We used the key words "biorefinery" and "bioeconomy" in the respective languages, in combination with the specific region, the names of the cluster organizations, and involved companies.[4] In total, we collected 555 newspaper articles for Delfzijl, 309 for Leuna, and 74 for Lisheen. To contextualize this more localized back talk in the broader bioeconomy transition, we examined 24 *policy and planning documents*, see Supplementary Material B.2 for an overview. Documents were either found online or were provided by interview partners to further substantiate claims or clarify points that they made during interviews.

For the analysis of processes and preconditions for hearing, listening, and learning as well as for identifying societal back talk in each case, we conducted an interpretative analysis (Yanow & Schwartz-Shea, 2015). We coded the data thematically in Atlas.ti 22 for instances of what interview respondents experienced or newspapers reported as important events in the development of the projects. Furthermore, we coded for the content of back talk in interviews with societal actors and newspaper articles. In interview transcripts, we coded statements congruent with the assigned topics of hearing, listening, and learning. We identified codes arising from the interview data and categorized them into the defined topics (Weiss, 1995). During an initial round of reading, we constructed the coding scheme, which we provide in Supplementary Material B.3. In a second round, we congruently coded the material based on the coding scheme.

4.5. Results

We present the analysis results of the three cases by starting with a brief description of the respective TH cluster and the connected bioeconomy project(s). Next, we outline per case (1) the content of back talk and (2) the empirical anchoring of processes of and preconditions for hearing, listening, and learning capabilities.

4.5.1. Chemport Europe (the Netherlands)

Chemport Europe has the mission to foster a bio-based chemistry in the Northern Netherlands, one of the major projects being Chemistry Park Delfzijl. The approximately 1,400-hectares site traditionally hosted chemical industries valorising proximate salt deposits. Nowadays, the site transitions towards bio-based chemistry. The Chemport Europe TH cluster originates from a collaboration of the provinces of Groningen and Drenthe to stimulate green chemistry investments, following on from a report of a commission around former Shell president and senator Rein Willems (Dagblad van het Noorden, 31

4 For Delfzijl, the search string was ("Chemport Europe" OR "Chemiepark Delfzijl"), for Leuna: ((Bioraffinerie OR "Bio-raffinerie") AND (Leuna OR Sachsen-Anhalt OR "Sachsen Anhalt" OR UPM)), and for Lisheen: ((Tipperary OR Lisheen) AND (biorefinery OR bioeconomy OR "bio-based" OR biobased)). Articles published before April 24, 2023 were included in the analysis.

May 2019; NL11_G[5]). The cluster is a loosely organized network of businesses, research institutes, and the provincial administrations. The management board is seconded from the different partner organizations.

Back talk

Local back talk in this case has centred around accidents on site, for instance a fire of unknown cause and resulting smoke generation (e.g., Eemsbode, 7 December 2022). In addition to this, a regional newspaper reported environmental nuisances in the neighbouring village of Borgsweer, such as noise and odour emissions (Dagblad van het Noorden, 14 June 2013). In the same article, a local action group expressed concerns that small, surrounding villages have to bear the environmental costs, while the town of Delfzijl reaps the economic benefits. From the interviews with societal actors, we learned that recently, societal back talk also contains less local concerns. Installations on site are discussed because of their required energy demand as well as sustainability concerns about overseas shipments of bio-resources to be used for production (NL8_A). Hence, societal back talk in this case ranges from on-site safety issues to local environmental concerns and more regional or even global possible downsides of large-scale bio-based production.

Hearing

We conceptualized hearing as the process of detecting societal back talk, with the pre-condition of having a network that spans beyond the cluster's boundaries. In this case, we find that hearing is mostly restricted to the own cluster or to experts in the cluster's network.

When asked about hearing capabilities, interviewees referred to hearing and knowing about general public concerns due to their ***processes*** of reading newspapers, engaging on social media and because in rural regions, people know each other (NL6_G; NL8_A; NL9_I). However, interview partners pointed out that the diffuseness of the general public impedes their hearing capabilities. As one interviewee expressed: In contrast to organizations with an organigram, it is hard to pinpoint contact persons in the broader public (NL6_G).

In relation to this, interview partners mentioned several ***preconditions*** for hearing: transparency as well as equipped personnel who are able to hear concerns and extend the organization's network. Regarding transparency, collaborating partners stressed that to provide input, the public first needs to be informed transparently about operations on site (NL9_I; NL11_G). Actors involved in the cluster claimed to achieve transparency, for instance by elaborating newsletters, informing the local press, and engaging on social

5 These codes refer to analysed interview transcripts, see Supplementary Material B.1.

media (NL9_I). In addition to transparency, cluster partners pointed out that organizations also need sufficiently equipped personnel to hear public back talk. However, Chemport Europe is merely a bridging organization with limited resources:

> *"We aren't actively engaging with citizens who are worried. […] If that were the case, we'd be moving too far away from our core mission. It's a very flat, small organization. We already struggle to get our work done. That would then no longer be manageable for us." (NL11_G)*

Another precondition to hear is a network exceeding the cluster's boundaries. In this case, we find that apart from talks within the own cluster or the connected industrial ecosystem, networking outside cluster boundaries only stretches as far as expert symposia (NL4_G) or information evenings for the direct neighbourhood (NL8_A). Consequently, cluster partners only hear aspects restricted to technical issues and local emissions or incidents. As expressed by several interviewees, fundamental issues, such as the availability of bio-based raw material, are less discussed (NL2_I; NL5_G; NL6_G). One way to solve this, according to interviewees, is that public concerns should be brought in by involved partners, in particular from the academic and government helices (NL6_G; NL8_A; NL9_I).

Listening

We conceptualized listening as the two-directional process of generating meaning between persons, provided that relationships with societal actors are in place that enable the utterance of underlying beliefs.

In Delfzijl, cluster partners claimed to achieve a dialogue of sufficient depth by the ***process*** of trying to properly *understand* stakeholder concerns (NL6_G). However, in this case, cluster partners aimed at *informing* the public (NL2_I; NL9_I; NL11_G). Such one-directional communication channels with the broader public does not reach the level of fundamental values and leaves little room for critical back talk to surface. As one interviewee said: discussions centre around technical aspects (NL4_G). This is because actors professionally involved in the cluster organization stressed that emotional concerns should be clearly separated from evidence-based discussions (NL1_I). For instance, cluster partners experienced that citizens connect the circular materials transition with the energy transition, which would interfere a productive dialogue. One interviewee explained:

> *"On the energy side, the coal-fired power plant at Eemshaven is also in play, with the idea that you will first add biomass to it and eventually switch over completely. That is a discussion that really plays in the public. […] The discussion on the energy side is really conducted and very relevant. The materials discussion is much less of*

an issue, but the discussion is polluted by what is happening on the energy side." (NL9_I)

Interviewed TH cluster collaborators confirmed the value of forming long-term relationships by continuous dialogue and regard this as a crucial ***precondition*** to properly understand stakeholders (NL4_G; NL5_G; NL6_G; NL9_I). However, it is unclear who precisely is responsible for establishing such relationships. While cluster partners pointed at other involved helices (NL11_G; NL6_G), provincial government officers regarded the national government as responsible for collecting stakeholder concerns and forming a clear vision (NL6_G; NL11_G).

Learning

According to our conceptualization, learning consists of reflecting on what is heard and listened to as well as the implementation of necessary adaptations. Preconditions are the ability to share knowledge across and beyond cluster boundaries and an organizational memory to not 'forget' what was learned. In this case, we find that learning from societal back talk does not exceed first-loop adaptations of already established business models by gradually sharpening funding criteria.

For Chemport Europe, cluster partners attributed positive effects to collaborations that include multiple perspectives, enabling a reflection ***process*** by looking at a problem with a different lens (NL4_G; NL5_G). Based on insights from these reflections, interviewees involved in the cluster noted that research calls and funding criteria have been sharpened gradually (NL3_G; NL6_G). For example, a stronger focus on the sustainability of raw material harvesting and transport (NL10_I) as well as emissions, have been considered more in operations in Delfzijl:

"We're learning in the sense that we're well aware that sustainability is a must […] That you have to take steps towards emission reduction." (NL11_G)

An organizational memory is a ***precondition*** for continuous learning from the dialogue with the cluster's societal environment. However, in this case, insights are stored in dispersed organizational memories because the cluster is organized as an informal network. A lacking common organizational memory is indicated by an interviewee who pointed out that it is unclear whether adaptations are due to public pressure or an intrinsic motivation of involved organizations to change operations (NL9_I). Moreover, several interview partners felt that a predominant risk-averse mentality, in particular of investors, impedes further learning (NL1_I; NL2_I; NL5_G; NL7_I). This mentality undermines the feasibility of experimentation and to develop radically new business models (NL5_G).

In sum, we find that learning experiences in Delfzijl are spread across the various partner organizations and the connected industrial ecosystem. Particularly valuable is listening to actors sponsoring divergent frames. However, in this case, cluster partners mainly listen to experts sponsoring congruent techno-scientific frames. Instead of a two-directional dialogue, communication with the public is restricted to one-way communication, as involved actors fear a 'pollution' of discussions by emotional and apparently unrelated concerns. Although framed by cluster partners as being clearly separable, the bioenergy and -material transitions share fundamental similarities, for example value-based questions on the scale of consumption and the availability of raw material. Such fundamental concerns are not heard and consequently remain undiscussed. While the shift from fossil to bio-based production in general is a major adaptation of underlying production logics, linear take-use-dispose logics within bio-based production remain widely unchallenged within this cluster.

4.5.2. Bioeconomy e.V. (Germany)

Saxony-Anhalt in Eastern Germany has a long industrial tradition in the chemical sector. Currently, the region strives to become one of Europe's forerunners in developing a more sustainable chemistry sector, facilitated by the Bioeconomy e.V. TH cluster. One of the region's major chemical industry ecosystems is the 1,300-hectares Leuna Chemistry Park, where the multinational wood company UPM constructs a large-scale biorefinery. The biorefinery is planned to become operational in 2024 to produce the platform chemicals bio-monoethylene glycol (bio-MEG) and bio-monopropylene glycol (bio-MPG) out of local beech wood. The industrial ecosystem in Leuna is closely intertwined with the cluster organization, since directors of UPM and the chemistry park's infrastructure company are also board members of Bioeconomy e.V. The TH cluster is a formally registered association with an honorary management board consisting of seconded members from the different partner organizations. A state government representative is advisory committee member.

Back talk

Local back talk in Leuna concerns the scale until which sustainably sourced wood is available in the region (dpa, 17 August 2023; DE3_C; DE5_A), which is the biorefinery's envisaged raw material. When more industrial actors start demanding regional wood resources, this could cause shortages (DE3_C). Moreover, an interviewed politician who is not affiliated with the cluster pointed out that in the future, water availability might be limited for industrial processes due to climate change impacts (DE4_G). Furthermore, the chemistry park's high energy demand is under scrutiny in the context of the German energy transition (taz, 11 January 2019). In addition to these national and regional concerns, more local back talk concerns fears about a further spreading of the industrial park towards agricultural areas, which might lead to land use conflicts (DE4_G).

Hearing

In Leuna, interviewed cluster partners noted similar processes of hearing back talk as in Delfzijl. Also here, transparency was pointed out as a precondition for gathering back talk. However, interviewed cluster partners focused on scientific input, which restricts the range of heard actors and concerns.

In this case, cluster partners stated that they gather back talk by the ***processes*** of engaging on social media (DE1_I), organizing expert conferences (DE6_I), publishing a newsletter (DE2_I; DE6_I), by making sure to appear regularly in local newspapers (DE2_I), and by organizing open days and bus tours on site (DE2_I). Accordingly, an interviewee underlined that the Leuna Chemistry Park has an award-winning visitor centre (DE2_I).

Cluster partners in Leuna stressed the importance of a broad network, both within the cluster and beyond cluster boundaries as a ***precondition*** to hear societal concerns (DE2_I; DE5_A). Within the cluster, involved partners are assumed to bring in societal input (DE1_I; DE2_I; DE5_A). To also gather input from beyond the cluster's boundaries, partners underlined transparency as a requirement. As one interviewee argued:

> *"It's important to us […] to be maximally transparent with regard to our activities, otherwise it is difficult to build trust. At the same time, it's important […] to argue in a fact-based manner and to base our arguments on scientific foundations. In my experience, we can then succeed in convincing even really critical voices." (DE1_I)*

However, this focus on the 'fact-based' discussion also establishes a bias of whose input is heard. Resultingly, cluster partners noted that input from outside the cluster organization is restricted to experts, for instance from the state government or the municipal administration (DE2_I; DE7_G).

Listening

In Leuna, both cluster partners and societal actors noted a generally supportive attitude for large-scale chemical industry due to the region's long industrial tradition (DE2_I; DE3_C; DE4_G; DE7_G). According to cluster partners, this attitude forms the basis for an informed listening ***process*** (DE2_I). According to one interviewee who is not affiliated with the cluster, it is precisely the long-standing chemistry tradition and the public's attitude of not having unsubstantiated concerns that would allow for a more fundamental debate:

> *"We have enormous expertise in this [chemistry] sector, we have a high level of acceptance among the population for these topics […]. There isn't an attitude of: Chemical industry? We don't want that here! [We should] use this positively as a starting point for a real […] societal debate that weighs up also broader issues." (DE4_G)*

Based on this supportive attitude, cluster partners underlined the careful explanation of fact-based information to the public as a ***precondition*** for fruitful dialogue (DE1_I; DE5_A). To this end, cluster partners strived to broadly invite to thematic events and open days (DE6_I). However, societal actors experienced that these formats do not form fora to bring in critical statements about currently unresolved issues (DE4_G). Such issues include to what scale a bioeconomy is sustainable in the region as well as unclear impacts on land use and biodiversity (DE3_C; DE4_G; DE6_I).

Learning

In Leuna, several adaptations have been implemented, although it is not always clear if this is a consequence of learning from societal back talk or rather a matching of public concerns with business adaptations that would have been implemented anyway.

According to an interviewee, adaptation ***processes*** include the introduction of a sourcing radius for utilized wood of 250 kilometres around the biorefinery (DE1_I). Although this measure could function to address broader societal concerns that biorefinery wood demand could cause tropical deforestation, a critical interviewee noted that the motivation to implement this measure could also be to prevent even stricter regulation (DE4_G). As another adaptation, the installation runs on beech wood residues from production forestry management (DE2_I; DE5_A; DE6_I), matching overarching political strategies in Saxony-Anhalt (Saxony-Anhalt State Government, 2021a,b). As an interviewee explained:

> *"[The biorefinery] uses beech wood that comes from forestry management. […] Beech wood is unsuitable as construction wood because it swells too much. So up to now, two-thirds of it ends up in the fireplace. […] It's precisely the demand for this beech wood that promotes forest conversion and makes forests more resilient to drought and pest infestation. In this respect, there is no fear that forests will be cut down. Rather, the forest will be strengthened." (DE2_I)*

However, another interviewee highlighted that this adaptation only partly addresses fundamental concerns, because reflections on future use conflicts lack:

> *"UPM itself says that they aim to use wood that is currently rarely used […]: thinning wood, crown wood, which isn't really interesting for the construction industry... This is in principle good and correct and can also help to overcome scepticism. [...] The question is whether the quantities that UPM needs can actually be obtained sustainably from the region. […] This will become more acute when UPM is not the only actor that focuses on a bioeconomy." (DE4_G)*

Sharing knowledge beyond cluster boundaries as a ***precondition*** for learning is restricted in this way. Since fora for fundamental discussions lack, societal actors cannot channel back their perspectives on how established adaptations fail to fully address fundamental concerns (DE4_G). As a result, divergent views between cluster partners and societal actors remain conflicting on whether implemented adaptations form learning successes.

In sum, also in this case, actors involved in the TH cluster focus on informing the public instead of seeking back talk. Cluster partners stress that dialogue needs to be fact-based, meaning a focus on their own techno-scientific framing. While this fact-based information might help to create a common language for mutual understanding, it also has exclusion effects, which limit the range of heard societal actors. Consequently, broader public concerns regarding the scale of production and possible future conflicting uses of limited wood resources are left unaddressed.

4.5.3. Irish Bioeconomy Foundation (Ireland)

To rehabilitate the site of a former zinc and lead mine, the Irish Bioeconomy Foundation aims to facilitate the establishment of a bioeconomy and renewable energy campus in Lisheen, a remote site in Northern Tipperary. Mining operations ceased in 2015 and a task force initiated a closure plan. The approximately 455-hectares site currently hosts renewable energy projects and bio-chemistry pilot installations. In the near future, cluster partners hope to attract further projects. Envisaged raw materials include dairy by-products, residual organic waste, and agricultural waste. Planned products entail energy, biogas, biochemicals, and nutritional goods. The cluster organization has a salaried Chief Executive Officer and a management team. Member organizations are corporate partners, universities, and Tipperary County Council, the regional administration. As such, Tipperary County Council has fragmented roles as cluster partner on the one hand and permit and planning authority on the other hand. Different departments take on the separate roles.

Back talk

In Lisheen, local back talk is scarce at the current stage. An official submission to a current planning process on site contained questions about expected traffic volumes and what forms of waste will be used (Tipperary County Council, 2022). Arguably due to the site's remote location, neighbourhood concerns about local environmental nuisances have not surfaced so far. Nationally, in particular the dilution of bio-methane with fossil gas in the national gas grid is discussed. In this vein, an environmental organization pointed out that this practice could lock-in grid infrastructure and perpetuate fossil gas use (An Taisce, 2020). Similarly, an interviewee feared that valorising dairy by-products could contribute to unsustainable scales of cattle farming (IE4_C). More generally, the interviewee stressed that just because a product is bio-based, it does not mean that it is more circular or sustainable: Single-use packing remains wasteful, even if it is bio-based (IE4_C). While

local back talk is scarce in this case, the bioeconomy in general is discussed controversially on national level.

Hearing

In this case, hearing societal back talk is restricted to formal planning procedures, with limited public attention and participation. Cluster partners in this case claimed to hear societal concerns in a similar fashion as in the other cases, namely by ***processes*** of being attentive of local newspaper reports, social media, and participating in expert consortia (IE3_I). In the other two cases, responsibilities for societal dialogue were unclear. In this case, this task was clearly concentrated in the cluster management.

In the other two cases, cluster partners underlined the value of transparency as a precondition for hearing back talk. In Lisheen, TH developers rather sticked to fulfilling minimum notification requirements for permitting processes. This is because current plans to hear public back talk centred around invited public participation: Neighbours may participate in formal planning procedures, for instance by means of formal objection procedures (IE1_G; IE2_G). However, participation in these procedures remained limited. An interviewee attributed this to the lacking tangibility of developments on site:

> *"It's very hard for the public to engage, where they can't find something tangible, what this means to them on the ground. […] Trying to roll out these very high-level policies that mean nothing to an ordinary Joe Soap until there's something happening on the ground in proximity to him is very, very difficult" (IE1_G)*

Listening

In this case, local actors voiced high hopes for the ***process*** of establishing a spatial master plan for the site:

> *"We have […] an objective to prepare a master plan for the campus. […] There are multiple landowners, multiple stakeholders... […] It needs to have engagement and it needs to have buy-in. That hasn't been done to date. And it's actually one of the key issues […] that we don't have a very coherent master plan." (IE1_G)*

However, as the project concerns a national flagship project, interviewees not affiliated with the TH cluster stressed that discussions would also require reflections on where the Irish bioeconomy should head to more fundamentally (IE1_G; IE4_C). If the planned approach remained restricted to spatial aspects, this would be insufficient to discuss underlying, fundamental concerns. To achieve a more meaningful dialogue, several interviewees regarded a clear national bioeconomy vision as a ***precondition*** (IE1_G; IE3_I).

Learning

At the current, early stage of development, reflection and resulting adaptations have remained limited in Lisheen. So far, reflection ***processes*** have not involved an exchange of conflicting visions between cluster management, the county administration, and the general public on the future of the site:

> *"Where there was a lack of discussion: While it was discussed at a higher level, the finer detail of a discussion around the master plan should have taken place and that should have been driven by the former mining operator. […] Further discussion around that would have possibly accelerated the process more." (IE3_I)*

To address this, cluster partners aimed to achieve tangible results as a ***precondition*** to stimulate dialogue with the general public. However, and perhaps paradoxically, partners felt that lengthy objection procedures during the planning process could impede the development of tangible results (IE3_I).

In sum, we find that conflict smoulders in mismatching, but undiscussed perspectives regarding the site's future. On the one hand, project developers aim at producing fast, tangible results and therefore have an incentive to be less restrictive on what initiatives settle on site. On the other hand, the county administration has the ambition to develop a national forerunner project. For this end, the county administration targets initiatives that develop activities higher on the ladder of circularity, requiring to be more selective on what initiatives operate on site.

4.6. Discussion and concluding remarks

This chapter started with the aim of exploring how bioeconomy TH clusters deal with societal back talk. Table 4.3 summarizes our results for the individual cases. Across the analysed cases, we find that cluster partners actively create a public of 'outsiders' by centring the debate around technical issues and disregarding emotional and fundamental concerns as unscientific or unrelated. As a consequence, cluster partners become 'insiders', who do not hear uninvited back talk that scrutinizes and challenges their tacit belief systems. Rather, 'insiders' focus on informing 'outsiders' about what they perceive as benefits of their projects. By this one-directional approach, listening is limited to issues that are already known within the cluster and can be answered by informing about technical adaptations. Fundamental issues, such as interlinkages with the energy transition (Delfzijl), future use conflicts about woody raw materials (Leuna), or what initiatives should settle on site (Lisheen) remain largely unaddressed. Learning from uninvited input is therefore restricted to single-loop adjustments. In shifting the resource base from fossil to bio-based, fundamental logics, such as linear extract-use-dispose production and unsustainable demand scales, are left undiscussed.

Table 4.3 *Hearing, listening, and learning capabilities in analysed cases.*

	Delfzijl	**Leuna**	**Lisheen**
Content of back talk	On-site safety issues; local concerns about environmental nuisances; regional and global possible downsides of large-scale biorefining.	Local concerns about land use conflicts; regional and national concerns about the sustainability and volume of required wood resources, water availability, and energy demand.	Local questions about expected traffic volumes and waste treatment; broader concerns about locking-in fossil gas infrastructure and unsustainable scales of cattle farming.
Hearing	*Processes:* (Social) media engagement.	*Processes:* (Social) media engagement; expert conferences.	*Processes:* (Social) media engagement; expert consortia.
	Preconditions: Heard network is restricted to the direct neighbourhood and expert circles. Cluster partners add transparency and equipped personnel as further preconditions.	*Preconditions:* Focus on techno-scientific aspects limits the range of heard actors. Cluster partners highlight transparency as paramount to build trust.	*Preconditions:* Limited to formal objection procedures in spatial planning processes; impeded by low tangibility of on-site developments.
Listening	*Processes:* One-directional public information around technical aspects does not reach the level of underlying concerns.	*Processes:* Supportive public attitude is regarded as beneficial for conducting an informed dialogue.	*Processes:* High hopes in master plan to stimulate dialogue, but concern that this plan is restricted to spatial aspects and cannot reach the level of underlying issues.
	Preconditions: Unclear responsibilities for establishing 'listening relationships'.	*Preconditions:* Cluster partners view the careful explanation of fact-based information as base to form relationships. However, societal actors point out that fora lack to discuss fundamental issues.	*Preconditions:* Cluster partners point at national government to deliver a clear bioeconomy vision.
Learning	*Processes:* Single-loop learning by sharpening funding criteria.	*Processes:* Several adaptations: sourcing radius; beech wood as raw material to stimulate forest diversification.	*Processes:* Lacking reflection on conflicting visions about who settles on site.
	Preconditions: Organizational memory is scattered across organizations. Cluster partners add that the risk-averse mentality of investors impedes further learning.	*Preconditions:* Limited knowledge sharing beyond cluster boundaries, resulting in a restricted reflection on societal concerns.	*Preconditions:* Cluster partners regard tangible results as necessary to stimulate dialogue.

Our empirical findings help sharpening the conceptualization of organizational hearing, listening, and learning capabilities, which we have developed by building on organizational learning literature (e.g., Argyris & Schön, 1978; Jacobs & Coghlan, 2005; Pahl-Wostl, 2009). Regarding *hearing* in TH organizations, cluster partners in Delfzijl and Leuna pointed out that transparency and sufficiently equipped personnel are additional preconditions for the conceptualized precondition of networking beyond cluster boundaries. In Lisheen, however, cluster partners are hesitant to exceed minimum transparency requirements because they fear that formal objections could further delay planning processes.

Listening involves deepening established communication channels towards value-based discussions. Achieving this depth requires commitment towards longer-term relationships. Moreover, instead of listening only to actors with uncritical or coherent perspectives, we have specified that TH collaborators need to actively seek actors sponsoring divergent frames and not avoid conflict. Innovative potential lies precisely in appreciating multiple, plural, and diverse perspectives. Our results indicate that a one-way sending approach does not suffice to expose bioeconomy projects to such critical perspectives.

To achieve *learning* effects, TH organizations need not only to task personnel and commit to long-term relationships, but also to institutionalize processes for structural and continuous reflection and improvement. Our results underline that the value of this learning process lies in the reciprocity with the public. For instance, being transparent as cluster partners enables uninvolved societal actors to utter back talk that is targeted to the specific operation. By listening to the cluster organization's reaction, societal actors learn what relevant issues are not yet discussed in relation to the specific project. Hence, learning is bidirectional: Cluster partners and societal actors continuously learn by listening to each other. Cluster organizations point towards involved helices as being responsible for and capable of organizing learning processes. However, not gathering learning experiences in the organizational memory of the cluster organization itself holds the risk that learning experiences remain dispersed across the various partner organizations.

This study contributes to the sustainability science literature by offering a novel perspective on the governance instrument of collaborative innovation clusters. For these collaborations, we point out the value of not only considering invited participation, but also uninvited societal input. This is required because also collaborations organized as a TH (without a helix representing the public) inevitably have to operate within a societal environment. Dealing with back talk from this societal environment in collaborative innovation projects is not a mechanistic process, but inherently political. In our cases, cluster partners – intentionally or not – work towards closing down the debate towards a biased perspective of what arguments are regarded as valid. This is done by dismissing concerns based on emotions or values as unscientific and not evidence-based. By steering

the discussion towards techno-economic aspects and imposing according standards, project developers exercise power over ideas (see Carstensen & Schmidt, 2016). Closing down discussions about how publicly fostered innovation processes align with societal sustainability missions towards technical issues and techno-economic knowledge misrepresent messy and ambiguous political process as value-neutral, objective, and analytical (Dorren & Wolf, 2023). This makes projects seem less controversial because fundamental concerns are not discussed (Stirling, 2008). As a consequence, cluster 'insiders' create supportive publics of 'outsiders', which hinders surfacing fundamentally different, value-based concerns (Chakraborty & Pandey, 2023). This impedes learning in a self-enforcing dynamic. A closed-down discussion leads to limited learning, which further diminishes opportunities to open up the discussion again. In this vein, decisionmakers in TH clusters should not avoid societal back talk, but regard it as an opportunity to surface undiscussed, fundamental issues.

Regarding the scholarship on the governance of the European bioeconomy transition, our findings further substantiate how the identified discursive lock-in towards techno-economic modernization pathways in broader discussions (Simoens et al., 2022; Starke et al., 2023) institutionalizes also in concrete projects. This is because cluster partners deal with societal input selectively, with a bias towards less critical, easily 'repairable' input. Arguably, closing down public debates towards technical issues favours adjustments that remain near to linear status quo practices. Instead of debating fundamental issues, such as how to reduce demand for energy and material or the distribution of the limited pool of available bio-based resources, the debate centres around technological optimization (see also Bogner & Dahlke, 2022). Innovation projects might therefore remain near to status quo ways of thinking and doing with less potential for more transformative solutions. These findings contribute to illuminating why the bioeconomy transition might fall short on its transformative potential regarding its sustainability and circularity promises (Ahola-Launonen & Kurki, 2022; Eversberg, Koch, et al., 2023; Lühmann & Vogelpohl, 2023; Ramcilovic-Suominen, 2022). In this sense, our analysis constitutes a further step in acknowledging the innovative power of controversies for a more transformative bioeconomy transition. These insights are not only of societal interest, but also prudent for bioeconomy innovators to consider: When fundamental issues are left unaddressed in early stages of innovation projects, controversies might surface at later stages, where negative effects are more tangible and public attention is higher. However, as the development process of bioeconomy projects continues, costly solutions are locked-in and adaptations towards alternative pathways are less feasible.

In addition to these contributions, our analysis also has limitations. The starting point of our interviews were cluster partners, in particular the management boards of analysed TH clusters. To assess the content of back talk, we referred to newspaper articles, policy

documents, and a limited range of interviewed unaffiliated actors. This approach does not allow conclusions about the extent of societal back talk in analysed cases. Future studies could study the back talk of a broader range of uninvolved societal actors. Due to a challenging identifiability of these actors, broader research designs would need to be applied, for instance surveys or social media studies. Moreover, we demarcated our analysis to bioeconomy TH clusters, which are particularly interesting due to the complexity of the bioeconomy transition and the range of back talk that includes localized concerns, but also broader input regarding the desirability and directionality of the bioeconomy transition. However, also other forms of collaborative innovation projects are relevant for exploring how societal back talk contributes to innovation. Beyond the bioeconomy transition, identified patterns might be relevant for adjacent sustainability transitions as well, for instance in the energy, mobility, food, or water management sectors. Further (comparative) analyses could contextualize our findings for other forms of collaborative innovation endeavours and in other sustainability transitions.

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5

Chapter 5

Learning from controversies in research and innovation

Abstract

The European Union has spent roughly half a billion EUR on European Training Networks within the Horizon 2020 framework. This framework – and its successor, Horizon Europe – aim to align research and innovation with societal missions to tackle sustainability challenges, such as the depletion and problematic use of fossil resources. One of the training networks funded under the Horizon 2020 framework is the AgRefine project on next-generation biorefineries in a circular bioeconomy, in which I took part myself. In light of the significant funding steered towards these training networks and their assigned role in addressing pressing sustainability challenges, the question arises of what participants in these networks learn and how this aligns with societal input on the sustainability challenges at stake. To tackle this question, I report on a collaborative reflection process, co-generated with the participants of the AgRefine project. By means of a learning history, my colleagues and I disentangle processes of how we managed (but also failed) to hear, listen to, and learn from different publics affected by the project's innovation process. These publics are (1) involved researchers, (2) societal partner organizations, and (3) the broader public. Results demonstrate that involved PhD researchers have developed a more nuanced perspective on the role of biorefineries in the transition towards a circular bioeconomy, resulting in adaptations of fundamental research questions and approaches. This learning was achieved by forming relationships that enabled researchers to listen to societal input, either directly, or to translations of this input by their peers. However, mismatches in timing research outcomes and conflicting expectations within the project obstructed further learning from interdisciplinary collaboration. Results indicate that to spark research and innovation that is more responsive to societal input, funding agencies need to allow more flexibility in deviating from pre-defined project goals. Involved researchers and partner organizations can develop and foster hearing, listening, and learning capabilities to become more responsive to societal input that contributes to the alignment of research and innovation projects with their societal missions.

5.1. Introduction

The current Horizon Europe framework and its precursor Horizon 2020 are key instruments of the European Commission in funding research and innovation projects. As governance tools, the Horizon frameworks navigate scientific innovation towards addressing societal missions defined by European Union (EU) institutions. One of these missions is the development of a sustainable and circular bioeconomy (European Commission, 2018). A bioeconomy entails the substitution of products made from fossil oil and gas resources, such as energy, chemicals, fuels, pharmaceuticals, or cosmetics, by bio-based alternatives (McCormick & Kautto, 2013). While EU policymakers widely cherish this transition as a suitable answer to tackle climate change and the (geopolitical) dependency on fossil resources, it is also controversial (Starke et al., 2023). Critics, for instance, question the potential of a bioeconomy to actually decrease greenhouse gas emissions (Zabaniotou, 2018), highlight environmental and social trade-offs (Riemann et al., 2022), the manifestation of injustices (Hamilton & Ramcilovic-Suominen, 2023), and criticize the perpetuation of the unsustainable economic growth paradigm (Eversberg, Koch, et al., 2023; Ramcilovic-Suominen & Pülzl, 2018).

Within the Horizon 2020 programme, the EU has spent 445,126,591 EUR on funding European Training Networks (European Commission, 2023). These training networks 'aim to train a new generation of creative, entrepreneurial and innovative early-stage researchers, able to face current and future challenges' (European Commission, 2023). One of these training networks is the *AgRefine* project, of which I am part myself. AgRefine has the objective to 'train PhD students to become bioeconomy leaders and position Europe as the global leader in an agri-bioeconomy industry based on advanced biorefinery technologies' (CORDIS, 2023). Advanced biorefinery technologies are industrial processes to produce a series of bio-based products (Cherubini, 2010) and as such considered by EU policymakers as a key technology to advance the bioeconomy transition (European Commission, 2018; Parisi, 2020).

To ensure that publicly funded research and innovation aligns with targeted sustainability challenges, Responsible Research and Innovation (RRI)[6] is a key funding principle in Horizon frameworks (Gemen et al., 2015; Owen et al., 2021; Tabarés et al., 2022). RRI refers to 'a transparent, interactive process by which societal actors and innovators become mutually *responsive* to each other […] [regarding the] societal desirability of the innovation process and its marketable products' (von Schomberg, 2011, p. 9, highlighting added). In particular, this responsiveness between innovators and societal actors is a key element of RRI (Rödl et al., 2022; Stilgoe et al., 2013). As such, responsiveness is an

6 RRI has emerged from discussions on the governance of innovations on the level of the European Union (Owen et al., 2012). The concept of Responsible Innovation (RI) has more academic origins (Rödl et al., 2022). Nevertheless, both concepts refer to a better responding to societal values in research and innovation practices alike. In this contribution, I therefore refer to RRI and RI interchangeably under the label of RRI.

adaptive learning process that entails the 'capacity to shape or direction in response to stakeholder and public values and changing circumstances' (Stilgoe et al., 2013, p. 1572).

Against the background of the amount of public funding directed to this form of training as well as the urgency of sustainability challenges to be addressed by Horizon-funded research and innovation, the question arises of what this 'new generation of creative, entrepreneurial and innovative early-stage researchers' (European Commission, 2023) learns in these training networks; in particular, how this knowledge relates to the fulfilment of the sustainability missions targeted by the Horizon frameworks.

This societal question is also of academic relevance. This is because despite the prominent role of the responsiveness principle in Horizon frameworks, recent research has pointed out that Horizon-funded research projects frequently struggle to implement stated RRI principles (Tabarés et al., 2022). To become more responsive, current RRI practices frequently aim to open up research and innovation processes beyond the input of formal project participants (Schuijff & Dijkstra, 2020). This is because in addition to invited input, also publics of societal actors who are not formally involved in the research projects, utter input (Genus & Iskandarova, 2018). Instead of targeted and invited, this input is diffuse and uninvited (Cuppen, 2018; Wehling, 2012). In spite of intentions and attempts to open up RRI practices, many research projects still fail to become responsive towards these broader, societal concerns (Rödl et al., 2022). Taken together, the knowledge gap is that processes are underexplored of how researchers in Horizon-funded research and innovation projects can become (more) responsive towards uninvited societal input.

To this end, I ask in this chapter: *To what extent and how have AgRefine PhD researchers heard, listened to, and learned from input from the different publics affected by the network's actions?* To identify processes and preconditions of how involved PhD researchers have managed – but also failed – to become responsive to input from the different publics affected by the AgRefine project, I have constructed a learning history together with all PhD researchers who have been involved in the AgRefine project. A learning history is a collaborative narrative of learning moments (Roth & Bradbury, 2008; Roth & Kleiner, 1995). To disentangle response processes, I draw on the conceptualization of organizational hearing, listening, and learning capabilities developed in Chapter 4. Unravelling these processes helps identifying entry points of how the responsiveness of EU-funded research towards societal input can be increased and what related pitfalls are.

5.2. Background: The AgRefine project

The AgRefine project was funded under the Horizon 2020 scheme as an interdisciplinary Marie Skłodowska-Curie Innovative Training Network (CORDIS, 2023). The project's paramount goal was to train 15 PhD students in the field of advanced biorefinery

technologies to foster a circular bioeconomy (CORDIS, 2023). To achieve its objective, AgRefine strived to integrate the work of 15 PhD researchers with diverse disciplinary backgrounds, ranging from (bio-chemical) engineering, to industrial and ecological economics, and political sciences (AgRefine, 2020). Within the project, these PhD students are referred to as Early-Stage Researchers (ESRs). ESRs are supervised by eight Principal Investigators (PIs) and several co-supervisors. Supplementary Material C.1 contains an overview of the 15 ESR projects.

The core of the training programme was a conceptual research and innovation process to advance different parts of biorefinery technology. To this end, the project grant agreement outlined a so-called Three-Phase Bioreactor to produce organic acids by fermentation as well as biogas in an anaerobic digestion process, based on ensilaged or fresh grass and seaweed (Ramonet, 2021). Moreover, the project contained the development of novel process technologies in the fields of biosensors, membranes, downstream purification, mass flow simulation, and bioreactor design. To accompany this technical work package 1, two broader work packages aimed to contextualize the research and innovation process in the circular bioeconomy transition. Work package 2 on systems-level design entailed life cycle analysis and supply system planning to avoid trade-offs on the broader bioeconomy system level. Work package 3 on value chains focused on overarching policies, market uptake, and business models.

These divergent work packages required bringing together and integrating the work of the different ESRs with different disciplinary backgrounds. With the aim of integrating knowledge of involved researchers from divergent disciplinary backgrounds, AgRefine had an interdisciplinary ambition. Interdisciplinary research projects integrate the different involved disciplines into own methodologies and concepts (Lawrence et al., 2022). In contrast, multidisciplinary research projects entail collaborations of researchers from different disciplines without integration of the diverse backgrounds (Hoes et al., 2008). To fulfil these objectives, the AgRefine training network entailed several educational opportunities, for instance five training weeks and secondments with AgRefine partner organizations for all ESRs.

In addition to the involved researchers, the AgRefine network included societal partner organizations, which are explicitly named in the grant agreement (AgRefine, 2020; CORDIS, 2023). Examples of these partner organizations are bio-technology companies, a regional government agency, and a European biogas producers' association. These partners were involved in the training programme by providing elements of the training weeks and by offering secondment opportunities for the ESRs. Apart from involved researchers and societal partner organizations, also the broader public is affected by the project's actions. This is because the technologies designed in the individual research projects impact

bioresource supply chains (relevant for primary producers), product properties (relevant for consumers), and more broadly shape the course of the circular bioeconomy transition (relevant for society in general). To underline the relevance of the broader public for the training network, AgRefine contained a work package with specific actions on dissemination, communication, and outreach activities. For instance, AgRefine had a Twitter account and ESRs wrote regular blog articles for the AgRefine website.

5.3. Conceptualization

This chapter has the goal of identifying how researchers within the Horizon-funded AgRefine project have become responsive to input from the different affected publics. My main conceptual argument is that research and innovation projects need to become responsive not only towards formal participants, but also towards more diffuse, uninvited input to fulfil their societal mission. To substantiate this argument, I first provide a short background on the responsiveness concept, drawing on RRI literature. To clarify *to whom to be responsive*, I subsequently outline three different publics affected by research and innovation projects. To explain *how to be responsive*, I then shortly recapitulate my previous conceptualization of hearing, listening, and learning capabilities in Triple Helix clusters and adapt it to the context of research and innovation projects.

5.3.1. Responsiveness in interdisciplinary research

Responsiveness is 'an iterative, continuous and flexible process of adaptive learning' (Owen et al., 2012, p. 755). For the context of research on emerging technologies, RRI includes deliberative approaches to direct innovation towards addressing societal challenges and to identify possible outcomes and trade-offs in this regard (Burget et al., 2017; Owen et al., 2012; von Schomberg, 2013). Instead of being limited to introspective reflection of the innovator, responsiveness therefore focuses on relationships (Nielsen, 2016).

Responsiveness is one of the key RRI dimensions suggested by Stilgoe et al. (2013), in addition to anticipation, reflexivity, and inclusion. Anticipation describes the intention to identify (in particular, harmful) implications and consequences of novel technologies and research ex ante; reflexivity means remaining critical about one's research activities and underlying assumptions; and inclusivity describes efforts to organize participatory processes that include new perspectives on ends and means of the innovative projects (Stilgoe et al., 2013).

In contrast to the other RRI principles, responsiveness does not only require inclusive and anticipatory deliberation but also that this deliberation results in actual adaptations of the research and innovation process. As such, responsiveness implies that divergent perspectives should not only be regarded but actually have an impact on shaping the research and innovation process, thereby also establishing a co-responsibility for its

outcomes (Owen et al., 2012; Stilgoe et al., 2013). This includes being attentive to changes in the external environment that require adjustments of the research and innovation process, also after the development of an innovation is finished and implementation began (Lubberink et al., 2017).

To enable self-critical innovation processes, responsiveness must not only include actors that think in a similar way as the innovators. On the contrary, RRI scholars regard radically different stakeholder perspectives as particularly valuable for learning (Blok, 2014). Indeed, restricting participation to uncritical publics results in creating a form of pseudo-responsiveness that only reproduces the innovators' thinking and thereby hinders learning (Chakraborty & Pandey, 2023). This raises the question to whom the AgRefine project can be responsive.

5.3.2. Responsive to whom? Different involved publics

Three different publics are affected by the project's actions, see Figure 1. The *first public* consists of the involved researchers. These are the ESRs, who are PhD candidates at beneficiary universities or research institutes. In addition to ESRs, involved researchers are their supervisors and the PIs, in their roles as promotors or main supervisors of involved ESRs. Both Horizon 2020 (European Commission, 2011) and Horizon Europe (Directorate General for Research and Innovation, 2021) strongly encourage partnerships with private and public partners from society. These partners form the *second public*. Societal partners are explicitly named in the grant agreement, for instance as secondment or training providers. The *third public* consists of the broader public, which could be every person or organization affected by or with an interest in the research topic or innovation at stake. In contrast to societal partners, actors of the third public are not listed in the grant agreement. These three publics are affected by the actions produced by the research and innovation networks and as such commonly form the core of the AgRefine programme.

Presented here analytically as distinct publics, boundaries between the different publics are blurry. Individual persons can take on different roles throughout the project. For instance, an ESR can become part of a societal partner organization during a secondment or actors from the broader public could be integrated into the consortium and thereby become societal partners throughout the project's duration.

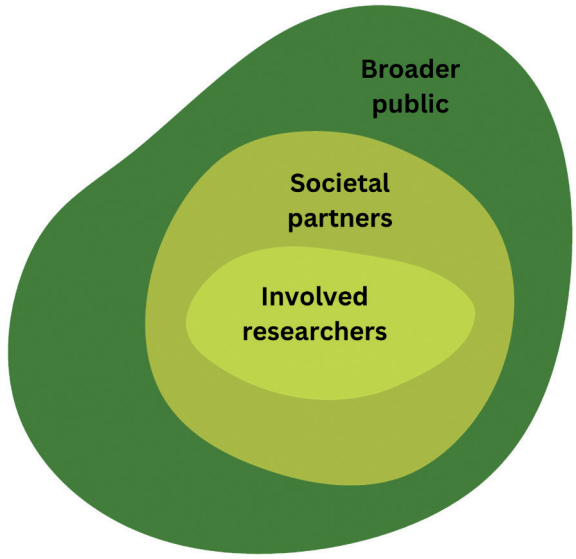

Figure 5.1 *Three different publics affected by the AgRefine project.*

The literature on collaborative research has carved out how *involved researchers* interact with each other as well as how researchers interact with involved societal partners (Bozeman et al., 2013; Cummings & Kiesler, 2005; Ju et al., 2022; Patel et al., 2012; Slade et al., 2023; Verwoerd et al., 2020). Researchers collaborate based on good, professional relationships. These relationships are relatively equal, based on congruent knowledge systems, beliefs, and interests (Ju et al., 2022). Relationships between involved researchers and societal partners, in contrast, are less symmetrical.

Societal partners have different needs, interests, and resources (Cummings & Kiesler, 2005). Also in the AgRefine project, instead of regular contacts, interactions between researchers and societal partners were less frequent and widely restricted to fixed periods, such as secondments.

In contrast to relationships between the first two publics, which are thoroughly examined, research lacks on interactions between involved researchers and actors from the *broader public* (Adomako & Tran, 2022). Unlike the first two publics, the broader public is not formally part of the collaborative research project. Actors from the broader public can be invited to provide input, for example by feedback rounds, surveys, or public consultation processes. However, invited participation likely results in input that is close to the perspectives already present in the project, as project partners define what actors are invited to participate, likely including actors with congruent perspectives.

In addition to this invited input, stakeholders can also provide uninvited input (Wehling, 2012). For instance, protests or engagement on social media are forms of uninvited participation (Cuppen, 2018). As pointed out in Chapter 4, this input can be critical, but also laudatory, or indifferent. While input from research partners is targeted towards the precise project, uninvited input from the broader public is more diffuse and hence less readily available for project partners. In addition to invited participation, uninvited input might bring in fundamentally new perspectives, in particular critical ones that scrutinize the perspectives held by project partners. Involved researchers can learn from these divergent perspectives, for instance to anticipate impacts of their innovations that project partners are currently unaware of (Rip, 1986).

5.3.3. How to be responsive? Hearing, listening, and learning capabilities

Having highlighted the relevance of the responsiveness concept for interdisciplinary research and innovation projects as well as whom researchers within the AgRefine project can be responsive to, I now turn to the question of *how* researchers within a research and innovation project can be(come) more responsive. To this end, I adopt the conceptualization of organizational hearing, listening, and learning capabilities developed in Chapter 4. My main conceptual argument in this contribution is that researchers can become more responsive by learning to deal with both invited and uninvited input from the different affected publics, based on hearing a broad network of formally involved and uninvolved societal actors and forming long-term listening relationships.

According to the adopted conceptualization, actors within organizations can deal with societal input by a sequence of hearing, listening, and learning, see Figure 2. *Hearing* entails the sensing of diffuse societal input. By broadening the network of an organization, more actors and their perspectives can be heard (Gieske et al., 2016; Lahtinen, 2013). *Listening* exceeds hearing and means establishing relationships to generate meaning (Van Quaquebeke & Felps, 2018). Listening is relational because it entails both the sending of messages but also responding signals of comprehension (Yip & Fisher, 2022). Reaching the level of underlying perspectives and tacit beliefs requires trustful, long-term relationships (Jacobs & Coghlan, 2005). *Learning* is then to reflect on what is understood and to adopt necessary adaptations. This step therefore entails the response to sensed and understood input. Learning can reach different depths. First-loop learning means adapting practices within established logics (Argyris & Schön, 1978). Second-loop learning means changing these underlying logics themselves (Argyris & Schön, 1978). Third-loop learning then means to adapt the context that shapes underlying logics (Hargrove, 2008; Pahl-Wostl, 2009).

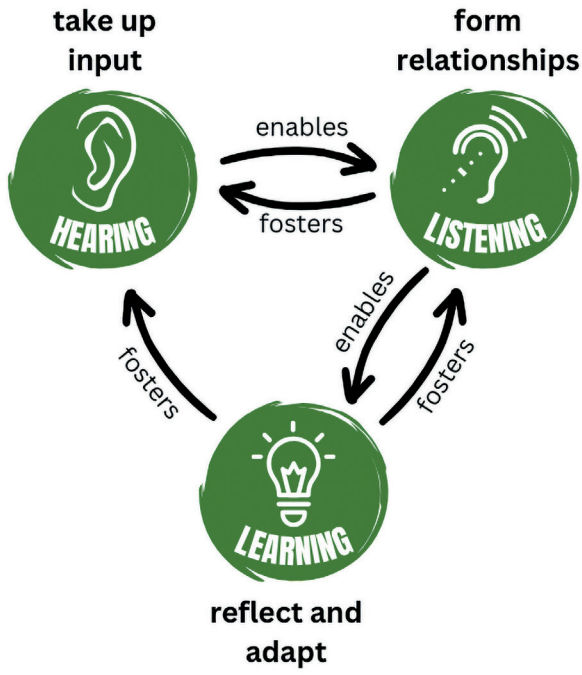

Figure 5.2 *Organizational hearing, listening, and learning capabilities.*

Formerly, we developed these capabilities for Triple Helix organizations as innovative collaborations of actors stemming from the spheres of academia, government, and industry. In this contribution, we apply this conceptualization to a Horizon-funded research and innovation project, organized as an International Training Network. Such projects might be organized as a Triple Helix collaboration, but not necessarily have to be. Usually, the structure of research project collaborations is envisaged to last for the project duration, so the organizational structure might be less durable than a Triple Helix organization. Still, the conceptualized capabilities fit the interdisciplinary nature of Horizon-funded training networks, which aim to spark innovation by integrating different forms of knowledge.

5.4. Learning history method

This chapter started with the aim of exploring how AgRefine PhD researchers have become responsive by hearing, listening to, and learning from input of the different publics that are affected by the project's actions. To this end, I initiated and facilitated a collaborative reflection process among the involved PhD researchers by means of a learning history (Roth & Bradbury, 2008; Roth & Kleiner, 1995). The learning history therefore describes the perspective of involved ESRs. It is particularly interesting to take the ESR perspective

as a point of departure, because they are, on the one hand, the main researchers dedicated to work on the project full time. On the other hand, their development and learning trajectory is also a main objective of the project (CORDIS, 2023). I can draw on my unique position as a project insider to achieve detailed participant reports and access to all involved ESRs. By this, I embrace the role of reflecting in action from an inside position (Schön & Rein, 1994). Moreover, within the group of ESRs, we have established close personal relationships throughout the project, which adds to creating a setting where participants can also share emotional and critical experiences.

To analyse hearing, listening, and learning processes to become responsive to various forms of input, I initiated the collaborative process of constructing a learning history, which is a 'participatory action research method designed to explore and foster learning in organizations' (Lyman & Moore, 2019, p. 473). In elaborating the learning history, I followed four process steps, on the basis of the learning history steps developed by Roth and Kleiner (1998). Figure 5.3. contains an overview of these steps.

Figure 5.3 *Process steps in the elaboration of the learning history.*

5.4.1. Step 1: Questionnaire

A list of noticeable results, which are successful learning outcomes considered as important by the organization for which the learning history is developed, functions as the

point of departure for the learning history (Kleiner & Roth, 1996). In my case, the list of noticeable results stems from the AgRefine grant agreement. These noticeable results were the provision of skills and knowledge; interdisciplinary cooperation; organized trainings by the network; access to partner institutions; public promotion and dissemination of results; the excellence objective of forming a disruptive, innovative, cooperative, and entrepreneurial training network; work package-specific objectives; and reflections on overall learning outcomes.

Noticeable results formed the base structure for a questionnaire, which I sent out to the other 14 ESRs. Questions included prompts to reflect on the learning process. In the questionnaire, I asked for elaborate, full-text answers and estimated a time investment of two to four hours to complete the questionnaire. All involved ESRs agreed to participate and returned questionnaires. The questionnaire is presented in Supplementary Material C.2.

5.4.2. Step 2: Interviews

Based on the returned questionnaires, I conducted reflective one-on-one interviews with the participants (Weiss, 1995). In these interviews, we zoomed in on some of the given replies to contextualize and clarify the answers. In particular, we reflected on how we heard, listened to, and learned from the different publics. To systematically include counter-evidence (Schwartz-Shea, 2015), I aimed to scrutinize these accounts by asking for reflections on where we failed to learn and why this was the case. This procedure allowed us to achieve more depth in the reflection (Roth & Bradbury, 2008) of what and how we learned throughout the training network. As a result, the learning history tells a nuanced and sometime ambiguous story, when participant accounts contradict each other. Interviews were structured in three blocks, accordant to the three affected publics. After the interviews, I transcribed the replies and added them as comments in the returned questionnaires. Subsequently, ESRs were given the opportunity to review and comment on the transcription. Ten ESRs participated in these interviews. Supplementary Material C.3 provides an overview of conducted interviews.

Participants signed informed consent forms, which outlined the goals of the study and the use of data. Moreover, I guaranteed as much anonymity as possible for participants. Interviewee numbers therefore do not correspond with the ESR numbers used throughout the project, the grant agreement, and on the project's website. Furthermore, I changed all references to names, project titles, specific research activities, and technologies to more generic descriptions in questionnaire answers and interview transcriptions. Participants had the opportunity to review the anonymization before the data was archived.

5.4.3. Step 3: Writing the 'joint told tale'

The learning history is a commonly developed narrative, 'described in the words of the people who had been directly involved' (Roth & Kleiner, 1998, p. 43). As such, the process entails an interactive reflection process (Roth & Kleiner, 1995). To this end, learning histories have a two-column format (Kleiner & Roth, 1996; Roth & Kleiner, 2016). The major, right-hand column - the 'campfire narrative' (Roth & Kleiner, 1998, p. 52) - contains a 'joint told tale' by the project participants, which entails retrospective, anonymized accounts of events or circumstances, documented by vivid participant quotes (Serrat, 2011, p. 3). The minor, left-hand column contains the researcher's analytical remarks, such as central recurring themes, comments on implicit assumptions, undiscussed topics, generalizations, or recommendations (Keller Johnson, 2016; Serrat, 2011). This commentary justifies why the respective quotes are chosen and provides an interpretation of what they mean (Roth & Kleiner, 1998). By this, also conflicting perspectives on the same situation can be communicated (Roth & Kleiner, 1995). I ordered the report by thematic sections, which are introduced by a background description of the story's context (Serrat, 2011). In my case, I structured the sections according to the different affected publics. Within the resulting sub-sections, I disentangled hearing, listening, and learning processes.

5.4.4. Step 4: Back-channelling workshop

To channel back my interpretation of the data to the participants (Serrat, 2011), I conducted a group discussion workshop at the AgRefine final conference in December 2023, which was access-restricted to the participants of the reflection process. Eight ESRs participated in this workshop. Stated reasons for (partial) non-participation in the interviews and workshop were time constraints due to ongoing work for finishing the dissertation or other professional commitments after their contract had ended.

During this workshop, I presented the conceptualization that underlies this paper. In continuation, I asked participants to order a selection of illustrative quotes from questionnaires and interviews in a results matrix, with hearing, listening, and learning processes on the x-axis and the three different affected publics on the y-axis. Afterwards, participants explained their ordering and made changes based on the discussion. A visual artist summarized the discussion on-the-go in a visual way.[7] This visualization will be presented in Section 5.6. The visual artist signed a non-disclosure agreement to ensure participants that also critical experiences can be shared. In the second part of the workshop, we contrasted the results of the discussion with my interpretation. After the workshop, I adjusted my preliminary interpretations based on the outcomes of the workshop discussion. The resulting final version of the learning history is presented in the Results section of this paper. A synopsis of the learning history is available upon request.

7 I thank Simone Haarbosch for her contribution to this part of the workshop.

5.5. Results

To disentangle hearing, listening, and learning processes, I report the 'joint told tale' (Serrat, 2011, p. 3) of the learning history in this section, structured into three sub-sections respective to the three affected publics. Every sub-section starts with a description of the public and a summary of the main analytical outcomes. The left-hand column entails my interpretations and guides the reader through the narrative. The right-hand column contains anonymized participant quotes and reports, which were shared during the workshop. The learning history can be read in different levels of detail and resultingly, at different speeds. For an overview, it is sufficient to read the descriptions at the beginning of each sub-section. Reading the left-hand column provides the general line of reasoning. The right-hand column substantiates the narrative and adds the lively descriptions of project participants.

Responsiveness among the involved researchers

Involved Early-Stage Researchers (ESRs) described the formation of the tight network of 'the ESR family' as paramount project outcome. Establishing listening relationships beyond disciplines enabled participants to contextualize their individual dissertation projects within the bigger picture of the circular bioeconomy. This includes that technical ESRs broadened their research focus to how their biorefinery technology innovations contributed to the circularity and sustainability of the broader bioeconomy project. Desk-based ESRs learned to connect their theoretical, socio-economical knowledge with the practical technicalities of biorefinery innovation. Alongside this contextualization, participants learned interdisciplinary skills. These skills include manoeuvring a complex research project and to stand with their own opinion, while navigating mismatching expectations, for instance between the training network and their supervisors at their home institutions. Participants became responsive to each other by adapting their research projects on the go, based on listening to each other's input. This entailed redefining their pre-defined research objectives and taking the organization of secondments into their own hands. However, some participants experienced more agency than others in shaping the framing and context of their project. This is because some project characteristics impeded learning from each other. For example, different starting points and lengths of PhD trajectories as well as planned-in dependencies between ESRs hindered timing interdisciplinary collaborations. Moreover, the format of training weeks frequently did not stimulate common problem solving and to explore fields for direct collaboration.

*ESRs **heard** input from other ESRs by following ESR presentations during training weeks, journal club discussions, and frequent informal talks, for instance during weekly coffee breaks.*

The AgRefine training network entailed five training weeks over the course of the project. During two training weeks (Vienna and Ghent), ERSs presented their individual, ongoing research projects to the other ESRs and present supervisors.

Journal club discussions were regular meetings (approximately every two months), in which one ESR prepared a presentation of a journal article, which they found inspiring or interesting to discuss. The presentation functioned as a discussion starter. Supervisors took turns in chairing the journal clubs.

As one ESR put it:

"The journal clubs and training schools were instrumental to me [in] understanding how all of our projects were interlinked and why each person and their research was important."

Another ESR added:

"Training weeks cemented how complex a bioeconomy is and how much networking and interdisciplinary actions are needed."

Even another ESR pointed out the value of these formats in looking beyond the horizon of the own project:

"During the journal clubs, I had the chance to hear opinions concerning the social aspects of biorefineries, which was not included as a parameter in my project. Even though I could not implement this aspect further, as my project was very specific and technical, I was happy to be informed and learn definitions and values that I could implement in my future work."

Between training weeks, the ESRs updated each other informally during weekly coffee breaks.	"Collaboration was facilitated by the weekly […] coffee breaks […] with the ESRs. This helped to form a strong network and a support system."
***Listening** involves establishing relationships to properly understand each other and thereby generate meaning. In particular, the ESRs highlighted the value of the in-person training weeks in planting the seeds for such relationships.*	*As one ESR explained:* "Gathering together as ESRs is the real purpose of the training weeks. I mean, you can learn things here and there, but they are the moments where we can actually gather together and exchange ideas, where we can also disagree and discuss." *One ESR underlined that the first live meeting was crucial in planting the seeds of collaborations within the project:* "I have a positive memory of the first live meeting of all ESRs. While I do believe there were significant differences in ways of thinking and doing research, I also think that we were all open to hearing the perspectives of others." *Asked about the first live meeting, one ESR explained:* "I remember feeling an instant connection with all ESRs. It did not feel like a stuffy networking event. It felt like a reunion of long lost, likeminded friends and we were all super excited to 'nerd out' together."
Even many friendships evolved.	*As one ESR explained:* "What I liked the most [about the training weeks] was spending time with my colleagues, getting to know them (not just their projects), bond, building connections and friendships." *Another ESR added:* "The kick off meeting in Austria facilitated a meeting in person event and cemented our strong friendship and professional networking."
Establishing listening relationships requires stepping out of the own comfort zone.	*As one ESR put it:* "You are in a context that you can learn from everything around you. So, I try to put myself outside the comfort zone and develop."
ESRs regarded particularly the formation of such relationships as valuable project outcome.	*One ESR stressed:* "It was in moments of deep and personal interactions that I learned the most and probably during presentations or informal talks during trainings, secondments or even by living with other fellow ESRs." *Another ESR added:* "[Forming meaningful relationships is] something very intuitive. It's not something that you choose. For example, also with [my current collaboration partner], our relationship started more as a working relationship, but then, we became very good friends as well. […] It happens with sharing experiences and that's also why I think the bonding moments we had during the trainings are very important."

To properly understand each other's work, ESRs teamed up as 'writing buddies' to proof-read each other's texts.	*As one ESR said:* "In many cases, we were proof-reading [each other's texts]. For example, I asked [other ESRs] to proof-read some things in English. Also, I once sent you what I wanted to hand in to the conference in Wageningen. With [another ESR from the same home institution], we were actively reading each other's works." *And another ESR added:* "I was glad to have the chance to interact with some of the ESRs reviewing their academic papers, as they did with mine and receiving or giving feedback to each other's work." *During the workshop, participants added that becoming 'writing buddies' not only involved the exchange of materials and opinions, but also to encourage each other to step out of the comfort zone. As an example, one workshop participant recalled that they were inspired by an 'unusual' poster presentation of an ESR peer during one of the training weeks. By listening to the peer's courageous action, the participant understood that it can be okay to stand with your own opinions, even if they mismatch with the expectations of supervisors or reviewers.*
Another example is the establishment of regular meetings with ESRs from another work package (WP).	*One ESR explained:* "I have also had discussions with WP3 ESRs, as together with [one WP2 ESR], we created a group for discussing social aspects of bioeconomy models." *Another ESR taking part in that group explained:* "I can't remember how that [social aspects] group started. […] It was the social parts of the project that we felt were missing. […] Because it was a tiny part of AgRefine, and our purpose was to raise the issue that there was a social dimension missing. […] That group was a core, where you could resonate these issues in a like-minded group. It was the only opportunity we had to discuss about that. Of course, it gave me ideas or insights I could work with, based on what we discussed." *Another ESR reflected:* "It was during the subversive meeting from the 'AgRefine Social' group that gave me strength to keep writing beyond where my supervisors could see my project going."
Listening to ESR colleagues with different disciplinary backgrounds and ways of thinking allowed ESRs to contextualize their research.	*As one ESR explained:* "The most important skills were the collaboration with scientists from different countries and scientific backgrounds. [This] multidisciplinary group helped me to broaden my ideas considering biorefinery outside of the strictly technical field. This happened […] during the Friday coffee meetings and the journal clubs."
Technical ESRs broadened their research focus to economic and societal implications of their innovations.	*Various ESRs highlighted:* "The non-technical ESRs taught me to look at the big picture. As a [researcher] with a heavy lab project, I tend to just focus on my experiments and not the project as a whole." "For me, the most crucial […] was to be able to see things beyond the technological aspects of any process or product. Given my technical background, my boundaries were always to see the technical feasibility and optimization but seeing the outcome of the same technology from social, economic, and other perspectives has always surprised me." "When a situation is given, I try to think from a technical point of view, where my field of expertise lies. But during discussions with the AgRefine group, I understood about the interdependencies of different actors."

Desk-based ESRs working on the economic and political work packages connected their theoretical knowledge to the technical explanations.	*For instance, an ESR with an economic background explained:* "From [a more lab-based ESR], I learned a lot about the technical aspects related to anaerobic digestion and fermentation. […] With him, I managed to understand the technical details […] and how I could use those in an economic assessment."
Over time, ESRs also felt confident enough to provide feedback on projects of ESRs with divergent disciplinary backgrounds.	*As one ESR pointed out:* "Most of the time, I would just listen to what other people say. But I realized, in particular after the second year of my PhD, that I was able also to add to the discussion and communicate my ideas."
However, listening to each other was impeded by some project characteristics. In particular, timing mismatches hindered the initiation of common projects and working on planned, shared deliverables.	*One ESR explained:* "Interdisciplinary work is also sometimes tricky because you rely on another person to be able to start your work. [In our case, we] also had discrepancies in the deadlines for deliverables." *Another ESR further elaborated:* "When I started, I was [one of the] last. [...] People were at different levels of research. One might have already published their research; one might be just working on the research. […] Even during deliverables, we couldn't collaborate much, because we had a different planning. Because of the short duration of time, we couldn't proceed it further. Now, ESRs are finishing, so I don't have much scope for mingling with their work." *Workshop participants specified that these timing mismatches made it harder to listen to ongoing research projects that were at a different step in their research process. For ESRs that had just started their trajectory, it was harder to follow the presentations during the first training week.*
The timing and sometimes also the format of training weeks partly lacked potential to establish interdisciplinary communication and collaboration.	*One ESR explained:* "I did not like that at times [the training weeks] felt overly focused on the technological aspects of the project, leaving behind some of the ESRs, and also wish that it focused more on initiating and planning collaborative works rather than on individual projects." *And another ESR said:* "After COVID travel restrictions have been lifted, all our trainings were arranged back-to-back. I found some difficulties in simultaneously organising research and preparation for the trainings. I expect that this would have been easier if we have had some months gap between each training."
One ESR offered some ideas of how the training weeks could have designed to spark further interdisciplinary collaboration.	"The training weeks […] should be accessible for everyone. [...] It would have been nicer if we had a workshop where we had to do a biorefinery concept from different perspectives: technical, LCA [life-cycle assessment], but also social. And then I could learn from you as a social expert and on the flipside, you learn from me if we talk about the technical aspects. Then we learn more from each other. If you just listen to a conference, then you are not engaged that much. You also learn less."

Between training weeks, updates lacked on changes of research projects that affected others.	*One ESR explained:* "To be honest, the only collaboration-dialogue with the other work package members was during the group deliverable. Afterwards, everyone was too busy performing their project tasks." *And another ESR confirmed:* "After the deliverable, we stopped having regular contacts and I didn't feel a team spirit within the work package. I only felt it with [another ESR from my work package], as we have been a team since a couple [of] years."
These lacking updates partly disrupted established listening relationships.	*One ESR explained:* "I don't think there was enough communication between institutes […] when things were changed. This led to a lot of really uncomfortable moments [*laughs*] […] There was a moment when I explained to my supervisors what I was doing, and they were completely surprised that the feedstock has changed [in the project of another ESR]. This put me in a really weird position, because it was not something that I was responsible for. […] And that was already a year after the change."
Two participants suggested 'shadowing' each other as a tool to improve listening to each other.	*One ESR suggested:* "You [should] spend a day or two with me, to shadow me in the lab, while I'm doing my research. And then I spend some time with you, and we compare how we found it." *And another ESR noted:* "Due to the nature of my research topic, I needed to understand the work undertaken in [a different work package] of the project. I therefore learned a lot about topics previously unfamiliar to me, such as microbiology, marine biology, and biotechnology. This occurred throughout the project by my requests for meetings and shadowing of the lab-based ESRs."
*Participants did not only experience the technological innovation products specified in the grant agreement as important **learning** outcomes.*	*In the words of one ESR:* "More than other skills, I have learned the capacity to consider all the aspects of a problems and of a situation and do not only focus on the technicality, as required for my PhD." *Another ESR highlighted:* "What I learned and improved during AgRefine was that I consider all the aspects at every time. […] It helps me not that in the sense that I learn something related to the economical part, but I learn that in the end, I have to integrate that part. I cannot consider a tree without considering all the leaves and all the roots and all the bark."
Rather, ESRs valued learning interdisciplinary skills, such as project management, navigating mismatching expectations, or communicating beyond disciplinary boundaries.	*Various ESRs noted:* "I have learnt numerous hard and soft skills throughout my journey. All of which I will use throughout my future career […] I also know how to manage and work on multiple projects at the same time. […] Most times, I have felt not like a PhD student but a PhD supervisor, advisor, technician, engineer, electrician, teacher, secretary, accountant and cleaner". "The additional skills which I […] obtained through this process were: patience, problem solving, conflict management, time organization, being proactive and open-minded when the study does not always work as required, transparency and honesty among the collaborators, open to receive both positive and negative feedback, [and] friendship." "[I learned] to be more confident, trust myself and my skills as a researcher even when I do not fit into academic boxes."

Sometimes, a valuable learning outcome was a new question rather than a new answer.

One ESR pointed out:
"Sometimes, working in interdisciplinary ways means arriving at more questions than answers. When we look at the technical things […] and we find a really good yield, we're happy with the process. […] But when we look at the same thing from different angles, a lot of problems arise."

Overcoming the challenges of a PhD trajectory allowed participants to grow into independent researchers, while also bonding as a group.
One of these challenging moments was the passing away of an ESR colleague due to an accident during the first year of the project.

As one ESR explained:
"What made us bond […] was […] the difficulties of the PhD [trajectory] and the similar challenges we were all having at the same time: Challenges with our supervisors and all these challenges of the PhD journey that we were all sharing. That is what made us bond [even] more than external circumstances, like COVID."
In the words of one ESR:
"Losing one of our ESRs in the first months was a tipping point in us becoming a family. […] I'm not saying that [my recommendation for other projects would be that] someone should die [*laughs*]. No, that's horrible. But for AgRefine, it was a moment that […] bounded us together."

As another example, one ESR pointed out the difficulty that there was a period without project manager.

"The change of the project manager affected the project a lot, because she was the one who was trying to put us together all the time. But then, she was gone, and nobody cared anymore about that."

For many ESRs, the most important learning outcome was therefore the establishment of the 'ESR family'.

As one ESR put it:
"It's all about the people and the ESR family we will carry for life".
However, the same ESR also noted:
"I think [the ESR family will fall apart] just like every family. There will be some that just don't keep in touch, there are members of the family that you don't like so much and others that you're very close with."
Still, many ESRs are confident that some contacts will remain:
"I think the only profit I will have in the future is the friendships I made. […] I won't continue in academia. But the network will still exist, even if there are no more possibilities in academia."

In this regard, AgRefine was a very successful project.

One ESR pointed out:
"The purpose of AgRefine is just about us, the ESRs. If individually, you reached your goal and you think you took as much as you could out of this, then AgRefine was a success. […] If you think you reached your potential and developed as a person, professionally and personally, then it's a success. And also as a group, we evolved."
Another ESR further expanded:
"In the end, the product is the ESRs. And, I think, everybody has evolved in this 3-year process. The goal was to get a PhD, to prove that you're able to perform research, that you're able to build up on existing knowledge and be innovative. In the end, I think [AgRefine] was successful."
During the workshop, one participant pointed out that the success of the training network was precisely to point out the 'bigger picture' of the ESRs' individual projects.

The project, as described in the grant agreement, entailed some designed-in dependencies. For instance, some ESRs needed samples or data from another ESR. If something does not work according to plan, this causes deviations in another ESR's project.	*One ESR explained:* "My project has changed substantially as a reaction to the work of other ESRs. The inputs and outputs to my models were intended to come from the WP1 ESRs. Thus, as the project progressed, poor results or a lack of results altogether from WP1 ESRs (due to no fault of their own, that is the nature of experimental science) required me to adapt my project in order to progress." *And another ESR added:* "[I adjusted my project] because the project as it was planned in the grant agreement with all the collaborations and exchanges of material or results produced by the ESRs couldn't happen in the right timeline and time frame."
Deviating from the grant agreement sparked innovativeness. *ESRs changed the practices of how they conducted their research (first-loop learning), redefined their research objectives (second-loop learning), and also worked towards shaping their research's context by establishing new collaborations that were not planned initially (third-loop learning).*	*One ESR explained:* "If [an innovative technology] is already written [in the grant agreement], we're not coming up with it, we're just developing it. That would have limited us a lot if we would have only built up on that." *One ESR fundamentally adjusted their research topic and objective:* "I changed the entirety of my project upon understanding what it's about beyond the pleasing words. Inputs from colleagues have been critical for this and it happened throughout the project's duration. […] I can't knowingly write falsehoods and omissions. […] My project in the Grant Agreement aimed at the economic part of this [novel biorefinery technology]. Nowadays, it focuses on the full supply chain sustainability." *Also other ESRs outlined their deviations:* "I found myself deviating the moment I started my first experiment. My topic was very vaguely (broad) written, giving me the possibility to take it everywhere as per my understanding, so I did. I am happy with where it led me." "My thesis was supposed to be very technical and focused on numeric values and simulations. By collaborating with others, I had to open up, not to be in a box, to not simply do what everyone was doing in this field. […] With this, my work was really enriched. Because it gave it a more systems-perspective." "I moved [away] from the project [description] at the beginning of the second year, when I realized that imposing the conditions described in the grant [agreement], the project was not feasible and the outcome not innovative as could have been following other ways." "Most of the things that happened, we made them happen. Also some collaborations that were not in the grant agreement worked out, because in the end, we wanted to work together."
However, these deviations also caused uncertainty.	"[I deviated from the 'job description' in the grant agreement] when I decided to have a more critical perspective on biorefineries and how they are currently deployed. Because of the detachment from the description, I felt insecure and scared of not finishing my project."
Some aspects were not feasible to be changed on-the-go. For instance, it was not possible to add another ESR, once we discovered that an important perspective was missing.	*As one ESR explained:* "Despite having 15 ESR's working on seeming vastly different but important and interlinked topics, we still lacked an ESR, since no one was tasked with the biodiversity aspect of the project."

Moreover, every ESR and their supervisors had own research lines to further develop.	*An ESR underlined:* "You also want to get your dissertation done. You want to publish your own results. You want to get good-quality work in your own field. […] It's […] hard to have an interdisciplinary project with 15 PhDs. Because the PhD researchers are also focused on disseminating their own work."
This caused mismatching expectations between fulfilling the project objectives and making a strong disciplinary contribution for the dissertation, which hindered establishing interdisciplinary collaborations.	*One ESR explained:* "The requirements of both the project and my university limited the extent to which I was willing to pursue potentially innovative, cooperative projects." *Other ESRs added the crucial role of supervisors in this:* "If your supervisor doesn't give the seal of 'yeah, that's okay', I cannot do anything, because it's a relation you're so dependent on to finish the PhD. […] I wished we had written more […] papers with shared contributions among the ESRs. Since the beginning, it was always: 'Oh no, you shouldn't do that', because there's an authorship issue there. You have to explain the board who wrote what […]. I understand it from a supervisor point of view. They're trying to care for you. Because if this is raised during your viva and there's issues or doubts on who wrote what, that's a problem." "Collaboration was hindered by obligations to supervisors, lack of time and resources, and lack of flexibility in the research program (e.g.: 'I am really interested in this, but I can't detract from that particular plan')". *According to some workshop participants, the extent to which ESRs were free to form interdisciplinary collaborations was therefore questionable.*
Prioritizing own dissertation projects therefore resulted in the overall project remaining multi-, rather than interdisciplinary.	*As one ESR explained:* "There is a big difference between multidisciplinary and interdisciplinary, and I would argue AgRefine was multidisciplinary and not interdisciplinary. While many different disciplines existed within the project, it seemed there was no incentive for individual research projects – particularly for WP1 ESRs – to perform interdisciplinary collaborations." *Another ESR added:* "AgRefine is a multidisciplinary project, but by no means an interdisciplinary project. Each project focuses on its own thing […]. Knowing better [what] others were doing facilitated knowing ABOUT other disciplines but did not enable collaboration." *One ESR even felt:* "Our project was very divided. […] I didn't work with [ESRs from other work packages]. At the end, I think everybody started to work by themselves and not among the whole project."
At least one ESR thought that the project should have encouraged more interdisciplinary work instead of individual, disciplinary contributions.	"If you were strongly encouraged to do a collaborative study, not just for the project, but for the PhD as well […] then there would be a better understanding of how it's all connected".
To further improve learning among the ESRs, participants offered the idea for future projects to have a workshop on how to conduct interdisciplinary research at the beginning of the project.	*Two ESRs pointed out:* "It would have been beneficial if there was something like a workshop on how to cooperate in an interdisciplinary way." "We didn't have a proper arrangement how to see if a possibility [for collaboration between ESRs] is there or not. [...] If there is a requirement on how to work together at the planning stage, that might be useful."

Responsiveness towards involved partner organizations

In principle, each ESR was based at two different partner organizations for three months during secondments. In particular during these secondments, but also during training weeks, ESRs worked together with AgRefine partner organizations that were not their home institution. Being based in a different environment contributed to forming listening relationships with partner organizations and to step out of the jargon bubble of their home institution. ESRs became responsive to the input of partner organizations by identifying blind spots in their own work. For instance, responses included adding a further research focus on the needs of primary biomass producers (such as farmers and fishers) in various ESR projects or even radical methodological adaptations, such as abandoning experimental approaches. Moreover, secondments helped ESRs to establish a network for their future career. Several ESRs felt empowered by spending time in a different setting than their home institution. However, participants also noted that the framing of the project limited the range of involved – and heard – partner organizations. In particular, no environmental organization was associated with the training network. Moreover, patenting and secrecy issues between organizations jeopardized learning from each other because some knowledge was secret and could not be shared between organizations. This caused some partner organizations to remain isolated at the side lines of the project. The COVID pandemic affected the organization of in-person secondments, which ESRs regarded as crucial to establish listening relationships. Furthermore, ESRs noted the danger of industrial capture when working together with organizations from the private sector and pointed out the importance of setting boundaries in this regard. A common recommendation to mitigate these learning restrictions is for funding agencies to allow more flexibility in letting ESRs shape their own secondments.

*ESRs **heard** the perspectives of AgRefine partner organizations during secondments.*	*As one ESR put it:* "The secondments were for me the most enlightening moments where I could really get out of my own box of knowledge. It gave me insights about new scholars, theories and practical experiences that made all the difference in my project, how I framed problems and solutions." *Another ESR said:* "I like that I visited new countries, places, and institutions. I liked that I saw how other institutions work and what's their level of research maturity both related to my topic and in other sectors." *And a lab-based ESR added:* "[My secondment] was very helpful, because [one co-supervisor] answered all of my questions at the right time. We had meetings every two weeks. […] She was in the lab with me, teaching me every technique that she knew. The collaboration was very close."
Some ESRs highlighted as crucial that secondments happened in person, rather than purely online.	*As one ESR explained:* "During secondments, it was easier to work in person, rather than on internet. […] I could see how other people were working and share more personal things than the project per se." *And other ESRs added:* "We had very good discussions [at my secondment] because we were in the same office. […] If I had questions, the people there would answer. I think, it was a good collaboration." "If I show up somewhere new [at a secondment institution], I'm more likely to reach out to people [and] […] people are more open to answer my calls for help or data. […] I think there's just the vibe around a visitor, where people are a little bit more receptive, both the visitor and the institution, because there is a limited amount of time that they're there."

However, various ESRs noted that – apart from the organizing university – the involvement of partner organizations lacked in training weeks.

One ESR explained:
"The involvement of AgRefine partner organizations varied a lot depending on the training and the organization but seemed to be limited in the case of the industry partners. In general, I feel the trainings could have benefitted from more involvement for a diversity of perspectives.
And another ESR agreed:
"Trainings could have definitively benefitted from more involvement [of the AgRefine partner organizations] because I have the feeling we always stayed in an academic environment and I think that the industry perspective would have also been valuable."
Workshop participants added that this lacking involvement caused some organizations to remain at the side lines of the project, while other partner organizations were more actively involved in the network.

A better involvement in the training weeks would have allowed ESRs to hear what all partner organizations were working on, not only their individual secondment partners.

One ESR explained:
"The trainings could have benefitted from more involvement [of the AgRefine partner organizations]. The reason is […] that we barely know who the partner organizations are and what they do."
And another ESR added:
"I still have no idea about what some partner organizations are doing. We never had a meeting where all the partner organizations introduced themselves […] At least this is the minimum to get to know them a bit better."
During the workshop, participants added that the classification of information as secret, for instance due to ongoing patenting processes, restricted what information could be heard.

*Stepping out of their jargon bubble helped ESRs to form **listening** relationships, in particular with non-academic partner organizations.*

One ESR explained:
"We are in our bubble of academics […] in our particular jargon and how we speak about anaerobic digestion, how we speak about the bioeconomy. It's always good to have someone else who tells you their point of view on what you're doing."
Another ESR added:
"If you know how things are being communicated outside [of academia] then it's easier for you to understand how to communicate your own research in that way."

To keep established relationships alive, ESRs intended to 'keep in touch' with their secondment organizations also after the secondment has ended.

As one ESR explained:
"I intend to keep in touch with the contacts I have made from my secondments, as it is always possible for these connections to be useful in my future career, either through job openings, collaborations, or interesting research outputs."
Also the partner organizations themselves sometimes contacted the ESRs after secondments:
"After [one of my secondments], people did reach out for me after I left and asked me for help. That felt really nice."
One workshop participant underlined that by keeping in touch with secondment partner organizations created a connection that resulted in a feeling of optimism for the own research project. Their research felt more relevant due to this connection.

However, the framing of the project limited what organizations could become AgRefine partner organization. In particular, no environmental non-governmental organization (NGO) was involved.

In the words of one ESR:
"If you frame this project as [developing] a prototype that aims to work towards using more biomass and extract as much value as possible from biomass and being very vague about sustainability, a more critical NGO probably won't engage […] But if the goal is us ESRs and our learning progress, […] and if you explain that to organizations, then I would say that an NGO would be willing to push for their view, explain it and work towards something, even if they have a lobby organization in the same board. It depends on how you frame it."
The same ESR expanded:
"[Involved partner organizations are] all organizations that work in the same direction, with the same view about the bioeconomy and how we use biomass. We didn't have NGOs in the partner organizations. […] You can [only] have a disruptive type of training if you have also critical perspectives in it."

Moreover, patenting and the connected secrecy hindered establishing relationships and sharing knowledge between organizations.

An ESR explained:
"For a training network, [patenting] is not so good, because you have to wait until the patent is delivered to write the article. And in the end, the patent belongs to one institution. […] It is stopping you a little bit in sharing knowledge. For instance, when I had to present [a specific part of the biorefinery], I couldn't show any picture of it."

Some ESRs reported that this secrecy also jeopardized having beneficial learning experiences during secondments.

"When I planned the secondment, it was something that was in the middle of my university and the host organization. But in some cases, [the other institution was] not open to change the project too much and to integrate an aspect […]. Instead, they were more focused on what they wanted to do. […] If one person is working with a specific process and we can integrate that part, it happened that that person did not want to share their knowledge."
"[During one of my secondments with an industry partner], I was doing some tasks for them, which I couldn't use for my own research, because they were confidential. But from some other tasks, I got something out [for my research]."
"Even though I travelled [to my secondment location] and stayed for 3 months, I was not allowed access to the laboratory or getting informed on the ongoing research. The reason was […]: "conflict of interest" and the requirement to sign a [non-disclosure agreement]. Therefore, I was just working on composing my research papers and thesis."

*ESRs **learned** to identify blind spots in their research projects by collaborating with partner organizations.*

One ESR explained:
"I had the opportunity to talk to stakeholders [during a secondment], to see their needs, see the actual technologies, talk to different people in different research institutes in the area and see how they're tackling the needs."
And another ESR stated:
"I was fortunate to work within the expertise of the host of my secondment, not doing 'my thing' in a different place. I managed to learn a lot in this process. This ended up broadening my research, now making it difficult to put it together for my thesis, but overall it was a win for me."
At least for one ESR, these insights also resulted in methodological adaptations:
"After my secondment, I gave up experimental work due to lack of purpose."

In this sense, spending some time away from the home institutions frequently helped ESRs to look beyond the study scope developed together with their supervisors back home.

One ESR noted:
"My secondment […] taught me so much. […] Most importantly, they showed me when to stop, when to say no to new idea/s from my supervisor and how to justify my decision for saying 'no' without being rude and without my opinion being disregarding."
Another ESR added:
"Moving to another institution gave me the courage to ask questions and seek help in a way that felt more difficult while at my home institution."
Workshop participants experienced the secondments as empowering and adding to personal growth. In particular, learning that one's research is relevant in practice contributed to this experience.

Moreover, secondments helped ESRs to form a professional network for their future careers.

An ESR explained:
"The contacts I made [during my first secondment] could be potentially future colleagues, or collaborators, as we work in similar fields. For example, we have already supported each other on ideas considering job finding."
And two other ESRs already benefitted from this network:
"I got a job from one of my secondments! I really believe it's a good [opportunity for] connecting with people and demonstrating the things you are passionate about […] and the connections could take you back there in the future."
"I actually have a consulting project with [a secondment host organization] for a few days after my contract with AgRefine finishes. And we have discussed to submit a project proposal on a different matter which resulted from the collaboration during the secondment."

Some ESRs took matters into their own hands by redefining the secondment planning initially laid out in the grant agreement. They thereby engaged in third-loop learning.

In the words of one ESR:
"[Two ESRs] who had the chance to organize part of their secondments in host institutes or organizations of their interest had a very positive experience."

However, some ESRs experienced more agency in shaping their secondments than others.

One ESR reported:
"I had a fixed start and end date for the secondment. But I didn't have a proper plan about what I was going to do during my secondment. […] I was initially thinking about doing some modelling work. But later, I realized that I needed some experimental data to work on to develop that modelling [...] At the time that I realized that I needed some experimental data, I didn't have enough time left."
And another one noted critically:
"I had the impression that several secondments were just to fulfil paperwork and did not really contribute to ESR projects."

Furthermore, the COVID pandemic jeopardized the organization of in-person secondments.

"In the beginning, we had like 1,5 years of COVID with nothing. [More involvement of the non-academic partner organizations would have] helped, because what does anyone, also our non-academic partner organizations, know about AgRefine? Nothing! Maybe, there would have been more outreach about the project and it would have been more active. In other projects that I see at [my home organization], there's way more attention, because there's actually a participation, also of non-academic partners."

Some ESRs also noted the trade-offs of involving industrial partner organizations due to the danger of industrial capture.	*Two ESRs said:* "There is a pretty big awareness among the ESRs that there's a lot of issues when it comes to integrating industry and academia. On the other hand, we live in a world were industry makes things [*laughs*]. So, to include them less would not be the answer. But […] I'm very concerned about the academic freedom and I know a lot of horror stories, in particular of […] PhDs completely based in industry. [They would] completely not be able to publish, because it wasn't going to make their industry look good. […] There're quite some projects coming up, where all the PhDs are based in industry and I think that's a horrible idea. So, not go in that direction, but also not cut [industry] out completely. Because then we'd be in an academic bubble." "I am glad that [partner organizations] were not too involved, as I have seen academic freedom can sometimes be hindered due to industry pressures." *Another ESR added that commercialization is also not the main goal of AgRefine:* "In the end, we are a training network. It's not for commercialization or for industry. […] I'm happy with that. […] For me, what's important: I love studying. That's my main goal. I love learning. And […] if my project would be for a company, I don't think I would have learned that much." *In the workshop, one participant pointed out the importance for and possibility of setting boundaries to prevent industrial capture.*
More flexibility in the planning of secondments would have allowed a better connection to ongoing and open-ended, innovative research projects.	*One ESR suggested:* "I think [the secondment planning] should be specified in the grant agreement, but the ESRs and supervisors should have flexibility [to deviate from it]." *And another ESR pointed out:* "It should be understood that secondment partners can be added during the project, so it could align more with the research as it unfolds."

Responsiveness towards the broader public

Individual ESR projects were not conducted in isolation from broader public discussions about biorefinery innovation and the bioeconomy in general. Some ESRs managed to become responsive to this form of input, while others did not. ESRs heard uninvited input from the broader public by following the news, social media, or being engaged in activism, for instance in environmental initiatives. By hearing this input, ESRs learned that the sustainability of the bioeconomy endeavour is more contested than what they thought at the beginning of the research project. Moreover, ESRs exposed their research to the broader scientific community by attending conferences. Letting go of the own jargon and to discuss their research with others in clear and accessible language enabled ESRs to form listening relationships with societal actors that are not part of AgRefine. By establishing such listening relationships, ESRs developed further communication skills to spread their produced knowledge. Moreover, ESRs learned to critically reflect about their own projects. In particular, several ESRs became more critical if biorefinery innovation is a silver bullet solution to targeted sustainability challenges or even contributes towards tackling these challenges at all. Listening to uninvited societal input was restricted by detaching the technological innovation process from its societal context, particularly in lab work. Moreover, focussing on fulfilling their individual research tasks hindered many ESRs from learning from broader societal discussions, which is in itself a time-consuming process. For ESRs that managed to become responsive to uninvited societal input, this input was very disruptive. As a result, several ESRs adjusted research questions and objectives of their individual research projects. 'Scary realizations', such as realizing that your own work does and will not suffice in tackling sustainability challenges, are tough lessons to digest; however, very valuable ones.

*The ESRs managed to **hear** broader societal debates about biorefinery innovation and the bioeconomy in general by engaging on social media.*	*Multiple ESRs pointed out the value of social media to follow specialized news:* "I usually check LinkedIn to see the news of what's happening". "[I follow broader bioeconomy debates] by reading some articles, following news and LinkedIn". *However, these platforms also form new restrictions:* "Twitter is very restricted on what you can read there. It's more in the form of dissemination that you use it than in the form of absorbing knowledge."
Moreover, ESRs followed other media outlets to remain updated about news related to their specific research projects.	*As several ESRs explained:* "I look around and read news or have discussions with other people in the field. I'm always open to chat with people and understand what their vision and their points are. That always helps me a lot." "Through journal clubs, conferences, and following the news I have learned a lot about the role of the bioeconomy from different societal lenses. I find that actually, this can at times make it more difficult to perform my work, as I feel constantly at odds with one narrative or another." "I follow a newsletter that gives updates on rural communities and the implementation on policies on the agricultural sector. That gives insight on producer level, what is happening in the changing environment of policies and regulation, and what they're doing in their supply chains."
Some ESRs used (social) media to share their research with the broader public.	*One ESR explained:* "I use social media like LinkedIn to share my publications and Research Gate to reach more scientists. Facebook is also a platform that I use to share my papers so that people who are not at university can read them." *And another ESR reported:* "I have done multiple blog features, social media post features (that is, a feature about me and my research posted by others), TV and written interviews, as well as a talk at my old university, a podcast episode, a [disciplinary] newsletter article, conference poster, presentation at an international [disciplinary] event and talks for different research groups while on secondment. I have also used my social media account and [my institute's] website".

Some ESRs became part in activist or practice communities and remained informed about societal concerns by means of these networks.	"I took part in this community group that was [an] international community of practice of people working with the bioeconomy. How to teach about the bioeconomy, how to educate and all that to bring the topic up in society." "[I communicate with the public about my results] through conferences, informal communication, activism networks, [the] AgRefine blog, [and] social media."
Another ESR sent surveys to practitioners in the field.	"I have sent out 2 surveys and many emails to non-academics in my research. The primary goal of these were to collect knowledge. This was the 'easiest' way I could include people from outside academia in my research."
Some ESRs even witnessed and became involved in direct protests against bio-resource production. In this case, protests concerned macroalgae cultivation in a coastal area.	*As one ESR explained:* "We have had people calling in directly on the phone. […] We have had articles in newspapers. There are different foundations and complaint platforms set up by these people. […] They also have local village meetings […], where people come, and they just complain. 'It blocks my view' and they sign different petitions, and they will submit these petitions to the relevant authorities."
In addition to broader public debates, ESRs followed scholarly debates beyond their particular disciplines, for instance by participating in conferences or in their university departments.	*Various ESRs explained:* "I have mainly communicated my results through conferences and journal publications. Regarding my research topic more generally, I have written a blog and tweeted for AgRefine and given some talks aimed at the general public." "I had a discussion with colleagues from my university […]. We had a course last summer […] and after a lecture, we started a conversation, because I was curious about a specific method that they use. We ended up talking about the impact on the society; not the technical aspects, but more the reflection." "I followed broader debates on bioeconomy through participating in conferences-seminars-lunch talks, google news, or by reading academic research papers."
Sometimes, ESRs got frustrated by following broader public debates.	*One ESR explained:* "I do not believe any of those 'broader' debates really changed the way I look at my own project […] The bioeconomy […] debate […] developed in silos of knowledge by those promoting technological developments […] to bring solutions to societal challenges while other sides criticise it from a very conceptual and normative point of view with little room for practicalities […]. I wonder where the integrators are and if anything, that is where I learned to place the last bit of strength holding me to my work and project." *And another ESR added that this frustration leads to ignoring (parts of) the public debate:* "For sure, I'm [also ignoring things], because you cannot read and hear everything. […] I started ignoring a lot about this food versus fuel debate. Because I think it's very superficial. Every time I see that, I'm annoyed by it [*laughs*]. I often think that it's far more complex than that."

*ESRs **listened** to societal input by forming relationships with primary biomass producers (such as farmers and fishers) and other individuals, who are not involved in AgRefine.*	*One ESR was closely involved with primary producers at the home institution:* "I have worked with individuals outside of academia for […] my PhD. I have continued to work closely with these individuals throughout my PhD journey. These individuals included fishermen who were private contractors, engineers from private research institutes, researchers from my institute not associated with the project, researchers from different private research institutes, [and] interns in my institute not affiliated with the project […] They have supported me emotionally and with tough situations". *Other ESRs interacted closely with primary producers during secondments.* "I have talked to the fishermen and the farmers. That comes from being in a very remote location and actually being involved in the industry […] You have all those farmers everywhere and they have so much knowledge. It would take me weeks and months of reading to figure out these things. […] [By just asking the farmers] I get so much information."
Sometimes, all it takes to start a meaningful conversation is to clean a boat.	"I was even invited to come back for the [seaweed] harvest next year because the fishermen asked for me. […] They perceived that I was very dedicated to the work they were doing. […] [Because] I was cleaning his boat very dearly [*laughs*]. So, [the fisherman] thought: Well, she cares about my boat, maybe she also cares about my work." *During the workshop, the participant who made this remark specified that actions are important to create new relationships.*
In addition to practitioners, ESRs exposed their research outcomes to the scholarly dialogue.	"I have discussed broader implications of my project during my participation in two international conferences […], where I gave an oral and a poster presentation to people both from academia and from the industry. We discussed these implications in order for them to understand the potential and reason of my study and how my findings could be implemented in their processes in the future."

A paramount skill to develop listening relationships is to manage to communicate in an accessible language. This requires a continuous learning process.	*One ESR explained:* "It's complicated to talk [with fishermen and farmers] about biorefining. I try. In a conversation that takes half an hour, I would say the word 'biorefining' once and that's because I need to use different words for them to understand. I would say things like: To get the good things out of the seaweed. I won't even say the words alginate, mannitol, or acid. Because these are words that they don't know." *Other ESRs added:* "It is hard to find a common language, it is hard for [people outside of academia] to feel legitimate if they come on academic turf (like conferences) and for me to feel legitimate when I come to their turf." "What was […] difficult [while talking to people from outside of academia] was to adapt my academic language to something more accessible." "[Farmers] always come up with two questions: Could I feed it [the biorefinery products] to the cows? And can I put it on my plants? I give them answers in terms of the circular bioeconomy, but without using the words circular bioeconomy. Because if they hear these big, fancy words, they shut down. I keep it extremely simple." *An ESR recommended:* "Use simple words […] about what the future could look like and explain why we develop our approach". *A positive aspect of this is also to encounter how much content-related knowledge you have already gathered during the PhD trajectory:* "One of the positives things [from talking with people outside of the project] […] is that I learn that I know a lot of stuff that other people don't. […] I don't realize this most of the time, because I'm so bogged down by my own insecurities in my research." *One ESR highlighted that this form of communication requires continuous practice:* "I don't know if I managed [to adjust my academic language to something more accessible]. […] I'm still learning. But it's something fundamental. I didn't get any training on this. […] Since I cannot express this complexity in a simple way, I also think that maybe I'm not able to express it at all and then I give up. But actually, it's just a matter of practicing how to make it simpler to yourself but then also to other people." *Workshop participants noted that discussing their research with others in clear language also helps to sharpen their thoughts about their projects.*
Listening was limited in some cases. In particular, several technical, lab-based ESRs struggled to connect their work with broader, public debates.	"As my project was more technical, I didn't have reactions from non-academics on the specific matter." "Some topics are so new that those [societal] actors aren't aware about it, yet. Then it's difficult to start a discussion, while having to explain what it is."
By filtering what is relevant or not, ESRs detached their individual technological innovation from the societal context. Everything falling outside of this niche was considered irrelevant.	*One ESR pointed out:* "My research is more focused on the technical points: […] How do I optimize the energy? How do I optimize the materials? Am I considering a safe material for the environment? [...] I don't take a wider focus on how I involve other actors in my work. It's just about technical points."

This resulted in not being 'understood' in a relevant way by the broader public.	*As one lab-based ESR highlighted:* "Most people don't really understand what I am doing, because my research is very niche". *Another ESR added:* "From my friends and family, I understand that the bioeconomy and related topics are still not well understood outside of its bubble."
Consequently, diffuse societal input was not taken up in some individual technological innovation projects.	*In the words of a lab-based ESR:* "I haven't changed anything based on other people's opinions. Also, nobody ever criticized the project [in a conversation] with me."
That being said, desk-based ESRs pointed out that they perceived it as a privilege to have the opportunity to regard broader, societal debates.	*As one ESR explained:* "I discussed [the broader implications of my project] a lot with my colleagues in the work package. Being all involved in projects that looked at biorefineries on a broader perspective, we had the opportunity (and privilege, too, I would say) to have more tools and time to reflect on the broader implications of our work, which I think is more difficult for ESRs with lab work." *Another ESR confirmed:* "It's a privilege of us [desk-based ESRs] to observe the wider perspective, compared to lab-based ESRs [because] the system is built in a way that [for lab-based ESRs] […] time is not allocated in a way that they can reflect on the meaning of what they're doing. There's no time for it. […] Especially in the PhD, you really want to finish your experiments and the rest is just considered a waste of time."
***Learning** from uninvited societal input includes the acquisition of new skills, particularly for science communication.*	*An ESR said:* "I will take with me project management, communication, presentation and media skills for sure." *And another ESR added:* "The most important things [that I learned] are communicative skills, mental flexibility and critical thinking". *And yet another ESR underlined:* "[Following broader debates] has made me more creative. As a person, I have certain ideas, based on what I've read and what I've seen. But […] when I see that my field is approached in a different way, that is a spark that I get: Okay, this can also be possible." *A workshop participant noted that these skills are essential to spread produced knowledge in the own (research) community, but also to other groups.*
Moreover, this exposure sparks critical reflection on the own research project.	*As one ESR uttered:* "Broader debates about the bioeconomy help me to understand different opinions […], gain a more critical view about the topic and express out loud my opinion." *In this sense, another ESR argued:* "I learned a lot about the broader debates and it made me look critically at my own project. Subsequently, I changed it entirely to something new. […] I changed the entirety of my project upon understanding what it's about beyond the pleasing words. Inputs from colleagues have been critical for this, and it happened throughout the project's duration. The reason for those changes is that I seek to understand what I do and do as best I can. I can't knowingly write falsehoods and omissions."

Multiple ESRs realized ambiguities for their own work, in form of negative trade-offs of the bioeconomy and biorefining, connected with over-consumption.	*One ESR explained:* "If you go with a simple type of crop, you'll lose biodiversity, like what we see with biodiesel and biofuels in many countries. We have to rethink this." *And another ESR added:* "[People] also have to change how they consume. If people eat meat seven days a week, that's not sustainable. We have to look at other alternatives to get the nutrients, not just animal products." *Another ESR realized:* "What we try to focus on with innovation is to solve a problem. But there might be some [new] problems coming up as well. […] If you could solve one problem, which might give rise to another one."
However, being kept running in a hamster wheel of working on one's own research tasks limits the ability to learn from societal input. By being busy with their research, in particular experimental lab work, some ESRs felt that public engagement was something they did not have time for.	*As one ESR put it:* "Most of the time, everyone was running." *Other ESRs added:* "I have played with the idea to communicate more to the general public. And I know that some of my peers that do other kinds of research are doing that. I have utmost respect for them, because it also costs a lot of time to do that. […] I don't do that because I don't have the time or don't make the time to do that. To communicate to the general public. If you're working on a niche thing, you cannot clearly explain in 2 minutes, what you're exactly doing, so that you also get some feedback. Because then there's more information needed for people to give you feedback and to ask follow-up questions." "I do not [consider protests in my research]. I would love to, really. But I think it comes down to the fact that I only have four years to do this PhD and I do have one main task. And I want to complete that task to the best of my ability." *An ESR put this characteristic into a broader perspective:* "We live in a society where we're just forced to do what we have to do, without really thinking of the consequences. It's more the norm to just do what you have to do, without thinking of the bigger picture. So, how can we blame everyone, us included?" *Another ESR added:* "I think it's not easy to challenge the system. It requires challenging […] also some of your superiors, friends, colleagues, whatever. It's never comfortable or easy. And if you don't really have the energy to invest in that and the most you want to do is to fulfil your job requirements, then that's completely valid, I think. Some people don't want to invest the emotional or mental capacity to be constantly questioning everything." *Workshop participants noted that dialogue with the broader public is in itself a time-consuming activity. In a research project with limited time, this time has to be prioritized between different activities.*

Still, several ESRs adapted their fundamental perspectives on the bioeconomy. This also includes lab-based ESRs.	*One ESR reported:* "[At the beginning of the project], I was so immersed in the topic. You could say, I was not biased, but brainwashed by reading so much about [biorefining]. […] If you take a step back and think about it, it's crazy [to assume] that we'd make such a big change. […] I took a step back and opened my mind again." *And two other ESRs added:* "When I started my project, I couldn't see any flaw in the reasoning behind [the bioeconomy concept]. These debates have changed the way I look at my project in a sense that they thought me that the bioeconomy concept is not always good and fair, before I was just very ignorant about it." "My view about the project and the bioeconomy in general changed pretty drastically during these years. Broader debates or also just reading the news about climate change and other environmental issues or social injustices linked to our economy made me way more critical toward the bioeconomy and how it is envisioned by the EU Commission. It brought me to ask broader and more fundamental question and also eager to find broader solutions – e.g. not just related to (bio)technology."
As a result, ESRs had to digest some 'scary', existential realizations.	*In the words of one ESR:* "You might find out that what you're doing makes no sense at all if you look at the bigger picture. And that's so risky and it's so scary. Sometimes, I think for people it […] feels safer to just continue looking into the specific, instead of the broader perspective." *The same ESR continued:* "[I learned that] alternative ways of production through innovative technologies won't save us from socioecological collapse, not even using renewable, biological materials. Producing and consuming less will."

5.6. Discussion and concluding remarks

This paper started with the aim of disentangling processes of how we AgRefine ESRs managed to hear, listen to, and learn from input of the different publics that are affected by our research and innovation project. To this end, we collaboratively reflected on our trajectory by means of a learning history. The learning history provides a room for common reflection that can be shared and discussed further (Roth & Bradbury, 2008). As such, the learning history is a way to process what is learned in an organization so that it can be stored in the organizational memory and be used for future action (Kleiner & Roth, 1997). Therefore, based on the outcomes of the learning history, I elaborate recommendations for funding agencies that aim to spark disruptive innovation as well as for other research and innovation projects.

The main outcomes of the learning history are that despite (or perhaps because of) challenges within the project and although many technological innovations did not work as envisioned, AgRefine was successful in stimulating third-loop learning in the training of ESRs. This third-loop learning entailed adjustments of ESRs' fundamental perspectives about the potential of the circular bioeconomy in addressing sustainability challenges and the role of biorefinery innovation therein. Changing these perspectives contributed to

substantial shifts in pre-defined research questions and objectives. To point out these learning outcomes, the learning history discerns how we ESRs have managed (but also struggled) to become more responsive to input from three different publics: (1) involved researchers, (2) societal partners, and (3) the broader public.

First, we as *involved researchers* learned to position our individual biorefinery research into the bigger picture of the circular bioeconomy. Many ESRs developed a more nuanced and critical perspective on the contribution of biorefinery innovation to the sustainability challenge of developing a circular bioeconomy. This led to fundamental adjustments in the research design and approach in the individual projects. For example, one ESR shifted their focus from economic aspects of novel biorefinery technologies towards a more overarching systems perspective on the sustainability of biorefinery supply chains. ESRs became responsive to each other by learning to manoeuvre a complex project with designed-in dependencies that resulted in mismatches in timing research outcomes. Listening relationships in a tight network of the 'ESR family' enabled this learning. In-person trainings were crucial in planting the seeds for the development of these listening relationships. At the same time, the results also highlight the crucial role of supervisors in either encouraging or discouraging the formation of tight relationships with peers from other institutions. Timing such collaborations into research trajectories requires a flexible and open-ended process that can mismatch with expectations at the home institution or planned deliverables. However, these relationships are crucial to be able to listen and learn from each other.

Second, we ESRs learned to identify the blind spots of our individual projects by secondments with the involved industrial and academic *partner organizations*. In particular, blind spots in many projects entailed an isolated understanding of a contribution to the particular, narrowly defined discipline. For one ESR, the identification of blind spots resulted in the fundamental methodological adaptation of abandoning experimental lab work towards a more desk-based social science approach. Another ESR shifted their main empirical focus from grass to seaweed in response to secondment experiences. Identifying these blind spots was achieved by grounding the obtained academic knowledge in the practical experiences of partner organizations. However, framing the project as a technology development endeavour instead of a personal development and training trajectory limited the range of involved partner organizations. For instance, primary producers of required grass and seaweed resources or environmental organizations were not part of the consortium but could have contributed important perspectives. ESRs did not form listening relationships with partner organizations during the official AgRefine trainings, where involvement of these partner organizations widely lacked. More important were one-on-one secondments. During these secondments, many ESRs benefitted from the 'change of scenery' to broaden their research scope beyond their initial focus defined in

the grant agreement. Secondment therefore opened the doors towards broader publics. Building up tight relationships with partner organizations contributed to a more practical grounding of the individual ESR projects.

Third, in particular technical, lab-based ESRs struggled to become responsive to input from the *broader public* by (1) being kept 'running' to fulfil expectations of time-intensive lab work and by (2) detaching technology development from its societal context. This hindered the formation of listening relationships with actors beyond the project's boundaries. Still, several other involved ESRs became responsive to uninvited societal input by learning to critically reflect on their own projects. For some ESRs, reflecting about uninvited societal input contributed to the development of a more critical perspective on the bioeconomy and biorefinery innovation, leading to changes in overall research questions and methodologies. For instance, one ESR shifted the focus of their research topic and methodology towards the perspective of farmers after a series of talks and workshops with primary producers. ESRs that learned from uninvited societal input then translated their learning outcomes to the rest of the ESR group, where functioning listening relationships were established (see above). This indicates that a permeability of a research and innovation project towards societal input can be achieved, even if not all members of the project are able to hear input from beyond the project's boundaries. This requires that involved peers are able and willing to translate such input for the rest of the project team. Figure 5.4 summarizes the hearing, listening, and learning processes identified by means of the learning history in a visual way.

The results of this learning history align with the outcomes of the draft of a hitherto unpublished AgRefine marketing strategy (Gabet, unpublished). That draft report came to the conclusion that the envisioned AgRefine Three-Phase Bioreactor should not be commercialized. Rather, the network and development of the ESRs should be regarded as the paramount 'product' of the training network. This learning history confirms that more than the predefined technological innovation outcomes, ESRs valued their own development throughout the training network trajectory as well as formed relationships with the other ESRs, involved partner organizations, and broader societal actors.

Beyond the AgRefine project, the results provide lessons for the RRI literature on the responsiveness concept (Blok, 2014; Chakraborty & Pandey, 2023; Nielsen, 2016). As outlined before, knowledge lacks on how Horizon-funded research and development projects can become more responsive to uninvited and diffuse societal input. Our results suggest that different publics affected by such projects might require different forms of responsiveness.

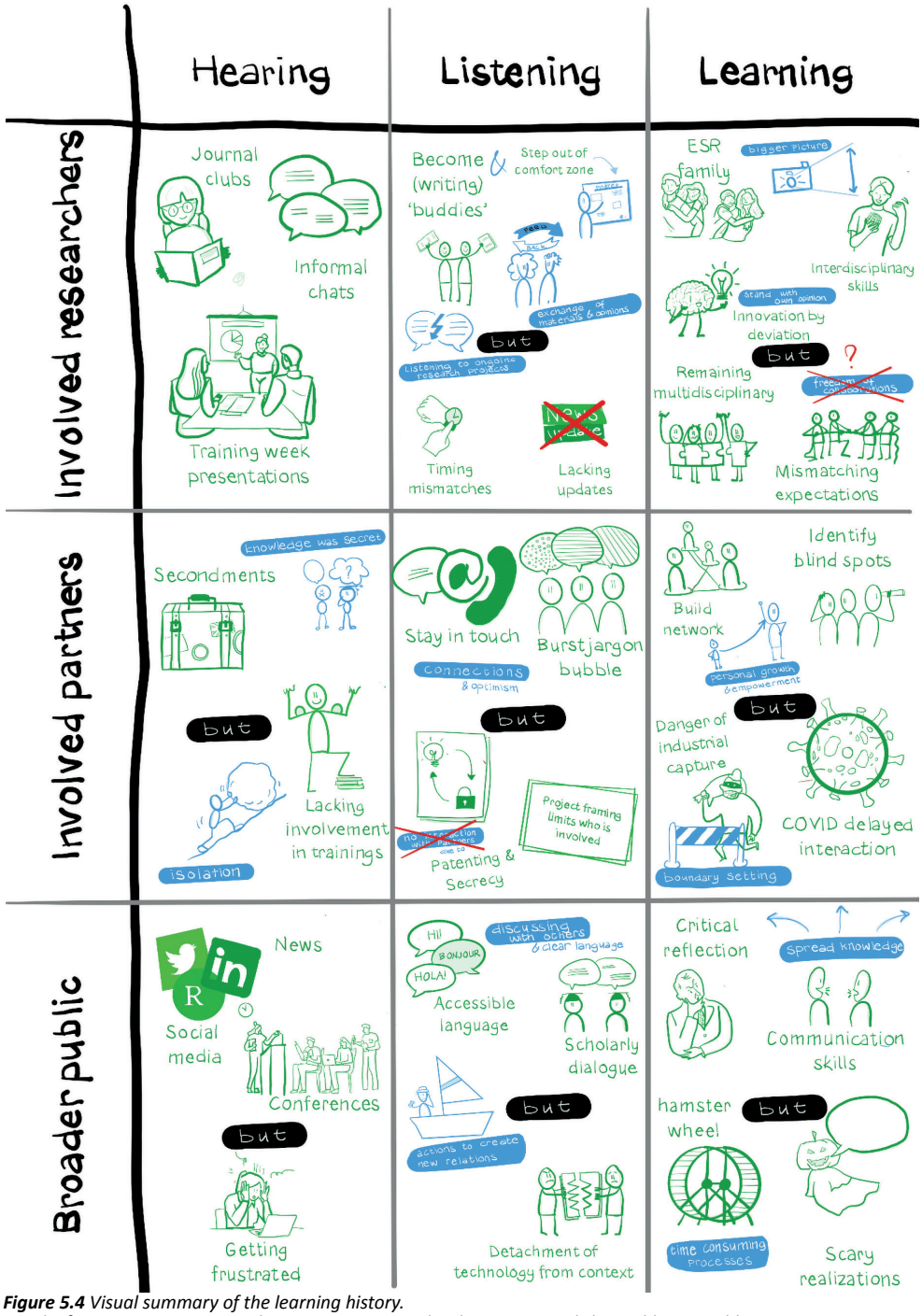

Figure 5.4 *Visual summary of the learning history.*
Results from questionnaires and interviews are visualized in green, workshop additions in blue.
Visualization by Simone Haarbosch.

The *first public (involved researchers)* is in regular contact with each other. The results of this learning history confirm that responsiveness between involved researchers means a continuous learning process, based on regular contacts and good professional relationships. Projects can stimulate this form of responsiveness between involved researchers by allowing more open-ended research trajectories and flexibility in required outcomes. A strict timeline for planned research outcomes can cause the disruption of established listening relationships if delays happen or unexpected (and perhaps even more innovative) outcomes arise. Hearing, listening, and learning capabilities of involved researchers regarding input of their peers are crucial as a 'safety net' for dealing with input from the other two publics. This is because if these capabilities are well developed among involved researchers, colleagues with relationships beyond the project's boundaries can translate taken up input for their colleagues. Then, the overall network can still benefit from innovative societal input, even if not all involved researchers are able to take up input from 'outside'.

Regarding the responsiveness to the *second public (societal partners)*, the learning history outcomes underline that learning entails crossing organizational boundaries and responding in a different language, namely in the language of practitioners. This does not only include letting go of jargon, but also to communicate on different time scales to address the oftentimes faster pace in non-academic environments. Continuous listening relationships are key in managing mismatching expectations, divergent needs in terms of output products, and to guarantee continuity in the context of mismatching time horizons.

Our results suggest that being responsive towards the *third public (the broader society)* requires hearing, listening to, and learning from uninvited, diffuse, and undirected input. However, engaging in public discussions about novel technologies and the societal effects of innovations is often an undervalued skill to be developed in the training of the new generation of scientists. In particular, lab-based researchers must also be given the room and agency to develop this skill.

This practice of responsiveness differs from other practices in innovation studies. In contrast to value-sensitive design (for biorefinery innovation, see Palmeros Parada et al., 2018, 2020), hearing, listening, and learning is a continuous process, rather than happening only in the technology design phase. Instead of inviting public actors to provide value-based feedback at a singular moment or a series thereof, this form of responsiveness calls for a continuous process of taking up also uninvited input. In contrast to value absorption capabilities (Garst et al., 2022), hearing, listening, and learning capabilities focus on forming sensemaking relationships with actors from the broader public. Moreover, the identified capabilities stress the political dimension of dealing with public input. Hearing,

listening, and learning is always selective and therefore subject to power relations, norms, and informal as well as formal rules.

This study also has limitations. First, a learning history should also include the perspectives of people from outside the organization (Roth & Kleiner, 1998). However, in this case, I restricted participation to the AgRefine ESRs. Reasons were that by this, I was able to achieve the required depth of reflection, because participants trusted me based on long-term professional relationships. As this study's goal was to analyse how PhD researchers respond to input from the different affected publics, learning among supervisors was not part of this study. This is because learning relationships between PhD students and their supervisors are already well documented (Gaunt, 2011; Halse, 2011; Lindén et al., 2013; Mammino, 2022; Stracke & Kumar, 2010). I considered also including the PIs and secondment providers, which would have provided a more complete picture of learning outcomes in the AgRefine project. However, the reflection process required a significant time investment, which was not feasible for PIs and partner organizations. Moreover, including supervisors in the group discussion would have likely impeded what participants shared. Furthermore, it was not possible to identify people from outside the AgRefine organization that are knowledgeable and informed enough about the learning processes within AgRefine. Still, this learning history can serve as a base of discussion for a reflection process that also includes supervisors and partner organizations as well as the general public. In a broader sense, future research might engage more systematically with the special form of responsiveness required to deal with uninvited societal feedback.

Second, while analysing the questionnaires and listening back to the interviews, I also reflected on the process of elaborating this learning history itself. In addition, also some participants provided uninvited input on the reflection process in the questionnaires and during the interviews. I tried to listen to this input. In particular, I realized that I used some dichotomies (ESRs versus PIs, engineers versus social scientists, involved societal partners versus broader societal actors, lab-based versus desk-based researchers) already during the elaboration phase. These dichotomies seldomly do justice to mixed experiences and realities of people involved or affected by AgRefine and might therefore result to be unproductive. However, these dichotomies also help in contrasting qualitatively different experiences, which was sometimes necessary to aggregate the reported different experiences. Furthermore, the sequence of hearing, listening, and learning artificially cuts apart a process that develops in a non-linear way. I regard the conceptualization as useful in disentangling learning processes of sensing input, forming relationships, and doing something with the input, which all require different skills and methods. Still, a contextualized picture requires appreciating hearing, listening, and learning as a non-linear and closely interconnected sequence. I therefore caution against analysing hearing, listening, or learning capabilities in isolation of each other in future studies.

Third, reflecting from an insider position entails the danger of being kept in a tunnel vision. To avoid that, I combined the different perspectives of 15 participants (including my own). Still, the learning history formulates the perspective of involved PhD students. This perspective is valuable in itself but might differ from the perspectives of involved supervisors, the project coordination, or involved societal partners. Moreover, in particular when it comes to critical remarks, it is necessary to avoid a spiral of negativity in this form of group reflection. Such a spiral could cloud the ambiguity of learning processes. I tried to mitigate this effect by regularly talking about preliminary insights and interpretations with colleagues from my department who were not formally involved in the elaboration of this learning history.

Also in light of these limitations, my results allow some recommendations for decisionmakers in funding agencies. To spark more disruptive innovation, funding agencies should foster more flexibility in planning secondments and trainings, while the research process unfolds. This is because pre-defined research outcomes, as specified in grant agreements, can jeopardize innovative and disruptive research. Several participants pointed out that common deliverables with pre-defined topics did not stimulate learning because they form designed-in dependencies and resulting timing mismatches. Stand-alone deliverables without connection to the individual dissertation project cause mismatching expectations between the training network and the home institution. Still, common reports can help to motivate participants to engage in collaborative research projects, if regarded as legitimate part of a dissertation. Supervisors have a crucial role in acknowledging the value of extending the pre-planned project scope towards open-ended collaborations to avoid a detachment of technologies from their societal context. To stimulate more responsiveness towards societal input, funding agencies should demand a better monitoring of the active involvement of societal partners, also in common publications and trainings. Furthermore, funding agencies could ask for a documentation of learning processes from uninvited input and stimulate related reflection processes. In particular, lab-based PhDs need to be given the time resources within working hours to engage in broader discussions, research contextualization, public outreach, and dissemination, as well as reflection.

Moreover, the results of this learning history allow me to formulate some recommendations for researchers and practitioners engaged in other research and innovation projects. Participants need to appreciate collaborative research as an open-ended process instead of pursuing pre-defined learning outcomes in demarcated deliverables. This includes letting the ongoing research process shape the planning of secondments and deliverables. To spark more inter- or even transdisciplinary collaboration, it is prudent to clarify and continuously review the roles of involved researchers and societal partners. This needs to include unambiguous agreements regarding the involvement in trainings, a planning

of common publications, and the engagement in public dissemination, without forming a tight and inflexible corset. This means to avoid designing-in dependencies between researchers or at least think of fall-back options. Moreover, participants need to regularly update each other on the research process and changes that affect other participants. Finally, to plan common publications and research outputs with societal partners, research and innovation projects need to avoid an exclusive focus on scientific contributions. This might require different forms of publication, such as podcasts, policy briefs, master classes, workshops, blogs, social media work, or popular newspaper articles.

To conclude, the AgRefine process was successful in forming a tight group of young professionals, the 'ESR family'. Perhaps paradoxically, project difficulties and hindrances to interdisciplinary collaboration contributed to realizing this outcome by bonding the group. In addition to the group process, also every ESR individually developed personally and professionally throughout the trajectory. Participants described acquired interdisciplinary skills and the contextualization of their disciplinary knowledge as most important learning outcomes. The bioeconomy in general and biorefinery innovation in particular were largely demystified for many ESRs by learning from uninvited societal input. Learning the art of critical reflection enabled the whole project to move from pre-defined learning outcomes to more innovative, disruptive, and deeper forms of learning. Realizing that your own work is not a silver bullet solution for sustainability challenges is a tough lesson, but the achieved personal growth is also a sign of hope. In the words of one participant: "In the end, you have to remain optimistic. If not, what is there for the world?"

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6

Chapter 6

Discussion, reflection, and conclusion

The point of departure of this dissertation is the observation that throughout the transition towards a sustainable and circular bioeconomy in the EU, controversies, such as the 'food versus fuel' debate, continuously resurface without being 'resolved'. The predominantly techno-economic bioeconomy literature struggles to find suitable answers on how to deal productively with such evolving controversies as a particularly intractable sort of conflict.

The central aims of this dissertation are therefore to (1) further develop the scholarly understanding of how controversies evolve throughout sustainability transitions and (2) to explore ways for stakeholders to deal more productively with these intractable controversies. Such stakeholders could have roles in diverse sectors, including policymaking, civil society, academia, and businesses. To address these objectives, I have posed the following main research question: *How can evolving controversies be dealt with productively in the European transition towards a sustainable and circular bioeconomy?* To answer this question, I have first worked towards a refined understanding of how controversies evolve throughout long-term sustainability transition processes. My first two sub-questions (SQs) contribute to this objective:

SQ 1. How do controversies evolve throughout a sustainability transition?

SQ 2. How do discourse coalitions evolve throughout a sustainability transition?

Building on these steps, the last sub-question serves the objective of exploring more productive ways to deal with controversies:

SQ 3. How can controversies be dealt with productively in sustainability transitions?

In Section 6.1, I synthesize the findings elaborated in the different chapters to provide answers to the main research question and the three sub-questions. In Section 6.2, I reflect on the strengths and limitations of my methodological and conceptual choices. Based on this, Section 6.3 provides avenues for future research. Section 6.4 closes by highlighting implications for different stakeholders involved in the European circular bioeconomy transition.

6.1. Synthesis

This dissertation begins with the observation that in the literature on bioeconomy governance, knowledge lacks on how intractable controversies continuously evolve in the circular bioeconomy transition. Such an understanding is required, though, to find productive ways of dealing with these controversies. This synthesis starts by answering the main research question, which has been posed based on this identified knowledge gap.

Main research question:
How can evolving controversies be dealt with productively in the European transition towards a sustainable and circular bioeconomy?

To answer this question, the main contribution of this dissertation is to provide a novel, more positive perspective on the role of controversies in the bioeconomy transition. Controversies are not always bad news, because they can surface alternative perspectives, which scrutinize biases and resulting lock-ins, adding to more disruptive forms of innovation in the bioeconomy transition. Instead of avoiding controversies or pursuing unfruitful resolution approaches that can even backfire and add to conflict escalation, stakeholders rather need to regard controversies as learning opportunities. Dealing productively with controversies therefore involves a continuous, reflective process of hearing, listening, and learning, where institutional innovation and governance can foster respective organizational and personal capabilities.

As elaborated in the literature review of Chapter 2, the currently dominant perspective in bioeconomy thinking regards controversies as something that can and should be out-designed, for instance in technology design and by a smart planning of supply chains and factory positioning. However, this understanding misrepresents the nature of controversies as deep-rooted framing conflicts, which cannot be resolved by producing new fact knowledge and therefore result to be an inherent and intractable element of sustainability transitions. As elaborated in Chapter 3, controversies are intractable in sustainability transitions because discourse coalitions continuously revive them throughout the ongoing transition process. Different loci provide constantly new settings, discourse coalition constellations, framings, and levels of attention. What is more, actors constantly adjust their use of storylines, which alters the constellation and network position of their discourse coalitions. This situation can only be captured by a dynamic understanding of controversies and involved discourse coalitions.

In line with the literature on conflicts and controversies, I have pointed out in Chapter 2 that the currently dominant engineering approach of trying to resolve controversies is unfit to deal with this intractability. What then, is a more productive way forward?

My results on the meso-level operations of so-called Triple Helix collaborations between actors from the three spheres of industry, academia and government indicate that instead of trying to avoid or resolve controversies, stakeholders can better focus their resources on (further) developing hearing, listening, and learning capabilities to deal with controversies in a more productive way (Chapter 4). In addition, my results on micro-level biorefinery research and innovation show that reflection and collaboration with actors who think fundamentally different is required to burst cognitive bubbles and resulting biases (Chapter 5). The productivity of controversies lies in disrupting established biases and in their innovative power of surfacing novel, perhaps marginalized problem definitions and solutions. To unlock the productive potential of controversies, decisionmakers, for instance in policymaking, civil society, academia, and businesses, can improve their capabilities to hear, listen to, and learn from societal input.

However, hearing, listening, and learning are not mechanistic processes, but inherently political. Actors constantly make choices on the relevance of invited, but also uninvited input, thereby creating effects of exclusion and bias manifestation. For instance, decisionmakers in analysed Triple Helix clusters have constructed uncritical publics by setting the terms of dialogue (Chapter 4) and some researchers within the AgRefine project have detached technological innovation from its societal context (Chapter 5). Still, characteristics of collaborative projects can help to foster frame diversification and responsiveness. For example, uninvited input can be regarded more systematically and dealt with more productively by extending the range of heard actors, pluralizing the array of involved perspectives, and introducing processes for reflection and learning. In a nutshell, the innovative power of controversies can be unlocked by democratizing research, innovation, and bioeconomy development processes.

In practical terms, the bioeconomy transition therefore requires further politicization. Practitioners and scholars alike, by listening to controversies, can surface currently widely undiscussed topics, for example by scrutinizing underlying assumptions and biases on a series of political questions related to the European circular bioeconomy transition: How do decisionmakers distribute the pool of sustainably sourced bioresources? What uses are circular and sustainable? What does circularity and sustainability actually mean in a particular context? What level of consumption can be satisfied based on the available resources? To what extent is the current 'green future' pathway indeed suited to fulfil the transformative sustainability ambition of the bioeconomy?

Unlocking the innovative potential of controversies provides no guarantee of steering the bioeconomy transition towards more sustainable and circular outcomes, which is an important topic for future research; see Section 6.3 below. Still, productively dealing with controversies enables decisionmakers to avoid discursive lock-ins and resulting biases.

Opening up bioeconomy debates in this regard surfaces alternative problem definitions and innovative solutions that deviate more radically from status quo practices. In this way, transition pathways that merely aim to improve linear status quo operations, business models, and governance arrangements, can be scrutinized. By this, learning from controversies helps broadening the array of policy options for decisionmakers to take into consideration. Moreover, politicizing the bioeconomy transition in this way can contribute to the identification and empowerment of new, formerly excluded, actors to raise their voice in decision-making processes in diverse loci. These actors with alternative perspectives might challenge established power relations, scrutinize status quo institutions, and advance novel regime constellations. Unlocking controversies therefore stimulates a more reflective and inclusive form of bioeconomy transition.

To substantiate these answers, the subsequent sub-sections zoom in on the three conceptual building blocks developed in Chapter 2 and formulated in form of the three SQs: (1) controversies reappear in different loci with different actors, frames, and communication rules throughout a sustainability transition; (2) while shifting through these loci, discourse coalitions evolve; (3) and controversies can have both productive and unproductive effects on the unfolding transition process.

6.1.1. Controversies reappear in different loci

SQ 1. How do controversies evolve throughout a sustainability transition?

To explore more productive ways of dealing with controversies in sustainability transitions, I first needed to elaborate a refined understanding of how they evolve throughout an unfolding transition. To this end, in Chapter 2, I provide a novel conceptualization of the role of controversies in the EU bioeconomy transition. In Chapters 3-5, I further develop and empirically explore the different building blocks of this conceptualization. The conceptual answer to the first SQ is that controversies evolve throughout a sustainability transition by reappearing in different loci of the transition process. Loci are divergent settings within a transition that involve different actors with different framings.

This first conceptual building block draws from the literature on sustainability transitions, in particular the Multi-Level Perspective (Geels, 2002, 2005, 2011). Throughout this dissertation, I situate entry points for controversies on and between the three levels of a transition: macro, meso, and micro. The macro level concerns long-term discursive, political, and cultural changes on a high level of abstraction (Geels, 2020). An example of a formal interpretation of such changes is the supra-national bioeconomy policy strategy on EU level. The meso level entails regime operations in a relatively stable structure of established regulations, markets, expectations, knowledge, and infrastructure (Markard & Truffer, 2008). The micro level, finally, entails non-established ways of thinking, doing,

and organizing (Van Der Minne et al., 2021). At each of these loci, I empirically identify the content of surfaced controversies in the form of conflicting considerations about the role of biorefineries in a sustainable and circular bioeconomy.

On the macro-level locus, I identify an emerging discursive lock-in in online debates about the future of the European bioeconomy (Chapter 3). The core of the dominant 'green future' discourse coalition is formed by industrial lobby organizations and large parts of the European Commission. Moreover, in the last period, vocal EU-funded research projects have joined this discourse coalition. Powerful actors therefore gather on one side of the discourse network. In such a situation, ideas from the minor part of the discourse network cannot find entry in policymaking (cf. Hajer, 1995). Hence, this emerging discursive lock-in constitutes biases in regarded problem definitions and attached solutions. This discourse network constellation indicates the danger that regarded solutions are closed down to technical approaches in line with the 'green future' discourse (cf. Stirling, 2008). These solutions might remain close to linear, take-use-dispose practices of production and consumption, while switching from fossil to bio-based raw materials. In such a situation, alternative ideas from the 'planetary boundaries' discourse coalition on how to develop a more circular and sustainable bioeconomy are less likely to feed into policymaking.

On the meso-level locus, current regime constellations are renegotiated (Bosman et al., 2014). In Chapter 4, I zoom in on regional transitions from fossil-based towards bio-based industries. In this sense, I analyse Triple Helix cluster collaborations of industry, government, and academia as endeavours to advance novel regime constellations of business models, infrastructure, institutions, and technology for bio-based production (Maciejczak, 2009; Murillo-Luna & Hernández-Trasobares, 2023). These Triple Helix collaborations develop in the context of controversies in other loci. For instance, the macro-level controversies identified in Chapter 3 form the context in which regional, bio-based industrial operations are developed. In Chapter 4, I therefore explore how actors involved in Triple Helix clusters deal with such 'outside' controversies. More specifically, I ask how actors engaged in Triple Helix clusters deal with uninvited input (for instance, in form of protests, social media engagement, local press releases, or spatial planning objections) from societal actors who are not part of the cluster. The results indicate that listening capabilities are limited in analysed cases, leading only to first-level learning, which constitutes in less transformative improvement trajectories. These findings indicate that actors can also construct a certain degree of impermeability for controversies between loci. In other words, skilful actors can manage to shield 'their' locus from controversies that surface in another locus. I argue that constructing this impermeability is unproductive, because it leaves controversies smouldering with the danger of erupting at a later stage, when adaptations in process designs, institutional set-up, governance arrangements, or planning processes are less feasible.

On the micro-level locus, I analyse how PhD researchers within the AgRefine research and innovation training network (including myself), have dealt with input from the different publics that are affected by the network's actions: involved researchers, societal partners, and the broader public (Chapter 5). The identified detachment of technological biorefinery innovation from its societal context shields the niche-level research and innovation process from controversies that surface in other loci. In the AgRefine project, this is found to be partly due to project characteristics, such as designed-in dependencies and resulting mismatches in timing research outcomes that hindered interdisciplinary collaboration. Moreover, the detachment is partly due to personal characteristics and choices of the individual researchers to regard the societal context as irrelevant for the technological innovation process in the technology design phase. However, locking-in choices made in this phase makes adaptations during the upscaling of the innovation at a later stage less feasible. This process of separating lab-based, technological innovation from its societal context constructs a protected niche on the micro-level locus, impermeable for controversies surfacing in other loci, which are resultingly left neglected. Still, the strongly developed listening relationships between involved researchers have enabled them to translate their insights from listening beyond the project's boundaries to their peers. This interdisciplinary translation skill helps to increase the permeability of the niche locus, which is prudent to not lose the opportunity to learn from controversies at early stages of technology and innovation development.

Bringing the insights from the different loci together, I observe that essentially the same controversies resurface in the different loci, albeit in different shapes. This is because groups of actors that share congruent perspectives on the circular bioeconomy operate across the different loci. For instance, the 'green future' discourse identified in Chapter 3 is widely shared by policymakers in the European Commission on Twitter (macro), collaborators in Triple Helix clusters (meso), and involved partner organizations in the AgRefine project (micro). These discourse coalitions 'carry' controversies through the different loci. Figure 6.1 illustrates how evolving discourse coalitions are positioned into the conceptual framework on controversies in sustainability transitions.

Different loci can be more or less permeable towards controversies that surface in other loci. This is because actors can actively work to create a certain degree of impermeability of their locus, which is done by disregarding broader concerns as irrelevant for their situation. For example, some AgRefine PhD researchers detached their technological innovation process from its societal context. Creating such an impermeability hinders learning from controversies in other loci. At the same time, different loci also entail different opportunities to open up debates, for instance due to differences in actor constellations, power balances, resource distributions, communication rules, and institutional set-ups. This implies that if debates in one locus are discursively locked-in in one locus, actors could have more productive debates in another one.

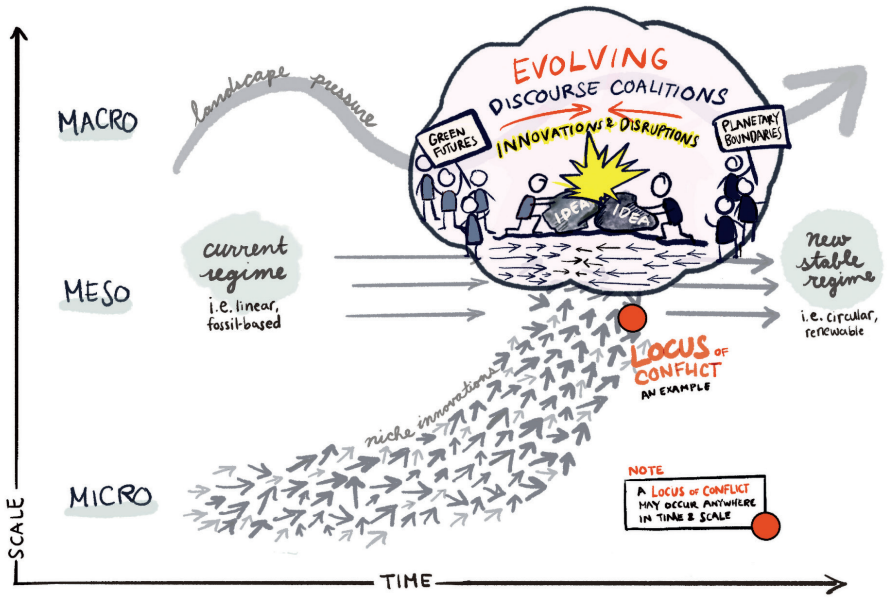

Figure 6.1 *Integration of evolving discourse coalitions into the conceptualization of controversies in sustainability transitions.*
Visualization by Emily Liang.

With these insights, I add to the politics of sustainability transitions literature by providing a conceptual framework of how controversies evolve throughout a sustainability transition. This is in line with an emerging branch of research on conflicts and power in sustainability transitions (Avelino, 2017; Avelino et al., 2016; Köhler et al., 2019). By integrating conceptual ideas from conflict resolution and public administration literatures and by demonstrating the use of the developed framework on transition controversies in various loci throughout the dissertation, I add a more refined understanding of the intractability of controversies, which helps contextualizing socio-technical transition processes.

6.1.2. Evolutions of discourse coalitions throughout the transition

SQ 2. How do discourse coalitions evolve throughout a sustainability transition?

This sub-question builds on the second conceptual building block, evolutions of discourse coalitions. Conceptually, I build on the literature on dynamic discourse coalitions (Metze & Dodge, 2016), which in turns builds on Hajer's (1995) conceptualization of discursive groups of actors. By actor-storyline dynamics of storyline confirmation, integration, disintegration, and polarization (Metze & Dodge, 2016), actors continuously reshape discourses, thereby also altering the constellation of their discourse coalitions. This implies that discourse coalitions can solidify, grow, shrink, merge, or fall apart over time. Rather than

static constructs, discourse coalitions continuously change their shape, internal composition, and relative network position towards other discourse coalitions. A more dynamic understanding of discourse coalitions is therefore required (Metze & Dodge, 2016).

Empirically, Chapter 3 takes controversies on the macro-level locus of overarching discursive changes as a point of departure. To further develop the understanding of the intractability of controversies in the EU circular bioeconomy transition, I explore the dynamics of how discourse coalitions evolve in online debates. To this end, I map longitudinal changes of debates about the future of the bioeconomy in the European Union on Twitter, nowadays known as 𝕏.

The unit of analysis is the discourse network, understood as the totality of actors and discourses in a debate (cf. Fergie et al., 2019; Leifeld, 2020; Markard et al., 2021; Mijailoff & Burns, 2023). In this perspective, discourse coalitions are clusters of actors around congruent ideas, which are aggregated in a coherent narrative and communicated through storylines. By providing a longitudinal analysis, I identify how the actor-storyline dynamics of integration, disintegration, confirmation, and polarization (Metze & Dodge, 2016) lead to a sequence of discourse network diversification and simplification, resulting in a polarization of the overall debate. Particularly, the debate about the future of the EU bioeconomy is found to be a rather exclusive expert discussion around different benefits of developing a 'knowledge-based' bioeconomy before the enactment of the initial EU bioeconomy strategy in 2012. In the period between the publication of the initial strategy and its update in 2018, more actors Joined the discussion and diversified the debate by bringing in novel storylines. At the same time, the debate simplified into two core argumentations, around which two discourse coalitions emerged: 'green future' and 'planetary boundaries'. After the 2018 update, storyline hijacking, an additional actor-storyline dynamic, contributed to a further polarization of the two coalitions, ultimately leading to the current, bipolar discourse network. The identified discourse network dynamics imply that online discourse coalitions continuously evolve in their composition of actors and embraced storylines. In doing so, actors not only influence the composition of their discourse coalition but also alter the underlying discourses themselves.

While forming structural characteristics of the discursive environment, these alterations on the level of the discourse network can be traced back to argumentative changes on the level of individual actors. This more fine-grained analysis then also enables the identification of entry points to open up debates again. Decisionmakers can work towards opening up debates by considering ideas from currently excluded parts of the discourse network. However, the subsequent chapters point out that this opening up is an inherently political process, entailing negotiations of what is heard, who is listened to, and what is learned.

Identified actor-storyline dynamics contribute to a refined understanding of the intractability of controversies in sustainability transitions because they demonstrate that involved discourse coalitions are not static, but continuously evolve. Throughout these evolutions, actors continuously reshape underlying discourses, which results in new – or perpetuated – problem definitions and innovative – or closed-down – solution approaches. These dynamics continuously revive controversies throughout the different loci of a transition process, adding to their intractability. The same discourses reappear in slightly different shapes (for instance, more localized concerns) throughout the different loci. Like-minded actors can be conceptually aggregated into discourse coalitions that can operate in different loci at once. Dynamic discourse coalitions therefore connect the different loci and 'carry' controversies throughout a sustainability transition, see Figure 6.1.

These findings contribute to the literature on policy controversies by further specifying dynamics of how actors adapt storylines over time. In addition to the dynamics suggested by Metze & Dodge (2016), in Chapter 3, I identify storyline hijacking as an additional actor-storyline dynamic in an online setting (see Vivien et al., 2019 on the concept of hijacking in bioeconomy policymaking). This dynamic consists of disintegrating the storyline of an opposing discourse coalition and integrating it into one's own argumentation, while adjusting the storyline's meaning to fit into the own narrative. An example from the macro-level locus of bioeconomy controversies is the hijacking of the 'planetary boundaries' coalition's use of the circularity storyline (bio-based production is not circular per se) by the 'green future' coalition ('novel biorefining technologies add to a more circular use of bio-based resources'). Moreover, I show that these storyline dynamics on the level of individual actors also have implications for the broader network of discourse coalitions. On the discourse network level, I identify diversification, simplification, and polarization dynamics as a result of alterations in the connections between actors and storyline.

In addition, I add to the literature on discursive lock-ins (Metze, 2018a; Simoens et al., 2022; Simoens & Leipold, 2021) by demonstrating productive ways of unlocking locked-in controversies. Instead of unproductive – or even backfiring (Wolf & Van Dooren, 2021) – resolution or avoidance approaches, actors can better learn from controversies by hearing divergent inputs and actively constructing and maintaining meaningful listening relationships with actors that sponsor divergent frames. This frame divergence can be identified by mapping the discourse network structure. Based on this knowledge, bioeconomy stakeholders and governance actors, such as policymakers, can foster the development of listening relationships between actors from different parts of the discourse network.

Apart from these conceptual contributions, I make a methodological contribution in Chapter 3. In particular, I further develop the Discourse Network Analysis method towards mapping changes of discourse coalitions in addition to the identification of advocacy coalitions, which was the original use of the method (Leifeld, 2013). Identifying discourse coalitions is an emerging ambition in studies applying the Discourse Network Analysis method (Fergie et al., 2019; Kukkonen et al., 2021; Mijailoff & Burns, 2023). However, when applying the method to map changes of discourse coalitions while maintaining the coding design intended for advocacy coalitions, scholars end up identifying a bipolar discourse network of two actor clusters around either the agreement or disagreement on a fixed set of policy instruments (Leifeld, 2017). This problem is referred to as the 'bipolarization by design' problem (Leifeld, 2017, p. 4). To avoid this problem, I first re-define concept nodes into storyline nodes (see also Kukkonen et al., 2021 who refer to 'moral justifications' with a similar purpose). Second, I use only agreement qualifiers to establish edges between actor and storyline nodes. This is because instead of simply disagreeing with a storyline, actors in discourse coalitions rather utter a new storyline to make their point. As a result, the discourse network does not consist of two opposing discourse coalitions by design, but various discourse coalitions around shared agreements on a complex set of storylines can be identified. These adaptations consequently enable the longitudinal identification and visualization of multi-faceted and -focused discourse coalitions in not-so black-and-white controversies. These adaptations help me to identify a multi-faceted situation in the first study period of my empirical social media analysis, which has increasingly become bipolar later on.

6.1.3. Dealing productively with controversies

SQ 3. How can controversies be dealt with productively in sustainability transitions?

By means of the third sub-question, I build on the third conceptual building block: productive and unproductive ways of dealing with controversies in sustainability transitions. For this building block, I draw on the literature on constructive conflicts (Cuppen, 2018; Kriesberg & Dayton, 2017; Wolf & Van Dooren, 2021; Wu & Laws, 2003). Applying this knowledge to the bioeconomy transition, I argue that on the one hand, controversies can develop in productive ways and bring the transition process forward by stimulating learning and innovation. On the other hand, controversies can become unproductive in transition processes by manifesting stalemates and paralysis. Exclusion and lacking responsiveness can cause losing sight of the transition's directionality and transformative ambition. This creates a self-perpetuating dynamic of deteriorated relationships and lost trust, endangering future collaboration (Kriesberg & Dayton, 2017).

To deal more productively with controversies than the currently dominant approaches of avoidance and unfruitful resolution approaches in bioeconomy thinking, I conceptualize

organizational capabilities of hearing, listening, and learning for bioeconomy stakeholders to deal more productively with uninvited input (Chapter 4). Hearing means sensing input from beyond the organization's boundaries. Listening is the interpersonal generation of meaning from this input (Jacobs & Coghlan, 2005). Learning is to reflect on this input and to implement necessary adaptations in the organization's operations.

In Chapter 4, I identify processes and preconditions of these capabilities in three regional Triple Helix clusters working on regional bioeconomy transitions in different member states of the European Union. Results are that actors engaged in the Triple Helix clusters isolate their operations from controversies by creating an 'outsider' public. This happens by centring discussions around technical issues and dismissing fundamental, value-based concerns as emotional, unscientific, and therefore unrelated. By this, uninvited input from the broader public that scrutinizes fundamental beliefs held by cluster 'insiders' is seldomly listened to and cannot contribute to innovation within the cluster. Learning consequently remains limited to first-loop adaptations of already established production logics (cf. Argyris & Schön, 1978). As a result, ideas to foster circularity and sustainability that deviate more radically from status-quo practices cannot find entry in these regional bioeconomy transitions, what adds to an institutionalization of the macro-level discursive lock-in identified in Chapter 3. These results correspond with findings in the neighbouring circularity and water management transitions that established actors successfully manage to close down debates to less disruptive technological improvement trajectories (Yalçın et al., 2024).

These findings contribute to the Triple Helix literature by pointing out that representation problems cannot be solved by invited participation alone. By this, I relate to recent conceptual and organizational advances in opening up Triple Helix collaborations to the broader society (Carayannis & Campbell, 2009, 2010; Etzkowitz & Zhou, 2006; Zhou & Etzkowitz, 2021). To go beyond a singular focus on *invited* participation, I conceptualize organizational hearing, listening, and learning capabilities to deal with *uninvited* societal input. This is achieved by adopting insights from the literature on uninvited participation (Cuppen, 2018; Wehling, 2012) and organizational learning (building on Argyris & Schön, 1978).

In Chapter 5, I carve out how PhD researchers within the AgRefine programme have managed, but also failed, to deal more productively with controversies by becoming responsive to controversies surfacing in other loci by identifying processes of hearing, listening, and learning from the different forms of input. My main result is that PhD researchers who invested time and effort in listening to uninvited input and had the agency to do so, achieved deeper forms of learning. In particular, many PhD researchers became more critical of the bioeconomy in general and biorefinery innovation in

particular. Consequently, they changed their research questions, objectives, and the research process, adopting a broader and more contextualized lens. However, detaching technological innovation from its societal context hindered in particular lab-based PhD researchers to become responsive to input from beyond the project's boundaries. It should be noted, though, that my desk-based peers regarded it as a privilege to closely engage with societal partners and the broader public, because lab-based PhDs were frequently (kept) busy with experimental work.

These results highlight the value of inter- and transdisciplinary collaborations in enabling niche researchers to productively hear, listen to, and learn from controversies that surface in other loci. Closely engaged societal partners can bring in their perspectives and experiences from these other loci. Including a plurality of perspectives can thereby contribute to a politicization of the constructed technological innovation niche. This politicization can help to overcome biases in problem definitions and solution approaches and prevent locking-in these biases in innovation processes. In other words, hearing, listening to, and learning from controversies can unlock more disruptive innovation that deviates more radically from status quo biases. In Figure 6.1, the spark resulting from the clashing discourse coalitions visualizes this productive role of controversies in stimulating innovation and disruption in sustainability transitions. In the AgRefine project, I conclude that the interdisciplinary ambition was not achieved on the level of the project. Still, all involved PhD researchers valued their individual learning and development processes, some even fundamentally adjusted underlying belief systems and became more critical about the sustainability of biorefineries. Despite widely shielding their research from broader, societal input, all PhD colleagues still closely listened to and learned from the other involved researchers. My findings indicate that – also beyond AgRefine – research and innovation projects can productively deal with controversies by becoming responsive towards a broader range of input stemming from all affected publics.

With this analysis, I contribute to discussions on the responsiveness principle in the Responsible Research and Innovation literature (Chakraborty & Pandey, 2023; Klerkx & Rose, 2020; Nielsen, 2016) by suggesting that different affected publics in research and innovation projects might require different forms of responsiveness. In the AgRefine project, involved researchers have become responsive to each other by developing tight relationships to discuss also underlying value differences. Becoming responsive to societal partners, in contrast, requires a better integration in all research steps and a more active role in shaping research agendas, outcomes, and timings. Responding to the broader public requires seeing the connection between the technological innovation process and its societal context. Also beyond AgRefine, the results of the collaborative learning history indicate that innovative potential lies in learning to hear and listen to the broader public in addition to formal project participation. Consequently, I argue that

my conceptualization of hearing, listening, and learning capabilities helps to sharpen the definition of responsiveness, in particular regarding the interpersonal processes of taking up input from inside and outside an organization's boundaries.

6.2. Reflection on methodological and conceptual choices

Every PhD trajectory is a journey of choices. In this section, I reflect on the strengths and limitations of the methodological and conceptual choices that I have made throughout the research process. I start this reflection with remarks on the overall approach of this dissertation. Consequently, I continue with a discussion of methodological and conceptual choices along the three conceptual building blocks and connected sub-questions presented above. These reflections accompany the sections on limitations of Chapters 2-5, which point out limitations of the individual studies and their possible impacts on the drawn conclusions in the respective chapters.

6.2.1. Overall research approach

First, I reflect on the overall research approach of this dissertation. Bioeconomy governance is an infant field in both policy and research (Böcher et al., 2020; Vogelpohl et al., 2022; Vogelpohl & Töller, 2021). On the one hand, overarching patterns and broad lines of a bioeconomy policy field start to emerge (Vogelpohl & Töller, 2021). For example, bioeconomy strategies have mushroomed in several countries and regions (Dietz et al., 2018), local bioeconomy projects are developed all over Europe (Parisi, 2018), and the bioeconomy is increasing discussed also in the broader public (Chapter 3). However, the bioeconomy concept is still ambiguous and segregated into several sub-areas, such as bioenergy, -fuels, and -plastics (Vogelpohl et al., 2022). Bioeconomy research is still predominantly an engineering field on advances in novel technologies (Böcher et al., 2020; Pfau et al., 2014). Research on politics and the governance of the bioeconomy is only taking off (Böcher et al., 2020; Eversberg, Holz, et al., 2023). Such a loosely structured, emergent field requires explorative research designs (Kumar, 2019). In particular, explorative research can flag current blind spots to inform theory-building and conceptual work but is not limited to this. In this sense, a strength of the research approach of this dissertation is to add more complexity to a field that widely sees the world as too under-complex.

To this end, I use divergent methods for different purposes. In particular, Chapters 3 and 4 show this divergence. Chapter 3 builds on a large-N setting of several thousand analysed tweets and a helicopter view analysis by means of social network analysis tools, integrated with a more detailed qualitative twist. Chapter 4, in contrast, is a more traditional interpretive analysis in a small-N setting and based on rich, textual data to generate thick descriptions (Schwartz-Shea, 2015). Still, these divergent methods function under the same ontological understanding of the interpretive research approach outlined

in the introduction of this dissertation. This illustrates that the place for interpretivist research is not limited to small-N, qualitative, and theory-building endeavours, as some positivist researchers would perhaps demarcate it (Yanow, 2015). Throughout the dissertation, the chosen interpretive research approach rather functions to achieve a detailed understanding of nuanced and partly ambiguous processes happening under the surface of seemingly clearcut developments.

However, in addition to opportunities, limitations lie in my positionality as bioeconomy researcher, analysing the very same processes and institutions that I am deeply involved in and partly dependent on. For instance, this 'being-part-of' the controversial setting closed some doors. In practical terms, for Chapter 3, I started by interviewing Brussels-based stakeholders with divergent perspectives. Upon a transparent outlining about my engagement in the AgRefine project, an interview partner from an environmental NGO who had already confirmed their availability for an interview dropped out minutes before the scheduled appointment. We had an informal talk afterwards, but the interview partner did not want to formally contribute to a research and innovation project where industry partners play a prominent role. Moreover, some interview partners might have felt restricted on what they shared with me. For example, a staff member from a Directorate-General of the European Commission only wanted to talk with me in a neutral setting (not in their office) and under strict confidentiality arrangements. For Chapter 4, I was dependent on the cooperation of regime actors in Triple Helix clusters who were not always keen on revealing heard societal back talk or controversial aspects of their projects. I often sensed an attitude of 'letting sleeping dogs lie'. I tried to address their concerns by transparently laying out the analytical goals of the study and by pointing out the value of critical research. Still, I cannot guarantee that these interview partners trusted me enough to share also negative aspects of their projects. In the analysis, I tackled this issue by triangulating the interviews with different data sources, namely policy and planning documents as well as newspaper articles. Another indication of my own positionality in analysed controversies is that the original Twitter data set used for Chapter 3 contains tweets from the AgRefine account, one of my supervisors, and myself. However, these tweets were filtered out already in the first thresholding step. This close entwinement of research object and researcher limits the establishment of a required objectivity assumed by positivist research approaches (Yanow, 2015). However, interpretivists argue (and I follow this argumentation) that a detachment of researcher and research object is in general unfeasible, particularly for complex, societal issues (Yanow, 2015). I have therefore continuously strived towards establishing an intersubjectivity in my findings (Schwartz-Shea, 2015), for instance by including expert interview partners with widely divergent perspectives in the elaboration of the coding scheme (Chapter 3), triangulating data sources (Chapter 4), or channelling back interpretations to participants (Chapter 5). Moreover, I have constantly discussed my interpretations with my supervisors and

co-authors, colleagues who are not involved in my project, as well as former interview partners.

Moreover, my analysis is demarcated (and thereby limited) to the European context. Decisions made on the trajectory of the European bioeconomy transition can have consequences all over the globe. For instance, when a large-scale bioeconomy requires the global import of bio-resources, unequal power balances in trading and value creation can lead to injustices in a global perspective (Hamilton & Ramcilovic-Suominen, 2023). Resulting concerns from outside of Europe are only included to a very limited extent in my analysis. My research design only captures concerns from outside of Europe, if they are either (a) reported in previous academic research that I have identified, or (b) uttered on social media in the context of European bioeconomy debate (Chapter 3). The latter would require that affected actors see a connection between their situation and European bioeconomy policymaking, have access to and are active on 𝕏, and voice their concerns there. Presumably, this group is very small. My conclusions can therefore be biased towards more localized, European concerns. Effects of European bioeconomy policies in other parts of the globe therefore require more research. Furthermore, also in finding solutions to the identified problem of dealing with controversies in the European context, I was also largely restricted in finding solutions stemming from a European or 'Western' point of departure, anchored in the academic knowledge system. However, alternative and perhaps more suitable solution approaches to deal more productively with controversies could stem from literature and sources from other parts of the world that are not readily accessible to me. My interpretations are therefore likely biased in this regard. To mitigate this, I tried to read and discuss broadly. Still, I regard my results as primarily applicable to the European context and I have demarcated this dissertation accordingly.

6.2.2. Analysis of controversy evolutions across transition loci

Second, I reflect on the conceptual and methodological choices regarding the analysis of how controversies evolve throughout the different loci of a sustainability transition. Conceptually, the identification of loci rests on the Multi-Level Perspective (Geels, 2002, 2005, 2020). This perspective foregrounds interactions between socio-technological innovation trajectories and societal change towards more sustainable systems. This perspective helped me to analytically differentiate different loci. However, this perspective also fogs the 'messiness' of sustainability transitions as highly conflictual, non-linear, and political processes. Moreover, in this perspective, a critical appreciation of the role of technological innovation processes in locking-in less transformative optimization and improvement trajectories is subordinated for the benefit of a more optimist perspective on technological innovations as enablers of societal change. As such, like every conceptual perspective, the applied underlying conceptualizations foregrounds some aspects, while disguising others. My conceptual adaptations give the conceptualization a more political

spin, which is in line with recent work on politics and conflicts in sustainability transitions (Avelino, 2017; Avelino et al., 2016; Cuppen et al., 2019).

In analysing controversies in the different loci, I necessarily had to be selective in the choice of arenas, settings, and cases. In Chapter 3, I empirically focused on an online setting, whereas macro-level controversies can also evolve offline, for instance in broader cultural changes, high-level strategic policy formulation processes, or in global governance institutions, such as the climate or world economy conferences. In Chapter 4, I focused on a small selection of cases. The casing strategy rather focuses on an accumulating interesting insights in divergent, yet comparable settings (Simmons & Smith, 2021), rather than the construction of a representative sample to generate generalizable findings for an overarching population (Stake, 1995; Yin, 2018). Identified back talk in these cases can therefore not be extrapolated to all bioeconomy operations in general. Still, the identified back talk content can be indicative for overarching patterns (such as the intermingling of voiced concerns about localized environmental nuisances and broader concerns about the future course of the transition) in bioeconomy politics more general. Chapter 5 even focuses on a single case. The impact of this limitation on my drawn conclusions is that I regard identified patterns and processes as an empirically substantiated conceptual entry point for future research on a broader range of cases, rather than universally applicable results.

6.2.3. Analysis of evolutions of discourse coalitions

Third, I move this reflection towards choices regarding the identification and analysis of discourse coalition evolutions. The chosen methodological approach allowed a clear visualization of how discourse networks have evolved throughout the three defined study periods. By adding a qualitative analytical element, I was able to add a more detailed account of actor-storyline dynamics. Regarding connected methodological limitations of this approach, I can widely refer back to my elaborations in Chapter 3. However, in the context of the overall dissertation, I have not analytically focused on how discourse coalitions evolve across different loci. This would have required a different methodology, perhaps based on combining different data sources, such as social media data with newspaper articles. Similarly, the identification of discourse coalition evolutions is restricted to the macro-level locus. Similar analyses in other loci have the potential of empirically scrutinizing whether and to what extent identified dynamics are specific for social media discussions, bioeconomy discussions, or sustainability transitions in general.

Moreover, storylines as discursive elements that bind identified discourse coalitions have been based on a rather limited set of seven expert overview interviews. This limitation was mainly due to COVID restrictions at the time of data collection, but also access biases resulting from my positionality (as outlined above). Therefore, I enriched this data by findings from the bioeconomy literature and a more inductive approach of identifying

storylines from identified tweets. I acknowledge that different researchers could identify a different set of storylines, which also affects the coding process and resulting network graphs. However, I regard this limitation of minimal impact on drawn conclusions. Due to the large number of storylines and the imposed thresholding, the set is rather robust: The overall network structure remains in place even if edges with low congruence values are deleted due to coding differences. Moreover, if not under the label that I put, tweets probably would have been categorized under a similar label. I therefore regard the identified evolutions of the overall discourse network structure (from dispersed to bipolar) as well as the identified actor-storyline and resulting network constellation dynamics as robust also if a different coding scheme was applied. Replication studies that include the step of formulating the coding scheme could provide more definite answers and reliability estimates on this.

6.2.4. Analysis of the productivity of controversies

Fourth, I reflect on my choices regarding the productivity and unproductivity of controversies in transition processes. In addition to a conceptual and empirical-analytical study, I have also directly applied knowledge-in-the-making in a real-world setting. This is because in Chapter 5, I apply a collaborative co-production approach. This action-oriented approach accompanies the more traditional desk-based research work conducted in the first chapters. By means of this approach, I shifted the focus from the research outputs towards the research process. For me personally, the initiated reflection process has provided a series of learning moments that replenish the outcomes outlined in the end product, the learning history. From what I heard from my peers, also the other participants benefitted from this reflective journey. The applied combination of more traditional analyses and this collaborative reflection approach stimulated my learning process, which is one of the major objectives of a PhD trajectory.

On the flipside, the analysis of the productivity versus unproductivity of controversies is empirically restricted in this dissertation to widely negative examples on the meso level (lacking listening in Triple Helix clusters) and a broadly positive example on the micro level (successful learning among ESRs in the AgRefine network). This restricts the drawn conclusions to primarily concern the analysed cases only, while the generalizability is widely limited to the identification of patterns that can be used in further theory-building. To explore more systematically (a) how micro- and meso level actors deal in similar or divergent ways with controversies, (b) whether Triple Helix operations are indicative of bioeconomy projects more broadly, and (c) if AgRefine is an exception rather than the rule, different research designs are required. For instance, different forms of collaborative governance in the different regions could be compared as well as different institutional set-ups of research and innovation projects.

Moreover, I stress that the conceptualized, inherently political sequence of hearing, listening, and learning is meant as one way to deal more productively, but by no means the only one. The chosen research approach is not fit to establish whether the approach of (further) developing hearing, listening, and learning capability is more or less 'effective' in dealing with controversies than possible alternatives. Such effectiveness could be conceptualized based on conflict escalation, but also on the sustainability or other forms of normative desirability of outcomes.

6.3. Recommendations for future research

Taking into consideration the strengths and limitations of both my overall research approach and the individual chapters, as well as my contributions to different strands of literature, in this section, I formulate recommendations and possible avenues for future research in the field of bioeconomy governance. More detailed ideas for follow-up research are named in the different chapters.

First, the governance of controversies as inherent element of transition processes leaves potential for further scientific inquiry, both conceptually and empirically. Metze (2018b, p. 671) suggests the concept of '*controversy governance* […] defined as the governance of wicked problems that creates a safe space to explore all aspects of an unstructured issue, including the normative differences between stakeholders on the desirability of the issue that may need governance, and an exploration of what actor or group of actors is most credible to decide on it'. The results of this dissertation suggest that this form of governance calls for innovative arrangements to stimulate more productive ways of dealing with controversies. Future work remains on (1) designing such arrangements, (2) testing and evaluating different forms of controversy governance arrangements, and (3) their implementation in practice. The adaptations of the Discourse Network Analysis method, developed in Chapter 3, provide a tool to explore and longitudinally map normative stakeholder differences, also beyond the EU bioeconomy transition. These mappings can inform the design and implementation of innovative controversy governance arrangements.

Second, in addition to my contributions on exploring how to unlock controversies for a more democratic and reflective bioeconomy transition, future research on the bioeconomy transition in the European Union can also explore how to solidify sustainability or circularity gains in the context of controversies that surface at different speeds in different loci. In other words, more knowledge is required on how to institutionalize more circular and sustainable outcomes, once they are achieved, while taking into consideration that perspectives on what is circular or sustainable continuously evolve. I suggest that this requires adaptability, thus the avoidance of lock-ins, in developing transition pathways. In this regard, a small wins approach (Schagen et al., 2023; Silvius et al., 2023; Termeer & Dewulf, 2019; Termeer & Metze, 2019) could be suitable to constantly work on a more

sustainable and circular bioeconomy transition. This approach enables bioeconomy stakeholders to realize transformative steps, while remaining reflective of the directionality of the transition without forming lock-ins. Such a governance strategy requires further empirical work in the bioeconomy domain (see Schagen et al., 2023 for a pioneering study in this regard).

Third, future research on biorefinery innovation needs to be further contextualized in the broader circular bioeconomy transition. For instance, opening up biorefinery debates towards different parts of the discourse network implies the search for innovations outside of the dominant, techno-economic discourse. Further research is required on designing principles as well as practical tools and processes to institutionalize this endeavour. This entails governance-related and legal questions on how to organize inclusive and pluralistic participatory research and innovation and more fine-grained procedures to consider also uninvited societal input.

Fourth, broader research on conflicts in sustainability transitions could work on situations where a *lack of conflicts* paralyzes a transition. An example of such a situation is when the unsustainable regime is so hegemonic that alternative ways of thinking, doing, and organizing are marginalized. These situations are likely characterized by discursive lock-ins. As indicated by this dissertation, controversies can be(come) productive in unlocking these lock-ins by opening up discussions. Just like sometimes a thunderstorm is needed to clear the muggy air, sometimes a conflict is needed to bring a transition forward. I suggest that such a lack of necessary conflicts can be characterized in terms of its *'mugginess'*, which means the degree of which a transition requires further politicization and perhaps also polarization to advance its transformative ambition. Conceptual work on these situations widely lacks in the sustainability transitions literature but could be instrumental in overcoming paralysis of urgently needed transitions.

6.4. Implications for bioeconomy stakeholders

The overall contribution of this dissertation is to show how controversies matter in the hitherto rather technocratic circular bioeconomy transition, where selective listening of decisionmakers creates locking-in a limited understanding, which is congruent with the 'Green future' discourse. Seemingly disruptive, nurtured (biorefinery) innovation and development niches contribute towards superficial transition processes that fail to deliver their transformative promises and ambitions. While shifting from fossil to bio-based raw materials, large parts of current bio-based production solidify overconsumption, global injustices, a further exploitation and problematic commercialization of nature, and linear production logics.

The findings of this dissertation can inform decision-making in the various sustainability transitions on current policy agendas (for example, in the energy, mobility, food, and water management sectors). My results first and foremost imply that decisionmakers need to alter their understanding of controversies in sustainability transitions. Instead of something to be avoided or outdesigned, a more productive way of dealing with controversies is to unlock their innovative potential. Hearing a broad network of affected actors, listening to actors that sponsor divergent frames, and learning to respond to both invited and uninvited forms of societal input contribute towards this goal. In light of increasingly urgent sustainability challenges, decisionmakers need to change their ways of dealing with controversies. However, solely appealing to the goodwill and interest of standing decisionmakers misjudges the political character of sustainability transitions. Therefore, I underline that unlocking controversies is functional in challenging status quo regime logics by uncovering current biases, lock-ins, and blind spots but does not guarantee more circular and sustainable outcomes. Still, actors that aim to challenge status quo practices can use these insights to raise attention for marginalized interpretations and thereby contribute to critical agenda setting and reframing.

My findings on productive ways of dealing with controversies in the European circular bioeconomy transition also have implications for EU bioeconomy policymaking in the broader context of the European Green Deal. In particular, insights of this dissertation can feed into the process of further updating the EU Bioeconomy Strategy. The European Commission has started to integrate more critical remarks on how planetary boundaries limit the scale of an industrial bioeconomy in the 2022 progress report (European Commission, 2022). Moreover, the EU Joint Research Centre has published a report that also contains critical voices (Giuntoli et al., 2023) as well as explorations of (conflicting) foresight scenarios (Borzachiello et al., 2024; Fritsche et al., 2021). According to my findings, these developments hint towards a discursive change by EU institutions in congruence with the outlined latest findings of the bioeconomy governance literature and broader scholarly discussion on the bioeconomy. In particular, one of the Green Deal pillars in mainstreaming sustainability in EU policies is the 'just transition' approach (European Commission, 2019, p. 15). Also the more recent named recent reports underline that the circular bioeconomy transition needs to be just (Borzachiello et al., 2024; Giuntoli et al., 2023). This extension of the range of adopted storylines in principle indicates that debates open up towards hitherto overlooked aspects and concerns.

However, it is prudent that these rhetorical adaptations also result in actual policy changes. Otherwise, the danger smoulders that bioeconomy policymakers could be accused of hijacking critical storylines without adjusting the course of the bioeconomy transition towards sustainability and circularity goals. A merely rhetorical uptake of critical storylines in form of buzzwords can backfire and result in unproductive polarization. To avoid this,

officials in the European Commission and other policymakers must form active listening relationships with critics to properly understand also underlying concerns. Learning from controversies does not mean to uncritically take over concerns of critics, though. Learning entails the reflection on critical input, but the definition of the transition's directionality remains the task of democratically legitimized representatives, continuously informed by society. This implies that instead of a singular focus on invited participation, bioeconomy policymakers also need to learn from uninvited input. At the same time, critical observers, including scholars, also have the responsibility to make their voices heard, because this form of listening and learning needs to be two-directional to be effective. This does not take away that especially actors that can bring in marginalized perspectives often require empowerment and a translation of their language into a language that is accessible for policymakers. (Social) scientists play a key role in this endeavour.

In addition to these high-level policies, local decisionmakers, for instance in Triple Helix collaborations, need to broaden their range of considered options in developing and implementing circular bioeconomy solutions. In particular, apart from the feasibility of technical process, also organizational and political issues need to be considered. For example, on the mission of phasing out fossil-based plastics, it should not only be considered how bio-based plastics can be produced, but first and foremost how the consumption of plastics in general can be decreased. Instead of producing superfluous products, research funding and investments rather need to be redirected towards decreasing society's overall energy and material demand towards the limits imposed by planetary boundaries. Business models that bring forward this mission need to be acknowledged. Examples could be sharing models, short and local supply chains, new packaging solutions, circular and sufficient lifestyles, or insulation initiatives. Inclusive, local collaborations of a plurality of stakeholders on the local level need to be facilitated, not only financially but also by legislation.

A bioeconomy with sustainability and circularity at its heart requires more responsive research, innovation, and development processes. In addition to the current focus on ever more complex, large-scale biorefining technologies, publicly financed research needs to become more open to alternative ideas. Examples for innovations beyond the current 'green future' lock-in include technological advances on flexible and small-scale biorefineries; social innovations, such as new bio-based business models away from take-use-dispose production logics; and governance innovations, such as more inclusive and pluralistic deliberations on what a 'Green future' within the 'Planetary boundaries' should look like. To this end, scholars and bioeconomy decisionmakers should appreciate the innovative potential of controversies in surfacing biases of dominant perspectives as well as resulting discursive lock-ins. To unlock this potential, bioeconomy decisionmakers and scientists can develop and foster hearing, listening, and learning capabilities. Rather than design faults in the bioeconomy transition, controversies are learning opportunities.

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SUPPLEMENTARY MATERIAL

Supplementary Material A

Belonging to Chapter 3

Supplementary Material A.1: Final coding scheme

I. Person, organizations, and actor categories

Person: Twitter handle (without @)

Organization: To be identified based on the Twitter handle and bio. If the actor's clear name is stated in the Twitter account bio, then the clear name is used.

For organization accounts, the organization's acronym is used, followed by the full name in brackets. For organizations with branches in different countries, one organization is coded for every branch, with the country indicated after the name.

For individuals stating in their bio that they are affiliated with an organization, the individual's name is used, followed by their affiliated organization's acronym. If an individual is affiliated with several organizations, then the individual's name is used, followed by all affiliation acronyms.

For Members of the European Parliament, the clear name is used, followed by the acronym of the group they are affiliated with and their country. For national politicians, their clear name is used, followed by their country and party affiliation. In all other cases, the name stated in the bio is used.

Actor categories: Attached as colour information to the organization node. If an actor falls into more than one category, then the actor is categorized into the prevailing one.

Table A1.1 *Colour information for actor categories.*

Category	Colour (code)	Category	Colour (code)
EU Commission	Dark blue (000BAC)	Business / Industry organization	Dark yellow (FFFF00)
Member of the EU parliament	Blue (0004FC)	Think tank / private research institute	Light yellow (FFFFCC)
Other EU institutions	Turquoise (00B1FC)	Social NGO / trade union	Red (FF3333)
EU research projects (H2020, Interreg, BBI JU)	Light blue (00FAEE)	Environmental NGO	Dark green (009900)
International organization	Dark orange (FF9900)	Journalists / authors / magazines / blogs	Dark grey (999999)
Member State administration / nat. politicians / Reg. organizations	Light orange (FFCC66)	University (professors/ researchers) / research organization	Light grey (CCCCCC)
Nuclear industry / NGOs	Purple (9900FF)	Citizens / Unknown	White (FFFFFF)

II. Concept

Concept nodes are coded as a storyline, which a statement from a tweet reproduces. A statement is an utterance of an opinion with reference to one of the overarching storylines below. A tweet is only coded as a statement if it is unambiguous what storyline is referred to. If a tweet refers to several storylines, several statements are coded from the same tweet. Paraphrasing is not coded, as the originality of the statement cannot be guaranteed. Not every tweet contains a statement. Only 'agreements' are used for the connections between actors and concepts.

Table A1.2 *Final coding scheme.*

Storyline (concept node title)	**Description**	**Total appearances** [n]	**Number of different organizations using the storyline** [n]
Agroecology	A truly sustainable bioeconomy could develop around agroecology principles (e.g., use of invasive species or wood clearances).	11	11
Biodiversity loss	The bioeconomy fosters deforestation and jeopardizes biodiversity goals. We have to save our forests from this industry!	221	125
Blue economy	The bioeconomy should turn blue. We should focus on marine feedstocks, such as algae.	146	91
Carbon sink	The energetic use of biomass is carbon-neutral or even carbon-negative. Energetic use is the production of electricity and/or warmth, the production of transportation fuel as energy carrier for all forms of mobility, and the production of biogas/biomethane as energy carrier. Therefore, the bioeconomy contributes to fighting climate change.	189	119
Cascading use	Production needs to live up to the principle of cascading use: If a product is necessary, go for the highest value and the maintenance of material integrity first. Only if this is not possible, we can use materials to produce energy.	56	36
Circularity	A bioeconomy only works if it is circular. Circularity first and foremost means to reduce. Waste streams can and should be prioritized. Focusing on circularity principles, a bioeconomy can also contribute to solving waste challenges.	244	127
Deforestation overseas	Pursuing a bioeconomy in Europe can cause the destruction of forests overseas.	218	130

Degrowth	The focus on economic growth is actually the root cause of unsustainability. Society should redefine what it regards as growth. This perspective is often referred to as degrowth perspective. Instead of increasing production, we should foster sufficiency and limit consumption.	15	12
Deliver EU Green Deal	Pursuing a bioeconomy means delivering the objectives of the EU Green Deal.	112	67
Democratization	The bioeconomy needs to be a democratic endeavour. Citizens should not only be informed but empowered to shape the way towards a bioeconomy.	72	42
Deserve public support	Building up a bioeconomy is in need of, but also deserves, public funding in form of subsidies. Also, regulatory support is needed to build up a legal environment that stimulates the bioeconomy.	163	85
Education	Key in implementing the bioeconomy is the education and proper training of the younger generations.	86	31
End the era of fossils	The circular bioeconomy is the best way to get rid of the fossil industry. Extreme positions would go so far as to claim that bioeconomy critics might be sponsored by fossil industries. The real enemy is the fossil industry, we must not forget this!	130	93
Energy security	The energetic use of biomass is needed for energy security.	37	26
Evidence-based decision making	Successfully transitioning towards a circular bioeconomy depends on expert assessments of what works and what does not. Experts should take the lead in finding the best solutions for everybody.	177	114
Free market	There should be a free market of biomass and no use should be prioritized per se. Consequently, also the energetic use of non-waste streams can be regarded as sustainable. Constructs like the cascading principle are signs of overregulation.	27	18
Global scale	The scale of a bioeconomy should be global, there should be free trade of bio-resources. Global partnerships could be designed to enable knowledge transfer.	63	49
Green Growth	The bioeconomy is an environmentally friendly way to maintain or increase economic growth in the EU (‘green growth’ or ‘decoupling’).	333	179

Green recovery	Bio-based industries are a crucial element of green recovery after the covid-19 crisis.	61	34
Helps achieving SDGs	The bioeconomy is a key instrument to achieve the Sustainable Development Goals (SDGs).	155	77
Land use competition	Pursuing a bioeconomy further increases the competition between different uses for suitable land (food, feed, fibres, fuel etc.). Agricultural land should be most efficiently used for food production.	41	34
Legal certainty	Pursuing a bioeconomy first and foremost needs a stable legal framework.	26	19
Lobbying	Policy-making about the EU bioeconomy is all about pursuing vested interests. Lobbyists ensure that particular industries as countries get money. Overarching goals, such as sustainability, are not pursued.	51	33
Local scale	A bioeconomy should be mostly local and the shipping of resources around the globe should be severely restricted.	49	33
More CO_2	The energetic use of biomass cannot be carbon-neutral, because CO_2 is released more rapidly than it is bound. Regarding biomass as part of the future energetic system is not a solution to fight climate change.	478	246
More harm than good	A large-scale bioeconomy can get us out of the frying pan into the fire. We should channel our energy to finding a really sustainable solution.	135	100
New market opportunities	The bioeconomy innovates new products for new markets.	53	47
No GMO	Genetic engineering is dangerous. We should not stimulate the development of GMOs to increase the productivity of the bioeconomy.	3	3
Not all biomass is CO_2-neutral	It cannot be said that biomass is CO_2-neutral across-the-board. Some forms of biomass have a positive CO_2 balance, others can be CO_2-negative.	60	47
Nuclear is better	Nuclear energy is more sustainable than biomass. Priority should be given to building up nuclear energy production sites.	15	14
Pollution	Burning wood for energy production causes air pollution that damages human health (e.g., due to (fine) particulate matter).	83	53
Prevent forest fires	Wood needs to be cleared out of forests to prevent forest fires. This wood is a suitable feedstock for the bioeconomy.	12	10

Public awareness	The public needs to be informed better about the benefits of the bioeconomy. We should pursue information campaigns to raise awareness.	89	54
Residues only	The only suitable feedstock for a bioeconomy is residues and waste streams.	50	39
Restore agricultural land	Uncultivated land provides opportunities for biomass production. We need to restore this land to harvest resources for a bioeconomy.	41	34
Rural development	The bioeconomy provides an opportunity for rural and peripherical regions to develop economically.	193	100
SMEs	Small and medium enterprises (SMEs) are the heroes in realizing a bioeconomy. They specifically need and deserve public support.	80	53
Social innovation	To achieve sustainability, social change is key: We as society need to redefine our values and change our behaviours.	35	29
Sustainability criteria	A bioeconomy can be sustainable. But we need working sustainability criteria, such as certification schemes or guarantees of origin, to ensure sustainable harvesting.	205	128
Sustainability criteria don't help	Envisioned EU sustainability criteria further justify the increasing demand for bio-resources. Hence, they do not tackle the root problem and actually make things worse.	54	31
Technological innovation	The key to achieving sustainability is technological innovation. We need to spread these innovations faster and de-risk up-front investments in research and development. We should embrace developments such as genetic engineering or geo-engineering. Large-scale integrated biorefineries and biotechnology are the future for the EU bioeconomy.	205	130
Techno-scepticism	Technology alone is not a solution and, on the contrary, can even backfire. Therefore, beware of techno-fixes and be cautious of negative side effects of new technologies.	1	1

Supplementary Material A.2: Research protocol

This protocol describes in detail the conducted steps for obtaining visualized networks in the results section. The social media platform formerly known as Twitter is currently being rebranded to '𝕏'. In this research protocol, we refer to the platform as 𝕏 and the user-generated content as tweets.

Step 1: Data set elaboration

To establish a search query for relevant tweets, we tried keywords connected to the EU Bioeconomy Strategy Update 2018. Examples are *circular*, CBE, bioeconomy, biomass, pollut*, CO2, carbon, wood*. Balancing the needs for manageable proportions of the acquired data set, its relevance for the research goal, and variability of uttered storylines, we opted for the query *(biomass OR bioeconomy) AND ('European Union' OR EU).*

On 31 August 2021, co-author Art Dewulf used the former Twitter API to extract a set of tweets for the search query *(biomass OR bioeconomy) AND ('European Union' OR EU) – IS: retweet* for the time period June 2008 until June 2021. In the search query, we excluded re-tweeted content to avoid duplicate content. This initial data set consisted of *N = 39,931* tweets. The data set was stored as a .csv file in the standard output format of the Twitter API.

Although many previous DNA studies rely on newspaper articles as textual data base, we opted to use tweets. However, we needed to make sure that our findings are not impeded by the algorithm of what tweets are displayed to a user. We achieved this by analysing a complete keyword-sampled data set. Applying tweet data might conceal the context of an utterance. In case of doubt, we therefore looked up the tweet to see where it was referring to, for instance if it was a reply to a previous tweet.

Step 2: Data set reduction

A Discourse Network Analysis (DNA) connects actors with ideas by coding a data matrix of actor information, the utterance of an idea, a dis-/agreement qualifier, and a time stamp. Based on the congruence of actor–idea connections, clusters of like-minded actors are visualized over time (Leifeld, 2020). An analysis using Leifeld's DNA tool currently requires manual coding. The advantage of manual coding is that the process allows for a simultaneous qualitative analysis of the tweet content. The drawback is that the amount of codable text is limited by time capacity constraints. We opted for a data set reduction strategy, balancing advantages of using the DNA tool and disadvantages of the requirement to work with a limited data set. We estimated our capacity for manual coding on 10,000

tweets, based on experiences for the speed of DNA coding from previous projects. This is roughly a quarter of the full data set obtained in step one. Therefore, we set a threshold goal of 25% for the data reduction.

Instead of randomly selecting 25% of the total data set, we opted for a data reduction strategy based on most impactful tweets. On 𝕏, users can like, retweet, or quote-retweet content to show their appreciation or comment their dissent and to further disseminate the content to their own public, thence to make the content impactful. For selecting the most impactful tweets, we ordered the data set hierarchically with information of the number of retweets per tweet on the first level, likes on the second level, and quote-retweets on the third level.

For this end, we applied a hierarchical sorting of the full data set in Microsoft Excel using the options displayed in Figure A2.1.

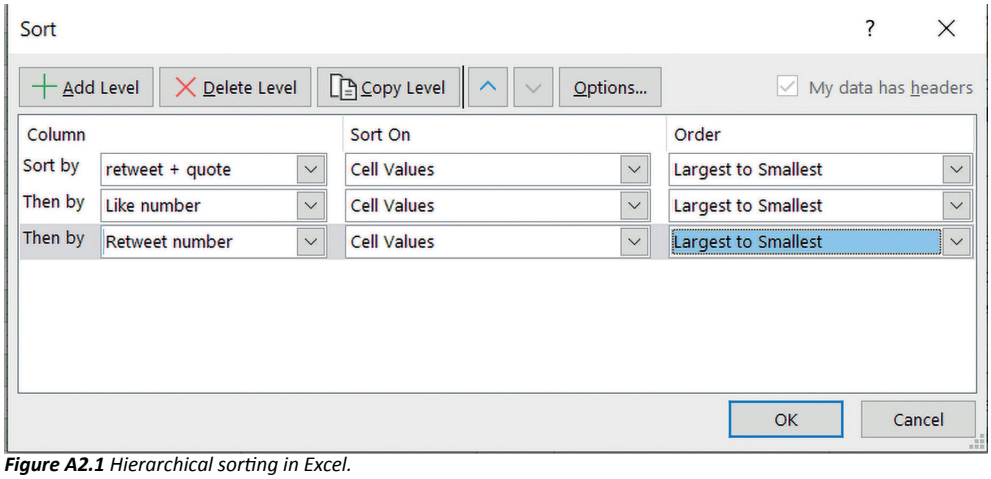

Figure A2.1 *Hierarchical sorting in Excel.*

Since the data set contains many more tweets in recent years than in the first years of the defined time period, we imposed the 25% threshold separately on every year, see Table A2.1. The data set contains information on the total number of retweets, likes, and quote-retweets on 31 August 2021. As a rule of thumb, interaction with tweets happens in the first couple of days after publication. The very last tweets might therefore have a lower probability to be included in the data set for 2021. For this reason, we did not include tweets from July and August 2021. Therefore, the data set stops on 30 June 2021. For every year, sorted tweets were separated into a new spreadsheet until the 25% threshold was reached. This new spreadsheet contains the reduced data set for analysis *(N = 9,983)*.

Table A2.1 *25% threshold for every year of the study period.*

Year	Total	25%	accum.
2008	2	1	9983
2009	111	28	9982
2010	926	232	9955
2011	617	154	9723
2012	1252	313	9569
2013	1565	391	9256
2014	1871	468	8865
2015	3250	813	8397
2016	4011	1003	7584
2017	3970	993	6582
2018	6516	1629	5589
2019	6019	1505	3960
2020	5966	1492	2455
2021	3855	964	964
TOTAL	39931	9983	

Step 3: Data management

To allow DNA coding, the information in the spreadsheet needed to be imported into Leifeld's Discourse Network Analyzer software (obtainable open source at https://github.com/leifeld/dna/releases). For our analysis, we used version 2.0 beta 25 (2019-09-08). To maintain the time stamp for every tweet, every tweet needs to be imported as a separate document into the DNA software. For the data import, we used Leifeld's rDNA package in R.

A first step was to build a .csv file in the format required by the rDNA package, thus containing the columns id (continuous identifier) | title (twitter handle) | text (tweet content) | coder (set to 1) | author (twitter handle) | source (left blank) | section (left blank) | notes (left blank) | type (left blank) | date (time stamp in the format YYYY-MM-DDThh:mm:ss.000Z). We called the resulting .csv file 220126 25 % most popular per year for DNA import.csv. In the DNA software, we opened a new project and called the file 220126 Tweets Database.dna. We stored both files in the same local folder C:/R/Working directory, which needs to be defined as working directory in R. Also the DNA software .jar file needs to be stored in the same folder.

In RStudio 1.4.1717, we run the following code:

```
### Set up rDNA package
install.packages("statnet")
install.packages("igraph")
install.packages("cluster")
install.packages("rJava")
install.packages("devtools")
library("rJava")
library("rDNA")
dna_init("dna-2.0-beta25.jar")

#setting up new data base
db <- dna_connection("220126 Tweets Database.dna", create = TRUE)

#import csv
dat <- read.csv(
   file = "220126 25 % most popular per year for DNA import.csv",
   header = TRUE,
   sep = ",",
   dec = ".",
   stringsAsFactors = TRUE
)
dat
dates <- as.POSIXct(dat$date)

docs <- data.frame(id = dat$id,
      title = dat$title,
      text = dat$text,
      coder = rep(1, 9983),
      author = dat$author,
      source = rep("", 9983),
      section = rep("", 9983),
      notes = rep("", 9983),
      type = rep("", 9983),
      date = dates)

docs
#load database into DNA
dna_setDocuments(db,docs,simulate = FALSE)
```

Step 4: Coding scheme elaboration

DNA requires manual coding in the format Person | Organization | Concept | Agreement/ Disagreement (binary). As person, we defined the user handle. For organization, we used a clear name of the actor, which ought to appear in visualized networks. According to the methodological adaptations described and justified in the main text, we set the binary agreement/disagreement variable on agreement for all statements. As justified in the main text, we redefined concept nodes as storyline nodes. A storyline is an opinionated, generic narrative, highlighting particular aspects of social reality. During coding, actors need to be connected to storylines by so-called *statements*. Statements are then coded as utterances of an opinion in a tweet with reference to a storyline. For the storyline variable, we elaborated a coding scheme.

For an initial coding scheme, we first noted some initial ideas for possible storylines to be used by actors based on the standing literature on conflicts and controversies in EU bioeconomy discussions, which we read in depth for the elaboration of the conceptual section of the paper. Moreover, we interviewed eight experts from the European Commission, NGOs, and industry associations, see Table A2.2.

Table A2.2 *Conducted expert interviews.*

ID	Organization Type	Interviewee position	Date	Length [min]
EU1	EU Commission Directorate-General for Research and Innovation (RTD)	Head of Unit	20 July 2021	27:37
EU2	EU Commission Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (GROW)	Policy Officer	19 August 2021	22:05
I1	Industry organization (bio-products)	Head of Unit	9 July 2021	37:33
I2	Industry organization (bio-energy)	Secretary-General	9 July 2021	32:56
I3	Industry organization (biogas)	Director	16 August 2021	37:08
I3a	Industry organization (biogas; follow-up)	Secretary-General	9 September 2021	12:18
N1	Environmental Non-Governmental Organization (waste)	Programme Coordinator	21 July 2021	42:23
N2	Environmental Non-Governmental Organization (biodiversity)	Head of Unit	20 August 2021	54:16

Moreover, the first author conducted an informal talk of about 1.5 hours on 18 August 2021 with a representative from another environmental non-governmental organization. The interview partner preferred the talk not to be recorded.

All interviews were transcribed and read for instances of what experts identified as controversies about the future direction of the bioeconomy in the EU. For identified controversies, we defined storylines representing the different positions in the controversy and included them in the coding scheme. The initial coding scheme (after expert interviews and literature study) is represented in Table A2.3.

Table A2.3 *Initial coding scheme.*

Controversy	Storyline(s)	Source
I. General	1. (bioeconomy is desirable) Further advancing a bioeconomy is generally desirable.	Overall 'safety net' code to have all statements included
II. Sustainability	2. (carbon sink) Using biomass is CO2-neutral or CO2-negative.	EU2:30-32; N2:30-34
	3. (biodiversity) Pursuing a bioeconomy does not jeopardize biodiversity goals.	EU1:42,90; EU2:35-36; 149; N2:56-57
	4. (proven sustainability) Studies convincingly show that using biomass is sustainable.	EU1:87-88; I2:55-56
	5. (no carbon stock changes) Using biomass does not result in harmful carbon stock changes. or indirect land use changes.	EU2:30-32
	6. (no ILUC) Using biomass does not result in harmful indirect land use changes (ILUC).	EU1:105; N2:102
	7. (jobs) Pursuing a bioeconomy results in new jobs and is thus socially beneficial.	EU2:70-73;201
	8. (development) Pursuing a bioeconomy results in rural development and is thus socially beneficial.	I1:112-113; I2:73
	9. (green growth) Bioeconomy allows for sustainable green growth.	EU1:68,195; EU2:130-133; N2:76,204-206
III. Feedstocks	10. (no food concurrence) A bioeconomy can be organized without concurrence for the food system.	EU1:27
	11. (sustainability criteria) We need sustainability criteria for biomass. This certified biomass can then be used for the bioeconomy.	(Ramcilovic-Suominen and Pülzl, 2018; Vogelpohl, 2021) EU1:38,45,58-59; EU2:28-29; I3:41; N1:73-75; N2:23-32

	12. (1st gen) Primary energy crops are a suitable feedstock for the bioeconomy.	I1:59; N2:95-97,109
	13. (2nd gen) Lignocellulosic plants (wood, grass), which are not waste streams, are a suitable feedstock for the bioeconomy.	EU1:84-86; I1:58; N2:95-97
	14. (3rd gen) Algae are a suitable feedstock for the bioeconomy.	Added for coherency (3rd generation feedstocks)
	15. (GMO) The use of genetic engineering for feedstock production should be allowed.	I1:322-323
	16. (not only waste) The scale of the bioeconomy should not be defined by the availability of waste streams.	EU1:29; I3a:394; N1:73-75; N2:235
	17. (global trade) Available biomass should be traded globally.	I3:47; N2:154-156
IV. Products	18. (energetic use) Using solid or gaseous biomass for energy (electricity; warmth) production or co-firing should be allowed.	EU1:46-47; EU2:87;94; I3:42-43
	19. (biofuels) Lightweight transportation fuels (bio-Diesel, methane, other biofuels) are a beneficial product of the bioeconomy.	EU1:46-47; EU2:87; I3:92
	20. (plastics) Plastics are a beneficial product of the bioeconomy.	I1:46
	21. (chemicals) Fine chemicals are a beneficial product of the bioeconomy.	I1:50
	22. (cosmetics) Cosmetics are a beneficial product of the bioeconomy.	Added for coherency (non-energy products)
	23. (medicine) Enzymes, vitamins or other medical products are beneficial.	Added for coherency (non-energy products)
	24. (cascading use) We should aim for the highest-value use first (materials, chemicals, medicine). When that demand is fulfilled, leftovers can be used for lower-value (energetic) purposes.	EU2:87-91; I1:172; N1:114-117, 146-149 (Leipold, 2021; Temmes and Peck, 2019)
	25. (techn. neutrality) There should not be different rules for different sectors, there should thus be a free market of biomass.	N1:73-75; N2:207
V. Procedures	26. (entrepreneurs) Entrepreneurs should lead the way in shaping a bioeconomy.	EU1:148-152
	27. (SMEs) Small and medium enterprises should be engaged in rule-setting for the bioeconomy.	EU1:137

28. (experts) Experts should define rules and criteria for the bioeconomy.	EU1:43,202; I1:50; I3:267-269; N2:283-287
29. (no overregulation) We should limit bureaucracy.	EU2:110-112; I2:102-103
30. (global partnerships) Global bioeconomy partnerships should be fostered.	N1:302; N2:369-370
31. (not more democracy) There is no need to further democratize decision-making.	EU1, 174-175; I3:267-269

To refine the coding scheme inductively, based on the tweets, we performed two training rounds on random quarters of the data set elaborated in step 3. For this end, we added a column randomizer with =RANDBETWEEN(1,4) for every cell in the 220126 25 % most popular per year for DNA import.csv file. Afterwards, we copied the column and pasted the contents in a new column as numeric values. We sorted by this new column and omitted groups 2-4. We repeated this procedure to establish a data set for group 2. We saved all spreadsheets in different files.

We coded the randomized group 1 data set based on the initial coding scheme. While coding, the first author adjusted the coding scheme whenever he felt that the content of a tweet does not match the established storylines in the coding scheme. Moreover, he merged similar storyline categories or omitted unused categories. After coding the group 1 data set, we discussed coding scheme adaptations among the group of authors. We repeated this procedure for group 2. A synopsis of the coding scheme is available upon request. After coding group 2, we agreed on a final coding scheme of storylines to be coded as concept nodes in the DNA software. The final coding scheme is presented in Supplementary Material A.1.

Step 5: Coding procedure

The first author coherently coded the full data set for analysis based on the final coding scheme. For this end, we marked a text segment representing a statement (an utterance of an opinion with reference to one of the overarching storylines in the coding scheme) in a tweet and coded information on the person (user handle), organization, and the respective storyline in the DNA software. Questionable cases were marked with a note, which explained the reason for doubt. We discussed these few questionable cases (n = 27 for the full data set) during regular meetings among the team of authors. During coding, we also noted qualitative observations that helped interpreting obtained network visualizations. We summarize descriptive statistics of the coded .dna data set in Table A2.4.

Table A2.4 *Descriptive statistics of the coded data set.*

Documents	9,983
Statements	4,512
Persons	1,353
Organizations	1,333
Concepts	43
Notes	27

The full coded data set can be requested by e-mail to the corresponding author.

Step 6: Network data export

To analyse changes over time, we split the data set into three time periods according to changes in EU bioeconomy policies. Period 1 spans the period from the first tweet in the data set from 13 August 2008 until the publication of the first EU Bioeconomy Strategy on 13 February 2012. Period 2 ranges until the publication of the strategy's update on 10 October 2018. Period 3 runs until the last included tweet from 30 June 2021.

Upon completion of coding the data set in the DNA software, we exported obtained network data by using the following specifications:

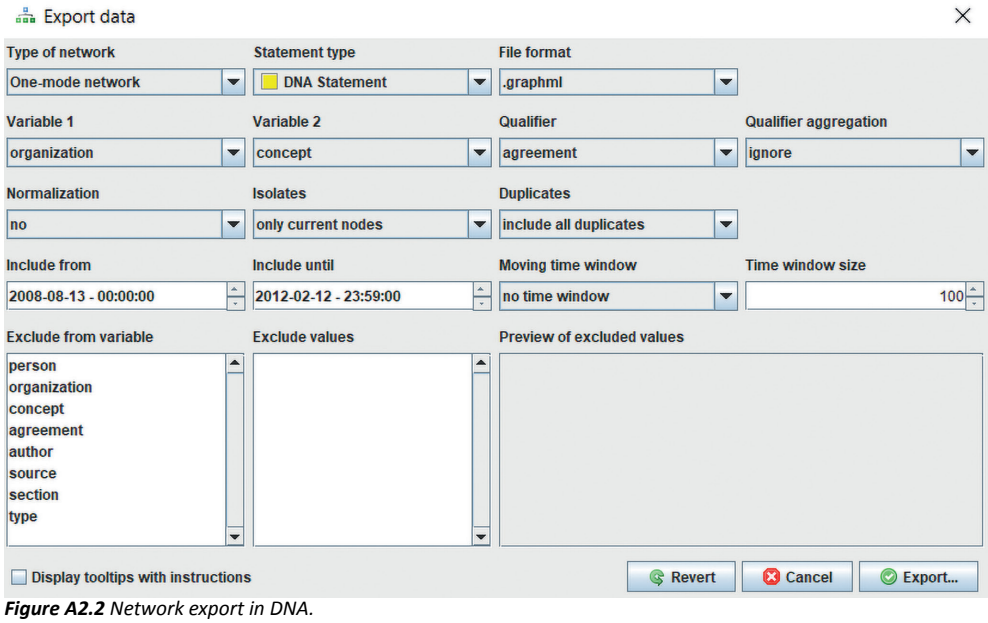

Figure A2.2 *Network export in DNA.*

We decided not to normalize the networks based on average activity (this normalization is explained in Leifeld (2017, p. 13)) to preserve tweet activity as one sign of impact. This results in a higher centrality of active users. To make this over-representation transparent, actor node size indicates statement frequency. Using non-normalized, weighted network data therefore does not allow for analyses based on centrality values, due to a possible overestimation of the centrality of very active accounts.

We exported separate networks for every study period and separate actor congruence networks (organization x concept) and storyline networks (concept x person) as well as 2-mode affiliation networks.

Step 7: Network analysis

Network files were imported into Visone 2.18 (available open source at https://visone.ethz.ch/html/download.html). Networks of the last two periods became too dense to be interpretable due to the large number of statements and resulting edges. In such cases, 'threshold values on the edge weights [can be imposed subsequently] in order to remove low-intensity [...] ties' (Leifeld, 2017, p. 14). We deleted edges until the 95th percentile – sorted from least to most edge weight – as well as resulting isolates. The trade-off of thresholding is that clusters on the network periphery might not be visualized. However, we did not notice peripheral clusters during the manual coding process. For the first period, we present the full network with different levels of edge weight thresholding due to the lower number of statements in this period. We opted to threshold based on edge weight, because we wanted to maintain also the least popular statement categories to avoid losing sub-groups within identified clusters. For an overview of network characteristics with different levels of thresholding, see Table A2.5 and Figures A2.3-5.

Table A2.5 *Overview of actor congruence network characteristics for different levels of thresholding.*

	Period 1	Period 2	Period 3
Number of edges [n]			
0% threshold	401	36,115	33,778
50% threshold	113	14,895	16,374
95% threshold	20	1,550	1,441
Number of nodes [n]			
0% threshold	77	776	668
50% threshold	52	763	666
95% threshold	19	393	407
Network density			
0% threshold	.137	.120	.152
50% threshold	.085	.051	.074
95% threshold	.117	.020	.017
Modularity (unweighted networks)			
0% threshold	-.021	-.002	-.002
50% threshold	-.051	-.004	-.003
95% threshold	-.088	-.017	-.018
Modularity (weighted networks)			
0% threshold	-.026	-.006	-.008
50% threshold	-.055	-.009	-.011
95% threshold	-.093	-.025	-.029

We specified changes in the number of nodes and edges, network density, and modularity for both weighted and unweighted networks as well as visual representations of changes in the network structure with increasing thresholds. In particular, modularity differences between 50% and 95% thresholding add towards a more modular structure. For period 1, changes are more gradual. These statistics confirm our choice for 95% thresholding for identifying a structure.

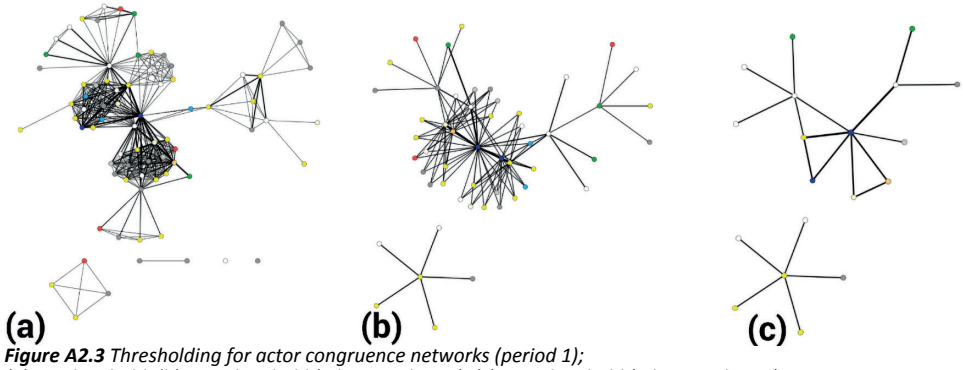

Figure A2.3 *Thresholding for actor congruence networks (period 1);*
(a) 0% threshold, (b) 50% threshold (edge weight ≥ 2), (c) 95% threshold (edge weight ≥ 3).

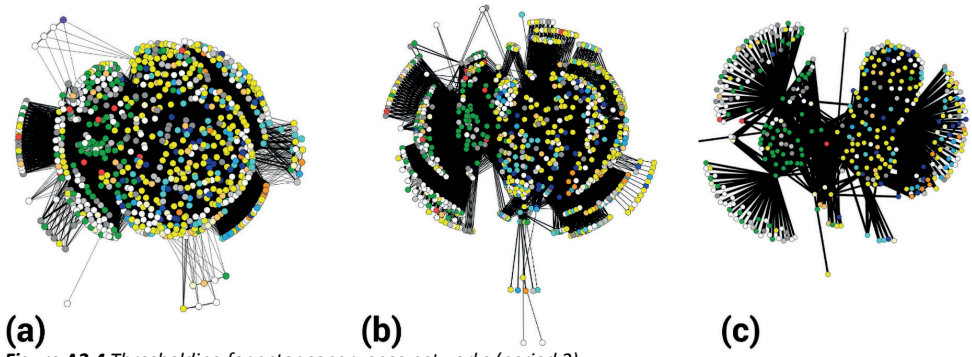

Figure A2.4 *Thresholding for actor congruence networks (period 2);*
(a) 0% threshold, (b) 50% threshold (edge weight ≥ 2), (c) 95% threshold (edge weight ≥ 9).

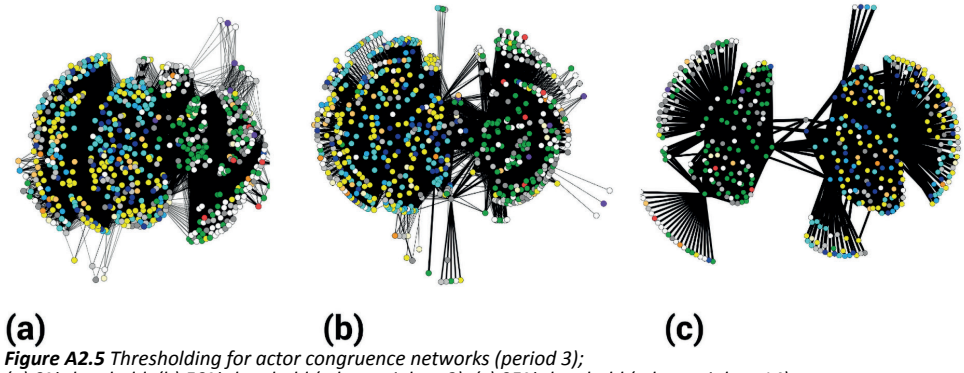

Figure A2.5 *Thresholding for actor congruence networks (period 3);*
(a) 0% threshold, (b) 50% threshold (edge weight ≥ 2), (c) 95% threshold (edge weight ≥ 14).

As visible in these graphical representations, the general structure of two main clusters in periods 2 and 3 remains robust, independent of imposed thresholds. Actors of the 'Planetary boundaries' coalition gather at one side and 'Green future' actors on the other one.

Edge weight in DNA typically indicates the congruence value of nodes (Leifeld et al., 2019, p. 6). Due to the omission of the dis-/agreement qualifier in our study, the congruence value describes the number of statements with shared storylines between actors for actor congruence networks or the number of actor statements referring to common storylines in storyline congruence networks. To impose the threshold, we conducted the following operation in Visone: visualization -> mapping -> size -> link width -> weight. This operation orders the edges according to congruence values. We continued by opening the attribute manager and conducted the following operations: select -> link -> weight -> select the edge weight threshold corresponding with 95% lowest values, see captions of Figures A2.3-5. In the main operating window, the following operations need to be conducted to delete the lowest-value edges and resulting isolates: links -> delete links. Afterwards, we ordered by using the quick layout stress minimization procedure described in Visone (2015) and manually deleted the group of resulting isolates.

We clustered actors endorsing similar storylines by applying a Girvan–Newman edge-betweenness community clustering (Girvan & Newman, 2002), analogous to Fergie et al. (2019) and recommended by Leifeld (2017).

Step 8: Network visualization

Resulting networks were graphically slightly optimized to enhance readability by using Visone's label placement optimization algorithm (visualization -> layout -> label placement -> use_opt). Afterwards, we first made all labels invisible (node -> properties -> label -> unbox 'visible'). Then, we made labels for nodes in bridging positions visible again and manually optimized label placement to enhance readability.

We exported resulting network visualizations as .png files. We manually added cluster labels and most used storylines in the online programme Canva. Most used storylines per cluster were identified by visually inspecting 2-mode affiliation networks. We counted the number of statements agreeing to the respective storylines by using separate event list exports from DNA.

Supplementary Material A.3: Storyline congruence networks

This supplementary material presents representations of storyline congruence networks for the three study periods as well as interpretations of the representations.

Period 1 (2008 – 2012):

In the first period, actors mostly uttered storylines highlighting different positive effects of pursuing a bioeconomy, see Figure A3.1. While there were critical storylines right from the start (upper left part of the graph), these storylines were still connected to other storylines, which put the development of a bioeconomy according to the EU Commission vision in a more positive light.

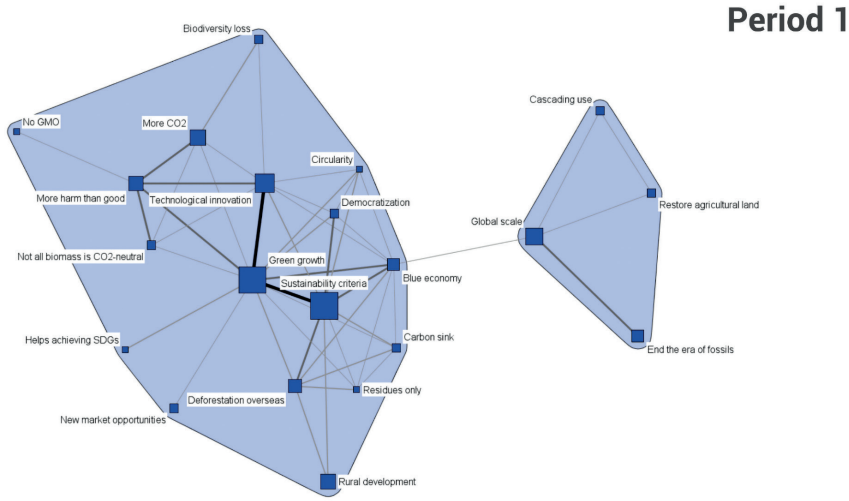

Figure A3.1 *Storyline congruence network for period 1.*
Storylines are presented as blue nodes; isolates are not displayed. Nodes are connected by an edge if storylines are uttered congruently by the same actor(s). Node size is proportional to the frequency of statements with reference to this storyline. Edge weight indicates the strength of congruence. The highest 5% of congruence values are visualized by black edges, 5-20% in dark grey and above that in light grey. Light blue group nodes show Girvan-Newman clusters of the highest hierarchy level.

Most storylines formed a single cluster, highlighting the benefits of pursuing a bioeconomy. 'Technological innovation', 'Green growth', and 'Sustainability criteria' storylines were bound by the highest congruence values, indicating that these storylines were uttered in concert by the same set of actors. These actors underlined that a bioeconomy, enabled by technological innovation, had the potential to contribute to the decoupling of economic growth and environmental impacts, but would require bio-resource harvesting criteria to

be sustainable. Storylines used to criticize this vision, such as 'Deforestation overseas', 'More CO_2', or 'Biodiversity loss' are integrated in this main cluster. The storyline cluster on the right of the graph also pronounced benefits of realizing a bioeconomy, such as ending the era of fossil resources and possibilities to restore uncultivated agricultural land but was less well connected to the main cluster.

Period 2 (2012 – 2018):

In period 2, we observe a more bipolar network constellation of storylines, see Figure A3.2. The network graph now clearly displays two clusters of storylines. On the one hand, the 'Green future' cluster consisted of a set of storylines underlying the vision of the EU Bioeconomy Strategy. Developing a bioeconomy would allow for further economic growth with decreasing environmental impacts, enabled by technological innovation. This growth would be achieved in rural areas, limiting differences in living standards between urban and rural regions. Furthermore, pursuing a bioeconomy would help mitigating climate change because bio-resources bind atmospheric CO_2.

On the other hand, in the 'Planetary boundaries' cluster, actors integrated storylines such as 'Deforestation overseas', 'More harm than good', and 'Biodiversity loss'. According to this understanding, the demand for bio-resources in the EU would cause deforestation overseas. Moreover, the shift towards a bioeconomy would do more harm than good due to biodiversity loss as a result of deforestation. We label this cluster 'Planetary boundaries', since the shared narrative highlights that pursuing a bioeconomy is limited by planetary boundaries.

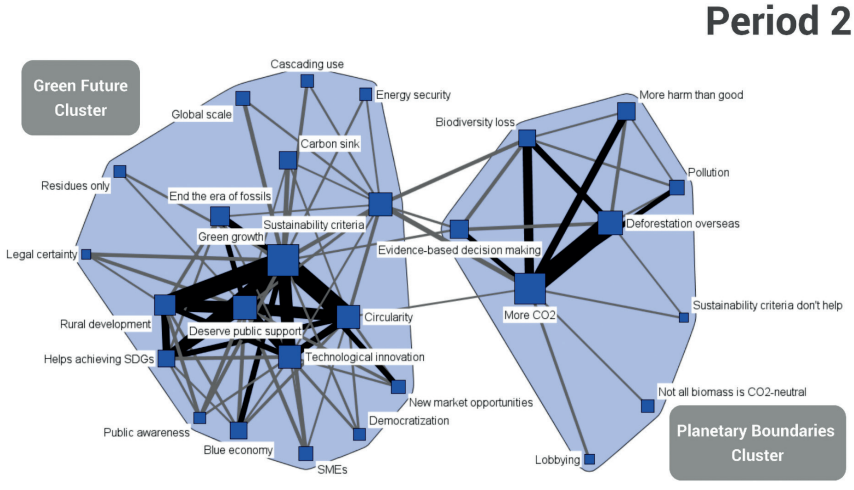

Figure A3.2 *Storyline congruence network for period 2.*
The highest 5% of congruence values are visualized by black edges, 5-20% in dark grey. Edges with lower congruence values are not displayed, nor are isolates. Grey rounded boxes display cluster labels.

Period 3 (2018 – 2021):

In period 3, the overlap between the two main storyline clusters reduced even more, see Figure A3.3. Only the 'Sustainability criteria' storyline still connected the two clusters, albeit with a low congruence value.

Compared to period 2, the 'Green future' cluster now consists of more storylines, thus got more complex. Actors introduced new storylines in reaction of events. Prominent examples are the 'Green recovery' storyline, highlighting opportunities for the bioeconomy for economic recuperation after the covid-19 pandemic as well as the 'Deliver EU Green Deal' storyline, underlining the importance of the bioeconomy in achieving EU Green Deal goals.

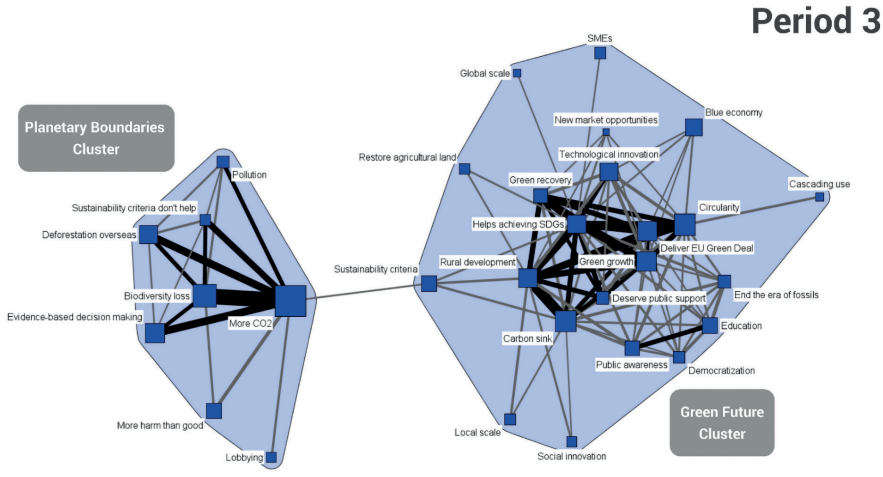

Figure A3.3 *Storyline congruence network for period 3.*
The highest 5% of congruence values are visualized by black edges, 5-20% in dark grey. Edges with lower congruence values are not displayed, nor are isolates.

Supplementary Material B

Belonging to Chapter 4

B.1 List of interview partners

B.2 List of policy documents

B.3 Coding scheme

Supplementary Material B.1: List of interview partners

ID	Organization Type	Interviewee position	Date [DD-MM-YYYY]	Length [min]
Chemical Park Delfzijl, Groningen (NL)				
NL1_I	Local company (cluster insider)	Top management	31-08-2022	54:43
NL2_I	Local company (cluster insider)	Top management	08-09-2022	34:02
NL3_G	Multilateral organization (cluster outsider)	Senior management	19-08-2022	59:43
NL4_G	National governmental organization (cluster outsider)	Senior management	12-09-2022	37:51
NL5_G	Regional government (cluster insider)	Policy officer	15-09-2022	46:40
NL6_G	Public investment organization (cluster outsider)	Policy officer	06-09-2022	72:00
NL7_I	Investment organization (cluster outsider)	Senior management	09-09-2022	33:40
NL8_A	University of applied sciences (cluster insider)	Senior management	26-06-2023	21:58
NL9_I	Cluster management (cluster insider)	Top management	26-04-2023	35:47
NL10_I	Cluster management (cluster insider)	Senior management	08-05-2023	30:31
NL11_G	Regional government (cluster insider)	Officer	09-05-2023	25:48

Leuna Biorefinery, Saxony-Anhalt (DE)				
DE1_I	Multinational company (cluster insider)	Top management	05-12-2022	30:29
DE2_I	Local company (cluster insider)	Top management	18-01-2023	45:42
DE2_I follow-up	Local company (cluster insider)	Top management	16-05-2023	17:59
DE3_C	Environmental NGO (cluster outsider)	Officer	26-01-2023	29:08
DE4_G	Local politician, state level (cluster outsider)	Parliamentarian	30-01-2023	42:03
DE5_A	Research institute (cluster insider)	Senior management	02-02-2023	36:59
DE6_I	Cluster management (cluster insider)	Top management	08-02-2023	30:39
DE7_G	State ministry (cluster outsider)	Officer	08-03-2023	26:16
DE8_A	Research institute (cluster insider)	Top management	17-05-2023	25:46
National Bioeconomy Campus, Lisheen (IE)				
IE1_G	Provincial administration, planning department (cluster outsider)	Officer	05-04-2022	32:02
IE2_G	Provincial administration, economic development department (cluster insider)	Senior management	04-05-2022	18:04
IE3_I	Cluster management (cluster insider)	Top management	04-05-2022	27:36
IE3_I follow-up	Cluster management (cluster insider)	Top management	14-12-2022	12:33
IE4_C	Environmental NGO (cluster outsider)	Officer	18-01-2023	30:34

Supplementary Material B.2: List of policy documents

Chemistry Park Delfzijl, Groningen (NL)

Policy strategy documents:

- Government (Rijksoverheid): Nederland circulair in 2050. Rijksbreed programma Circulaire Economie. September 2016.
- Government (Rijksoverheid): Uitvoeringsprogramma Circulaire Economie 2019-2023. February 2019.
- Government (Rijksoverheid): Uitvoeringsprogramma Circulaire Economie 2020-2023. September 2020.
- Government (Rijksoverheid): Uitvoeringsprogramma Circulaire Economie 2021-2023. October 2021.

Websites:

- Government website, Ministerie van Economische Zaken en Klimaat (https://www.topsectoren.nl/innovatie)
- Government website, Ministerie van Infrastructuur en Waterstaat (https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050)

Leuna (DE)

Policy strategy documents:

- Federal Government (Bundesregierung): Biorefineries Roadmap as part of the German Federal Government action plans for the material and energetic utilisation of renewable raw materials, May 2012.
- Federal Government (Bundesregierung): National Bioeconomy Strategy, March 2021.
- Saxony-Anhalt State Government (Staatskanzlei und Ministerium für Kultur): Bioökonomie als Treiber für Wertschöpfung und Innovation - Strategiepapier zur Schlüsselrolle des Landes Sachsen-Anhalt bei der Etablierung einer Modellregion der Bioökonomie im Mitteldeutschen Revier, April 2021a.
- Saxony-Anhalt State Government (Staatskanzlei und Ministerium für Kultur): Strukturentwicklungsprogramm Mitteldeutsches Revier Sachsen-Anhalt, December 2021b.

Websites:

- Cluster website, Bioeconomy Cluster Central Germany (https://www.bioeconomy.de/)
- Company website, InfraLeuna (https://www.infraleuna.de/)
- Company website, TotalEnergies (https://totalenergies.de/ueber-uns/standorte/raffinerie-leuna)

- Company website, UPM Biorefinery Leuna (https://www.upmbiochemicals.com/about-upm-biochemicals/biorefinery-leuna/)
- Research institute website, Fraunhofer CBP (https://www.cbp.fraunhofer.de/en.html)

Lisheen (IE)

Policy strategy documents:

- Tipperary County Council (Comhairle Contae Thiobraid Árann): Draft Tipperary County Development Plan 2022 - 2028, Strategic Environmental Assessment Report, Vol. 5, July 2021.
- Tipperary County Council (Comhairle Contae Thiobraid Árann): Tipperary County Development Plan 2022-2028, Written Statement, Vol. 1, August 2022.
- Mid-West Regional Authority (Cathaoirleach), Mott MacDonald, pwc, McGill Planning: Mid-West Area Strategic Plan 2012-2030. Planning, Land Use and Transportation Strategy. May 2013.
- Government of Ireland (Rialtas na hÉireann): National Policy Statement on the Bioeconomy, February 2018.

Planning and management documents:

- AECOM Ireland Ltd. for the Exploration and Mining Division of the Department of Communications, Climate Action, and Environment: A social, environmental, and economic assessment of Galmoy and Lisheen Mines. Final Report, February 2020.
- The National Trust for Ireland (An Taisce): Submission to the Commission for Regulation of Utilities on Gas Networks Ireland's Draft Ten-Year Network Development Plan 2019, September 2020.
    - Connected press release draft, n/d
- Tipperary County Council (Comhairle Contae Thiobraid Árann): Planning Report [report number], August 2022.
    - Connected submission, August 2022
    - Connected submission, n/d
    - Connected permission, November 2022

Websites:

- Cluster website, Irish Bioeconomy Foundation (https://bioeconomyfoundation.com/)

Company website, AgriChemWhey (https://www.agrichemwhey.com/)

Supplementary Material B.3: Coding scheme

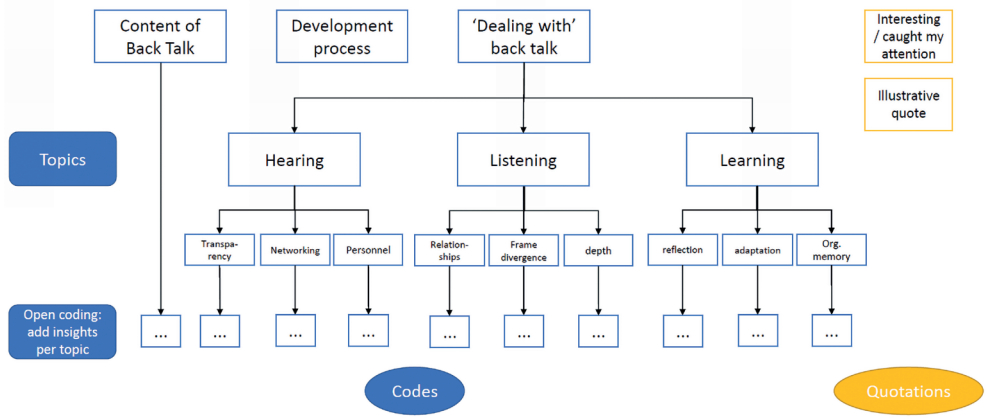

Figure B3.1 *Hierarchy of codes*

We coded interview transcripts in Atlas.ti 22.2.5.0. Topics were established deductively based on the conceptual framework. In a first round of open coding, we attached content to identified sub-topics and labelled insights as new codes within the respective topic. In addition to codes, we also added quotations. After having worked through the data set, we applied the coding scheme coherently to the whole data set of interview transcripts in a second round of coding.

Table B3.1 *Coding scheme for Chapter 4.*

Code		Mentions
Content of back talk		101
	acceptance due to tradition	4
	already achieved great achievements	7
	availability of raw material	1
	biodiversity	10
	bioeconomy needs to target circularity	12
	circularity means reduction	4
	concurrence of uses for bio-resources	2
	controversial bioenergy	2
	deforestation	1
	dependency on industry operations	3
	ecological trade-offs	2
	emissions	1
	energy demand	2
	fear of mining residues	3
	feel local support	1
	food system concurrence	3
	foster fact-based discussion	5
	future of forest: production site or nature?	2
	global justice	1
	good for the region	1
	greenwashing	2
	job creation	5
	land use conflicts (raw materials)	4
	local tax revenues	2
	locking-in fossil infrastructure	3
	locking-in unsustainable agricultural practices	4
	locking-in unsustainable consumption	1
	overseas transport of biomass	3
	planetary boundaries need to be regarded	1
	project is regarded as part of the community	1
	recycling needed in addition to biomass	1

			region has to suffer unproportional environmental trade-offs	1
			space demand (industrial site)	1
			strengthens rural areas	2
			unclear what bioeconomy is	1
			water quality deterioration	1
			wood certification not conclusive	2
Dealing with back talk				328
	Hearing			132
		transparency		38
			community engagement	2
			miss concerns if you do not do it	3
			more public attention needed	9
			newsletter	4
			only minimum public participation requirements fulfilled	5
			privacy and commercial sensitivity rights	2
			public relations campaign (sending approach)	1
			questions raised by permit authority during planning procedure	1
			radio adverts	1
			responsibility shifting to other level	1
			risk of public rejection	1
			social media engagement	1
			specialized trade fairs	3
			transparency as precondition	1
			visitor centre	1
			visitor tours	1
			website	1
		personnel		5
			hotline	3
			no personnel and resources to broaden dialogue	1
			personnel for stakeholder management	1
		networking		89
			administrative boundaries impede networking	4

		cluster organization as bridging actor	10
		common participation in expert commissions	9
		concerns brought in by academia helix	3
		concerns brought in by government helix	2
		concerns brought in by industry helix	2
		connect sectors	5
		contact via trade union	4
		contact with other clusters	1
		different helices reach different target groups	1
		expert conference	2
		forming industrial network	1
		hard to identify contact person	9
		in rural regions, people know each other	6
		input via expert associations	1
		international networking	2
		local press	2
		matching SMEs with civil society organizations	1
		missing fora for fundamental exchange	6
		multiple stakeholders make it complex	1
		networking across helix boundaries	9
		organize public discussions	4
		personal talks	2
		proactive approach	1
		public participation in planning process	1
		research projects on public opinion	1
Listening			92
	frame divergence		9
		approach another helix in their own language	2
		black-and-white thinking impedes dialogue	1
		exclusive expert elite discussion	1
		invite outsiders	1
		stimulate public discussion	1

	take up also criticism	3
relationships		41
	achieve congruence of strategic interests	3
	avoid public scepticism due to not being informed	3
	build trust	3
	careful explanations	1
	cluster organization is content-related contact expert for government	3
	continuity of dialogue	2
	develop common understanding	1
	dialogue between involved helices	1
	do not let concerns smoulder	1
	engineering societal acceptance	1
	good relationship with local government	1
	government is responsible	4
	industry does not invest in long-term thinking	3
	industry is responsible	3
	maintain good relationships	1
	participation in municipal council meeting	1
	pragmatic attitude of env. NGOs needed	1
	remain open organization	1
	rural mentality of helping each other	2
	sell benefits to public	1
	sending approach	3
	take concerns seriously	1
depth		42
	address concerns	3
	bad image of chemical sector overshadows dialogue	2
	bad image of waste sector overshadows dialogue	7
	confidence due to long-standing operations	6
	emotions make it a difficult discussion	1
	focus on technical aspects impedes listening	1

		form a vision	6
		informed dialogue requires evidence-based discussion	1
		lack of localized discussion	2
		lack through focus on acceptability	1
		one-directional information	2
		properly understand stakeholders	3
		real problems are not addressed	1
		responsibility to make project understandable	1
		spatial master plan	3
		structured multi-party dialogue needed	1
		tangibility enables direct feedback	1
Learning			104
	adaptations		43
		alignment with circularity principles	3
		alignment with national strategies	4
		cascading principle	4
		definition of funding criteria sharpened	7
		on-the-fly adaptations (incremental changes)	9
		reduce emissions	4
		seeking consensus	1
		sourcing radius	3
		stimulate forest diversification	1
		sugar agenda	1
		sustainable forest management	1
		use local resources	1
		use residues only	3
		wood certification	1
	reflection		42
		also focus on SMEs	4
		complex system makes it difficult	2
		constant, iterative process	4
		different functions of helices	3
		do not seek consensus	3
		due to public pressure or intrinsic?	1

		encourage reflection by cluster management	1
		encourage reflection in involved companies	4
		experimentation	1
		find common language for transformative ideas	3
		flexibility of financers needed	1
		focused on technology choice and process	1
		greening of education needed	1
		job discussion too central	1
		locking-in options is problematic	1
		look at problem with different lens	1
		more risk-taking mentality needed	1
		motivation to prevent too restrictive rules	1
		need of new space-intensive infrastructure	1
		non-linear learning	1
		participation at early process stage	1
		patience	1
		pioneering	2
		sufficiency approach needed	2
	organizational memory		19
		change attitude	1
		change buildings on site	6
		gain motivated personnel	3
		helix permeability (personnel switches between helices)	1
		lacking information uptake by government helix	1
		lengthy planning and objection procedures halt processes	3
		need of long-term funding continuity	2
		sustainability as advantage to recruit people	1
		value know-how as competitive advantage	1
Development process			283

Supplementary Material C

Belonging to Chapter 5

C.1 Overview of AgRefine ESR projects

C.2 Questionnaire

C.3 Overview of conducted interviews

Supplementary Material C.1: Overview of AgRefine ESR projects

ESR nr.	ESR name	Project title	Home institution
Work package 1: AgRefine technology development			
1	Roderick van Roosmalen	Three phase bio-reactor biosensor development	University College Dublin (UCD)
2	Anna Visentin	Downstream contaminant removal purification process	University College Dublin (UCD)
3	Eleftheria Papadopoulou	Process optimization for enhanced lactic and amino acid production	Technical University of Denmark (DTU)
4	Mayuki Cabrera González	Enhanced biorefinery lactic acid and amino acid generation and recovery	Technical University of Vienna (TU Wien)
5	Francesco Vigato	Bio-succinic production from biogas and AD-biorefinery residues	Technical University of Denmark (DTU)
6	Alexandra Nastouli	A continuous flow contaminant removal membrane bioreactor system for LA purification using genetically modified organisms	Centre for Research & Technology Hellas (CERTH)
7	Priya Pollard	Seaweed-ensiling process and cultivation optimisation strategy	Bantry Marine Research Station (BMRS)
Work package 2: Systems-level design			
8	Mariana Cerca	Bioeconomy supply chain management	University College Dublin (UCD)

9	Rushab Chopda	Nutrient recovery	Ghent University (UGhent)
10	Fernando Ramonet	Three-phase-bioreactor scalability and anaerobic digestion retrofitting analysis	Technical University of Vienna (TU Wien)
11	Srija Balachandran	Development and optimisation of downstream processes for carboxylic acids	Ghent University (UGhent)
12	Charlene Vance	Life cycle sustainability assessment	University College Dublin (UCD)
Work package 3: Value chains			
13	Xavier Gabet	Assessment of green biorefinery archetypes and implementation scenarios	TBW Research
14	Francesca Magnolo	Financial sustainability and sustainable business models	Ghent University (UGhent)
15	Jan Starke	Enabling governance arrangements for next-generation agri-biorefinery technology	Wageningen University & Research (WUR)

ESR: *Early-Stage Researcher*
Based on: https://agrefine.eu/ (last access: 19 January 2024, 14.06) and AgRefine grant agreement.

Supplementary Material C.2: Questionnaire

Learning History: AgRefine

Very dear AgRefine colleague,

Thinking back and reflecting about the AgRefine project, I would like to invite you to identify the key moments were you learned most, thus where you acquired new skills and knowledge and where your view on the project, the bioeconomy, or biorefinery technology shifted.

Every section of the table starts with a defined learning goal from the grant agreement. Instead of evaluating to what extent the learning outcome was fulfilled, I am more interested in your learning moments related to the respective goal.

Please answer the questions in your own words in the right column.

Please use around 20 – 150 words per answer and try to answer every question. If something is unclear, please contact me. Also, please **answer in full sentences** and not only in bracket points. This will help me to include direct quotes in the final product.

This will take about 2 – 4 hours of your time. I realize that this is a huge up-front investment, but I hope that this also helps you for your own dissertation, especially when you have to reflect on your learning process. Also, I hope that this will be fun to work on!

All the best,

Jan

1. Provision of skills and knowledge

'This AgRefine European Training Network (ETN) will provide Early-Stage Researchers (ESRs) with the necessary skills and knowledge to position Europe as the global leader in developing an agri-bioeconomy industry based on advanced biorefinery technologies'.
(Research Executive Agency et al., 2019, p. 3/33 of Annex 1A).

1.1. What do you think why were you hired for your position? What skills and knowledge did you bring in already at the start of the project?
1.2. What are the most important skills and knowledge that you learned from other ESRs during the AgRefine project? When and how did that happen?
1.3. At what moments have you learned an important skill or acquired new knowledge from a project participant who is not another ESR or one of your supervisors? This could be for instance during secondments. How did that happen?
1.4. What skills or knowledge have you learned by following broader debates about the bioeconomy, for instance during our journal clubs, by talking to friends and family or by following the news? How have these broader debates changed the way you looked at your work and the overall project?

2. Interdisciplinarity

'*The ETN will consist of 15 highly interdisciplinary and inter-sectoral PhD projects, each specialising in specific aspects of the bioeconomy […] including chemical and process engineering, biological science, life cycle assessment, and economics. The network will combine assessment of legislation and policy as it applies to the bioeconomy, with industry-led innovation of AgRefine technology, and market-led experience of sustainable value creation'.*
(Research Executive Agency et al., 2019, p. 3/33 of Annex 1A)

2.1. What have you changed in your project as a reaction to the actions/results/input of another ESR? At what moments did that happen? Why have you made these adjustments?
2.2. How do you remember the first 'live' meeting of all ESRs? What were differences in our ways of thinking and doing research? What hindered collaboration? What facilitated collaboration?
2.3. How did the collaboration during your secondment work? What have you changed in your own work due to what you experienced during the secondments? Why?
2.4. At what moments have you included people from outside of academia in your research? What did you do to make this work? What was difficult?

3. Training

'The ESRs will receive training on adopted RRI principles, project management, communication, presentation and media skills.

(Research Executive Agency et al., 2019, p. 3/33 of Annex 1A)

3.1. What are the most important things that you learned during the training weeks? What did you like most about the training weeks? What did you dislike?
3.2. How do you think the other ESRs liked the training weeks? What have they learned? Have they put more or less effort in the trainings than yourself?
3.3. How were the AgRefine partner organizations involved in the training weeks? Could the trainings have benefitted from more involvement? Or would it have been better if they were less involved? Why?
3.4. What skills or knowledge did you acquire that will help you to make an impact after you have graduated? What skills or knowledge will you never use again?

4. Access to partners

'The network will provide ESRs with access to partners with key-expertise in the bioeconomy, gaining a range of relevant transferable skills and expertise in environmental, economic and social aspects of AgRefine'.

(Research Executive Agency et al., 2019, p. 3/33 of Annex 1A)

4.1. What did you like most about your secondments? What did you dislike?
4.2. How did the collaboration with the partner organizations look like, for instance during secondments? With whom were you in touch? How did you communicate? What worked well? What was challenging?
4.3. Do you think the other ESRs have benefitted more or less from their secondments? Why? Who do you think had the most interesting secondment? Why?
4.4. How do you think can you profit from the contacts you made during your secondments in your future career?

5. Public promotion of results

'The beneficiaries [universities or research institutes that employ the ESRs] must promote the action [AgRefine] and its results, by providing targeted information to multiple audiences (including the media and the public) in a strategic and effective manner.'
(Research Executive Agency et al., 2019, p. 45)

5.1. How did you communicate with the public about your results? With that I mean people who are not involved in AgRefine.
5.2. How do you follow broader debates about the bioeconomy?
5.3. Have you also heard back reactions from people who are not involved in AgRefine, for instance friends, family, or colleagues at your department? What did they say about what you're doing?
5.4. With whom outside of AgRefine do you talk most about the project? What do they say? At what moments do they get annoyed/bored/excited/inspired by talking with you about AgRefine? Why?
5.5. How did these reactions impact your research or how you think about the bioeconomy? What have you changed? What did you ignore?

6. Excellence objective: Disruptive, Innovative, Cooperative, Entrepreneurial (DICE)

'This project proposes to disrupt the mechanism by which biomass is currently being used by cooperatively integrating innovative stand-alone technologies so that the highest value, socio economically [sic] beneficial products per input substrates, can be achieved (entrepreneurial)'.
(Research Executive Agency et al., 2019, p. 6/22 of Annex 1B, original highlighting)

6.1. What do the objectives disruptive, innovative, cooperative, and entrepreneurial mean to you?
6.2. By looking at the projects of the other ESRs, what project do you think was most disruptive? Why? What did that ESR do different than you?
6.3. To what extent do societal research partners (in fact, the secondment providers) have had an impact on how disruptive, innovative, cooperative, and entrepreneurial your project was?
6.4. What do you think how people not involved in AgRefine think how disruptive, innovative, cooperative, and entrepreneurial the project was?

The next section (7.) is separated per work package.

Please only fill in the section for your respective work package.

7.A. Work package 1 objective: AgRefine technology development *'To create a three-phase reactor technology to implement AgRefine's valorisation cascade, whereby high to low quality leachates will be re-directed to ensures [sic] that optimal high to low valorisation cascade product per input feedstock qualities, are observed at all times'.* (Research Executive Agency et al., 2019, p. 11/33 of Annex 1A)
7.A.1. How does your specific project relate to this overall objective? What skills and knowledge did you learn by working on this objective? How? *7.A.2. At what moments and how did you deviate from your 'job description' in the grant agreement? How did that feel?* *7.A.3. At what moments did you feel a team spirit within your work package? How did that happen? What were you working on?* *7.A.4. How does your work package relate to the other work packages? At what moments did you have content-related talks with an ESR from another work package?* *7.A.5. At what moments have you discussed broader implications of what you are working on in your work package? With broader implications, I mean impacts of your work on biorefinery technology or the bioeconomy in general. Why have you (not) discussed this?*

7.B. Work package 2 objective: Systems-level design *'To deliver a system-level analysis that considers impacts across the full life cycle of the AgRefine bioeconomy to avoid "burden shifting"'.* (Research Executive Agency et al., 2019, p. 15/33 of Annex 1A)
7.B.1. How does your specific project relate to this overall objective? What skills and knowledge did you learn by working on this objective? How? *7.B.2. At what moments and how did you deviate from your 'job description' in the grant agreement? How did that feel?* *7.B.3. At what moments did you feel a team spirit within your work package? How did that happen? What were you working on?* *7.B.4. How does your work package relate to the other work packages? At what moments did you have content-related talks with an ESR from another work package?* *7.B.5. At what moments have you discussed broader implications of what you are working on in your work package? With broader implications, I mean impacts of your work on biorefinery technology or the bioeconomy in general. Why have you (not) discussed this?*

7.C. Work package 3 objective: Value chains

'To develop a full supply chain sustainability plan to create economically robust supply chains and sound business models'.

(Research Executive Agency et al., 2019, p. 18/33 of Annex 1A)

7.C.1. How does your specific project relate to this overall objective? What skills and knowledge did you learn by working on this objective? How?
7.C.2. At what moments and how did you deviate from your 'job description' in the grant agreement? How did that feel?
7.C.3. At what moments did you feel a team spirit within your work package? How did that happen? What were you working on?
7.C.4. How does your work package relate to the other work packages? At what moments did you have content-related talks with an ESR from another work package?
7.C.5. At what moments have you discussed broader implications of what you are working on in your work package? With broader implications, I mean impacts of your work on biorefinery technology or the bioeconomy in general. Why have you (not) discussed this?

8. Some last questions

8.1. Apart from the goals at the beginning of each section, what are other important learning outcomes that are not named in the grant agreement?
8.2. What is the single most important thing you learned during the AgRefine project?
8.3. On a scale of 0 (not at all) to 10 (incredibly much): How much did you learn from AgRefine?
8.4. What have you learned by filling in this questionnaire? Did you find this reflection useful? Why (not)?
8.5. Is there anything you would like to add?

Supplementary Material C.3: Overview of conducted interviews

Participant number *(does not correspond with ESR number)*	**Date [DD-MM-YYYY]**	**Length [min:sec]**
1	05-09-2023	60:21
2	07-09-2023	56:17
3	07-09-2023	50:13
4	11-09-2023	61:59
5	14-09-2023	58:38
6	15-09-2023	54:32
7	04-10-2023	54:22
8	13-10-2023	56:25
9	13-10-2023	61:15
10	19-10-2023	60:20
11	Questionnaire only	Questionnaire only
12	Questionnaire only	Questionnaire only
13	Questionnaire only	Questionnaire only
14	Questionnaire only	Questionnaire only

SUMMARY

Humanity currently lives on a diminishing stock of fossil mineral oil and gas resources. Using these resources in industrial production processes generates greenhouse gas emissions, which cause harmful climate change. To tackle this urgent sustainability challenge, policymakers in Europe, but also elsewhere, cherish the sustainability transition towards a circular bioeconomy. Such a sustainability transition is a large-scale, systemic change process of an unsustainable socio-technical regime towards a novel, more sustainable one. In this case, instead of a regime around fossil resources, a bioeconomy aims to utilize bio-based resources, such as crops, grass, wood, or algae, for the production of a wide range of products, including bioenergy, plastics, chemicals, pharmaceuticals, food products, and fertilizers. While being cherished by policymakers and many scholars, transitioning towards a bioeconomy is also controversial. Critical observers scrutinize how sustainable and circular such an endeavour is, due to possible negative consequences for sustainable land use, biodiversity, environmental quality, justice, and locking in unsustainable scales of demand for energy and materials. Moreover, local public concerns about bioeconomy production sites, such as biorefineries or biodigesters, centre around environmental nuisances and injustices.

Bioeconomy stakeholders, such as policymakers, but also private actors in business, civil society actors, as well as scientists, struggle to deal with these controversies. This is because controversies result to be intractable to resolution attempts by producing new fact knowledge, such as impact assessments, supply chain management approaches, or optimal installation positioning strategies. Instead of resolving these controversies, such efforts provide new framing material for involved discourse coalitions and therefore continuously revive this evolving form of conflict. Despite upcoming research interest in the role of power and conflicts in sustainability transitions, evolutions of long-term controversies and how to deal with them remain under-conceptualized and empirically under-explored in the bioeconomy governance literature.

To tackle this knowledge gap, this dissertation aims to address the main research question: *How can evolving controversies be dealt with productively in the European transition towards a sustainable and circular bioeconomy?* This dissertation therefore has the dual objective of increasing the scholarly understanding of how controversies evolve throughout a sustainability transition and to explore how stakeholders can deal with these controversies productively in bioeconomy governance. To answer the main research question, the dissertation is structured around three sub-questions:

1. How do controversies evolve throughout a sustainability transition?
2. How do discourse coalitions evolve throughout a sustainability transition?
3. How can controversies be dealt with productively in sustainability transitions?

Chapter 2 outlines the conceptual framework of this dissertation. After reviewing the state-of-the-art of the bioeconomy literature, this chapter elaborates a novel conceptualization of the role of controversies in the European circular bioeconomy transition. The chapter starts with the observation that the bioeconomy literature approaches conflicts about the direction and manner of the bioeconomy transition in two ontologically different ways. On the one hand, the dominant, techno-economic perspective regards conflicts as a design fault that can and should be outdesigned in technology development. According to this perspective, this can be achieved by integrated impact assessments, smart supply chain planning, and an optimal modelling of production site locations. On the other hand, an upcoming social sciences perspective analyses framing conflicts between opposing groups of actors. Authors that adhere to this perspective map what groups of actors promote what transition pathways. While the former perspective disregards the nature of controversies as an intractable form of conflict that cannot objectively be resolved, the latter widely falls short on how these argumentative conflicts have evolved in interaction with the unfolding transition process and how resulting discursive situations might change. Based on these observations, I develop a more suitable conceptualization of controversies in sustainability transitions, building on broader literatures on sustainability transitions, policy controversies, and constructive conflict resolution. To this end, the framework introduces three conceptual building blocks: (1) controversy loci, (2) discourse coalition dynamics, and (3) the productivity of controversies.

First, I argue that controversies surface in various loci throughout the transition process. Loci are different settings of actors, used framings, and communication rules on the diverse levels of a sustainability transition: macro, meso, and micro. The macro-level concerns landscape pressures on the regime constellation, such as cultural and high-level political changes. The meso-level centres around shifting regime constellations of technologies, infrastructure, rules, and norms. The micro-level describes innovative niches of alternative ways of thinking, doing, and organizing. Controversies are intractable in sustainability transitions because they pop up again and again in the different loci on and between the three levels of a transition.

Second, while moving through the different loci, discourse coalitions evolve. Discourse coalitions are like-minded groups of actors that frame problem definitions and solution options coherently around shared storylines. Instead of static constructs, discourse coalitions are dynamic and constantly evolving. This is because involved actors adjust their use of storylines, resulting in the solidification, growing, shrinking, merging, or falling apart of 'their' discourse coalitions. This conceptual building block underlines the agency of actors in continuously reshaping discourses.

Third, controversies are not always bad news. Indeed, controversies can evolve in unproductive ways, for instance in stalemates that paralyze the transition process. However, controversies can also evolve in productive ways, which stimulate learning from alternative perspectives, leading to a broader range of available policy options and a more reflective transition process.

The three subsequent chapters take the different loci introduced as first building block (macro, meso, and micro) as a point of departure. Chapter 3 further elaborates the second conceptual building block, discourse coalition dynamics. The third conceptual building block, controversy (un)productivity, is applied and further sharpened in Chapters 4 and 5.

Chapter 3 further elaborates the second conceptual building block from the conceptual framework and takes the macro-level locus as a point of departure. In this chapter, I map evolutions of landscape controversies in debates on the future of the EU bioeconomy on 𝕏, the social media platform formerly known as Twitter. Previous studies have identified competing discourses on the bioeconomy in Europe. Most prominently, an ecomodernist perspective argues for a 'green growth' trajectory to position Europe as a bioeconomy world leader by uncoupling economic growth from environmental impacts. An alternative perspective centres around the notion of planetary boundaries that limit the scale of a future bioeconomy and warns about environmental and social trade-offs. However, it remains unclear how this discursive conflict has emerged and can change, particularly online. Therefore, this chapter provides a more in-depth analysis of how argumentative changes of actors alter the network of online dynamic discourse coalitions on social media. The analysis is based on interviews and a qualitative discourse network analysis of 9,983 tweets from the period 2008–2021.

The results show that initially, expert debates centred around bioeconomy advantages. After the publication of the first Bioeconomy Strategy in 2012, the debate diversified because new actors joined the debate and brought in new storylines. As a result, two opposing discourse coalitions, 'Green future' and 'Planetary boundaries', emerged around divergent storyline clusters. After the 2018 Bioeconomy Strategy update, the online debate simplified into argumentations of few, highly conflicting storylines, which led to a polarization of the discourse network. Ultimately, the discourse network evolution indicates an emerging discursive lock-in, where one perspective becomes institutionalized in policymaking and leaves no room for alternative perspectives, causing problematic biases.

In addition to the actor-storyline dynamics conceptualized in previous research, I identify storyline hijacking as a further dynamic that adds to polarization and conflict. By carving out how the discourse network changes by adaptations in the way of how actors use

storylines, I identify how discourses evolve over time. These insights help to identify opportunities to open up entry points for alternative problem definitions and new, currently overlooked solutions. This can contribute to prevent locking-in the limited range of solutions in congruence with the dominant 'Green future' discourse.

Chapter 4 sharpens the third conceptual building block, the productivity of controversies in sustainability transitions. To this end, I introduce a novel conceptualization of organizational hearing, listening, and learning capabilities to deal with controversies in a more productive manner. Taking the meso-level locus as a point of departure, I zoom in on how so-called Triple Helix clusters, which can be regarded as re-configuring regime constellations of local governments, businesses, and academia, deal with controversies. Previous Triple Helix research has criticized the rather exclusive nature of the Triple Helix model vis-à-vis the social environment of these clusters. Consequently, scholars have worked on an expansion of the model to better include societal actors that do not form part of the Triple Helix cluster. However, these approaches singularly focus on *inviting* societal actors to become part of the collaboration. In contrast, this chapter analyses how involved cluster partners deal with *uninvited* input from societal actors that do not form part of the collaboration.

To this end, I conceptualize this uninvited societal input as back talk and distinguish the sequence of hearing, listening, and learning to explore how back talk contributes to innovation. The study zooms in on processes in three bioeconomy Triple Helix clusters in the Netherlands, Germany, and Ireland. Results are based on a qualitative content analysis are based on interview transcripts, newspaper articles, as well as policy and planning documents.

The results indicate that actors involved in the analysed Triple Helix clusters frequently do not hear back talk that fundamentally scrutinizes their underlying beliefs. This is because cluster partners focus on a one-directional approach of informing the local public about what they consider technical, economic, and environmental benefits of their projects. Cluster partners become 'insiders', which jeopardizes listening to fundamentally different problem definitions. Since alternative solutions of 'outsiders' are disregarded as unscientific, irrelevant, or emotional, learning from uninvited back talk is restricted to minor adjustments. This restriction contributes to a further institutionalization of the identified emerging macro-level lock-in of a techno-economic 'Green future' perspective. To avoid that innovative solutions remain unexplored as a result of this lock-in, Triple Helix 'insiders' must engage in a reflective, two-directional dialogue with critical 'outsiders'. Further developing their hearing, listening, and learning capabilities can help cluster partners in this endeavour.

Chapter 5 further develops the third conceptual building block and departs from the micro-level locus. In this chapter, I analyse how PhD researcher within the project that I was part of, the AgRefine training network, have managed (but also failed) to productively learn from controversies. I do so by means of a collaborative learning history, which is a reflection process that is co-generated with my AgRefine PhD researcher peers. My colleagues and I disentangle processes and preconditions of how we managed (but also failed) to become responsive to controversies by hearing, listening to, and learning from different publics affected by the project's innovation process. These publics are involved researchers, involved societal partner organizations, and the broader public.

The results demonstrate that involved PhD researchers have mostly learned from each other. In particular, we learned the interdisciplinary skill of forming listening relationships. By listening to the input of each other, several PhD researchers performed content-related adjustments of their individual research projects. In this regard, many colleagues have become more critical of biorefinery innovation and the bioeconomy transition, demystifying the idea of working on a silver-bullet solution towards a sustainable and circular future. This deep form of learning was enabled by common training weeks and regular contact moments in formal and informal chats. However, mismatches in timing research outcomes and conflicting (supervisor) expectations within the project obstructed further interdisciplinary collaboration. Regarding input from the second public, involved societal partners, some PhD colleagues learned more than others. For some, secondments with partner organizations were very formative, leading to adjustments in their project set-ups and changes of their underlying perspectives. For others, secondments mainly meant to work on the same project but at a different location. In particular lab-based PhD colleagues struggled to hear input from the third, uninvolved public due to detaching the technological innovation process from its societal context. Uninvited societal input was widely disregarded as irrelevant, at least at this initial stage of technology development. Identified reasons were the construction of an impermeable niche by the use of exclusive expert language but also project characteristics and the role of supervisors, resulting in being kept 'running' in lab work. Desk-based (economic and social science) colleagues, in contrast, experienced it as a privilege to also take up broader, societal concerns in their work.

In general, the outcomes of this reflection process indicate that researchers who were able to invest more into listening to societal project partners and the broader public became more responsive to input from outside the project's boundaries. PhD researchers learned not only interdisciplinary skills of navigating a complex research project and to communicate their research in a more accessible way, but also deeper forms of learning, for instance to flexibly adjust their research planning in response to changing circumstances. Some even changed their fundamental research objectives in response to

societal input. Also beyond AgRefine, these results indicate that different publics affected by research and innovation projects might require different forms of responsiveness. Funding agencies and supervisors can foster more responsive innovation by allowing more flexibility in deviating from pre-defined project outcomes and demand a closer engagement with societal input.

Chapter 6 synthesizes the insights from the individual chapters and provides an answer to the research questions. Moreover, after reflecting on methodological choices and resulting limitations, I position my research in the literature by suggesting avenues for further research. Based on this, I formulate indications for stakeholders that aim to shape the European bioeconomy transition towards more sustainable and circular outcomes.

In a nutshell, controversies have productive potential in a sustainability transition by surfacing alternative perspectives. This can be functional in scrutinizing biases and therefore contribute to 'unlocking' discursive lock-ins. In the European bioeconomy transition, a macro-level discursive lock-in of the dominant, ecomodernist 'Green future' perspective emerges, at least online. This perspective becomes institutionalized by being taking over in meso-level regime reconfigurations, for instance in the operations of bioeconomy Triple Helix clusters. On the micro level, technological innovation niches can become impermeable to controversies in other loci by detaching the innovation process from its societal context. Discourse coalitions operate in several loci simultaneously, contributing to a translation of controversies to other loci. These interrelations of discursive situations in diverse loci obtain the danger of resurfacing discursive lock-ins and resulting biases throughout a sustainability transition. To avoid this, controversies have the innovative potential of surfacing alternative perspectives, which scrutinize biases, throughout the different loci. Instead of avoiding controversies or pursuing unfruitful resolution approaches that can even backfire, bioeconomy decisionmakers therefore need to regard controversies as learning opportunities. This involves a continuous, reflective process of hearing, listening, and learning. These capabilities can help bioeconomy stakeholders to 'unlock' the innovative potential of controversies.

SAMENVATTING

De mensheid leeft momenteel op een slinkende voorraad fossiele bronnen. Het gebruik van deze voorraad in industriële productieprocessen leidt tot de uitstoot van broeikasgassen, die schadelijke klimaatverandering veroorzaken. Om deze urgente duurzaamheidsuitdaging aan te pakken, koesteren beleidsmakers in Europa, maar ook elders, de duurzaamheidstransitie naar een circulaire bio-economie. Zo'n duurzaamheidstransitie is een grootschalige, systemische en ingrijpende overgang van een niet-duurzaam socio-technisch regime naar een nieuw, duurzamer regime. In dit geval gaat het om een bio-economie die zich richt op het gebruik van bio-gebaseerde bronnen, zoals gewassen, gras, hout of algen, voor de productie van een breed scala aan producten, zoals bio-energie, plastics, chemicaliën, geneesmiddelen, voedingsmiddelen en meststoffen. Hoewel de transitie naar een bio-economie door veel beleidsmakers en wetenschappers wordt gekoesterd, is hij ook controversieel. Critici betwijfelen hoe duurzaam en circulair zo'n proces is, vanwege mogelijke negatieve gevolgen voor duurzaam landgebruik, biodiversiteit, milieukwaliteit, rechtvaardigheid en de lock-in van een niet-duurzame omvang van de vraag naar energie en materialen. De bezorgdheid van het lokale publiek richt zich op milieuoverlast en een rechtvaardige verdeling van kosten en baten, met oog op productielocaties voor de bio-economie, zoals bioraffinaderijen of -vergisters.

Belanghebbenden in de bio-economie, zoals beleidsmakers, maar ook bedrijven, maatschappelijke spelers en wetenschappers, worstelen met deze controverses. Dit komt doordat controverses hardnekkig zijn. Het simpelweg aandragen van nieuwe feitenkennis leidt daarom niet tot een oplossing van het onderliggende waardenconflict. Voorbeelden voor dit soort oplossingspogingen zijn effectbeoordelingen, modellen en certificeringen voor het beheer van de toeleveringsketen of modelleringen voor de optimale positionering van installaties. In plaats van deze controverses op te lossen, leveren dergelijke pogingen nieuw materiaal op voor *framing* door rivaliserende actoren. Zodoende blazen zij deze conflicten nieuw leven in en ontwikkelen controverses zich voortdurend door. Echter, deze evoluties bieden ook kansen voor *reframing* van de probleemstelling en de ontwikkeling van nieuwe oplossingsideeën. Ondanks een opkomende onderzoeksinteresse in de rol van macht en conflicten in duurzaamheidstransities, blijven evoluties van langdurige controverses en hoe hiermee om te gaan onvoldoende geconceptualiseerd en empirisch onderzocht in de beleidsliteratuur over de bio-economie.

Om deze kennislacune aan te pakken, richt dit proefschrift zich op de hoofdonderzoeksvraag: *Hoe kan productief worden omgegaan met evoluerende controverses in de Europese transitie naar een duurzame en circulaire bio-economie?* Dit proefschrift heeft daarbij een tweeledig doel: het vergroten van het wetenschappelijke begrip van de ontwikkeling

van controverses gedurende een duurzaamheidstransitie; en het onderzoeken hoe belanghebbenden in de governance van de bio-economie productief met deze controverses kunnen omgaan. Om de hoofdonderzoeksvraag te beantwoorden, is het proefschrift opgebouwd rond drie deelvragen:

1. Hoe evolueren controverses in de loop van een duurzaamheidstransitie?
2. Hoe evolueren discourscoalities in de loop van een duurzaamheidstransitie?
3. Hoe kan productief worden omgegaan met controverses in duurzaamheidstransities?

Hoofdstuk 2 schetst het conceptuele kader van dit proefschrift. Na een bespreking van de *state-of-the-art* van de bio-economie literatuur, wordt in dit hoofdstuk een nieuwe conceptualisatie uitgewerkt van de rol van controverses in de Europese transitie naar een circulaire bio-economie. Het hoofdstuk begint met de constatering dat de bio-economie literatuur conflicten over de richting en manier van de bio-economie transitie op twee fundamenteel verschillende manieren benadert. Aan de ene kant beschouwt het dominante, techno-economische perspectief conflicten als een ontwerpfout die kan en moet worden 'outdesigned' in technologieontwikkeling. Volgens de literatuur die dit perspectief volgt, kan dit worden bereikt door geïntegreerde effectbeoordelingen, slimme planning van toeleveringsketens en een modellering van optimale productielocaties. Anderzijds analyseert een opkomend sociaalwetenschappelijk perspectief framing-conflicten tussen rivaliserende groepen actoren. Auteurs die dit perspectief aanhangen, brengen in kaart welke groepen actoren welke transitiepaden voorstaan. Beide perspectieven hebben tekortkomingen als het gaat om de analyse van de rol van controverses in de bio-economie transitie. Het eerste perspectief gaat voorbij aan de aard van controverses als een hardnekkige vorm van conflict die niet objectief kan worden opgelost. Het tweede perspectief laat na te onderzoeken hoe deze conflicten zijn geëvolueerd in interactie met het zich ontvouwende transitieproces en hoe het resulterende maatschappelijk debat kan veranderen. Op basis van deze observaties ontwikkel ik een geschiktere conceptualisatie van controverses in duurzaamheidstransities. Deze conceptualisatie bouwt voort op bredere literatuur over duurzaamheidstransities, beleidscontroverses en constructieve conflictoplossing. Daartoe introduceert het raamwerk drie conceptuele bouwstenen: (1) 'loci' van controverses in duurzaamheidstransities, (2) de dynamiek van discourscoalities en (3) de productiviteit van controverses.

Ten eerste stel ik dat controverses op verschillende 'loci' in het transitieproces opduiken. Loci zijn verschillende samenstellingen van actoren, *framings* en communicatieregels op en tussen de verschillende niveaus van verandering in een duurzaamheidstransitie: macro, meso en micro. Het macroniveau betreft veranderingen van de invloed van het bredere politieke en culturele landschap op de regimeconstellatie, zijnde de vorm en eigenschappen van het dominante socio-technisch systeem. Het mesoniveau draait om

veranderende regimeconstellaties van technologieën, infrastructuur, regels en normen. Het microniveau beschrijft innovatieve niches van alternatieve manieren van denken, doen en organiseren. Controverses zijn hardnekkig in duurzaamheidstransities omdat ze steeds weer opduiken in de verschillende loci op en tussen de drie niveaus van verandering in een transitie.

Ten tweede evolueren discourscoalities terwijl ze zich door de verschillende loci bewegen. Discourscoalities zijn gelijkgezinde groepen actoren die probleemdefinities en oplossingsrichtingen op een coherente manier framen rond gedeelde verhaallijnen. In tegenstelling tot statische constructen zijn discourscoalities dynamisch en evolueren ze voortdurend, doordat betrokken actoren hun gebruik van verhaallijnen aanpassen. Dit resulteert in het verstevigen, groeien, krimpen, samenvoegen of uiteenvallen van 'hun' discourscoalities. Deze conceptuele bouwsteen onderstreept de agency van actoren in het voortdurend aanpassen van discoursen.

Ten derde zijn controverses niet altijd slecht nieuws. Controverses kunnen zich inderdaad op onproductieve manieren ontwikkelen, bijvoorbeeld door het creëren van impasses die verandering in de weg staan. Controverses kunnen zich echter ook op productieve manieren ontwikkelen. In dat geval wordt het leren van alternatieve perspectieven gestimuleerd, wat leidt tot een breder scala aan beschikbare beleidsopties en een meer reflectief en democratisch transitieproces.

De drie volgende hoofdstukken nemen de verschillende loci die als eerste bouwsteen zijn geïntroduceerd (macro, meso en micro) als uitgangspunt. Hoofdstuk 3 werkt de tweede conceptuele bouwsteen, de dynamiek van discourscoalities, verder uit. De derde conceptuele bouwsteen, de (on)productiviteit van controverses, wordt toegepast en verder aangescherpt in hoofdstuk 4 en 5.

Hoofdstuk 3 werkt de tweede conceptuele bouwsteen uit het conceptuele raamwerk verder uit en neemt de locus op macroniveau als uitgangspunt. In dit hoofdstuk breng ik evoluties van landschapscontroverses over de toekomst van de bio-economie in de EU in kaart op 𝕏, het sociale mediaplatform dat voorheen bekend stond als Twitter. Eerdere studies hebben twee tegenstrijdige discoursen over de bio-economie in Europa geïdentificeerd. Een dominant ecomodernistisch perspectief pleit voor 'groene groei' om van Europa een wereldleider op het gebied van bio-economie te maken door economische groei los te koppelen van negatieve milieueffecten. Een alternatief perspectief draait om de notie van planetaire grenzen die de schaal van een toekomstige bio-economie beperken. Dit perspectief waarschuwt voor ecologische en sociale trade-offs. Het blijft echter onduidelijk hoe dit discursieve conflict is ontstaan en kan veranderen, vooral online. Daarom biedt dit hoofdstuk een diepgaande analyse van hoe argumentatieve veranderingen van actoren

het netwerk van dynamische discourscoalities op sociale media veranderen. De analyse is gebaseerd op interviews en een kwalitatieve discoursnetwerkanalyse van 9.983 tweets uit de periode 2008-2021.

De resultaten laten zien dat expertdebatten zich in eerste instantie concentreerden rond de voordelen van de bio-economie. Na de publicatie van de eerste Europese bio-economiestrategie in 2012 werd het debat gediversifieerd omdat nieuwe actoren zich bij het debat aansloten en nieuwe verhaallijnen inbrachten. Als gevolg daarvan ontstonden twee tegengestelde discourscoalities, 'Groene toekomst' en 'Planetaire grenzen', rondom verschillende groepen van aanverwante verhaallijnen. Na de update van de bio-economiestrategie in 2018 vereenvoudigde het online debat zich tot argumentaties van enkele, sterk tegenstrijdige verhaallijnen. Dit leidde tot een polarisatie van het discoursnetwerk. Uiteindelijk wijst de evolutie van het discoursnetwerk op een opkomende discursieve lock-in. Hierbij raakt één perspectief geïnstitutionaliseerd in de beleidsvorming, wat geen ruimte laat voor alternatieve perspectieven en leidt tot problematische biases in oplossingsrichtingen.

Naast de dynamieken tussen actoren en verhaallijnen die in eerder onderzoek zijn geconceptualiseerd, identificeer ik het 'kapen' (*hijacking*) van verhaallijnen als een verdere dynamiek die bijdraagt aan polarisatie en conflict. Dit houdt in dat verhaallijnen van een rivaliserende discourscoalitie worden overgenomen en zodanig herdefinieert dat zij het eigen standpunt bevorderen. Door in kaart te brengen hoe het discoursnetwerk verandert door aanpassingen in de manier waarop actoren verhaallijnen gebruiken, identificeer ik hoe discoursen in de loop van de tijd evolueren. Deze inzichten helpen bij het identificeren van mogelijkheden om ingangspunten te openen voor alternatieve probleemdefinities en nieuwe, momenteel over het hoofd geziene oplossingsrichtingen. Dit kan een lock-in van een te beperkt spectrum aan oplossingen in overeenstemming met het dominante 'Groene toekomst'-discours helpen voorkomen.

Hoofdstuk 4 scherpt de derde conceptuele bouwsteen aan, de productiviteit van controverses in duurzaamheidstransities. Hiertoe introduceer ik een nieuwe conceptualisatie van organisatievaardigheden om productiever met controverses om te gaan: horen, luisteren en leren. Met de locus op mesoniveau als uitgangspunt zoom ik in op hoe zogenaamde Triple Helix clusters omgaan met controverses. Deze clusters kunnen worden beschouwd als herconfigurerende regimeconstellaties van lokale overheden, bedrijven en de academische wereld. Eerder Triple Helix onderzoek heeft kritiek geuit op de nogal exclusieve aard van het Triple Helix model ten opzichte van de maatschappelijke omgeving van deze clusters. Als gevolg daarvan hebben wetenschappers gewerkt aan een uitbreiding van het model om maatschappelijke actoren die geen deel uitmaken van de Triple Helix cluster beter in het model op te nemen. Deze benaderingen richten zich

echter alleen op het bewust vragen aan maatschappelijke actoren om *formeel* onderdeel te worden van de samenwerking. Dit hoofdstuk analyseert daarentegen hoe betrokken clusterpartners omgaan met *ongevraagde* input van maatschappelijke actoren die geen deel uitmaken van de samenwerking.

Hiertoe conceptualiseer ik deze ongevraagde maatschappelijke input als *'back talk'* en onderscheid ik de sequentiestappen van horen, luisteren en leren om te onderzoeken hoe back talk bijdraagt aan innovatie. Het onderzoek zoomt in op processen in drie bio-economie Triple Helix clusters in Nederland, Duitsland en Ierland. De resultaten zijn gebaseerd op een kwalitatieve inhoudsanalyse op basis van transcripties van interviews, krantenartikelen en beleids- en planningsdocumenten.

De resultaten duiden erop dat actoren die betrokken zijn bij de geanalyseerde Triple Helix clusters vaak geen back talk horen die hun onderliggende overtuigingen fundamenteel onder de loep neemt. Dit komt doordat clusterpartners zich richten op een eenzijdige benadering van het informeren van het lokale publiek over wat zij beschouwen als technische, economische en milieuvoordelen van hun projecten. Clusterpartners worden *'insiders'*, wat het luisteren naar fundamenteel verschillende probleemdefinities in de weg staat. Alternatieve oplossingen van *'outsiders'* worden genegeerd omdat ze als onwetenschappelijk, irrelevant of emotioneel worden gezien. Hierdoor wordt het leren van ongevraagde back talk beperkt tot marginale aanpassingen. Deze beperking draagt bij aan een verdere institutionalisering van de geïdentificeerde lock-in op macroniveau van het techno-economische 'Groene toekomst'-perspectief. Om te voorkomen dat innovatieve oplossingen onbenut blijven als gevolg van deze lock-in, moeten Triple Helix *'insiders'* een reflectieve tweerichtingsdialoog aangaan met kritische *'outsiders'*. Het verder ontwikkelen van hun hoor-, luister- en leervaardigheden kan de clusterpartners hierbij helpen.

Hoofdstuk 5 werkt de derde conceptuele bouwsteen verder uit en vertrekt vanuit de locus op microniveau. In dit hoofdstuk analyseer ik hoe promovendi binnen het project waar ik deel van uitmaakte, het AgRefine trainingsnetwerk, erin geslaagd zijn (maar ook gefaald hebben) om op een productieve manier te leren van controverses. Ik doe dit aan de hand van een collaboratieve *'learning history'*, een reflectieproces dat ik samen met mijn AgRefine-collega's heb uitgevoerd. Mijn collega's en ik ontrafelen processen en randvoorwaarden van hoe we responsief werden ten opzichte van controverses. Dit deden wij door te luisteren naar en te leren van verschillende publieken die beïnvloed werden door het innovatieproces van het project, namelijk de betrokken onderzoekers, de AgRefine-partnerorganisaties en het bredere publiek.

De resultaten laten zien dat betrokken promovendi vooral van elkaar hebben geleerd. In het bijzonder hebben we de interdisciplinaire vaardigheid aangeleerd om luisterrelaties

op te bouwen. Door naar elkaars input te luisteren, hebben verschillende promovendi hun individuele onderzoeksprojecten inhoudelijk aangepast. In dit opzicht zijn veel collega's kritischer geworden over bioraffinage-innovatie en de transitie van de bio-economie. Hierdoor werd het idee gedemystificeerd dat wij aan een wondermiddel voor een duurzame en circulaire toekomst werken. Deze diepe vorm van leren werd mogelijk gemaakt door gemeenschappelijke trainingsweken en regelmatige contactmomenten in formele en informele gesprekken. Echter, discrepanties in de tijdsplanning van onderzoeksresultaten en tegenstrijdige verwachtingen binnen het project belemmerden verdere interdisciplinaire samenwerking. Wat betreft de inbreng van het tweede publiek, betrokken partnerorganisaties, leerden sommige promovendi meer dan anderen. Voor sommigen waren de samenwerkingen met partnerorganisaties zeer vormend. Dit leidde tot aanpassingen in hun projectopstellingen en veranderingen van hun onderliggende perspectieven. Voor anderen betekenden deze detacheringen vooral dat ze aan hetzelfde project werkten, maar op een andere locatie. Met name promovendi in laboratoria hadden moeite om input van het derde, niet-betrokken publiek te horen, omdat ze het technologische innovatieproces loskoppelden van de maatschappelijke context. Ongevraagde maatschappelijke input werd vaak gezien als irrelevant en daarom genegeerd, tenminste in het eerste stadium van technologieontwikkeling. Een geïdentificeerde reden hiervoor was de constructie van een ondoordringbare niche door het gebruik van exclusieve experttaal. Daarnaast resulteerden ook projectkenmerken en de rol van begeleiders in de prioritering van laboratoriumwerk. Economische en sociaalwetenschappelijke collega's ervoeren het daarentegen als een privilege om ook bredere, maatschappelijke kwesties in hun werk op te kunnen nemen.

In het algemeen geven de resultaten van dit reflectieproces aan dat onderzoekers die meer konden investeren in het luisteren naar projectorganisaties en het bredere publiek, ontvankelijker werden voor input van buiten de kaders van het project. Promovendi leerden de interdisciplinaire vaardigheden aan om een complex onderzoeksproject te hanteren en hun onderzoek op een meer toegankelijke manier te communiceren. Ze leerden echter ook diepere vormen van leren aan, bijvoorbeeld de flexibiliteit om hun onderzoeksplanning aan te passen als reactie op veranderende omstandigheden. Sommigen veranderden zelfs hun oorspronkelijke onderzoeksdoelstellingen in reactie op maatschappelijke input. Ook buiten AgRefine geven deze resultaten aan dat verschillende publieken die betrokken zijn bij onderzoeks- en innovatieprojecten verschillende vormen van responsiviteit nodig kunnen hebben. Financieringsinstanties en begeleiders kunnen responsievere innovatie bevorderen door meer flexibiliteit toe te staan voor het afwijken van vooraf gedefinieerde projectresultaten en een nauwere betrokkenheid met maatschappelijke input te eisen.

Hoofdstuk 6 synthetiseert de inzichten uit de voorgaande hoofdstukken en biedt een antwoord op de onderzoeksvragen. Bovendien positioneer ik, na reflectie op method-

ologische keuzes en daaruit voortvloeiende beperkingen, mijn onderzoek in de literatuur door suggesties te doen voor verder onderzoek. Op basis hiervan formuleer ik aanbevelingen voor stakeholders die de Europese transitie naar een duurzamere en meer circulaire bio-economie vorm willen geven.

Samengevat hebben controverses productieve potentie in een duurzaamheidstransitie door alternatieve perspectieven zichtbaar te maken. Dit kan nuttig zijn om biases onder de loep te nemen en zo bij te dragen aan het ontsluiten van discursieve lock-ins. In de Europese bio-economie transitie ontstaat momenteel op macroniveau een discursieve lock-in van het dominante, ecomodernistische 'Groene toekomst' perspectief, in ieder geval online. Dit perspectief wordt geïnstitutionaliseerd door het over te nemen in herconfiguraties van het regime op mesoniveau, bijvoorbeeld in de activiteiten van de onderzochte Triple Helix clusters. Op microniveau kunnen technologische innovatieniches ondoordringbaar worden voor controverses in andere loci, door het innovatieproces los te koppelen van zijn maatschappelijke context. Discourscoalities werken op verschillende loci tegelijk en dragen bij aan de doorvertaling van controverses naar andere loci. Deze verwevenheid van discursieve situaties op verschillende loci brengt het gevaar met zich mee dat discursieve lock-ins en daaruit voortvloeiende biases steeds opnieuw opduiken in de loop van een duurzaamheidstransitie. Controverses hebben het innovatieve potentieel om alternatieve perspectieven in andere loci aan de oppervlakte te brengen en zo biases bloot te stellen. In plaats van controverses te vermijden of onproductieve oplossingspogingen na te streven die zelfs averechts kunnen werken, moeten besluitvormers in de bio-economie controverses beschouwen als leermogelijkheden. Dit impliceert een continu, reflectief proces van horen, luisteren en leren. Deze vaardigheden kunnen belanghebbenden in de bio-economie helpen om het innovatieve potentieel van controverses te ontsluiten.

ZUSAMMENFASSUNG

Die Menschheit lebt derzeit von einem abnehmenden Vorrat an fossilen Mineralöl- und Gasressourcen. Die Nutzung dieser Ressourcen in industriellen Produktionsprozessen erzeugt Treibhausgasemissionen, die den schädlichen Klimawandel verursachen. Um diese dringliche Nachhaltigkeitsherausforderung in Angriff zu nehmen, setzen politische Entscheidungsträger*innen in Europa, aber auch andernorts, auf die Transformation in Richtung einer nachhaltigen und kreislauforientierten Bioökonomie. Eine solche Nachhaltigkeitstransformation ist ein groß angelegter, systemischer Veränderungsprozess eines nicht nachhaltigen sozio-technischen Regimes hin zu einem nachhaltigeren Modell. In dem in dieser Dissertation thematisierten Fall der Bioökonomie werden anstelle von fossilen Grundstoffen, biobasierte Ressourcen wie Pflanzen, Gras, Holz oder Algen für die Herstellung einer breiten Palette von Produkten genutzt. Dazu gehören zum Beispiel Bioenergie, Kunststoffe, Chemikalien, Pharmazeutika, Lebensmittel und Düngemittel. Politische Entscheidungsträger*innen und viele Wissenschaftler*innen haben Hoffnung in diese Transformation, sie ist aber auch umstritten. Kritische Beobachter*innen hinterfragen, wie nachhaltig und kreislauforientiert ein solches Unterfangen ist. Gründe sind mögliche negative Konsequenzen für eine nachhaltige Landnutzung, Biodiversität und Umweltqualität. Daneben können neue Ungerechtigkeiten entstehen und wird möglicherweise ein nicht-nachhaltiges Ausmaß der Nachfrage nach Energie und Materialien manifestiert. Darüber hinaus konzentrieren sich die Bedenken der lokalen Öffentlichkeit in Bezug auf Produktionsstätten der Bioökonomie, wie Bioraffinerien oder Biogasanlagen, auf Umweltbelastungen und die örtliche Verteilung von Kosten und Nutzen.

Akteure in der Bioökonomie, wie zum Beispiel politische Entscheidungsträger*innen, aber auch Akteure in der Privatwirtschaft, Zivilgesellschaft und Wissenschaft, haben Schwierigkeiten, auf eine produktive Art und Weise mit diesen Kontroversen umzugehen. Dies liegt daran, dass Kontroversen nicht durch die Produktion neuer Fakten (wie zum Beispiel Folgenabschätzungen, Lieferkettenmanagement oder die Modellierung optimaler Produktionsstandorte) aufgelöst werden können. Anstatt diese Kontroversen aufzulösen, liefern solche Bemühungen neues Framing-Material für beteiligte Diskurskoalitionen und beleben daher diese sich kontinuierlich entwickelnde Form des Konflikts stets wieder. Trotz des aufkommenden Forschungsinteresses an der Rolle von Macht und Konflikten in Nachhaltigkeitstransformationen bleiben die Entwicklungen langfristiger Kontroversen und der Umgang mit ihnen in der Bioökonomie-Governance-Literatur unzureichend konzeptualisiert und empirisch untersucht.

Um diese Wissenslücke zu schließen, zielt diese Dissertation darauf ab, die folgende zentrale Forschungsfrage zu beantworten: *Wie kann auf eine produktive Art und Weise mit sich kontinuierlich entwickelnden Kontroversen im Kontext der europäischen Trans-*

formation zu einer nachhaltigen und kreislauforientierten Bioökonomie umgegangen werden? Diese Dissertation hat dabei ein doppeltes Forschungsziel. Zum einen soll das wissenschaftliche Verständnis verbessert werden, wie sich Kontroversen im Rahmen einer Nachhaltigkeitstransformation entwickeln. Zum anderen soll untersucht werden, wie Bioökonomie-Stakeholder produktiv mit diesen Kontroversen umgehen können. Zur Beantwortung der Hauptforschungsfrage gliedert sich die Dissertation in drei Teilfragen:

1. Wie entwickeln sich Kontroversen im Rahmen einer Nachhaltigkeitstransformation?
2. Wie entwickeln sich Diskurskoalitionen im Rahmen einer Nachhaltigkeitstransformation?
3. Wie kann in Nachhaltigkeitstransformationen produktiv mit Kontroversen umgegangen werden?

In **Kapitel 2** wird der konzeptionelle Rahmen dieser Dissertation entwickelt. Nach einem Überblick über den derzeitigen Stand der Bioökonomie-Literatur wird in diesem Kapitel eine neuartige Konzeptualisierung der Rolle von Kontroversen in der europäischen Bioökonomie-Transformation ausgearbeitet. Das Kapitel beginnt mit der Feststellung, dass die Bioökonomie-Literatur Konflikte über die Richtung und Art der Bioökonomie-Transformation auf zwei ontologisch unterschiedliche Weisen angeht. Einerseits betrachtet die dominante, techno-ökonomische Perspektive Konflikte als Designfehler, die im Rahmen der Technologieentwicklung aufgelöst werden können und müssen. Entsprechend dieser Perspektive kann dies durch integrierte Folgenabschätzungen, eine intelligente Lieferkettenplanung und eine Modellierung optimaler Produktionsstandorte erreicht werden. Andererseits nimmt eine aktuell aufkommende, sozialwissenschaftliche Perspektive als Ausgangspunkt, wie miteinander in Konflikt liegende Gruppen von Akteuren die Problemstellung framen. Autoren, die sich an diese Perspektive halten, kartographieren, welche Gruppen von Akteuren welche Transformationspfade unterstützen. Die erste Perspektive berücksichtigt nicht die Natur von Kontroversen als eine besonders hartnäckige Konfliktform, die nicht durch die Produktion von objektivem Faktenwissen gelöst werden kann. Die zweite Perspektive bleibt weitestgehend hinter der Frage zurück, wie sich diese argumentativen Konflikte im Zusammenspiel mit dem sich entfaltenden Transformationsprozess entwickelt haben und wie die sich daraus resultierende diskursive Situation verändern könnte. Basierend auf diesen Beobachtungen entwickle ich eine geeignetere Konzeptualisierung von Kontroversen in Nachhaltigkeitstransformationen. Dabei basiere ich mich auf breiteren Literaturen zu Nachhaltigkeitstransformationen, politischen Kontroversen und konstruktiver Konfliktlösung. Dazu benutze ich drei konzeptionelle Bausteine: (1) Loci von Kontroversen, (2) Dynamiken von Diskurskoalitionen und (3) die Produktivität von Kontroversen.

Erstens argumentiere ich, dass Kontroversen während des Transformationsprozesses in verschiedenen Loci auftauchen. Loci sind dabei unterschiedliche Zusammensetzungen

von Akteuren, verwendeten Framings und Kommunikationsregeln auf den verschiedenen Ebenen einer Nachhaltigkeitstransformation: Makro, Meso und Mikro. Die Makroebene betrifft den sogenannten Landschaftsdruck auf die Regimekonstellation. Beispiele sind kulturelle und politische Veränderungen auf hohem Abstraktionsniveau. Die Mesoebene konzentriert sich auf sich verändernde Regimekonstellationen von Technologien, Infrastruktur, Regeln und Normen. Die Mikroebene beschreibt innovative Nischen, in denen alternative Denk-, Handlungs- und Organisationsweisen entwickelt werden. Kontroversen sind im Rahmen von Nachhaltigkeitstransformationen nicht aufzulösen, weil sie immer wieder an den verschiedenen Loci auf und zwischen den drei Ebenen auftauchen.

Zweitens entwickeln sich Diskurskoalitionen fort, während sie sich durch die verschiedenen Loci bewegen. Diskurskoalitionen sind gleichgesinnte Akteursgruppen, die Problemdefinitionen und Lösungsoptionen kohärent framen, im Rahmen von gemeinsamen Storylines. Diskurskoalitionen sind dabei keine statischen Konstrukte, sondern dynamisch und entwickeln sich ständig weiter. Dies liegt daran, dass beteiligte Akteure ihre Storylines kontinuierlich anpassen, was dazu führt, dass sich 'ihre' entsprechenden Diskurskoalitionen verfestigen, wachsen, schrumpfen, verschmelzen oder auseinanderfallen. Dieser konzeptionelle Baustein unterstreicht die Handlungsmacht von Akteuren bei der kontinuierlichen Neugestaltung von Diskursen.

Drittens sind Kontroversen nicht in jedem Fall schlechte Nachrichten. Natürlich können sich Kontroversen auf unproduktive Weise entwickeln, zum Beispiel in Form von Pattsituationen, die Transformationen lähmen. Kontroversen können sich jedoch auch auf produktive Weise entwickeln. Sie können Akteure dazu anregen, von alternativen Perspektiven zu lernen, was zu einem breiteren Spektrum verfügbarer politischer Optionen und generell zu einer reflexiveren Transformation führt.

Die drei folgenden Kapitel nehmen verschiedene Loci auf Makro-, Meso- und Mikroebene als Ausgangspunkt, welche als erster konzeptioneller Baustein entwickelt wurden. In Kapitel 3 wird der zweite konzeptionelle Baustein, die Dynamiken von Diskurskoalitionen, weiter ausgearbeitet. Der dritte konzeptionelle Baustein, die Produktivität von Kontroversen, wird in den Kapiteln 4 und 5 angewendet und weiter geschärft.

Kapitel 3 entwickelt den zweiten konzeptionellen Baustein weiter und nehmt die Makroebene als Ausgangspunkt. In diesem Kapitel arbeite ich Entwicklungen von Kontroversen auf der Makroebene über die Zukunft der europäischen Bioökonomie aus. Dabei behandele ich Debatten auf 𝕏, dem sozialen Medium, das früher als Twitter bekannt war. Vorherige Studien haben konkurrierende Diskurse zur Bioökonomie in Europa identifiziert. Eine prominente, ökomodernistische Perspektive argumentiert für den Transformationsweg des „grünen Wachstums“, um Europa als Bioökonomie-Weltmarktführer zu positionieren,

indem Wirtschaftswachstum von negativen Umweltauswirkungen abgekoppelt wird. Eine alternative Perspektive konzentriert sich auf das Konzept der planetaren Grenzen, die den Maßstab einer zukünftigen Bioökonomie begrenzen, und warnt vor ökologischen und sozialen Zielkonflikten. Es bleibt jedoch unklar, wie dieser diskursive Konflikt entstanden ist und sich verändert, insbesondere online. Daher bietet dieses Kapitel eine eingehende Analyse, wie argumentative Veränderungen von Akteuren das Netzwerk dynamischer Diskurskoalitionen in sozialen Medien verändern. Die Analyse ist basiert auf Interviews und einer qualitativen Diskursnetzwerkanalyse von 9.983 Tweets aus dem Zeitraum 2008–2021.

Die Ergebnisse zeigen, dass sich Debatten zunächst in einem abgegrenzten Expert*innenkreis auf die Vorteile der Bioökonomie konzentrierten. Nach der Veröffentlichung der ersten Europäischen Bioökonomie-Strategie im Jahr 2012 diversifizierte sich die Debatte, indem sich neue Akteure der Debatte anschlossen und neue Storylines einbrachten. Infolgedessen entstanden zwei gegensätzliche Diskurskoalitionen, „Grüne Zukunft“ und „Planetare Grenzen“, rundum einander entgegenstehenden Storylines. Nach dem Update der Bioökonomie-Strategie im Jahr 2018 vereinfachte sich die Online-Debatte zu wenigen, unvereinbaren Storylines, was zu einer Polarisierung des Diskursnetzwerks führte. Letztendlich deutet die Entwicklung des Diskursnetzwerks auf einen entstehenden diskursiven Lock-in hin. In einer solchen Situation wird eine dominante Perspektive politisch institutionalisiert, die keinen Raum für alternative Perspektiven lässt. Dies führt zu problematischen Biases und blinden Flecken.

Zusätzlich zu den Dynamiken zwischen Akteuren und Storylines, die bereits in früheren Forschungen konzipiert wurden, identifiziere ich das "hijacking" (Entführen) von Storylines als eine weitere Dynamik, die zu Polarisierung und Konflikten beiträgt. Indem ich herausarbeite, wie sich das Diskursnetzwerk durch Anpassungen in der Art und Weise verändert, wie Akteure Storylines nutzen, identifiziere ich, wie sich Diskurse im Laufe der Zeit weiterentwickeln. Diese Erkenntnisse helfen dabei, Möglichkeiten zu identifizieren, wie alternative Problemdefinitionen und neue, derzeit übersehene Lösungen Einzug in politische Diskussionen erhalten können. Dies kann einen Beitrag dazu liefern, dass verhindert wird, einzig und allein das beschränkte Spektrum von Lösungsansätzen anzuwenden, das in mit dem dominanten 'Grüne Zukunft'-Diskurs übereinkommt.

Kapitel 4 schärft den dritten konzeptionellen Baustein, nämlich die Produktivität von Kontroversen in Nachhaltigkeitstransformationen. In diesem Rahmen konzeptualisiere ich organisatorische Hör-, Zuhör- und Lernfähigkeiten, um produktiver mit Kontroversen umzugehen. Ausgehend vom Locus der Mesoebene gehe ich näher darauf ein, wie sogenannte Triple-Helix-Cluster mit Kontroversen umgehen. Diese Cluster sind Kooperationen der lokalen Verwaltung mit Unternehmen und Forschungseinrichtungen und können

als Neukonfiguration von Regimekonstellationen angesehen werden. Frühere Triple-Helix-Studien haben den exklusiven Charakter des Triple-Helix-Modells gegenüber dem sozialen Umfeld dieser Cluster kritisiert. Infolgedessen haben Wissenschaftler*innen an einer Erweiterung des Modells gearbeitet, um gesellschaftliche Akteure, die nicht Teil des Triple Helix-Clusters sind, besser einzubeziehen. Diese Ansätze konzentrieren sich jedoch ausschließlich darauf, gesellschaftliche Akteure als *formellen* Teil der Kooperation einzubeziehen. Im Gegensatz dazu analysiert dieses Kapitel, wie beteiligte Clusterpartner mit *informellem* Input von gesellschaftlichen Akteuren umgehen, die nicht Teil der Kooperation sind.

Zu diesem Zweck verstehe ich diesen informellen gesellschaftlichen Input als sogenannten „Back Talk“ und unterscheide die Abfolge von Hören, Zuhören und Lernen. Hierdurch analysiere ich, wie Back Talk zu Innovationsprozessen beiträgt. Die Studie untersucht diesbezügliche Prozesse in drei unterschiedlichen Bioökonomie-Triple-Helix-Clustern in den Niederlanden, Deutschland und Irland. Die Schlussfolgerungen basieren auf einer qualitativen Inhaltsanalyse von Interviewprotokollen, Zeitungsartikeln sowie Verwaltungs- und Planungsdokumenten.

Die Ergebnisse zeigen, dass Akteure, die Teil der analysierten Triple Helix-Cluster sind, häufig keinen Back Talk hören, der ihre Überzeugungen grundlegend hinterfragt. Dies liegt daran, dass sich die Clusterpartner auf einen einseitigen Kommunikationsansatz konzentrieren, bei dem die lokale Öffentlichkeit über den technischen, wirtschaftlichen und ökologischen Nutzen ihrer Projekte informiert wird. Clusterpartner werden so zu 'Insidern', was das Hören radikal anderer Problemdefinitionen behindert. Da alternative Lösungen von 'Außenseitern' als unwissenschaftlich, irrelevant oder emotional ignoriert werden, beschränkt sich das Lernen anhand informellen Back Talks lediglich auf geringfügige Anpassungen. Diese Einschränkung trägt zu einer weiteren Institutionalisierung des auf Makroebene identifizierten Lock-Ins der techno-ökonomischen Perspektive einer 'Grünen Zukunft' bei. Um zu vermeiden, dass innovative Lösungen als Ergebnis dieses Lock-Ins unberücksichtigt bleiben, müssen Triple Helix 'Insider' in einen reflexiven, bidirektionalen Dialog mit kritischen 'Außenseitern' treten. Die Weiterentwicklung ihrer Hör-, Zuhör- und Lernfähigkeiten kann den Clusterpartnern dabei helfen.

Kapitel 5 entwickelt den dritten konzeptionellen Baustein weiter und nimmt den Locus auf der Mikroebene als Ausgangspunkt. In diesem Kapitel analysiere ich, wie es uns AgRefine-Doktorand*innen gelungen ist (aber auch, woran wir scheiterten), um produktiv von gesellschaftlichen Kontroversen zu lernen. Ich tue dies anhand einer kollaborativ erarbeiteten „Learning History“. Das ist ein strukturierter Reflexionsprozess, den ich gemeinsam mit meinen AgRefine-Kolleg*innen erarbeitet habe. Meine Kolleg*innen und ich entwirren dabei Prozesse und Voraussetzungen, wie wir mit Kontroversen umgegangen

sind, durch verschiedene, von unserem Innovationsprozess betroffenen Öffentlichkeiten zu hören, ihnen zuhören und von ihnen zu lernen. Bei diesen Öffentlichkeiten handelt es sich um (1) beteiligte Wissenschaftler*innen, (2) beteiligte Partnerorganisationen und (3) die breitere Öffentlichkeit.

Die Ergebnisse verdeutlichen, dass beteiligte Doktorand*innen vor allem voneinander gelernt haben. Insbesondere haben wir die interdisziplinäre Fähigkeit zur Bildung von Zuhörbeziehungen erlernt. Durch gegenseitiges Zuhören führten mehrere Doktorand*innen inhaltliche Anpassungen ihrer individuellen Forschungsprojekte durch. In dieser Hinsicht sind viele Kolleg*innen kritischer gegenüber Bioraffinerie-Innovationen und der Bioökonomie-Transformation geworden. Die Idee wurde entmystifiziert, dass wir an einer Silberkugellösung für eine nachhaltige und kreislauforientierte Zukunft arbeiten. Diese tiefe Form des Lernens wurde durch gemeinsame Trainingswochen und regelmäßige Kontaktmomente in formellen und informellen Umständen ermöglicht. Diskrepanzen in der zeitlichen Abstimmung der Forschungsergebnisse und widersprüchliche Erwartungen innerhalb des Projekts erschwerten jedoch die weitere interdisziplinäre Zusammenarbeit. In Bezug auf Input der zweiten Öffentlichkeit, der beteiligten Partnerorganisationen, haben Doktorand*innen in unterschiedlichem Ausmaß gelernt. Für einige waren Kontaktmomente mit Partnerorganisationen sehr prägend, was zu Anpassungen in ihren Projekten und Änderungen ihrer grundsätzlichen Perspektiven führte. Für andere bedeuteten diese Kontaktmomente jedoch hauptsächlich, am selben Projekt zu arbeiten, lediglich an einem anderen Ort. Insbesondere im Labor arbeitende Doktorand*innen hatten Schwierigkeiten, Input der unbeteiligten Öffentlichkeit zu hören, da sie kognitiv den technologischen Innovationsprozess von seinem gesellschaftlichen Kontext trennten. Informeller gesellschaftlicher Input wurde zumindest in dieser Anfangsphase der Technologieentwicklung weitgehend als irrelevant vernachlässigt. Identifizierte Gründe waren der Aufbau einer undurchlässigen Nische durch die Verwendung exklusiver Fachsprache, der Projektaufbau und der Einfluss von Betreuer*innen, was dazu führte, dass die Laborarbeit 'am Laufen' gehalten werden musste. Wirtschafts- und sozialwissenschaftliche Kolleg*innen hingegen erfuhren es als ein Privileg, auch breiteren, gesellschaftlichen Input in ihrer Arbeit aufzugreifen.

Im Allgemeinen deuten die Ergebnisse dieses Reflexionsprozesses darauf hin, dass Wissenschaftler*innen, die in der Lage waren, mehr in das Zuhören von Input unserer Partnerorganisationen und der breiteren Öffentlichkeit zu investieren, empfänglicher für Input von außerhalb der Projektgrenzen waren. Doktorand*innen lernten nicht nur die interdisziplinären Fähigkeiten, ein komplexes Forschungsprojekt zu navigieren und ihre Forschung zugänglicher zu kommunizieren, sondern erreichten auch tiefere Formen des Lernens. Dies schließt beispielsweise ein, die Forschungsplanung flexibel an veränderte Gegebenheiten anzupassen. Einige passten sogar ihre grundlegenden Forschungsziele

als Reaktion auf gesellschaftlichen Input an. Auch über AgRefine hinaus deuten diese Ergebnisse darauf hin, dass in Forschungs- und Innovationsprojekten auf unterschiedliche Weise mit Input von verschiedenen Öffentlichkeiten umgegangen werden muss. Finanzierungsagenturen und Begleiter*innen können die Aufnahmefähigkeit gesellschaftlichen Inputs von Innovationsprojekten fördern, indem sie mehr Flexibilität von vordefinierten Projektergebnissen ermöglichen und eine bessere Auseinandersetzung mit gesellschaftlichem Input fordern.

Kapitel 6 synthetisiert die Erkenntnisse der einzelnen Kapitel und beantwortet die Forschungsfragen. Darüber hinaus positioniere ich meine Forschung in der Literatur auf Grundlage einer Reflexion über methodische Entscheidungen und daraus resultierenden Einschränkungen. Dabei leite ich mögliche Wege für die weitere Forschung ab. Darauf aufbauend formuliere ich Empfehlungen für Stakeholder, die eine europäische Transformation in Richtung einer nachhaltigeren und kreislauforientierten Bioökonomie gestalten wollen.

Zusammengefasst weisen Kontroversen produktives Potenzial in Nachhaltigkeitstransformationen auf, indem sie alternative Perspektiven ans Tageslicht befördern. Dies ermöglicht die Identifikation von blinden Flecken und Biases und trägt daher dazu bei, diskursive Lock-Ins zu aufzubrechen. Momentan entsteht innerhalb der Europäischen Bioökonomie-Transformation ein diskursiver Lock-in auf Makroebene in Richtung des dominanten, ökomodernistischen Diskurses der 'Grünen Zukunft'. Diese Perspektive wird institutionalisiert, indem sie in Regime-Rekonfigurationen auf der Mesoebene übernommen wird, zum Beispiel in den untersuchten Bioökonomie-Triple-Helix-Clustern. Auf der Mikroebene können technologische Innovationsnischen für Kontroversen in anderen Loci undurchlässig werden, indem der Innovationsprozess von seinem gesellschaftlichen Kontext getrennt wird. Diskurskoalitionen operieren in mehreren Loci gleichzeitig und tragen zu einer Übertragung von Kontroversen auf andere Loci bei. Diese Zusammenhänge diskursiver Situationen in verschiedenen Loci bergen die Gefahr, dass diskursive Lock-ins und daraus resultierende Biases während einer Nachhaltigkeitstransformation immer wieder auftauchen. Um dies zu vermeiden, haben Kontroversen das innovative Potenzial, alternative Perspektiven aufzudecken, die blinde Flecken in den verschiedenen Loci hinterfragen. Anstatt Kontroversen zu vermeiden oder unproduktive Lösungsansätze zu verfolgen, die Kontroversen sogar anheizen können, müssen Bioökonomie-Entscheidungsträger*innen Kontroversen daher besser als Lernmöglichkeiten betrachten. Dies beinhaltet einen kontinuierlichen, reflexiven Prozess des Hörens, Zuhörens und Lernens. Diese Fähigkeiten können Bioökonomie-Akteuren dabei helfen, das Innovationspotenzial von Kontroversen zu erschließen.

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One of my favourite places is the Wadden Sea coast. The stability found in the constant ebb and flow of high and low tides in this unique environment is a source of tranquillity. My PhD journey has also been a process of high and low tides, much like any other PhD journey. It began on an absolute high when my inspiring sister had beaten cancer, and I was able to move back to the Netherlands, close to my love, Corine, who is now my wife. Shortly after, the world entered the ebb of the COVID pandemic. In hindsight, this time was deeply restrictive, but it also provided an opportunity for forced deceleration, reflection, and deep reading. For me, this was crucial in working on the conceptual part of this dissertation. Many highs and lows followed, but importantly, I never felt alone. Now, I have the opportunity to thank the many people who joined me on this adventure and to whom I owe the million thanks my Irish friends so frequently mention.

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EDUCATION CERTICATE

Jan Rudolf Starke
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
A1 Managing a research project			
WASS Introduction Course	WASS	2020	1
Writing the research proposal	PAP	2020	3
Creativity and Innovation Academy	AgRefine; University College Dublin	2020	5
Scientific Writing	Wageningen In'to Languages	2021	1.8
'Conflict Types in the Transition towards a Circular Bio-based Economy'	6th Network for Early-Career Researchers in Sustainability Transitions (NEST) Conference, Sofia	2021	1
'From fossil to bio-based: the regional transformation process in Lisheen; County Tipperary (Ireland)'	Biorefine Conference 'The role of biorefineries in European agriculture', Ghent	2022	1
'Why is the bioeconomy controversial? And why is this good news?'	Bioeconomy Research Symposium Ireland, Dublin	2022	1
Workshop: 'Looking beyond the Horizon? Responsiveness of the AgRefine project'	Green Biorefinery Conference, Dublin	2023	1
Reviewing a paper	Policy Sciences	2023	1
A2 Integrating research in the corresponding discipline			
Research Methodology: From topic to proposal	WASS	2020	4
MOOC: Bioeconomy and Society	Perform	2020	2
Summer School: Biorefinery: Can it solve society's waste challenge	AgRefine; Ghent University	2022	5
Philosophy of Responsible Innovation	OZSW (Dutch Research School of Philosophy)	2022	5
B) General research related competences			
B1 Placing research in a broader scientific context			
Summer School: The Technology Solutions – possible or theoretical	AgRefine; Technical University of Vienna	2021	5
A bio-based society: from principles to practice	WiAS	2021	1.5

Summer School: Entrepreneurship and circular society (presentation; workshop; organization of 1-day training event)	AgRefine; WUR	2022	3
B2 Placing research in a societal context			
Blog article: *'Of Wizards and Prophets'*	AgRefine website	2020	0.1
C) Career related competences/personal development			
C1 Employing transferable skills in different domains/careers			
Teaching: Studying Public Governance	PAP	2021	1
Supervision of 2 MSc theses	PAP	2022	1
Career Perspectives	WGS	2023	1.6
Total			**45**

*One credit according to ECTS is on average equivalent to 28 hours of study load

ABOUT THE AUTHOR

Jan Starke was born on June 6, 1993, in Bremen, Germany. He obtained his BA degree in Political Sciences and Law from Münster University. During his time in Münster, Jan developed an interest in environmental law and governance issues. He wrote his thesis on differences in the implementation of the Water Framework Directive in EU member states with varying federal structures. His studies included internships at the parliament of the federal state of Bremen, the German Federal Ministry for the Environment, and the ombudsman for the autonomous region of Aragón, Spain.

After completing his studies in Münster, Jan moved to the Netherlands and earned an MSc in 'Sustainability Sciences: Environmental Governance' from Utrecht University, graduating cum laude. During this programme, he specialized in discourse (network) analysis and wrote his thesis on the debate about banning wild circus animals in Germany. At the same time, he worked as an assistant for a German Member of Parliament. Subsequently, he returned to Bremen to work as a quality manager in a chemical-technical laboratory, while completing an LLM in Sustainability Law from Leuphana University Lüneburg. His thesis focused on exemptions from the deterioration ban, a crucial instrument in the Water Framework Directive's goal achievement regime. During this period, Jan gained technical knowledge of environmental quality analysis and became fascinated by the interplay between technical, legal, and governance issues. He also became deeply concerned about how industrial processes impact our air, soil, and water; and noticed knowledge imbalances between private and public actors in environmental affairs. This motivated him to return to academia to research the governance of sustainability transitions.

In January 2020, he began his PhD with the Public Administration and Policy Group at Wageningen University. His PhD was part of the 'AgRefine' International Training Network, funded by the European Commission's Horizon 2020 research and innovation program. AgRefine brought together early-career researchers from diverse disciplines, including microbiologists, chemical engineers, economists, and social scientists, to promote interdisciplinary learning and explore the role of next-generation biorefinery technology in transitioning to a sustainable and circular bioeconomy.

Jan currently works as a researcher on the topic of 'Public Design for the Water Transition' at KWR Water Research Institute. There, he continues his research on controversies in sustainability transitions, transdisciplinary research methods, and the role of law in transformative change. His ambition is to contribute to the development of a sustainable drinking water supply and a more circular, future-proof water management system in a healthy environment. He lives with his family in Zwolle.

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