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Empty Promises of Growth: The Bioeconomy and Its Multiple Reality Checks

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The BMBF junior research group Mentalities in flux (flumen) combines sociological and historical research to explore how people's mentalities change in post-fossil transformations and how this change is reflected in the employment structure of society.

Today, there is broad agreement that fossil fuels, due to their limited availability and damaging effects for the climate, will need to be phased out within the coming decades. One proposed alternative is the idea of a bioeconomy, in which raw materials and energy are gained from renewable sources of plant and animal origin.

But this implies more than just a shift to renewable resources. In fact, the whole way modern economies are organized will have to change: Fossil-fueled economies rely on a constantly accelerating linear throughput of materials, from extraction through production and distribution to consumption and waste disposal. In contrast, bio-based economies draw on materials and energy sources that regenerate cyclically. Their production cannot be increased at will, but is subject to the natural limitations of these circular flows of matter and energy.

The historical emergence of economies based on linear flows of fossil resources radically transformed human work and was closely linked to basic mindsets, attitudes and shared imaginations compatible with the logic of constant growth. These mentalities differ between social groups, and they will undergo far-reaching change once again in the transformation toward bio-based economies. In short, mentalities evolve in parallel with the transformations of societies' material and energetic basis – they are: Mentalities in flux.

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Abstract

In this paper, we want to make two arguments. Firstly, we observe that the current trend in official policy concepts and strategies of the bioeconomy is toward a moderation of the promises of economic growth that it has been associated with since the beginning of this millennium. We argue that this process of moderation is at least partly due to the effects of a series of 'reality checks' that the different existing strands of research on the bioeconomy have (willingly or unwillingly) subjected the promises to, forcing governments to move away from obviously unrealistic visions and adopt more humble ones. We identify four such reality checks, coming from research on (a) bioeconomy discourses and strategies, (b) actors and interests in the political economy of the bioeconomy, and (c) the economic and biophysical materialities that make up 'the bioeconomy'. Secondly, we propose that a fourth, sociological reality check is currently being mounted, exposing the social implausibility and democratic illegitimacy of the bioeconomy's promissory visions. Using survey data from Germany to develop a provisional analysis of the tensions and conflicts within the population that disagreements about the bioeconomy are embedded in, we suggest putting the bioeconomy in its proper political place as part of the larger societal challenge, rather than promise, of achieving a post-fossil transformation of modern societies.

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Keywords

bioeconomy, economic growth, reality check, discourses, mentalities, conflicts

Inhalt

1. Introduction

From its inception, the notion of the bioeconomy has been intimately linked to the concept of economic growth – albeit in highly contrary ways. Two of the original sources to whom the emergence of the term 'bioeconomy' is often traced in the literature may serve to illustrate this contradictoriness: For one, Nicholas Georgescu-Roegen, the pioneer of biophysical economic analysis who coined the term 'bioeconomics' in the early 1970s, was at the same time a harsh critic of economic ideas built around the premise of everlasting economic expansion and is deemed one of the inventors of the idea of *décroissance,* or degrowth (Georgescu-Roegen, 1971; Vivien et al., 2019). At the other extreme has been a highly promissory discourse around the purported unprecedented growth potential of new biotechnologies, often traced to the writings of Harvard economics graduate and Life Science venture capitalist Juan Enríquez Cabot (Enríquez, 1998; Enríquez and Goldberg, 2000)[1], which co-emerged with the equally techno-optimistic hype around the so-called 'dotcom bubble' in the late 1990s. This promissory techno-political discourse was to be highly influential in shaping policy debates around the bioeconomy in the ensuing years (Meyer, 2017; Mittra and Zoukas, 2020; Petersen and Krisjansen, 2015). When the first dotcom hype evaporated in 2000, the promises of a 'biotech revolution' stayed around, and policy circles began reflecting on the implications. By 2009, the OECD had kicked off the current bioeconomy debate with a strategy paper (OECD, 2009) that framed bioeconomy explicitly as a growth regime driven by advances in biotech. The EU and many governments followed suit and adopted bioeconomy strategies. As early as in the EU's 2012 strategy, however, the promise of growth began to morph: Gradually decentering (but by no means discarding) the role of biotechnology, a second model of a biomass-based bioeconomic growth strategy took shape. It was an attempt to reconcile the growth promises of the early business-centered bioeconomy discourse with the demands for sustainability voiced by other policy actors at the same time, in a conception trying 'to use consistency and efficiency strategies to reduce environmental burdens to such a degree that remaining within the classical growth paradigm will be (largely) possible' (Grunwald, 2020: 20). This model of 'biomass-bioeconomy' (Befort, 2020) is closely linked to current strategies of 'green growth'. Although somewhat distanced from the sci-fi visions of the biotech-bioeconomy, it remains much further removed from the ideas associated with Georgescu-Roegen: Sufficiency, strong sustainability or social transformations as called for in the degrowth debate are usually not taken into account, not framed as part of a bioeconomy, or deemed unnecessary or undesirable (D'Amato et al., 2017; Hausknost et al., 2017; Priefer et al., 2017; Vivien et al., 2019).

1 Although often cited in this regard, Enríquez never seems to have used the term 'bioeconomy'. Only 'biotechonomy' is on record (Enríquez, 2002).

It is, however, highly doubtful whether the promised green growth, or the decoupling of growth from unsustainable patterns of resource use, is possible at all (Giampietro, 2019; Haberl et al., 2020; Hickel and Kallis, 2019; Wiedenhofer et al., 2020). A growing body of research shows that the practically unlimited availability of fossil fuels, far from being a contingent factor in a long history of unceasing human endeavor, was a 'historically specific and internally necessary' (Huber, 2008: 113) condition for the trajectory of long-term economic expansion that capitalist societies successively embarked on in the course of the past two centuries (Malm, 2016, 2012). It has deeply shaped modern capitalist societies not merely in their material infrastructures (Smil, 2017) and institutional design (Di Muzio, 2015; Mitchell, 2013; Unruh, 2000; Unruh and Carrillo-Hermosilla, 2006), but also in their collective imaginaries, perceptions and expectations (Bridge, 2011; Daggett, 2018; Welzer, 2011). If growth cannot be 'greened', as Georgescu-Roegen had insisted all along, then all of this, including our own concepts of ourselves and the world, will need to be reinvented and rebuilt.

The most recent bioeconomy strategies, although still far from explicitly acknowledging this, seem markedly more modest in their promises and the claims to a purported growth potential of the bioeconomy than their predecessors of ten years ago (BMEL and BMBF, 2020; European Commission, DG Research and Innovation, 2018). As we want to argue here, this process of moderation is the result of a series of 'reality checks' that the bioeconomy has been subjected to in the meantime. These reality checks have come from two different, albeit closely interrelated, sides: From a number of different strands of research on, and from socio-political contestation around issues related to the bioeconomy. The reality checks from research, which we will examine in more detail in section 2 of this paper, arise from the findings of a broad range of work in different scientific fields on the discursive, socio-political, economic and biophysical dimensions of the bioeconomy. These findings have, from different angles and sometimes intentionally, sometimes unwittingly or even contrary to the researchers' intentions, challenged the high growth ambitions posited by the first wave of strategies and policies. We propose to make a distinction between three levels of analysis on which these challenges to the growth promise have been mounted, corresponding to the three levels of bioeconomic reality that Hausknost et al. (2017) distinguish in their mapping of the bioeconomic 'option space':

a) The level of *processes of representation*, investigated by the voluminous literature analysing policies and discourses around the bioeconomy;
b) The level of *institutional processes*, addressed in analyses of constellations of actors, strategies and interests from political science and political economy;
c) And the level of *material processes*, enlightened by research into the structure and possible future pathways of the sectors and activities that constitute the bioeconomy, both in its economic (jobs, firms, supply chains, profits) and its socio-metabolic (resource and energy flows) materiality.

Building on this distinction, we will discuss each of these literatures in some more detail in section 3, to draw out the ways in which their findings have presented reality checks to the promises of the bioeconomy discourse, requiring moderation of the claims made in the new, revised versions of official strategies.

The 'reality checks' from bioeconomy-related science have corresponded with, and partly fueled, processes of social change and political contestation concerning the societal nature relations that have been going on concomitantly, most importantly around the increasing urgency of fighting the escalating climate crisis. This level of social and mental processes unfolding around the bioeconomy has not yet received significant attention within research and debate, but we think that it ought to. The competing narratives and political decision-making processes concerning the bioeconomy, we claim, cannot be understood in separation from the broader constellation of different socially specific ways of relating to nature that are present within society (Eversberg, 2020a), and the conflicts and struggles that unfold between them (Eversberg, 2020b, 2020c). In a time of evident crisis of the fossil-based and growth-oriented societal model that the most powerful industrialized nations still seem locked into, these conflicts are bound to further escalate, and the economic and societal transformations discussed under the rubrum of bioeconomy are part of the stakes. If the goal of the bioeconomy is to make societies independent from fossil resources, as stated prominently in the current generation of 'moderated' bioeconomy strategies, then its social preconditions and implications cannot be understood in isolation from all those other aspects of such a post-fossil transformation. For social science research, this requires adopting a broader view beyond the confines of the perspectives of engineering, economics or even political science applied so far, to adequately understand the social practices and meanings of what 'bioeconomy' can be. Such a broader view must furthermore entail the recognition that, in everyday life, these bioeconomy-related practices and meanings are invariably embedded in broader contexts of societal contestation and change around whether and how to move away from the fossil basis of the economy. This implies that research on the bioeconomy must become much broader in scope – and much more political.

We thus hold that understanding the current state of the struggles around the issue of post-fossil transformation, the different contending visions and mentalities involved, and the possible pathways of democratic transitions toward a kind of post-fossil, bio-based societal model that is both freed from the unsustainable dependence on growth and finds broad support among majorities of the population, is a crucial task for sociological research on the bioeconomy. In section 4 of the paper, we therefore propose to add the societal space of practices, mentalities and conflicts around socio-ecological transformation as a fourth analytical level to the framework of the 'option space' suggested by Hausknost et al. (2017) as a preliminary heuristic for doing this. Building on a typology of eleven different types and three broader 'camps' of socio-ecological mentalities that we identified using the dataset of the survey

'Environmental Consciousness in Germany 2018', we locate the different types within the option space and analyze the conflicts and coalitions among them as well as the interrelations between subjective orientations, patterns of practice and socio-demographic characteristics.

2. The bioeconomy in Europe: The rise – and decline? – of a promissory discourse

The promissory character of the policy discourse around the bioeconomy has long been pointed out and critically debated by social scientists. McCormick and Kautto (2013: 2597), in an early comprehensive account of the discourse, concluded that the bioeconomy was engaged in active 'future making', others diagnosed a 'hegemony of optimism' (Pfau et al., 2014: 1238). Giampietro calls the dominant techno-based vision of bioeconomy an 'economics of technological promises' (2019), Sanz-Hernandez et al. talk of a 'promissory economy' (2019: 113), Petersen and Krisjansen (2015: 28) invoke a 'promissory discourse'. What sticks is the promise. As critical observers note, policy discourse portrays the bioeconomy as a regime of hope, presented as a necessity and an opportunity at the same time. Its promises revolve around the supposed 'opportunities' accorded by biotechnological innovation, and those opportunities are invariably seen as tied to economic growth. In recent years, however, with the urgency of debates around impending climate disaster and escalating biodiversity loss, the core promise has more and more come to be that economic growth and ecological sustainability can at all be reconciled (Hackfort 2015), i.e. that 'green growth' is possible. Grunwald (2020) states that the bioeconomy can be seen as a strategy to preserve a growth-oriented societal model even in the face of the urgent need to quickly get rid of the fossil energetic basis on which that model rests (see also D'Amato et al., 2017). Or, in the words of Levidow et al. (2019: 14): The "dominant bioeconomy trajectory aims less at decarbonising society and more at substituting renewable biomass for fossil carbon.' (ibid.). Yet by upholding the win-win narrative of green growth, bioeconomy policies claim to contribute to efficiency gains and innovations that allow policy-makers, firms and the public to avoid facing up to the prospect that growth may be part of the problem rather than the solution and that degrowth or sufficiency will need to be guiding principles of sustainably bio-based societies (Grunwald, 2020, 2016). And still, a cursory look at how recent bioeconomy strategies have been framing their promises suggests that policy-makers have not been able to fully ignore such critiques, voiced not only by notorious NGOs, but also by an increasingly diverse and multidisciplinary range of researchers, fording them to significantly reframe and moderate earlier growth ambitions.

With hindsight, the boom of biotech and the 'promissory life sciences' (Petersen and Krisjansen, 2015) on the one and the debates surrounding sustainability in general

and the need to combat global heating in particular on the other hand can be seen as the twin seeds of recent bioeconomy policy handed over from the heritage of the final years of the previous millennium.

For the first couple of years, the utopian sci-fi visions unleashed by the sequencing of the human genome and promoted by the likes of Juan Enríquez Cabot were the defining element. Biotech promised to be the 'next big thing' after, closely modelled on and amalgamated with the 'digital revolution', and its proponents were more than explicit in presenting it as that, calling it 'the life science revolution' (Enriquez and Goldberg, 2000). Even after the dotcom bubble had burst,[2] it took only a few years for the technopolitical promise to catch on: The promissory policy discourse on bioeconomy in the narrower sense dates back to the OECD's 2007-8 foresight project on 'The Bioeconomy to 2030', and it was clearly built on those visions. The OECD's concluding report promised that biotechnological progress was about to bring a 'second great technology revolution of the late 20th century, the bio-revolution' and a 'new wave of innovation, driven by the contributions of the biosciences to new and better products affecting every aspect of human existence' (OECD 2009: 14). The publication of that document initiated a wave of policy initiatives and strategies, with governments and regional coordinating bodies eager to secure their countries' share of the coming benefits (BMBF, 2010; BMEL, 2014; European Commission, 2012; The White House, 2012; for an overview: Fund et al., 2015).

It is perhaps not too much of an exaggeration to say that the OECD *invented* the bioeconomy as a biotech-based growth promise in a way much like it invented the very concept of economic growth as a policy goal in the post-World-War-II era (Schmelzer 2016). And this is more than a coincidence. Both inventions rely on the same basic logical operation: The subsumption of a huge, heterogeneous diversity of things and processes (work and economic transactions in the one, life and organic processes in the other case) to an abstract, uniform logic of valuation that allows their 'measurement' and mathematical aggregation into a virtual 'whole' (GDP, bioeconomic value creation) whose quantitative expansion could be portrayed as an end in itself. This abstract, recompositional logic (Allaire and Wolf, 2004) was at the heart of the thinking that guided the OECD's strategy-building (Levidow et al., 2019, 2013, 2012).

With regards to the EU, its 2012 bioeconomy strategy 'Innovating for Sustainable Growth: A Bioeconomy for Europe' (European Commission, 2012) was hardly less

2 Given the close link between the financial bubble around digital technology and the promissory bubble around biotech at the time, it would probably be a worthwhile endeavor to study in greater detail the impact of the financial crises of 2000 and 2008/9 on bioeconomy discourse and policies. Important lessons concerning the impact to be expected from the current pandemic-induced crisis seem highly likely.

conspicuous in putting the promise of growth front and center. In Europe, too, the bioeconomy debate was initially closely linked to and dominated by biotechnology-oriented visions promoted by the life sciences and biotechnology industry (Hausknost et al., 2017: 3-4). Early criticism from actors insisting on sustainability aspects in line with Agenda 21, the UN's Millennium Development Goals and the Kyoto protocol, and especially the initiatives of the newly founded technology platform 'TP Organics', however, had had an impact on the strategy. Along with the language of sustainability, the alternative concept of bioeconomic growth based on agroecology and products with an integral identity (Allaire and Wolf, 2004; Levidow et al., 2019) entered in, and by way of compromise, the idea of an economy based on renewable biomass and 'green growth' became a focal point of the EU's bioeconomy narrative. The central promise was not so much that of unlimited growth opportunities through biotechnological innovation, but that of being able to reconcile ongoing economic growth and ecological sustainability.

The 2018 update of the EU strategy 'A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment' (European Commission, DG Research and Innovation, 2018) goes a further step in this direction. As the title suggests, it handles the language of growth quite differently: Although it is still present, it now plays a much less prominent role as one out of five objectives next to food security, sustainable resource management, independence from fossil imports and climate protection (ibid.: 26). This reframing results from the 'mainstream[ing]' (ibid.: 27) of the UN's Sustainable Development Goals. However, as in the goals themselves, this orientation amounts not so much to an overall sidelining of the growth promise, rather than its articulation within a greater promissory framework. Bioeconomic growth is now linked to promises of **job creation** ('one million new jobs could be created by 2030, according to industry estimates. The strong and fast-growing startup ecosystem in the biotechnology sector will play a leading role in realising this potential', ibid.: 5), ecological and economic '**win-win-situations'** ('For instance, in the construction sector engineered wood offers great environmental benefits as well as excellent economic opportunities', ibid.: 5), significant contributions to **reaching the EU's emissions targets** (the commission hopes for the bioeconomy to not merely be carbon neutral, but to actually achieve negative net emissions and become a 'carbon sink' - implicitly promising other industries the opportunity to go on causing emissions, ibid.: 5-6) as well as to the promise of **circularity** as a way to reduce resource consumption while basically leaving existing patterns of economy and social practice untouched (ibid.: 6)[3]. In other words: While the thorough couching of the EU's current bioeconomy

3 Circularity is understood to mean finding ways to a) reduce food waste through 'innovation' - such as genetic modifications that increase shelf life – and b) reuse the food waste that is still produced as feed for animals or as raw material for other processes. If waste is always also a valuable resource, living

policy in terms of the SDG framework certainly implies a *moderation* of the one-sidedly 'recompositional' biotech-led logic driving the EU's earlier conceptions of 'knowledge-based bioeconomy' (KBBE), this is by no means a departure from the fixation on growth as such, but rather an attempt to reinforce it by integrating criticism into a larger 'green growth' strategy. A similar redefinition and rearticulation within the SDG framework can be observed in the German government's new bioeconomy strategy published in early 2020 (BMEL and BMBF, 2020). Here, however, the concessions to critics go even further: Growth actually appears only as a subordinate point that is mentioned rather in passing in the latter chapters, while sustainability in its different dimensions moves to center stage. The first sentence is: 'Sustainability and climate protection are the central issues of the 21st century' (ibid.: 3), and the glossary at the end of the brochure mentions not only a number of bioscientific terms, but also the notion of sufficiency.

This seems to reflect a constellation within the broader bioeconomy discourse that scholars have long noted: Recent analyses of discourses and narratives around the bioeconomy have tended to identify a bifurcation or conflictual relation between 'technology-driven', highly growth-oriented visions based on promises of life science innovations on the one and 'socio-ecological' counter-concepts based on agro-ecology and inimical to such technological solutionism on the other hand (Hausknost et al., 2017; Priefer et al., 2017; Vivien et al., 2019) – sometimes amended by a third, 'biomass-based' or 'bio-resource-driven' model located somewhere in between, but closer to the former (Befort, 2020; Bugge et al., 2016), and/or the concept of 'circularity' as another purported solution to the dilemma (Befort, 2020; D'Amato et al., 2019, 2017; Giampietro, 2019). On this continuum, at least the cited European strategies seem to slowly, but surely have moved away from the unbridled promissory optimism of the biotech visions, and increasingly closer toward acknowledging that a growth-oriented bioeconomy and successful de-fossilization are conflicting, rather than compatible, goals. The change in rhetoric (albeit not necessarily in basic orientation at the level of concrete measures, see Lühmann, 2020) observed here is certainly a reaction to critical interventions from civil society actors and non-governmental organizations (Civil Society Action Forum on Bioeconomy, 2019, see also nachhaltige-biooekonomie.de), as well as of the need to reflect in policy the commitment to the SDGs ratified in 2017. However, not least because most of the debates around these strategies have hardly been noticed by the general public, rendering effective public pressure effectively absent, we argue that the change in tone has also been driven by the scientific debates on the bioeconomy. Different

wastefully is no longer a problem (that situation – no value loss if something goes to waste – is not actually expected, but the ultimate intention seems to be to create a situation where wasting food can be seen as just as legitimate a customer's choice as any other. For a more fundamental critique of the idea of circularity, see Giampietro (2019).

strands of research on its biophysical, economic and social implications have each mounted 'reality checks' for the promises made by industry and policy actors, in effect requiring policymakers to include an increasingly broader set of ecosystemic, economic and social relations that are affected by bioeconomic change in their considerations. This in turn, we argue, has contributed to the marked moderation of the growth promises in the recent second wave of bioeconomy strategies. In the following section, we give an overview of some of these debates and draw out the corresponding 'reality checks' that have resulted from them.

3. Multiple reality-checks for the promise

As early as 2007, biologists Jonathan Latham and Allison Wilson mounted a sharp critique of the promissory visions surrounding the EU's concept of 'knowledge-based bioeconomy', claiming that it was 'not so much a real and substantial prospect but more a fantasy future—one designed to meet present political needs for envisioning sustainability without at the same time abandoning a belief in technological 'progress" (Latham and Wilson, 2007). Their critical invectives may be seen as one of the starting points of a long series of scientific challenges to the bioeconomy and related concepts that have been mounted on multiple levels. Our goal in this section is to consider a number of these multiple reality checks. To do this in a systematic way, we introduce a distinction between three different levels of analysis at which these reality checks can be seen to have been launched, based on the distinction between three levels of the bioeconomic 'option space' deployed by Hausknost et al. (2017). We thus distinguish scientific work addressing:

a) Processes of *representation* and discursive construction of the bioeconomy (section 3.1.): Discourse analyses comparing different bioeconomy strategies; literature reviews distinguishing different and competing visions or concepts of bioeconomy; STS work showing how bio-based 'resources' are constructed and processed using technologies of knowledge and information. The challenge mounted by this body of work is that it counters technologically determinist visions by revealing the contingent and contested nature of both the concepts of bioeconomy and the bioscientific as well as economic knowledge procedures they rest on.
b) *Political-institutional processes* (section 3.2.): Analyses from Political Science and Political Economy on interests and strategies of actors, actor coalitions and the relations between different 'stakeholders'. These studies subject the bioeconomic growth promises to the reality check of revealing the interests behind and the power resources deployed in advancing them, illuminating the instrumental nature of the promises and the resulting tendencies to ultimately hinder or block any serious transition away from fossilist societal models.

c) *Material processes* in the dual sense of what Pichler et al. (2020) call the 'double materiality' of the social in capitalist societies: Economic accounts on the structure of employment, productivity and value creation in the bio-based sectors (3.3.a) as well as socio-metabolic studies on the material and energetic throughput of the bio-based economy (3.3.b). These recently proliferating studies have repeatedly demonstrated the continuing quantitative insignificance of the (biotech) industries promoted as new 'growth engines', as well as the overall inertia and limited expansionary potential of bio-based production, highlighting instead the highly unequal distribution of biomass production and use across the globe, raising serious concerns about justice. Their findings have rendered increasingly questionable both the growth promises themselves and the claims to their compatibility with concerns for sustainability and social-ecological justice.

Hausknost et al. (2017) is an important reference point for us not only because it integrates these different analytical levels that are treated separately in most bioeconomy-related research, and links the corresponding analyses systematically. It is also helpful in suggesting a two-dimensional 'option space' (see figure 1) of possible bioeconomic trajectories as a heuristic applicable to each level, in which the common distinction between biotech-based and agroecologically oriented conceptions is juxtaposed with a dimension in which the different ideas and models of potential pathways are located on a continuum between ones highly fixated on capitalist growth and those geared to achieving sustainability through strategies of sufficiency. This two-dimensional heuristic is particularly helpful for analyzing the nature of the challenges posed to the bioeconomic growth promises. Also, using the three levels of discourses/strategies, actors/stakeholders and economic/biophysical materialities as a framework to order the landscape of existing research allows us to suggest, in section 4, that addressing the challenge of defining what a post-fossil, bio-based transformation of society may be requires the introduction of a fourth analytical level.

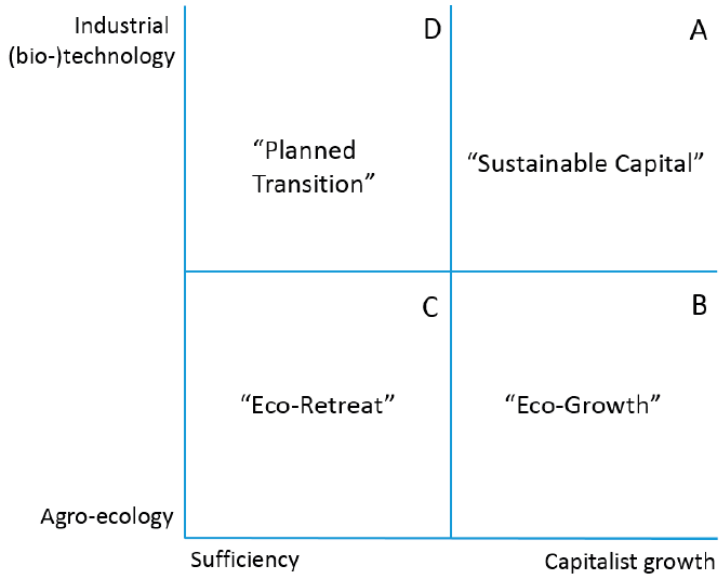

Figure 1: Two-dimensional 'option space' from Hausknost et al. (2017: 6)

3.1. Processes of representation: Analyses of bioeconomy discourses and strategies

There is a vast body of social science research that analyses strategies, policy papers, programs and the respective discourses around the bioeconomy. This work on the processes of representation and discursive construction of the bioeconomy encompasses three subcategories: **discourse analyses** that scrutinize and compare different bioeconomy strategies and related policy documents (e.g. Backhouse et al., 2017; de Besi and McCormick, 2015; Kleinschmit et al., 2017; McCormick and Kautto, 2013; Meyer, 2017; Petersen and Krisjansen, 2015; Staffas et al., 2013), **literature reviews** distinguishing different and competing visions or concepts of and approaches to bioeconomy in the scientific debate itself (e.g. Böcher et al., 2020; Bugge et al., 2016; D'Amato et al., 2017; Konstantinis et al., 2018; Pfau et al., 2014; Pülzl et al., 2014; Sanz-Hernández et al., 2019), and a strand of **Science and Technology Studies (STS) work** that focuses on the discursive processes in which bio-based 'resources' are constructed and processed using technologies of knowledge and information (e.g. Allaire and Wolf, 2004; Birch et al., 2010; Birch, 2017a; Levidow et al., 2012, 2013; Mittra and Zoukas, 2020).

Many papers in this far-flung 'debate on the debate' have pointed out incoherences, gaps, open questions and competing visions to be found within the documents and

statements analyzed. Others have demonstrated that the promissory discourse on bioeconomy as a growth engine is the dominant, but not the only vision present in the debates around bio-based economic transitions, and that there are widely varying degrees of emphasis on growth as compared to other goals pursued in bioeconomy policies. Others yet have challenged the very epistemological basis on which the biotechnological growth promises are made, and their foundations in bioscientific knowledge. We cannot provide a comprehensive review of this broad literature here, but will instead illustrate our argument with reference to a few key publications from each sub-literature.

Firstly, the countless **discourse analyses** that exist focus on international, national or regional bioeconomy strategies, analyzing differences and similarities in rhetoric or priorities with regard to the definitions of bioeconomy deployed as well as to aspects such as the respective roles of sustainability and growth, the roles accorded to different actors, the sectors included etc. Concerning the differences in strategies, Pietzsch and Schurr (2020) argue that different national governments pursue a range of diverging motives with their respective strategies: While some focus on bioeconomy as a strategy to ensure food security, such as in Paraguay or Kenia, others promote it as a means to intensify the use of abundant natural resources, such as Finland with its forest-centered bioeconomy strategy 'sustainable growth from bioeconomy' (Ministry of Employment and the Economy et al., 2014). To countries such as Germany or the US, bioeconomy is more of a strategy to ensure sufficient (bio-based) resources for their highly fossil fuel-dependent resource-intensive industry branches, and finally, governments such as those of India, South Africa or Thailand articulate their bioeconomy strategies as efforts to catch up with wealthy industrialized by generating a higher value added from their natural resources. Economic growth is central to some, but not all of these motives. Also, as described in our own account above, these studies typically find that the emphasis on growth within bioeconomy policies tends to change over time, and that rearticulating the growth in sustainability terms does not necessarily imply a shift away from biotechnology: Hausknost et al. (2017: 4) note that in the 2012 strategy, the EU did 'not discard its original focus on biotechnology [but] changed the framing of the bioeconomy's main purpose toward an overarching post-fossilistic sustainability agenda, within which biotechnology still has an important – albeit less talked about – role'. The research funding programme, for example, remained 'dominated by a life sciences vision' (ibid.). Backhouse et al. (2017) identify one of the main similarities between most bioeconomy strategies both from the Global North and South in their shared belief in technological progress as a means to overcome both social and environmental crises. Despite that common continuing technological optimism, growth is found to be articulated in more diverse ways in the more recent political strategies, presented less as a central goal than rather as a self-evident part of the deal. The concrete goals stated then vary, including job creation, rural development,

green growth, competitiveness, innovation or sustainability in industrial processes, etc. (McCormick and Kautto, 2013). Kleinschmit et al. (2017: 41) compared the bioeconomy strategies of four European countries – Germany, Finland, The Netherlands and France – with regard to the way they integrated environmental concerns, judging that integration to be mainly 'rhetorical'. Environmental concerns, they found, were mostly presented as either benefitting from economic growth or as being a challenge to be overcome, while a second, less prominent approach tended to frame environmental sustainability as kind of a 'standard' feature of a bioeconomy (ibid.). Some studies have not limited themselves to pointing to such assumptions, but critically commented on them from a sustainability-oriented perspective. For instance, Gawel et al. (2019: 1) challenge the common policy assumption that a bio-based economy is per se sustainable, and implicitly question the growth orientation by claiming that 'markets alone will not suffice to fulfil this path transition' and calling for an 'innovative governance' that actively intervenes both in an 'enabling function' to subsidize bio-based alternatives and in a 'limiting function' to prevent overuse of biological resources. Vivien et al. (2019) even make the charge that the use of the term bioeconomy in current policy narratives is a 'semantic hijacking of the original term' (ibid.: 189), which they locate in the radically growth-critical bioeconomics of Georgescu-Roegen. To them, the growth promise of bioeconomy policy turns Georgescu-Roegen's own term against his fundamental insight that all economies are based on and bound by nature's limitations, and the 'industrial promises offered by the biotechnological revolution' effectively amount to 'a bio-based carbon economy' that can under no circumstances be sustainable (ibid.).

As a second subcategory, various **literature reviews** survey, sort and summarize the constantly growing amount of (mostly social scientific) research on different aspects of the bioeconomy and related concepts such as Circular Economy, Green Economy or sustainability. What is common to these publications is that they systematically include not only the optimistic visions guiding the dominant policy narratives, but also radically critical perspectives that fundamentally challenge the growth orientation, which are much less marginalized in science than in policy discourse. In general, the authors of these reviews agree in seeing the bioeconomy as a semantically polyvalent 'master narrative', and identify differing substrands of the debate that emphasize different aspects. In a classic of this genre, Bugge et al. (2016) introduced the tripartite segmentation of bioeconomy already referred to here and subsequently taken up by many others, distinguishing between a 'bio-technology vision', a 'bio-resource vision' and a 'bio-ecology vision'. The first two are seen to be clearly set apart from the latter in terms of their relation to technology, economic growth and sustainability: 'While economic growth and employment creation is a main concern in the bio-technology and bio-resource visions, these aspects are clearly secondary to sustainability concerns in the bio-ecology vision' (ibid.: 12). Regarding technology, the bio-technology and bio-resource visions 'are technology-focused

and give a central role to R & D in globalised systems, [while the bio-ecology] vision emphasises the potential for regionally concentrated circular and integrated processes and systems' (ibid.: 9). In a rather similar way, Pfau et al. (2014: 1222) had earlier suggested distinguishing between four different visions of bioeconomy, which again differ in how they conceive of the relation between sustainability and a bioeconomy associated with growth and biotechnology: '(1) the assumption that sustainability is an inherent characteristic of the bioeconomy; (2) the expectation of benefits under certain conditions; (3) tentative criticism under consideration of potential pitfalls; and (4) the assumption of a negative impact of the bioeconomy on sustainability'. The aspects of relation to sustainability, technology and growth as defining and dividing aspects of bioeconomy visions were also taken up by D'Amato et al. (2017) in a literature review aiming to systematize the differences between bioeconomy, circular economy and green economy/green growth. They concluded that the bioeconomy could be classified as an integral part of the 'green economy', while all 'three concepts can be considered limited in that they largely embrace the idea of economic growth [… and] none of the three concepts (CE, GE and BE) are in fact embedded in strong sustainability' (ibid.: 725). While all of these suggestions imply effectively treating sustainability's relation to growth and technology as directly related and locating the different visions on a single continuum from unsustainable growth- and technology-focused visions to sustainability-minded ones opposed to both, Hausknost et al. (2017) suggested treating both as independent axes to come up with the two-dimensional structure of the 'option space' reproduced in the beginning of this section. Although their findings in applying this heuristic (as well as our own to be developed in section 4) essentially confirm the close mutual relation of both dimensions in policy discourse, science and stakeholder relations, this is an important addition.

A third strand of work on the discursive, i.e. language- and knowledge-related, dimension of the bioeconomy discourse builds its arguments around insights from **Science and Technology Studies (STS)**. Works in this tradition enable challenges to the growth promise by shedding light on the contingent and contested nature of the concepts and knowledge procedures they rest on. By reconstructing the ways in which the promise of the bioeconomy and the vision of generating economic value from the commodification of life is made possible 'performatively' through the use of different technologies of knowledge production and circulation, it offers a strong counternarrative to the determinist visions of self-driving technological development and the inevitable success of superior 'innovative' technologies in the market that underlie the dominant bioeconomy visions. In that understanding, bioeconomy is framed 'as an emergent, present, or sometimes promissory economic regime underpinned by particular socio-technical practices' (Mittra and Zoukas, 2020: 2). A particularly important pioneering study in this field was Allaire and Wolf's (2004) analysis of two competing modes of innovation in the agro-food

sector. In their account, the distinction drawn elsewhere between 'biotech-based' and 'agro-ecological' conceptions of bioeconomy plays out as that between different ways of turning living things into objects of knowledge and using that knowledge to produce, process, convert and commodify them – a 'recompositional' model dealing with abstract 'resources' made of chemical compounds that can be taken apart and rearranged as desired in the biotech-based and an 'integral' model based on product and producer identity as well as concrete qualities inseparable from that identity in the agroecological versions. The subsequent work of authors in this tradition has built on and further developed this understanding into a critical analysis of the bioeconomy debate as a whole. Birch et al. (2010) emphasize the close connection between the abstract 'recompositional' conception and the equally abstract, exchange value-driven logic of neoliberal capitalism. To them, the idea of the 'knowledge-based bioeconomy', then the focal point of EU bioeconomy policy, epitomized this confluence, turning bioeconomy into a 'master narrative' favouring and pushing a 'European policy framework around specific technological choices and neoliberal accounts of nature' (ibid.: 2899). Crucial to those accounts is the equation of 'renewable' and 'sustainable' effected by the KBBE narrative, creating a vision in which 'technological innovation unlocks the renewable, biophysical characteristics of nature itself through genetic and bio-molecular knowledge, thus enabling the continuing expansion and accumulation of capital. This can be analyzed as a techno-knowledge fix, which provides a basis for creating *sustainable capital*, not just sustainable capitalism' (ibid.). This conception of 'sustainable capital', which Hausknost et al. (2017) adopt as the moniker for the upper right quadrant of their 'option space', is thus the *dominant* option not by chance, but because it expresses an 'elite master narrative' that does not need democratic confirmation, or even acknowledgement, from a majority of people, but derives its power simply from being embedded in the way the knowledge-based bioeconomy formats, uses and commodifies life. Building an economy around abstract life as a source of value thus develops a 'fetishistic' dynamic of its own, providing 'the rationale for particular institutional and policy changes to achieve this end', i.e. for a deeper neo-liberal reconfiguration of the social itself (Birch et al., 2014: 2). The vision and the narrative become 'self-fulfilling' as they create 'the conditions for what they seek to promote' (ibid.). Still, the promise ultimately remains empty, as Birch claims: Born of the abstract financialized logic of neoliberal capitalism, the real business of biotech is the generation of expectations in the stock market, so that much of the sector, though sucking in enormous sums in research funding and investor money, has consistently failed to come up with any products actually marketable at scale, effectively rendering it a 'political economy of nothing' (Birch, 2017b: 916). 'Sustainable capital', from this perspective, is thus a powerful force at work in reshaping society in ways that effectively elude democratic control – and that effectively undermine and contravene, rather than foster, solutions to the ecological crisis.

Taking stock of the different accounts offered of the processes of representation connected to the promissory bioeconomy discourse, a recurring image emerges: one of a tension between dominant biotechnology-based conceptions of the bioeconomy laden with promises of growth on the one and marginalized socio-ecological models prioritizing sufficiency and sustainability on the other side. Although the intention of this literature is to show the variation in the discourses and the availability of different avenues to policy actors, the initial reality check here often seems to be one for the researchers' own sustainably-minded intentions: A sustainable circular bioeconomy should be a priority of industry and government, but is often found to be subordinated to technoscientific promises and economic power, just as ethical and social issues are often found to be given secondary priority (D'Amato et al., 2017; McCormick and Kautto, 2013). In a way this is also experienced by Hausknost et al. (2017), who deploy their analytical framework in a first step to the relational comparison of different governments' bioeconomy strategies. Locating seven such strategies on the two dimensions of their 'option space', they appear somewhat surprised to arrive at the conclusion 'that all official policy papers are located in the 'Sustainable Capital' quadrant that combines a vision of biotechnological progress with a narrative of green growth' (ibid.: 18). From the vantage point of the literature that they derive the name of that sector from, this should not come as a surprise at all: To Birch, Levidow and others in that tradition, whose work presents itself less as a reality check than as a full-blown attack on the dominant vision of the bioeconomy, the finding that governmental strategies strongly tend toward 'sustainable capital' options may well appear as a confirmation of their assumption that under conditions of an abstract, financialized capitalist regime and its corresponding paradigm of technoscientific innovation, 'sustainable capital' is indeed not a mere 'option', but a trajectory imposed both by elite power and by entrenchment of abstract modes of knowledge that are becoming ever harder to challenge the longer this dominant model operates.

3.2. Political-institutional processes: Political economy, actors, interests and strategies

As a second dimension, we want to focus on social science research approaching the bioeconomy from a **Political Science** or **Political Economy** perspective, focusing on the interests and strategies of actors and actor coalitions, as well as on the stances taken by and the relations among different 'stakeholders'. The kind of reality check that analyses from this angle can confront the bioeconomic growth promise with consists in revealing the interests behind and the power resources deployed in advancing promises of bioeconomic growth, and the ways in which their pursuit jeopardizes or ultimately hinders efforts at a serious, wide-ranging and fast transformation away from an economy and society dependent on fossil fuels.

A first group of papers discussed in this context base their arguments partly on the **mapping of actors and network analysis** of bioeconomy actors in certain sectors or countries, or on research among scientists in bioeconomy-related research institutions (Giurca, 2020; Giurca and Metz, 2018; Korhonen et al., 2018; Peltomaa, 2018; Zeug et al., 2019). The second group forms around the (rather scarce) work that has been done to reconstruct the conflicts and actor coalitions shaping bioeconomy politics and processes of policy formulation, mostly from a **Political Economy** perspective. These studies are mostly associated with a more pronouncedly critical view of the bioeconomy's promises and a clear identification of the economic and political interests hampering effective transformative steps (Lühmann, 2020; Richardson, 2012; Kröger and Raitio, 2017; Levidow and Papaioannou, 2014).

This is of course not all there is: Böcher et al. (2020: 2–3), in an overview of the existing social and political science literature on the political dimensions of bioeconomy, find that this field is mostly strongly characterized by a wealth of existing work on bioeconomy 'governance' and its problems. To our present concern, however, engaging with this literature would hardly add much, since, as Böcher et al. critically note, it tends to reduce politics and policy-making to issues of 'management', thus de-emphasizing conflict and downplaying conflicting interests and structural contradictions such as that between growth and sustainability (ibid: 3).

In the first category mentioned above, **actor mappings and network analysis** exist for different sectoral, regional or national-level policy networks: For instance, Giurca (2020; Giurca and Metz, 2018) takes a national-sectoral approach and maps the actors and stakeholders of the German forest-based bioeconomy network. He describes the bioeconomy as 'primarily a political project where actors with different interests and strategies pursue different agendas' and diagnoses a 'series of internal conflicting and consenting storylines' that 'lead to a lack of clear objective-setting which may ultimately affect the success of the bioeconomy project' (Giurca, 2020: 1). With regard to the studied network, Giurca highlights both 'conflicting' and 'consensual storylines'. With disagreements concerning matters such as the availability of the necessary natural resources or the sustainability of the whole concept (ibid.: 8). Although insisting on the importance of actors' interests and strategies, however, the strongly discourse-focused conception of network analysis, as well as the implicit assumption that networks are not inherently conflictual fields of struggle, but ought to have a sense of common purpose, seem to make Giurca shy away from drawing more far-reaching conclusions as to what social and economic conflicts and interests the disagreements he notes may be rooted in. Korhonen et al. (2018) deploys a similar approach towards the Finnish forest-based bioeconomy: The field is characterized by differing terminologies and approaches, the relations between different actors and groups of actors are charted, and the policy goals and priorities set by the groups compared. The authors diagnose that 'power struggles can be

expected within the relatively young BE arena' (ibid.: 2), resulting in formations of different policy coalitions and a growing divide within the policy field. Contrary to what the analyses of the discourse might lead us to expect, however, this is on closer inspection less a conflict between a pro-growth and a socio-ecological coalition, but rather, at least within the confines of the network analyzed, between two separate subgroups of economic and political actors: a 'business as usual' coalition of mainstream forest-industry and government actors on the one side and a coalition of more startup-like businesses and researchers promoting the use of new technologies and business models aimed at commodifying the forest in new and innovative ways on the other (ibid.: 14). The really striking finding of that study, however, is the degree of agreement among all categories of actors counted as part of the policy network that the prime goals of bioeconomy policy should be enhancing economic competitiveness and pushing new technologies, while the notion of prioritizing sustainability over economic concerns and the idea of broader citizen participation were consistently ranked significantly lower (ibid.: 10). Perhaps contrary to the authors' intentions, this might be seen as evidence to support Birch et al.'s claim that the bioeconomy is and remains an 'elite master narrative', and even for the will of the (Finnish) elites to actively preserve that state of affairs – at the expense of democratic participation and a more serious concern for socio-ecological matters.

With a focus on **scientists as one stakeholder group** involved in shaping the bioeconomy, a second subgroup of studies (Bauer, 2018; Biber-Freudenberger et al., 2020; D'Amato et al., 2019; Issa et al., 2019; Lovrić et al., 2020; Priefer and Meyer, 2019) investigate the motives, perspectives and opinions of researchers and experts working in the field of the bioeconomy. Based on surveys among scientists, their conclusions mostly mirror those found in reviews of the literature (which, after all, is written by these people): they typically find that the 'technology fix meets criticism and that there is a controversial discussion about possible ways to shape the transition process' (Priefer and Meyer, 2019: 1), depending on the disciplinary, theoretical and institutional background of the scientists as well as the subfields they work in and the state of their projects. Although it would be interesting to know more about how the very different kinds of involvement of researchers in biotech and bioeconomy firms, political and business consulting or the kind and extent of funding their research receives is related to the ideas and strategies they promote, most of these studies offer little in this regard. It does, however, appear highly likely that these factors are not without significant influence especially on researchers' views and interests concerning the question of bioeconomic growth, and that this also implies that the tension between pro-growth 'sustainable capital' visions and sustainability-focused alternatives within the scientific field is also tied to significant imbalances in economic, political and scientific capital: According to Levidow et al. (2019), the life sciences remain hegemonic and dominant at EU level regarding both funding sums and numbers of projects, and use this clout to exert a formative influence

to strengthen a technological and growth-oriented vision of the bioeconomy; in comparison, approaches from different disciplines and with a focus on agro-ecological solutions remain marginal, although they are no longer fully excluded from the research agendas and have gained a certain amount of presence by now.

The scarcity of work in the other, more **Political Economy**-based tradition has also been noted by Böcher et al. (2020: 3), who find that ‚specific political aspects such as actors' power and resulting interest conflicts in the bioeconomy field have so far hardly been scientifically investigated' and that 'only few scientific contributions develop a proper political science perspective on political processes of bioeconomy'. A pioneering study by Richardson (2012) is mentioned as one of the few exceptions. Explicitly referring to the 'promises' of industrial biotechnology, Richardson referred to the 'tension that capitalists face in balancing accumulation imperatives with the need for legitimacy' (ibid.: 292), which promises of 'green growth' by biotechnological means are to help solve. Somewhat counter to Birch et al. 2020's narrative of the power of 'sustainable capital', he assumed that active efforts at securing legitimacy were necessary, and that the efforts from biotech firms and governments to do this were actively contested, citing controversies around the 'extension of biobased commodity chains', EU-level debates on whether biotech can meaningfully contribute to lowering GHG emissions, and conflicts within civil society between business-friendly and more radical NGOs and assuming that challenges to the hegemony of 'sustainable capital' were possible at least to some degree.

In a 2014 case study, Levidow and Papaioannou investigated the roles the interests of scientists, industry and government played in developing new bioenergy policies in the UK. One of their findings was that for government and industry, intensely promoting the promissory concept of 'advanced biofuels' was a way to deflect mounting criticism around the socio-ecological problems associated with using farmland to cultivate crops for biofuels. More recently, Kröger and Raitio (2017) discussed the process of reviewing the Finnish Forest Act and of its reframing in terms of the bioeconomy discourse in terms of 'tensions and goal conflicts' between different 'pathways to sustainability', associated with different actor coalitions. Their study reveals the interest-based omissions and one-sidedness of the goals proclaimed by government and business, and concludes that the 'more of everything' pathway that resulted as a seeming compromise profoundly alienated not only environmental NGOs, but even the environmental ministry, all of whom insisted that crucial sustainability criteria could not be met because of the unwillingness of business and forest owners to accept stricter regulation and of parts of the government to enforce such regulation at the expense of potential future growth. This case study shows that even in a political culture of compromise such as the Finnish, 'bioeconomy' tends to be a vehicle for effectively promoting the interests of powerful economic actors in

safeguarding profits and ensuring prospects for growth, even at the obvious expense of environmental protection.

In a very recent study from an International Political Economy perspective, Malte Lühmann (2020) has scrutinized the interests pursued and strategies deployed by different actor groups in the process of updating the EU's bioeconomy strategy before 2018. Comparing the outcome of the review process with the demands and strategic orientations advocated by selected actors from business, agriculture, science and civil society, he finds that despite some changes in rhetoric toward a greater emphasis on sustainability, the actual priorities in terms of goals and measures were hardly altered, reflecting the calls for a continuation of the previous growth-centered orientation voiced from business and science, and discounting the calls for a change of course form agriculture and civil society. As a result, in the updated document 'the further expansion of the bioeconomy is seen as a means to solve environmental problems, while the logic of growth reproduced by this position and its ecological consequences are never fundamentally questioned' (ibid.: 8).

In the analysis of Hausknost et al. (2017), which provides our guideline here, stakeholders and their understandings of the bioeconomy are mapped as the second level of analysis. After mapping the political strategies in the first level and coming up with the striking result that the positions of all of the governmental documents concentrate within the 'sustainable capital' sector of the techno-political option space, the authors added the respective positions along the vertical (technological) and horizontal (economic) axes of 29 interviewed stakeholders from various bioeconomy-related actors groups in Austria. On this level, a 'milky way'-like structure emerges: While the positions of a number of stakeholders (mainly from business interest groups and public administration) are to be found in broad alignment with the official strategies in the upper right 'sustainable capital' sector, other actors broadly align along the diagonal toward the 'eco-retreat' positions in the lower left – with a smaller group composed mostly of researchers tending a little bit toward the upper-left 'planned transition' sector and most of the NGO representatives more toward the 'eco-retreat' pole. Still, the diagonal 'milky way' strongly suggests that the field of stakeholder positions is indeed strongly structured by a one-dimensional opposition between a clear prioritization of both growth and technology and skeptical attitudes toward both – precisely the constellation that numerous studies also find in analyzing bioeconomy-related discourses. 'Eco-Growth' and 'Planned Transition', as theoretically conceivable alternative modes of combining stances on economic growth and technology, do not play a significant role among the different positions of stakeholders involved in the field.

In sum, the reality checks to the bioeconomy's growth promises that such research delivers lie mainly in exposing the interest-driven motives behind those promises, and revealing that it is not ultimately 'facts' or the outcomes of democratic deliberation

that determine how policies are defined and/or realigned, but ultimately the (highly unequally distributed) ability to mobilize different (economic, scientific, symbolic, social, political…) power resources. Questioning the interests behind the promises and, accordingly, the realism of the strategies derived from them can put governments and companies under pressure to concede that they will have to limit their aspirations or base their claims on different foundations (as in the case of the debate around 'advanced biofuels'). Also, focusing attention on the power resources and strategies deployed to advance questionable promises renders apparent that those promises are often more part of the resistance to, rather than a driving force of, the necessary transformations that they claim to be uniquely suitable to help achieve. However, the very recent insights from Lühmann's work also seem to indicate that this kind of reality check to the bioeconomy, and especially to its dominant 'sustainable capital' variant, has so far influenced renewed policies mainly on their rhetorical surface, whereas the underlying ways in which power and resources are distributed remain mostly intact – a diagnosis that is more in line with Birch et al.'s fundamental skepticism than with other researchers' more optimistic positions.

3.3. Material processes of the bioeconomy

We propose to understand the material processes of the bioeconomy in the dual sense of what Pichler et al. (2020) call the 'double materiality' of the social in capitalist societies. This implies sorting the research into two categories: Economic accounts on the **structure of employment, productivity and value generation** (material processes I) in the bio-based sectors on the one, **socio-metabolic studies** on the material and energetic throughput of the bio-based economy (material processes II) on the other hand. Research on both levels can be interpreted to mount severe reality checks on the growth promise of the bioeconomy, revealing both a continuing quantitative insignificance of the (biotechnology) industries promoted as 'growth engines' and 'job motors', and the overall inertia, stagnation, low job quality and limited potential of bio-based productive sectors. Research on bio-based socio-metabolic flows also highlights the highly unequal distribution of biomass production and use across the globe, making exaggerated promises of expansion appear increasingly unrealistic and at odds with concerns for sustainability and socio-ecological justice. Research in the first category is currently much more voluminous than in the second, from which comprehensive and methodically sound studies have only recently started to emerge. We will discuss only a few key studies from each category that provide particularly relevant insights on the issue of bioeconomic growth.

a) Material processes I: Economic accounts of sectoral development

On the first of these two levels, a large number of economic studies have been engaged in defining the contours of what makes up 'the bioeconomy' as a segment of the economy (Bringezu, 2019; Efken et al., 2016; Ronzon et al., 2017; Ronzon and M'Barek, 2018; Wesseler and von Braun, 2017; for critical views see Mittra and Zoukas, 2020; Hilgartner, 2007) and tracking its development in terms of employment, revenue and industry structure (Bringezu et al., 2020; Iost et al., 2019; Konrad et al., 2020; Kuosmanen et al., 2020, Ronzon et al., 2020). It has often been noted that 'the economic quantification of the contribution of the bioeconomy is extremely complex because the boundaries between the bioeconomic and traditional sectors are not delimited and several value chains are not formally established' (Sanz-Hernández et al., 2019: 113). In any case, researchers trying to come up with concepts for how to do this have had to come up with *sectoral* definitions, or definitions of the 'bio-based economy' as a collection of industries and activities producing and processing materials of biological origin. Most of these are not at all new, but rather – like agriculture or forestry – among the most traditional sectors of the economy. Compared to the mystified new high-tech bioeconomy of the biotech startups, which is in macroeconomic terms so minuscule as to hardly make a dent in the overall metrics, these traditional sectors are relatively relevant as far as their contributions to overall employment and GDP are concerned. At the same time, they are not nearly as dynamic: Research commissioned by the EU itself, as well as the recent pilot report for Germany's future bioeconomy monitoring, show that employment in the European bioeconomy, broadly[4] defined as the totality of sectors operating on a biological basis, has declined rather than grown over the last decade (Ronzon et al. 2020, Bringezu et al. 2020) – and the coming developments that agriculture, forestry or fisheries are likely to face in connection with the bioeconomy debate, relying heavily on automatization and digitization (such as 'precision agriculture'), seem likely to accelerate the decrease in employment.

In 2017, according to EU-commissioned research, the bio-based sectors of the economy in the EU27 employed 17,5 million people and generated 614 billion € of value added, representing 4,7% of GDP and 8,9% of the labour force (Ronzon et al., 2020: 4). These developments are not equally distributed among member states, but differ significantly between those countries mostly supplying the bio-based raw materials and those importing and processing them with the help of advanced

4 In the German monitoring's case, the definition is indeed so broad as to encompass the whole of the food sector, including restaurants, catering services and food delivery – a choice that certainly generates significantly more impressive job numbers to report, but also contributes to the overall impression that the bioeconomy as a sector is first and foremost characterized by low wages, bad working conditions and highly precarious employment.

biotechnology: 'Gains in apparent labour productivity were concentrated in Western and Northern Member States' (ibid.: 8), resulting in a widening productivity gap. The authors observed nothing to warrant the assumption of a great potential for economic growth in the European bio-based economy. Quite to the contrary, they saw its main potentially beneficial role in providing a 'buffer' that could secure the livelihoods of rural citizens 'in times of economic crisis', in potentially contributing to the development of an 'innovative, inclusive, and climate-ready' economy, in ensuring 'resilience' and the opportunity to 'balance economic and social objectives' (ibid.: 10). It is remarkable that these promising prospects suggested by Ronzon et al. are not expected from economic growth, but precisely from turning toward concepts of a resilient, regionally based bioeconomy especially for regions in Central and Eastern Europe (ibid.: 10). However, as the notion of 'resilience', which should always be taken with caution (Graefe, 2019), suggests, this is not to be misunderstood as some version of a degrowth vision: Conceived as something of a subsidiary economy to accommodate people in peripheral regions, while the overall European economy of the future is still imagined as 'innovative, resource-efficient, and competitive' (ibid.), this kind of idea of a bioeconomic, growth-independent 'buffer' is more likely to ultimately amount to a large-scale 'poverty management' and to the deepening and perpetuation of existing intra-European inequalities.

Regarding Germany, the recently published pilot report of the government's bioeconomy monitoring (Bringezu et al., 2020) also arrives at humbling, if not pessimistic conclusions concerning the bioeconomic growth potential. The report deploys a rather broad definition of the bioeconomy, including as 'bio-based' all sectors and processes in which at least ten percent of the resources used as input are derived from renewable raw materials. Among other things, this leads to the inclusion of all food-related service employment as part of the bioeconomy (ibid.: 38). According to this metric, ten percent of the overall workforce in Germany in 2017 were employed in the bioeconomy (4.4 million), with the manufacturing and catering sectors making up the biggest parts. The authors predict that under current trends, the bioeconomic workforce will moderately shrink until 2030 (to 4.3 million). In revenue terms, the report expects the bioeconomy to grow at a rate of 2.6% per year until 2030 – half a percent less than the overall economy (ibid.: 47). The highest growth rates of over 3% are expected for the bioenergy and catering sectors as well as for R&D[5], while the primary sectors agriculture and forestry are projected to expand at a significantly lower rate (1.5%) (ibid.: 9).

In this light, the promise of employment growth from the bioeconomy appears increasingly less credible, as it would require a reversal of long-term trends. That reversal is normally promised as an effect of impending biotechnological

5 Although a projected growth rate of 3.3% p.a. seems feeble for a persistently hyped boom sector from which all kinds of breakthroughs are expected at any time.

breakthroughs, but the actual evidence compiled in the economic reports offers little to support such claims. Employment in the biotech R&D sector is comparatively minuscule and highly unlikely to expand at a rate that would make an overall difference, while in the larger, more labour-intensive sectors (agriculture, food processing), technological rationalization continues to make jobs obsolete. And even if some bioeconomic product innovations should materialize, there is little to go on for the assumption that they would amount to more than substituting currently existing processes and jobs, or even that they would not lead to rationalization and job loss themselves. Such doubts are typically countered by economists with Schumpeterian arguments (Pyka, 2017; Pyka and Prettner, 2018) claiming that growth in biotechnology and innovation will spark the creation and demand for jobs in other sectors (e.g. education, software and digital technology, related services). That, however, not only presupposes an unshakable belief in the beneficial power of innovation impossible to confidently ground in facts as well as a questionable 'trickle-down' theory of the diffusion of economic benefits, but it would also require a different – and even broader – sectoral definition of the bioeconomy to detect those purported benefits.

In its updated strategy, the European Commission claims: 'In the bio-based industries one million new jobs could be created by 2030, according to industry estimates. The strong and fast-growing startup ecosystem in the biotechnology sector will play a leading role in realising this potential' (European Commission, DG Research and Innovation, 2018: 5). The promise is explicitly to create a million new jobs *in the bio-based industries.* And unlikely though that is: Even if a million jobs were created by 2030, this would amount to a mere 5.7% jobs growth from the 17.5 million workers attributed to the bioeconomy by EU JRC researchers for 2017 – half a percent per year.[6] This is actually a very modest promise, and it is further weakened by the reference to 'industry estimates'. Whether this growth promise actually holds any value in social terms is thus itself a matter for critical observation.

As the very short account of the evidence presented by Ronzon et al. (2020) and Bringezu et al. (2020) shows, assessing the state and prospects of the European bioeconomy empirically, even within the narrow understanding of value and the meagre criteria of employment and revenue, is a sobering exercise. Or, as Mittra and Zoukas (2020: 16; cf. also Petersen and Krisjansen, 2015) describe the reality check effected by such studies: 'If we take some of these crude economic metrics at face value, they suggest that the supposed biotechnology revolution is not perhaps as revolutionary and profitable as has been assumed; instead being based on unfulfilled

6 The promise appears all the more unlikely considering that at the same time, agrarian economists are advocating large-scale intensification of agriculture in EU member states like Romania and Slovakia, which is likely to lead to severe declines in employment in those sectors (Liobikiene et al., 2020).

expectations driven by promissory discourses'. The economic accounts show the bio-based economy to be a very significant segment of the overall economy, but also demonstrate that there is very little dynamism and that the quantitative significance of the changes induced by the bioeconomy discourse is limited. As things stand, the bio-based economy in European industrialized societies is more prone to shrinking than to growing in the future. Moreover, the biotech R&D sectors are minuscule in terms of jobs and turnover, and totally inflated in stock markets. In short, there is little that justifies continuing to portray the bioeconomy in Europe as a growth sector. In a way, the look at the economic accounts ‚demystifies' the bioeconomy, by relegating the hyped, highly promise-laden biotechnology sector to a quantitatively marginal role, while highlighting the stable, but largely stagnant existence of a very broad spectrum of bio-based economic activities, for instance in the forest sector, that always have been and always will be a vital part of all economies.

b) Material processes II: Resource and energy flows

The bioeconomy depends on the use of natural renewable bio-based resources from plants, animals and microorganisms, grown in fields, forests and waters. The analysis of these biophysical flows, or the social metabolism, that makes up the material substrate of the economy (Behrens et al., 2007; Bringezu et al., 2020; Haas et al., 2015; Jander et al., 2020; Lewandowski, 2015), is even more complex than the accounting of economic metrics discussed above. It has emerged as a field of study in its own right only recently, and unified evaluative frameworks at national and EU level are only gradually emerging (Egenolf and Bringezu, 2019; Robert et al., 2020). As the first comprehensive accounts of the biophysical structure, composition and dynamics of the bioeconomy are now gradually coming out, it is becoming evident that they pose another reality check to the promise of bioeconomic growth, namely in making it appear questionable that such growth to any significant extent is actually possible at all based on the metabolic reality (Giampietro, 2019; Giampietro and Funtowicz, 2020).

Looking again at the case of Germany through the lens of the monitoring report by Bringezu et al. (2020), which for the first time provides this sort of systematic account for this dimension. It reports that 185 million tons of biomass were domestically produced in Germany in 2015, and that Germany was a net-importer of biological materials and resources, with imports exceeding exports by 7 million tons, or 3.8% of domestic production (ibid.: 9). Almost half of the total biomass used (89 million tons) was grain for animal feed – more than four times as much as the food produced for humans (ibid.: 19). The bio-based economy as a whole is found to account for between 9% and 13% of Germany's greenhouse gas emissions – a higher share than that of GDP. The bioeconomy's emissions had risen significantly since 2000 due to increased bioenergy production, but are expected to remain largely constant until 2030 (ibid.: 95-6).

What is significant in terms of the possible growth potentials of the bioeconomy is that it is hard to see from the report from whence these should materialize. The authors do identify a certain amount of side and waste streams that may be economically used in the future – something in the range between 14 and 49 million tons a year (ibid.: 36) – but specify that most of this is made up of materials like straw, manure or mowed grass that have a very low energetic content. Also, both extending domestic cropland and further increasing biomass imports hardly appear as options. Biofuels, too, are no longer considered a sector that can grow in future, as exclusive usage of cropland for cultivation of energy crops is now ruled out and there is only limited potential for 'advanced biofuels' from waste streams, as the latter are expected to be needed for material rather than energetic utilization when substituting for fossil resources e.g. in the chemical industry. The bottom line of these numbers is that there does seem to be scope for mobilizing some amount of extra biomass from sources not yet fully used, as well as for making biomass that is currently simply burned amenable to cascading uses (i.e. to material utilization in some kind of product before that product is eventually discarded and burned. Considering the enormous scale of the challenge that lies in finding bio-based substitutes for all those uses of fossil materials that are currently common practice and that society cannot or will not discontinue, it is hard to see how this might in any way amount to overall economic growth, rather than at best to a sectoral expansion that will only be able to cover for a moderate part of what affluent societies will have to forfeit in fossil resource use.

Crucially, however, the report also raises a number of issues that become particularly problematic concerning their implications not only for long-term sustainability of prevailing modes of living, but also for questions of global justice. A central finding is that the biotic material footprint of the German economy *significantly exceeds* the capacity for biomass production that is domestically available (ibid.: 10). In particular, the agrarian footprint of German domestic consumption (51 million ha) is about three times the amount of agrarian land that exists in Germany (17 million ha) (ibid.: 85). This means that the mode of living prevalent in Germany is dependent on high net imports of land – as well as of CO_2 emissions (ibid.: 96-7) –, making it structurally unsustainable and implying that it cannot be generalized globally. This raises far-reaching questions concerning inequality and justice.

These numbers seem to us to provide significant support for the conclusion that ensuring both environmental sustainability and social justice on a global level will require substantially altering both the current forms of usage of biomass – consider the staggeringly high share of cultivated crops fed to animals to produce meat – as well as the global distributional patterns of its production and consumption. This in turn implies, as advocates of environmental justice and degrowth have long argued, that the primary pathway toward a sustainable and just supply of food

and other necessities of life for everybody worldwide would be changes in the mode of production and living of affluent countries, rather than hoped-for future technological innovations to further improve productivity.

Of course, this proposition is not uncontested. Another purported solution for overcoming the challenges regarding emissions and available land area for a future bioeconomy is the concept of **circular bioeconomy,** a currently fashionable answer for how to ensure 'resource-efficient biomass use' (Stegmann et al., 2020) and 'move our societies beyond the limits to growth' (Leipold and Petit-Boix, 2018: 1125). The circular economy is one of the main cornerstones of the European Green Deal (European Commission, 2019: 7–9; Simon, 2019). Among its core principles are cascading use of resources, recycling, efficiency and waste management, combined into a policy imaginary that enables a renewal of the promise of reconciling growth and sustainability. This notion is fundamentally challenged as a 'policy legend' by Giampietro and Funtowicz (2020; see also Giampietro, 2019), who argue that the concept itself contains a 'logical contradiction' by at the same time acknowledging the dependence of any economy on nature and promoting a 'business model guaranteeing a full decoupling of the economy from natural resources' as the solution (Giampietro and Funtowicz, 2020: 64). Counter to such 'economics of technological promises' (Levidow et al. 2019), they reject the circular economy along with any other vision promising 'green economic growth', instead calling for 'a post-growth caring economy' is the only realistic solution (Giampietro and Funtowicz, 2020: 70). The account of the German bioeconomy given by Bringezu et al. may be seen as part of the process of scaling down expectations needed for wealthy societies to come to terms with this insight – it renders cornucopian visions increasingly less credible (although readings detecting the possibility of 'circular growth' in their findings retain some plausibility). The further bioeconomy research advances into these foundational dimensions of the bioeconomy, the more the specter of its denied ancestor Georgescu-Roegen seems to return (Vivien et al. 2019). It is clear that the fossil sector will need to be discontinued, but it is hardly imaginable that the bio-based sectors could provide substitute resources at anything like a comparable scale (Krausmann and Fischer-Kowalski, 2010) – especially when considering that the bioeconomy itself will need to be thoroughly transformed to be able to function in a sustainable, post-fossil way (Vivien et al. 2019; Giampietro 2019; D'Amato et al., 2017).

The biophysical processes discussed here are also addressed by Hausknost et al. (2017) as a third level of analysis (see figure 2): By modelling three scenarios of a low-carbon bioeconomy for their case – Austria – and locating them in terms of their respective reliance on technology and (non-)growth, they match the 'techno-political options-space' of the strategies and stakeholder perceptions to the 'biophysical option-space of society' as a frame of reference for their modelling outcomes (ibid.: 14-17). The core reality check derived from this exercise, which is quite in line

with the claims of Giampietro and others as well as with the more critical readings the German bioeconomy monitoring report allows, is that the 'Milky Way' of the first two levels, and in particular the visions of the official bioeconomy strategies, by far miss the mark of biophysical reality. A huge gap exists between the officially promoted narratives of the bioeconomy and the possible realities indicated by system modelling procedures. None of the models indicated that trajectories anywhere near the 'sustainable capital' quadrant – or, for that matter, an 'eco-growth' scenario, were biophysically feasible: 'all viable options for a low-carbon bioeconomy in Austria are necessarily tied to a rather substantial politics of sufficiency, without which the limited biogenic resources will not suffice to keep a bioeconomy going' (ibid.: 16).

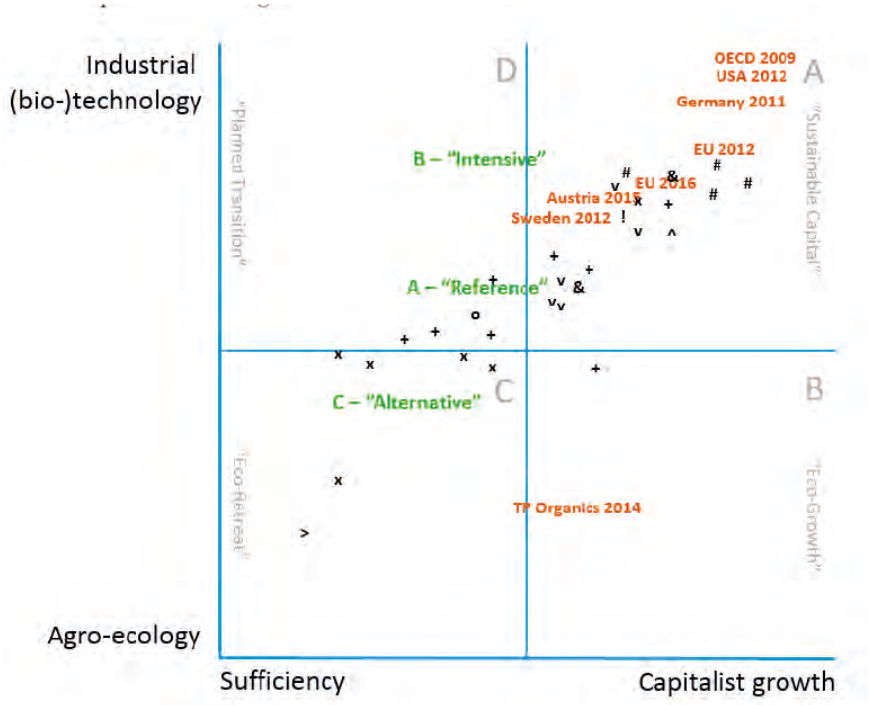

Figure 2: 'Option space' of the bioeconomy including all levels of analysis (Hausknost et al. 2017: 16).

4. Bioeconomy as a societal transformation: Mentalities, conflicts, social practices

As we have demonstrated, the promises of technology-driven economic growth advanced by proponents of the bioeconomy have been the subject of intense contestation and serious challenges at all of the three levels of analysis distinguished by Hausknost et al. (2017). Rather than a technological magic bullet holding the

key to solving many of mankind's vital problems and opening the door to limitless further increases in wealth and well-being, the bioeconomy seems to be shrinking to size: It increasingly appears as one piece in the puzzle of larger societal, rather than merely economic and technological, solutions to the challenges of combating climate disaster, preserving biodiversity, and ensuring justice and equality on a global level. Moreover, it is becoming increasingly evident that these concerns cannot be validly addressed and legitimately catered to by technoscientific 'innovation' alone, as the technological determinism of promissory bioeconomy discourse would have it. Solving 'problems' and improving people's lot, it turns out, is a thoroughly political issue, which societies considering themselves 'democratic' cannot, at peril of losing legitimacy, primarily assign to the market and to companies' purported superior innovative capacities. The broader post-fossil transformation that a multiply humbled, 'reality-checked' bioeconomy will be but a part of must be both socially just and environmentally sustainable on a global level if it is to succeed, and the criteria for justice and sustainability cannot be imposed by scientists and politicians (or even by some seemingly unavoidable technological fate), but need to be the matter of open and inclusive societal debate and political contestation. The strength of the analytical approach proposed by Hausknost et al. (2017) is that it foregrounds the existence of alternatives in a multidimensional 'option space' and the processes of contestation as well as the contradictions between ideas and realities. As a way to proceed for sociological inquiry into the state and perspectives of bioeconomic, post-fossil change, we therefore propose to build on this conception, but go one step further and apply the analytic to the level of the population as a whole.

Ultimately, the prospects for the kind of far-reaching transformation that is gradually being recognized as necessary as a consequence of the different reality checks launched toward the bioeconomy depend on the balance of power in society. The shape of future post-fossil economies is not a matter of policymakers 'understanding' and acting in line with some definite scientific truth, but a crucial issue for democratic deliberation and transformative struggles for visions of a just and sustainable future that must be compatible with biophysical reality, but also established as achievable and desirable in processes of political contestation and experienced changes in societal practice. The language of ‚stakeholders' that pervades the bioeconomy discourse sidelines the fact that the question of societies' future resource base knows no 'non-stakeholders' – it is a political question of the utmost importance for the future of society as a whole, the answers to which will be highly consequential for everybody, including future generations.

From 'acceptance' to mentalities

So far, however, this level of broader societal involvement is mainly addressed in so-called 'acceptance research', which tends to narrow down the role of the public to that of consumers and the involvement of citizens to a matter of passive consumer or electoral choice. Rather than conceiving of people as social and political agents actively involved in shaping the transformation, the vision underlying such research tends to depoliticize the role of citizens, reducing them to 'rule takers' that may choose between different ready-made products or policy options offered to them by companies and political parties. Typically, 'acceptance' studies approach the people interviewed in focus groups, 'Q methodology' exercises or surveys from this angle, trying to gauge factors that foster or inhibit openness to the purchase and consumption of bio-based products among the population (Hempel et al., 2019a, 2019b; Lynch et al., 2017; Rudolph, 2018; Sijtsema et al., 2016) or assessing the degree to which contemporary scientific and technological developments are seen as desirable (ZIRIUS, 2020). One example is the study by Hempel et al. (Hempel et al., 2019a, 2019b), which combines all three of the methods mentioned. They find a high degree of heterogeneity regarding people's opinions about bioeconomy, techno-political preferences and environmentally relevant habits and practices of their respondents. Based on this, the authors make a distinction between three groups holding different views on the bioeconomy, called 'sufficiency and close relation to nature', 'technological progress' and 'not at all costs' (Hempel et al., 2019: 45). From the differences in these groups' opinions regarding the role of politics, biotechnology, circular economy and related issues, they conclude that different forms of political communication are necessary and that adequate solutions should be offered to address the differing expectations and gain the acceptance of the respective groups. Like many other studies in this tradition, they also diagnose a lack of information and knowledge among the population, which they consider a hindrance to forming a more informed public opinion about the bioeconomy as such (ibid.: 46). They plead for more dialogue and open communication regarding potential risks and limits of the bioeconomy in order to overcome the 'knowledge gap' and gain acceptance for bioeconomy and transition processes. They also find the role of personal practices and changes in consumption behaviour (e.g. meat consumption) as well as fears of rising prices for e.g. energy consumption to be particularly controversial subjects that should be politically addressed in adequate ways, as mere pledges for reduction and sufficiency might be regarded as paternalism (ibid.: 47). An interesting finding is that many of the respondents drew a false connection between the term 'bioeconomy' and mostly positively connoted concepts of organic farming and food production (probably aided by the fact that organic products are typically labelled as 'bio' in German) (ibid.: 48) – a result that, probably unintentionally, lends supports to the argument made by Vivien et al. (2019) about the 'hijacking of the bioeconomy'. This study provides a typical example of how acceptance research tends to view

reservations expressed towards the bioeconomy not as an expression of actual, serious objection to the products, technologies or policies at hand – or even to the assumption that any kind of transformation is necessary at all –, but rather as exposing 'problems of acceptance' of something that researchers and politicians already know with certainty to be necessary, which need to be overcome by means of marketing, communication and education, or by technological innovation.

Beyond such rather instrumentally oriented acceptance research, social scientific work on the different socially specific ways of perceiving, evaluating and practically contributing to or counteracting processes of change toward bio-based and post-fossil ways of producing and living, as well as on the forms of conflict and contestation that evolve around this is scant. Most immediately relevant are studies on socio-ecological inequalities and conflicts around local manifestations of the bioeconomy, mostly in the Global South, such as the case studies produced by the junior research group *BioInequalities,* that give rich accounts of what the agro-industrial production systems that 'bioeconomy' stands for in those countries cause for inequalities of working conditions, income and social security or workers' and residents' health, as well as of the global dependencies and power relations these situations are embedded in (Backhouse and Lehmann, 2019; Puder, 2019; Tittor and Backhouse, 2019; Tittor and Toledo López, 2020). What these qualitative studies show is how reservations, opposition and open resistance against economic practices and the use of technologies promoted under the rubrum of the bioeconomy are not expressions of irrational aversions, but the product of the collective social experience of communities that directly experience and engage with the consequences of 'bioeconomic' change in their everyday lives. Acknowledging that bioeconomic transitions are part of broader post-fossil transformations of course opens the door to situate this specific research in the context of broader efforts to understand the dynamics of contestation and struggle that unfold around a multitude of dimensions and local instances of such transformative processes – or indeed, of communities actively calling for them against the interests of businesses and governments[7]. What such work renders very clear is that in many cases, it is actually affected citizens and local grassroots movements that advocate the post-fossil, sustainability-oriented transformation that bioeconomy strategies promise – against the organized power and entrenched interests of the companies often portrayed as its key actors.

In affluent European societies, such open contestation and struggles has so far mostly remained the exception rather than the norm. Yet here too, the different ways people perceive and practically engage with manifestations of 'the bioeconomy' are not a matter of individual psychology to be resolved or 'managed' by educational

7 See, for example, the impressive range of examples collected by the EJOLT project at https://ejatlas.org/.

campaigning, but expressions of embodied collective experience that need to be understood as position-takings in the ongoing conflict around the future trajectory of European societies. Social and political tensions around the issue of post-fossil transformations, for example in the field of energy transitions, are brewing (Eversberg, 2020c), and at times escalating (Eichenauer, 2018; Eichenauer et al., 2018; Neukirch, 2018, 2016; Weber and Cabras, 2017).

Sociological research that aims at a fuller understanding of the dynamics of contestation around the bioeconomy as part of larger conflicts surrounding social-ecological transformation, we suggest, needs to more systematically take into account these looming and mounting tensions between the mentalities and habitual patterns of practice of different social groups, which tend to remain 'under the radar' of analyses focused on policies or the direct involvement of organized 'stakeholders', but that are crucially important for the prospects of such transformation within democratic societies. Here too, the 'option space' proposed by Hausknost et al. provides a helpful starting point. Where in the option space are the ideas shared by majorities today, and how does this relate to the stakeholder constellations and the powerful interests mapped in the work of Hausknost et al. and others? It would be a mere scholastic exercise to try to determine what social groups or parts of the population are 'for' or 'against the bioeconomy' – yet adding the mentalities of the broader population as a fourth level of analysis and mapping out how the stances of different social groups relate in the two-dimensional space can offer an idea of *what visions* of 'bioeconomy' are seen as desirable or undesirable in different sectors of the populace, and of how this constellation relates to those on the three levels discussed by Hausknost et al. (2017) themselves.

How people cognitively, affectively and practically relate to specific issues and challenges such as those posed by the concepts and practices associated with the bioeconomy is not a matter of spontaneous choice in specific situations or determined by narrowly defined 'preferences' that can be separated from their views, beliefs and habits with respect to other matters. Rather, from the perspective proposed here, opinions voiced on and actions taken toward those concepts and practices are expressions of incorporated dispositions, or patterns of perception, evaluation and action that are acquired through biographical experience and, taken together, form the overall structure of what we, by reference to a long tradition in German sociology (Geiger, 1972; Vester et al., 2001), call *mentalities*, but might equally well describe in Bourdieu's (Bourdieu, 1990, 1984) terms as *habitus*. As habits of seeing, feeling and acting acquired during lived experience under certain socially typical conditions of existence, mentalities render people capable of creative, yet structured verbal and practical responses to novel, unfamiliar questions and situations, by applying a repertoire of habitual tactics acquired in the course of previous experience. What provides orientation to actors and structures the regularities observed in the social world is the *relationality* of those dispositions and

the tactics they generate – without conscious reflection, people are immediately aware even in contexts completely new to them what and who they are intuitively close to and what they feel distant from; similar dispositions are sought and aligned with, conflicting ones shunned and opposed. Understanding the tensions and conflicts that arise around societal transformations such as the ones at hand in the bioeconomy debate thus requires what the relevant mutually conflicting perceptions, feelings and practices in the respective field are, how they are related to the different socioeconomic contexts for which they are typical, and how the differences and tensions play out in social interaction.

From bioeconomic to socio-ecological 'option space'

The model offered by Hausknost et al. (2017), with its two intersecting dimensions, conceived as continua along which such relational tensions can be assumed to exist, lends itself particularly well to this perspective. In the remainder of this section, we want to demonstrate for the case of Germany how this fourth level of analysis can be conceived of, by drawing on analyses conducted using the dataset of the survey *Environmental Consciousness in Germany 2018*, the latest instalment of a biannual survey commissioned by the Federal Ministry of the Environment (BMU) and the Federal Environmental Agency (UBA) (Rubik et al., 2019). The representative survey with just over 2000 respondents includes a range of questions concerning socio-ecological attitudes, socio-environmentally relevant practices, and sociodemographic data, as well as a number of items concerning respondents' stances and practices regarding questions of energy and the transformation of the energy system in Germany (*Energiewende*).

Based on these assumptions, we used the responses to the complete set of 36 statements on socio-ecologically relevant attitudes that survey participants were asked to rate to construct a typology of eleven different kinds of socio-ecological mentality, which we found could be grouped into three broad 'camps':[8]

1. An *ecosocial camp*, comprising around a third of the population, which encompasses social groups characterized by clearly pro-ecological, growth-skeptical and pro-transformative dispositions. People in this camp tend to identify with far-reaching ideas of a post-fossil transformation not only of the economy, but also of the prevailing mode of living.
2. A *liberal-escalatory camp* of around 40 %, holding mostly contented and optimistic views, consumerist attitudes and positive stances on economic

8 For a detailed description of the procedures and a comprehensive account of the results, see Eversberg (2020c). For a comparable exercise using the dataset of the same survey's 2016 edition, see Eversberg (2020a, 2020b).

growth. Although the dominant self-image is one of openness to progress and change, ideas about transformations that could impact on one's personal mode of living are eyed with reluctance. Prospects of changes in the material and institutional makeup of European societies are only seen as acceptable if they promise to come with ongoing economic growth and increasing material prosperity, making this a key constituency for narratives of 'green growth' and the promissory discourses around the bioeconomy.

3. And an *authoritarian-fossilist camp* that comprises up to a quarter of the population. The mentalities of this camp are dominated by feelings of loss and the perception of omnipresent threats as well as by fervent opposition to any kind of change. The ideal these groups aspire to seems to be the unconditional preservation of the status quo, or even a return to outdated economic and social models of the 20th century, which is of course irreconcilable with most ideas of a bio-based transition. None of the kinds of societal vision offered by the bioeconomy discourse are therefore likely to find much support in this camp.

As these very short descriptions suggest, the comprehensive patterns of mentalities that this style of analysis allows us to discern provide an overarching logic according to which we can formulate at least reasoned expectations about how people will evaluate and position themselves toward different ideas about future societal transformation as discussed in the bioeconomy debate, even though questions specifically addressing the bioeconomy were not asked in the survey.[9] The dataset does, however, provide a number of items on respondents' evaluations of economic growth as well as of technology, which we used to construct indices for their positions on both issues, allowing us to provisionally locate individuals and groups of respondents on the two axes of Hausknost et al.'s (2017) option space.[10] The fact

9 A large set of questions concerning agriculture was asked in a second wave of the survey, but to a different group of respondents. Although here, too, the bioeconomy was not explicitly mentioned, many of those items could have provided more specific indications as to respondents' views and evaluations of many issues more concretely associated with the bioeconomy. However, since that second wave did not contain many of the items on attitudes and practices that our analyses are based on, that data could not be used. In a survey planned for 2021 as part of the work of our own group, we aim to remedy this problem and focus the whole set of questions around people's perceptions, evaluations and practices in relation to the bio-based economy within the broader context of post-fossil transformations. This will then also allow us to come up with a more focused and robust representation of the relations sketched out here.

10 The index for belief in or skepticism toward growth was constructed using the statements "We need more economic growth in the future, even if it is at the expense of the environment"; "There are natural limits to growth that our industrialized world has long run up against"; "We need to find ways to live well independently of economic growth"; "For the benefit of the environment we should all

that we can only determine stances on growth and technology in a very generic sense, without specific reference to *bio*tech and *bio*economy is certainly a limitation to be kept in mind when interpreting the results – but since among the general population, we cannot assume that questions of bioeconomy are seen and evaluated in isolation from other dimensions of societal change, they provide a reasonably good proxy to depart from for an initial analysis.

Three 'camps' along the 'milky way'

Figure 3 indicates the mean positions of the different types of mentalities found in our cluster analyses,[11] as well of the three broad 'camps' they were grouped into, within the space thus constructed. What is immediately evident is that the same 'milky way'-like structure that Hausknost et al. (2017) found for the visions expressed in official bioeconomy strategies and by experts and stakeholders replicates itself in a very similar way when assessing the corresponding mentalities found among the broader population. This may be taken to indicate that the constellation within the more narrowly defined bioeconomy debate as mapped in said paper, with its tension between orientations supporting high-tech, growth-focused models of 'sustainable capital' on the one and critics advocating sufficiency- and agroecology-based ideas of 'eco-retreat' on the other hand, with moderate intermediary stances mediating between the extremes, reflects a more general structuring opposition between mutually opposed socio-ecological mentalities, or in other words: a broader line of socio-ecological conflict, among the population at large.

be prepared to reduce our standard of living" and "I trust in the forces of the free market. The market will ensure that what needs to change will change". For the index for belief in technology, we used the following items: "In agriculture, less artificial fertilizer and chemical toxins should be used"; "When in doubt, what should be the priority: Environmental protection or technological progress?"; "I use digital technology to control devices in my household" and "I am keen to always have the newest technology". All responses were recoded to values between 0 and 1 and their polarity reversed where appropriate.

11 The 30 subcategories included here are displayed merely to indicate the overall distribution and the degree of spread along both axes within each of the camps. Characterisations for all of them can obviously not be provided here, but are available in Eversberg (2020a). The signs marking their mean positions indicate which of the three cluster analyses each of them originate from, while the colors show which camp they were assigned to.

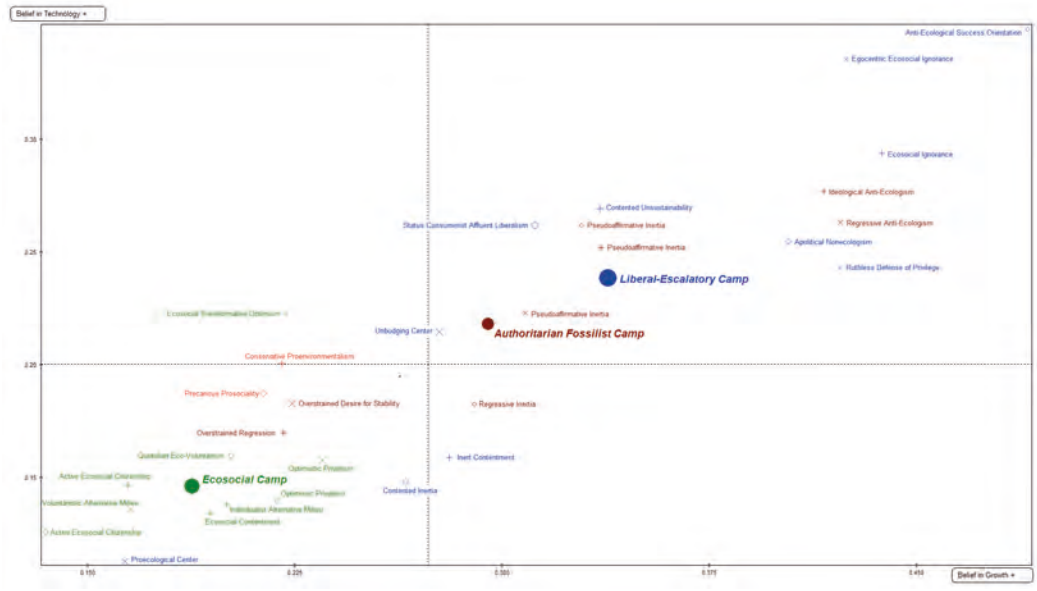

Figure 3: The socioecological ‚option space' in the mentalities of the German population – 30 subgroups and three broad camps, centers of gravity

Not only to bioeconomy experts, but also to most citizens, broadly critical or broadly positive stances on both technology and economic growth are closely connected, rather than mutually independent. The diagonal 'milky way' thus reveals a very basic disagreement of orientations concerning the approach to dealing with socio-ecological challenges and the ways that societal nature relations as well as humans' capacities for changing those relations are conceived of. The tension manifests between those sectors and forces in society believing in imminent and unavoidable technological innovation as the driver of change and solution to all problems, while perceiving established modes of living, power relations and economic arrangements as immutable, and those advocating *social* innovation, democratic political decision-making on the futures socially desired and thorough changes to those relations while avoiding the escalating risks associated with unchecked, market-driven introduction of technologies. In other words, the basic conflict is one between an economistic, technoscientifically centered and an ecosocial political vision of societal change.[12] What is interesting in his context is that the locations of the different subcategories of both the *authoritarian-fossilist* and the *liberal-escalatory* camp spread out far along the

12 Hausknost et al. (2017) seem to be concerned that the effectively one-dimensional structure of actual discourse within the option space may also be a problem for serious political debate around the question what kind of socially embedded use of biotechnology may be acceptable or necessary even for a society that consciously embarks on a democratically planned sufficiency-oriented transformation. This concern seems similarly valid at the level of the broader population.

diagonal 'milky way', while those of the *ecosocial* camp appear rather tightly bundled in the lower left. This points to a greater degree of coherence and commonality among the different mentalities making up that camp compared to the other two: the *ecosocial* camp is very clearly and unanimously positioned in the conflict, while the others seem more divided.

It should be noted that the axes of the coordinate system, each drawn to separate one half of the respondents from the other, intersect at very low values,[13] indicating that the majority of respondents is quite critical of economic growth and even more unenthusiastic about technology.[14] One might thus wonder why a thorough socio-ecological transformation toward sufficiency and simplicity has not long occurred, given that it seems to be the will of a significant majority. One reason for the lack thereof is certainly that such verbal support often ends in the face of impending actual changes to one's accustomed practices, another, arguably more important one is that the most economically powerful and socially influential groups among the survey's participants are much more likely to be found in the *liberal-escalatory* camp and at the upper right end of the spectrum. Not only the critical literature on the bioeconomy (Birch, 2017a, 2006; Birch and Tyfield, 2013; Levidow et al., 2019) suggests that the organized interests, economic power and political influence of capital in the bioeconomy as well as in almost all other sectors, which simply don't map here, even more heavily skew the power balance in that direction.

Another parallel with the space of stakeholder positions as mapped out by Hausknost et al. is that there are hardly any types of mentality located in the upper left and lower right quadrants. The only subcategory diverging to the upper left is a cluster called 'Ecosocial transformative optimism' – a mentality mostly found among very young and highly educated respondents with a strong penchant for activism, which might be seen as the ideal typical mindset of the 'Fridays for Future' protests. Should this be

13 Both indices are scaled to a range between 0 and 1. A respondent fully rejecting economic growth as well as technology in all respects will thus score 0 on both axes, one fully affirming both will score 1 on each, marking the two extremes of the diagonal. The median point of the horizontal at just below 0.3 indicates that the average respondent moderately rejected each statement that affirmed economic growth.

14 This is consistent with previous research showing that pro-ecological statements tend to be overwhelmingly affirmed in such surveys. It should not be taken as an indication that most Germans are fervent ecologists, but has a lot to do with social desirability effects. In the context of the relational approach applied here, however, it is of limited consequence for the further interpretation of results, since what is interesting here is not the 'face value' of the opinions expressed, but the mutual differences among the patterns of these opinions found among the respondents: What's relevant is not so much that there is a broad tendency to agree with certain ideas, but how the relations between those agreeing most and those agreeing least play out, and how they correlate with differences in socio-demographic characteristics and patterns of practices.

more than a contingent result,[15] finding this group in the quadrant that Hausknost et al. 2017 named 'planned transitions' does seem to fit in with the calls of the new climate movement for strong state action to tackle climate disaster and a much more political and planned mode of dealing with the crisis. If anything can be said about the bottom right sector, it seems to be predominantly a domain of mentalities we call 'inert' – attitudinal patterns that include an habitual, commonsensical affirmation of growth to some degree, but combined with an equally habitualized distance from technology and the kinds of adaptive pressures associated with it. Not much seems to signal the existence of a constituency for the kind of 'Eco-Growth' option that Hausknost et al. associate with this quadrant.

It seems apparent from these few details that the names assigned to the quadrants of the *bioeconomic* option space do not quite fit the orientations within the *socio-ecological* option space mapped out here. Considering the different kinds of imaginary of the desired societal trajectory associated with each, we suggest to call the growth- and techno-optimist upper right sector '**technoeconomic advance**', the opposed lower left '**less is more**', the lower right '**growth by whatever means**' and the upper left '**sufficient progress**'.

One more consequence of shifting the level of analysis to the general population warrants noting: Once the focus is widened beyond the immediate actors and experts of the bioeconomy, 'fossilist' attitudes rejecting any kind of turn toward a more strongly bio-based economy are pervasive – concentrating not on the fringes, but in the center of the space. At first sight it might be surprising to some to find the *authoritarian fossilist* camp in the center, and thus relatively close to its mutually perceived antipode, the *ecosocial* camp, but on closer inspection this is not without reason, as the specific differences constituting the two correlated dimensions of this space play out in a way that the *ecosocial* and the *liberal-escalatory* camps appear as opposing poles. Clearly, it requires a greater technological optimism to believe in bio-based solutions to mounting problems than to insist on coal- and oil-based business as usual regardless of the environmental consequences.[16]

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15 Given the questions used to construct the index for technological optimism, this cluster's location on the vertical may simply be an expression of a generationally specific greater personal affinity for digital technologies. More detailed data is needed to substantiate this.

16 In a certain sense, the 'sandwiched' position of fossilism in between the other two camp might also be seen to reflect the fact that even in bioeconomy-related discourse, the boundaries between advocacy for a fully bio-based economy and one still burning fossil fuels to some extent while technologically mediating the climatic impact are not always quite clear. After all, the field of 'carbon capture and usage', not least as a basic material to be metabolized by microorganisms, has recently advanced to become a relevant subsector of the promissory life sciences. The highly entropic nature of CO2 renders the prospects of its actual economically reasonable use and processing without phenomenal inputs of external energy extremely doubtful, and reality checks of the 'resource and energy flows' type seem imminent, but the material for the promissory machine of bioeconomic discourse to turn into a resource for further growth is there. In this sense, the spatial constellation may also be taken to illustrate the different, diametrically opposed directions in which both camps imagine the 'post-' in post-fossilism: As driving the fossilist logic of techno-driven advance beyond itself toward a 'more-fossil-than-fossil'

In terms of how the interrelations of the different levels of the option space are to be conceived of theoretically, it can be concluded that the *bioeconomic* option space should not be thought of as depicting a subsector of this greater *socioecological* option space (for instance, a zoomed-in subsection located in the lower left), but as a relatively autonomous, yet homologous *field* (Bourdieu, 1996a, 1996b; Martin, 2003), in which debates, political contestation and decision-making around possible trajectories of bio-based transformations are taking place among a limited set of actors and according to its own logic, but not in total disconnection from the relations of power prevailing in the broader political field as well as among the population as a whole. Within this field, positions all across the societal spectrum from the most growth- and techno-pessimist to the most optimist mentalities on both counts are represented. The common belief that unites all actors in that field (or, in Bourdieu's terms, the *illusio*) is that some kind of bio-based transformation is desirable or necessary. This excludes from the option space of the bioeconomic field the fossilist and anti-transformative 'business as usual' options openly or tacitly supported by most of the *authoritarian fossilist* and probably also by parts of the *liberal-escalatory* camp.

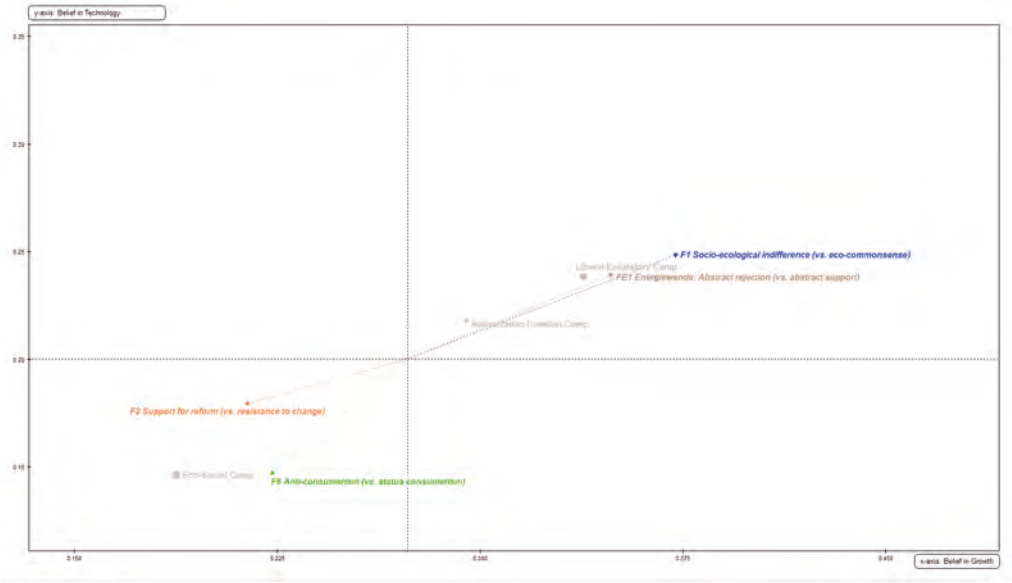

Figure 4: The socioecological ‚option space' in the mentalities of the German population – four significantly correlated factors of socio-ecological attitudes

Not surprisingly, the diagonal ‚milky way' along which the ideal typical mentalities distinguished in our analysis are distributed is also closely correlated with a number of the dimensions of socio-ecological attitudes that the types were constructed

future in the case of the liberal-escalatory, as reversing it toward a both material and logical de-fossilization in the case of the ecosocial camp.

from: Rejection of or indifference to ecosocial ideas, resistance to societal change and consumerist attitudes concentrate in the upper right, while pro-ecological dispositions, support for ecosocial reform and anti-consumerism increase toward the bottom left. What is interesting with regard to the issues of societal transformation at hand is that there is an equally strong correlation with an additional factor, based on items that were not used in constructing the types or the axes displayed here, that captures respondents stances' on the post-fossil transformation of the energy system (*Energiewende*) as an abstract concept. This implies that belief in both growth and technology is not typically associated with support, but rather with principled rejection of the kinds of change that come with attempts to rebuild societal infrastructures on a post-fossil, sustainable basis.

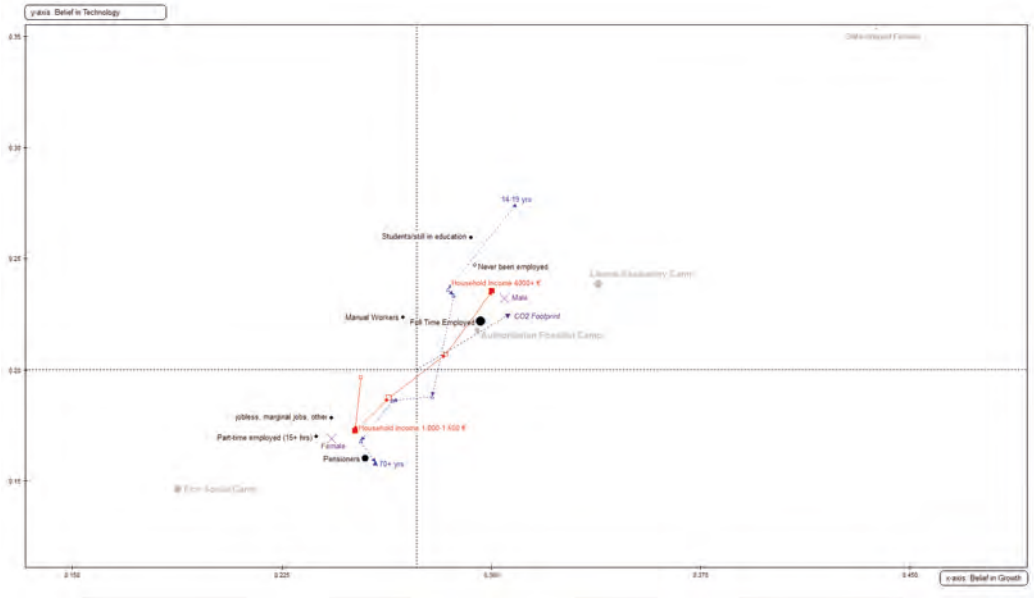

Figure 5: The socioecological ‚option space' in the mentalities of the German population – significant correlations with selected sociodemographic attributes

Figure 5 gives some indications as to how support for the different possible scenarios of post-fossil transformation, or opposition to any such transformation, is distributed among different socio-demographic categories. Again, significant differences play out almost exclusively along the diagonal from lower left to upper right. Options implying a departure from economic growth and an orientation toward low-tech or agro-ecological solutions thus seem to be more in line with the orientations of women, pensioners and older age groups (over 60), people in contingent employment situations or with no paid employment, and those with low household incomes between 1000 and 1500 €. At the other end of the spectrum, growth-oriented and technology-based trajectories are more often favoured among men, among the very

young[17] (and especially among those still in education) as well as those in full-time employment, and in high-income households.[18] Among the latter, however, nothing indicates that techno-optimist visions of a solar- and biotech-based post-fossilism play a greater role than mentalities that prioritise growth and technological progress regardless of the material base on which it may be achieved or of the ecological and social cost.[19]

17 Considering the recent wave of climate protest led predominantly by young people, this appears counterintuitive. One reason for this result is probably that young people are generally more open to new technologies than their elders, structurally shifting them upward (and older age groups downward) here. Another is that the young generation does seem split into highly pro-ecologically minded and highly indifferent factions (Eversberg, 2020a). In addition, one could argue that the survey was carried out before the start of the school strikes and the initiation of the Fridays for Future movement – hence, the massive mobilization and politicization of that age group had not yet started. We will need to wait for the 2020 version of the study in order to identify possible effects of the increasing politicization of the climate issue (not only) among the young generation.

18 What is especially striking, although not statistically significant, is that the professional category of self-employed farmers, which comprises only five respondents, constitutes an extreme outlier at the far pro-technological and growth-optimistic end. Given their very small number this may well be an artifact. But if, as Hausknost et al. suggest, there is a controversy within the field of agriculture between a 'sustainable capital' model of highly industrialized and biotech-based agriculture on the one and an organic 'eco-growth' option on the other hand, the five farmers in the sample seem very clearly in favor of the first, to the point of discounting the 'sustainable' aspect in favor of greater growth and profits. The self-employed farmers are also much more fossilist in orientation than any other occupational group or sociodemographic category.

19 To make clearer distinctions here, a third axis to the socio-ecological option space would be needed: one that represents the continuum between 'fossilist' attitudes aiming to preserve existing fossil-based modes of production and living even at the price of further escalating socio-ecological crises, and post-fossil mentalities affirming the necessity of a swift departure from coal, oil and gas. A provisional calculation of an index for (post-)fossilist attitudes suggests that third axis is again strongly correlated with the first two, and that the common sense among respondents decisively leans toward the post-fossil end of the spectrum. Men and the full-time employed again significantly lean toward fossilism, women and the precarious or out-of-work toward post-fossilism. Those under thirty years of age are also significantly more post-fossilist, while those between 30 and 40 are the most fossilist in orientation. As may be expected, the mentalities of the authoritarian-fossilist camp clearly tend toward a more strongly fossilist attitude, and those of the ecosocial camp are consistently post-fossilist. The liberal-escalatory camp, however, while leaning toward fossilism in its overall average, appears as split: while a number of subtypes here are among the most radically fossilist, the radically growth-skeptical proecological center as well as the contented-consumerist clusters yielded by all three analyses are significantly more post-fossilist than average. This split within the liberal-escalatory camp appears highly relevant to how the camps may realign in future conflicts around climate policy and de-fossilization. Further exploration of this third dimension will need to be postponed to future work. One question to discuss at the workshop could be whether we should use this dimension to substitute for the technology dimension altogether when further developing the paper, given the distortions caused by the way the latter is constructed.

In light of the overall constellation, it does not come as much of a surprise that the more optimistic orientations toward technology and economic growth are also significantly associated with a higher CO_2 footprint. This highlights another aspect of the underlying societal line of conflict: Hoping for tech-based solutions to ecological problems and a reconciliation between growth and environmental protection is typically a mental coping strategy of those whose resource- and emissions- intensive modes of living would most likely be strongly impacted by the more radical, agro-ecological and sufficiency-oriented concepts of a transformation. As the locations of the three 'camps' within the space as well as the distribution of average CO_2 footprints across the camps suggests – the mean calculated individually attributable footprint of people in the *liberal-escalatory* camp is two thirds of a ton higher than the overall mean of six tons, that of respondents in the *ecosocial* camp is more than half a ton below average, and the *authoritarian fossilist* camp lies in between – this 'hard', interest-based dimension of the conflict primarily plays out between the materially affluent and socially secure groups gathered in the *liberal-escalatory* camp and the more economically precarious and socially burdened segments of the *ecosocial* camp.

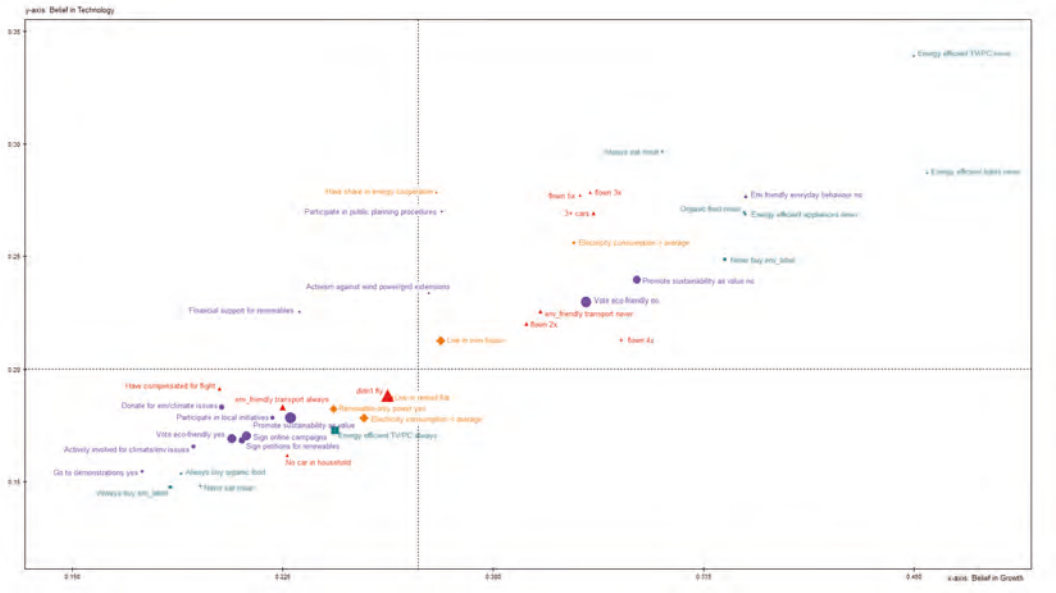

Figure 6: The socioecological ‚option space' in the mentalities of the German population – significant correlations with socioecologically relevant practices

Finally, figure 6 depicts a number of socio-ecologically relevant practices reported in the survey that are significantly associated with typical locations in the space. These, too, are mostly aligned along the diagonal. The pattern renders evident that the tension between ideas of transformation centered around sufficiency and social

adaptation and imaginaries of technology- and growth-based solutions not only correlates with inequalities of gender and socioeconomic status, but also maps onto clearly distinct patterns of everyday practice, or modes of living. As may be expected from the CO_2 footprints, people expressing more growth-critical and techno-skeptic attitudes are much more likely to engage in all kinds of resource-light and ecologically compatible activities, both of the intentional type (active involvement, ethical consumption) and of the kind more often imposed by material restrictions (no flights, no car, low electricity consumption). Conversely, the upper-right sector displays a concentration of particularly high-impact practices (frequent flights, driving, high meat consumption), explicit rejection of pro-ecological involvement, and consumer choices without consideration of the eco-social consequences. While there is not a single practice associated with above-average belief in growth, but less-than average trust in technology, there are a few points significantly diverging from the diagonal toward the upper left, i.e. that tend to be connected with ideas of 'advancing toward sufficiency'. All of these are related to the technical aspects of the ongoing energy transition: Financially supporting renewable energy projects, holding a share in an energy cooperative, participating in public planning procedures – and, perhaps surprisingly, engaging in activism against new wind turbines or power grid extensions. All of these are very rare practices reported by consistently less than 5% of respondents, indicating that there is a small community of people actively involved in shaping – or contesting – socio-ecological transformation on a practical, technological level, but also that this type of activism so far remains marginal and only weakly connected to the mainstream of the pro-ecologically minded parts of the population. At the same time, this might also imply that at least some of those currently opposing the concrete manifestations of the *Energiewende* in their mostly rural environments and often claiming environmentalist motives may actually be ready to accept even broader transformations in their local context *if* these are credibly part of a society-wide plan that fairly distributes burdens and benefits, especially between urban and rural areas.

Interim conclusions

From this analysis of people's active position-takings and emergent tensions within the socio-ecological option space of post-fossil transformation, we can take away at least three main insights:

- If and when it becomes increasingly evident that a transformation toward an economy that can do without fossil sources of materials and energy cannot be achieved by technical means alone, but will require significant adaptive efforts concerning the mode of production and living that most of the population is accustomed to, then the social forces that actively support it are most likely to come from the parts of the population adhering to a 'less is more' vision

(lower left of the space), and particularly the *ecosocial camp,* while resistance may be expected particularly from those still firmly attached to an imaginary of 'technoscientific advance' (upper right), i.e. certain segments of the *liberal-escalatory* as well as of the *authoritarian fossilist* camps (see figures 3 and 4).

- The relations displayed in Figure 5 provide at least some initial indications that the tension between different concepts and imaginaries of possible future socio-ecological trajectories is structured by several lines of social inequality: It is a gendered tension, a tension between ways of life centered around paid employment and ones on the fringes or outside the labor market, and a tension between the affluent and those in more precarious material situations.[20]
- What our analysis has demonstrated in a number of respects is that questions of inequality and justice along a whole number of intersecting dimensions are no less important for the chances of success of any bio-based and post-fossil transformation than the technicalities of how it is to be implemented (Backhouse and Tittor, 2019). This, however, requires that transformation is pursued as the result of a democratically negotiated, participatory and adaptive plan, rather than as the result of democratically unchecked market forces that cannot be held to account for equal democratic participation and a fair distribution of both gains and burdens. Inequality and injustice blocks transformation, and equal participation can only be achieved politically, not by leaving things to the market. In this respect, unilaterally innovation-centered visions of bioeconomic development that place all hope in startups and impending biotechnological breakthroughs are inherently at odds with the needs of affected citizens – both locally and in distant regions linked up by supply chains – for democratic participation and self-determination.

In general, the analysis presented here has shown that the ultimate one-dimensionality (i.e. the close correlation of views on growth and technology) of the maps of the discourse and the field of actors produced by Hausknost et al. (2017) also holds for the general population. This may be taken to indicate that the disagreements around questions of growth and technology that structure debates in the bioeconomic policy field are part of a larger, homologous conflict around the shape of future societal nature relations that lingers in society at large. What enters the picture at this level, however, is the role of persistently *fossilist* mentalities, practices and structures in that conflict. Fossilist orientations, which are effectively opposed to any type of bio-based economy at all, are off the radar in Hausknost et al.'s (ibid.) accounts, but continue to play an important role at the level of attitudes

20 The generational aspect that the graph seems to suggest should be viewed with care, however (see note 11).

and everyday practices of the general population. In our mapping, they are present through the way we have constructed the typology of mentalities.[21]

The center of the coordinate system in our graphs is not at a neutral position on technology and growth, but significantly skewed toward the skeptical side in both dimensions. This mirrors the findings from specifically bioeconomy-related survey research, which consistently diagnose overwhelming support for most goals and aspects of a bio-based economy (Hempel et al., 2019a; ZIRIUS, 2020). It could be taken to indicate that, as Chan et al. (2020) suggest, the values to motivate support for a broader ecosocial transformation are indeed present among large parts of the population, but what is needed are policies enabling them to act accordingly. Yet, this should also be viewed with caution, as it seems likely that the ostensible majorities for transformation in fact hide the more deep-seated, entrenched structures of unsustainability and persistent fossil patterns at the level of practices ('attitude-behaviour gap') as well as in the inner structure of contemporary subjectivities (Blühdorn et al., 2020). The relational approach we propose provides a holistic perspective from which to assess these incongruencies. It is also a tool for countering unwarranted optimism and achieving greater analytical depth, by casting aside the appearance of near-unanimous support for bioeconomic change and uncovering the persisting, and arguably escalating, tensions that only move into view when considering the overall structure of mentalities, their mutual differences and distances within an overall societal constellation, as well as the ways in which they are connected to resiliently fossilist practical modes of living.

21 The fact that some of the 'most fossilist' types appear in the center of the coordinate system suggests that a third dimension of analysis is required at this level, to allow a distinction between fossilist and post-fossilist mentalities and modes of living. If we introduce this, the structure of the tensions and conflicts around socio-ecological transformations will emerge even more clearly.

5. Conclusions: The empty promises of the bioeconomy

In this paper, it has been our intention to demonstrate that the promises of the bioeconomy – bringing economic prosperity to rural regions, raising employment, fostering sustainability, enabling food sovereignty, all by virtue of economic growth enabled by biotechnological innovation – have been thoroughly challenged on several levels as research on the bioeconomy in different disciplines has advanced. Using the three levels of analysis proposed by Hausknost et al. (2017) as a guideline, we have reconstructed how the different strands of research have come to conclusions that present a series of reality checks on those promises, progressively challenging their credibility and enforcing a moderation of recent official bioeconomy strategies.

At the level of *processes of representation*, researchers have found a large diversity of goals and aims pursued by governmental bioeconomy policies and demonstrated that beyond the initial appearance of the bioeconomy as driven by promissory techno-optimism alone, the visions associated with the concept and the degree of emphasis on growth as compared to other goals vary widely. The picture that emerges from these analyses is one of a contested field of debates ranging between two poles, with the dominant imaginary of 'sustainable capital' being countered by an opposing socio-ecological discourse centered around agro-ecology, sufficiency and post-growth ideas. Other, more critical work on the epistemological foundations and technoscientific bases of bioeconomic knowledge and value creation, however, has presented a reality check to that topology of the bioeconomy's discursive option space itself, by analyzing the structural, rather than politically contingent, dominance of the 'sustainable capital' vision as being rooted in the logic and mode of functioning of a financialized neo-liberal economy itself.

Work on the *political-institutional processes* around the bioeconomy has demonstrated that bioeconomy policies result from tough strategic battles, rather than from open and inclusive democratic deliberation. In these battles, it is ultimately the power resources that economic and political actors can deploy to promote their interests and strengthen their positions that decide over the outcome, and empirical analyses of these processes shows that there is a strong tendency for the power of business and governments to win out at the expense of socio-ecological concerns. Rather than solid scientific evidence for the validity of the promises of technological innovation, their proponents routinely win out due to their significantly greater endowment in economic, political, social, scientific and other capitals. Exposing this presents a reality check to the promises by allowing critical scrutiny of why they are actually made, and challenging unrealistic propositions on the grounds of the interests that their proponents have in making them, and leads to the conclusion that these promises are often more part of the resistance to, rather than a driving force of, the necessary transformations.

Research that investigates the *material processes* of the bioeconomy, in the double sense of its economic materiality as an ensemble of sectors and its biophysical materiality in terms of resource and energy flows, has amounted to significant reality checks in coming up with findings that enforce a more humble, sober view on the bioeconomy's asserted 'potentials'. The work on its economic materialities has done this by demonstrating the quantitative insignificance of the much-hyped biotech sectors, as well as the largely inert and stagnant nature of the primary bio-based economy as a whole, which exposes expectations of large-scale expansion within the coming years or decades as illusory. And in the biophysical dimension, the recently emerging comprehensive accounts reveal not only the unsustainable and globally unjust structure of the patterns of biomass use prevalent in affluent European countries, but also the very limited scope for potential future expansions of biomass production and use. Seeing that the bioeconomy will be hard pressed in coming decades to make up just for the most imminent of the losses of resource supply that result from the necessity to phase out the huge volume of fossil materials currently used, assuming it to present a vehicle of overall economic growth appears thoroughly misguided. Concepts of cascading use and partial circularity may help in substituting for hitherto fossil-based uses in some fields, but will not be able to fully make up for the losses. Resolving the disputes that arise and setting priorities for what societies consider essential, desirable or expendable will be a crucial political issue and must be made the subject of broad and inclusive democratic deliberation, rather than left to the market.

This last reality check highlights the need for a further broadening of the purview of research on the bioeconomy to include a fourth analytical level – that of the mentalities and social practices prevalent in society as a whole and the processes of contestation around the *if, why* and *how* of the coming socio-ecological transformations toward a post-fossil society, of which the question of the bioeconomy is but a part. The overall picture that emerges from the provisional analysis, based on German survey data from 2018, that we have presented on this level is quite clear: At the heart of the statistical relations on and between the layers of expressed attitudes, self-reported practices and sociodemographic characteristics, there is an overarching tension between a complex of ecosocial, pro-transformative attitudes, low-impact practices and active proecological envolvement associated with typically female and precarious social positions on the one and a nexus of growth- and techno-optimism, socio-ecological indifference, masculinity, full-time employment, affluence and persistently fossilist modes of living on the other hand. Given that the expressed ideas and the values endorsed by a large majority very clearly tend towards the former pole, while the distribution of wealth, economic power and influence over policy-making continues to privilege the visions associated with the latter in policy fields such as that of bioeconomy policy, ensuring democratic legitimacy for bio-based transformations first and foremost requires much broader, more open and inclusive debates and forms of bottom-up decision-making on what such transformations can and should be. Bioeconomic democracy would require the voices of the majority of people

who, quite in line with the reality checks from the other strands of research, support solutions based on sufficient adaptation of modes of living and a de-prioritisation of economic growth to be given adequate space, counter to the hegemony of 'green innovation' promises still maintained by powerful economic interests and elites. The reality check to that hegemony should be: There is a broadly shared common sense that a turnaround much more profound than 'green growth' is needed, and this should be taken as a sign of a widespread sense of reality, rather than dismissed as an expression of irrational fears or of 'acceptance problems' to be addressed by pedagogical means. As expressions of embodied collective experience they need to be understood and taken seriously as position-takings in the ongoing conflict around the future trajectory of European societies. The greater problem than the oft-assumed power of the narratives of growth and technological innovation seems to be the structural perseverance of the factually existing, deeply entrenched, unsustainable and globally unjust structures of a stagnant, outdated, business-dominated model of bioeconomy that itself remains dependent on fossil fuels and large-scale biomass imports. The broader post-fossil transformation that a multiply humbled, 'reality-checked' bioeconomy will be but a part of must be both socially just and environmentally sustainable on a global level if it is to succeed, and the criteria for justice and sustainability cannot be imposed by scientists and politicians (or even by some seemingly unavoidable technological fate), but need to be the matter of open and inclusive societal debate and political contestation.

This, of course, opens up a host of further questions for research: How do the structural tensions that we can identify from survey data materialize in specific forms of local contestation and struggle when and where 'bioeconomy' becomes a concrete practice? What hinders the emergence, and more so: the generalization, of concrete local bioeconomies that function in ways compatible with the biophysical option space? What political decisions and infrastructural as well as institutional changes will be necessary to enable such compatibility at larger spatial scales, and what has so far prevented the emergence of political majorities for such structural change? Social scientific research addressing these issues is only in its beginnings. Some projects funded by the German ministry of education and research (BMBF) have recently begun to make inroads into this field, including the case work on local processes and conflicts of the bioeconomy in different locations across the world pioneered by the BioInequalities group (Backhouse and Lehmann, 2019; Puder, 2019; Tittor and Toledo López, 2020), the case studies currently in progress in our own project (Pungas, 2019), and the work of the Food for Justice group of food sovereignty movements in Latin America and Europe (Motta and Meinicke, 2020; Teixeira and Motta, 2020). Important insights can also be expected from more regionally and locally oriented research on concrete projects and initiatives that aims to apply the 'stakeholder' perspective to the local level. Finally, the existing survey research on attitudes toward the bioeconomy can be said to have run up against the conflicts and disagreements and the mutual relationships between patterns of subjective

orientations, practical habits and socio-structural characteristics that our analysis has addressed (ZIRIUS, 2020). However, for grasping the dynamics of contention and social change at work here, the focus on single variables and the causal models usually deployed in these studies have not proved ideal. As we hope to have shown, examining the same type of data with the kind of relational approach we propose promises to be more adequate to this task.

In conclusion, one might hope that the politicization and broadening of the societal conflict around social-ecological transformation that we are currently witnessing will reinforce the multiple reality checks we have discussed to lead to a more fundamental change in policies. What could – and from our perspective: should – gain in importance in this process is a strand of debates that bioeconomy policy has not reflected so far (but is debated at least on the fringes of the scientific literature), namely the broad, multidisciplinary grounded critique of the 1990s sustainability discourse that has been mounted from the degrowth spectrum in the course of the past decade (Asara et al., 2015; D'Alisa et al., 2015; Muraca, 2013; Schneider et al., 2010). This revision of the core tenets of the 1990s sustainability discourse, and the current 'green growth' visions it has fed into, is gradually entering the mainstream debate on the bioeconomy not only through radically provocative work such as that of Mario Giampietro (2019), but also through the rather prosaic findings of sober accounts such as that by Bringezu et al. (2020). This way, the more bioeconomy policy is compelled to acknowledge the biophysical limitations imposed by the finite materialities that a sustainable bioeconomy is ultimately restricted to, the more the heritage of its denied ancestor Georgescu-Roegen demands its due.

Literature

Allaire, G., Wolf S.A., 2004. "Cognitive Representations and Institutional Hybridity in Agrofood Innovation" *Science, Technology & Human Values* 29(4), 431–458.

Asara, V., Otero, I., Demaria, F., Corbera, E., 2015. "Socially sustainable degrowth as a social–ecological transformation: repoliticizing sustainability" *Sustainability Science* 10(3), 375–384.

Backhouse, M., Lehmann, R., 2019. "New 'renewable' frontiers: contested palm oil plantations and wind energy projects in Brazil and Mexico" *Journal of Land Use Science* 15(2-3), 373–388.

Backhouse, M., Lorenzen, K., Lühmann, M., Puder, J., Rodríguez, F., Tittor, A., 2017. *Bioökonomie-Strategien im Vergleich. Gemeinsamkeiten, Widersprüche und Leerstellen*, Working Paper Nr. 1 der BMBF-Nachwuchsgruppe 'Bioeconomy&Inequalities'. Friedrich-Schiller-Universität, Jena.

Backhouse, M., Tittor, A., 2019. „Für eine intersektionale Perspektive auf globale sozial-ökologische Ungleichheiten", in: Dörre, K., Rosa, H., Becker, K., Bose, S., Seyd, B. (Eds.), *Große Transformation? Zur Zukunft moderner Gesellschaften*. Sonderband Nr. 1 des Berliner Journals für Soziologie. Springer Fachmedien, Wiesbaden, 297–309.

Bauer, F., 2018. "Narratives of biorefinery innovation for the bioeconomy: Conflict, consensus or confusion?" *Environmental Innovation and Societal Transitions* 28, 96–107.

Befort, N., 2020. "Going beyond definitions to understand tensions within the bioeconomy: The contribution of sociotechnical regimes to contested fields" *Technological Forecasting and Social Change* 153, 119923.

Behrens, A., Giljum, S., Kovanda, J., Niza, S., 2007. "The material basis of the global economy: Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies" *Ecological Economics* 64(2), 444–453.

Biber-Freudenberger, L., Ergeneman, C., Förster, J.J., Dietz, T., Börner, J., 2020. „Bioeconomy futures: Expectation patterns of scientists and practitioners on the sustainability of bio-based transformation" *Sustainable Development* 28(5), 1220–1235..

Birch, K., 2017a. "Rethinking Value in the Bio-economy: Finance, Assetization, and the Management of Value" *Science, Technology & Human Values* 42(3), 460–490.

Birch, K., 2017b. "The problem of bio-concepts: biopolitics, bio-economy and the political economy of nothing" *Cultural Studies of Science Education* 12(4), 915–927.

Birch, K., 2006. "The Neoliberal Underpinnings of the Bioeconomy: the Ideological Discourses and Practices of Economic Competitiveness" *Genomics, Society and Policy* 2(3), 1 –15.

Birch, K., Levidow, L., Papaioannou, T., 2014. "Self-Fulfilling Prophecies of the European Knowledge-Based Bio-Economy: The Discursive Shaping of Institutional and Policy Frameworks in the Bio-Pharmaceuticals Sector" *Journal of the Knowledge Economy* 5(1), 1–18.

Birch, K., Levidow, L., Papaioannou, T., 2010. "Sustainable Capital? The Neoliberalization of Nature and Knowledge in the European 'Knowledge-based Bio-economy'" *Sustainability* 2(9), 2898–2918.

Birch, K., Tyfield, D., 2013. "Theorizing the Bioeconomy: Biovalue, Biocapital, Bioeconomics or… What?" *Science, Technology & Human Values* 38(3), 299–327.

Blühdorn, I., Butzlaff, F., Deflorian, M., Hausknost, D., Mock, M., 2020. *Nachhaltige Nicht-Nachhaltigkeit. Warum die ökologische Transformation der Gesellschaft nicht stattfindet*. transcript Verlag, Bielefeld.

BMBF (Ed.), 2010. *Nationale Forschungsstrategie BioÖkonomie 2030: Unser Weg zu einer bio-basierten Wirtschaft.* BMBF, Berlin [et al.].

BMEL, 2014. *Nationale Politikstrategie Bioökonomie: Nachwachsende Ressourcen und biotechnologische Verfahren als Basis für Ernährung, Industrie und Energie*. BMEL, Bonn.

BMEL, BMBF, 2020. *Nationale Bioökonomiestrategie*. Kabinettvorlage, 15.01.2020. Bundesregierung, Berlin.

Böcher, M., Töller, A.E., Perbandt, D., Beer, K., Vogelpohl, T., 2020. „Research trends: Bioeconomy politics and governance" *Forest Policy and Economics* 118, 102219.

Bourdieu, P., 1996a. *The rules of art*. Polity, Cambridge.

Bourdieu, P., 1996b. *The State Nobility - Elite Schools in the Field of Power*. Polity, Cambridge.

Bourdieu, P., 1990. *The Logic of Practice*. Polity, Cambridge.

Bourdieu, P., 1984. *Distinction - A Social Critique of the Judgement of Taste*. Harvard University Press, Cambridge, MA.

Bridge, G., 2011. "Resource geographies 1: Making carbon economies, old and new" *Progress in Human Geography* 35(6), 820–834.

Bringezu, D.S., 2019. Systemisches Monitoring und Modellieren der Bioökonomie: Einführung und Übersicht des Projekts. Vortrag auf der zweiten Statuskonferenz zum Monitoring der Bioökonomie, Berlin, 19 09 2019. Slides online at https://symobio.de/wp-content/uploads/SymobioStatusKonferenz20190919/SYMOBIO_Einfuehrung_Bringezu_19Sep2019.pdf

Bringezu, S., Banse, M., Ahmann, L., Bezama, A., Billig, E., Bischof, R., Blanke, C., Brosowski, A., Brüning, S., Borchers, M., Budzinski, M., Cyffka, K.-F., Distelkamp, M., Egenolf, V., Flaute, M., Geng, N., Gieseking, L., Graß, R., Hennenberg, K., Hering, T., Iost, S., Jochem, D., Krause, T., Lutz, C., Machmüller, A., Mahro, B., Majer, S., Mantau, U., Meisel, K., Moesenfechtel, U., Noke, A., Raussen, T., Richter, F., Schaldach, R., Schweinle, J., Thrän, D., Uglik, M., Weimar, H., Wimmer, F., Wydra, S., Zeug, W., 2020. *Pilotbericht zum Monitoring der deutschen Bioökonomie. Center for Environmental Systems Research (CESR)*, Universität Kassel, Kassel.

Bugge, M.M., Hansen, T., Klitkou, A., 2016. „What Is the Bioeconomy? A Review of the Literature" *Sustainability* 8(7), 691.

Chan, K.M.A., Boyd, D.R., Gould, R.K., Jetzkowitz, J., Liu, J., Muraca, B., Naidoo, R., Olmsted, P., Satterfield, T., Selomane, O., Singh, G.G., Sumaila, R., Ngo, H.T., Boedhihartono, A.K., Agard, J., Aguiar, A.P.D. de, Armenteras, D., Balint, L., Barrington-Leigh, C., Cheung, W.W.L., Díaz, S., Driscoll, J., Esler, K., Eyster, H., Gregr, E.J., Hashimoto, S., Pedraza, G.C.H., Hickler, T., Kok, M., Lazarova, T., Mohamed, A.A.A., Murray-Hudson, M., O'Farrell, P., Palomo, I., Saysel, A.K., Seppelt, R., Settele, J., Strassburg, B., Xue, D., Brondízio, E.S., 2020. "Levers and leverage points for pathways to sustainability" *People and Nature* 2(3), 693–717.

Civil Society Action Forum on Bioeconomy, 2019. *Declaration of German Environmental and Development Organizations on the Bioeconomy Policy of the Federal Government of Germany*. Denkhaus Bremen, Bremen.

Daggett, C., 2018. "Petro-masculinity: Fossil Fuels and Authoritarian Desire" *Millennium* 47(1), 25–44.

D'Alisa, G., De Maria, F., Kallis, G. (Eds.), 2015. *Degrowth: a vocabulary for a new era*. Routledge, New York, NY.

D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lähtinen, K., Korhonen, J., Leskinen, P., Matthies, B.D., Toppinen, A., 2017. "Green, circular, bio economy: A comparative analysis of sustainability avenues" *Journal of Cleaner Production* 168, 716–734.

D'Amato, D., Droste, N., Winkler, K.J., Toppinen, A., 2019. "Thinking green, circular or bio: Eliciting researchers' perspectives on a sustainable economy with Q method" *Journal of Cleaner Production* 230, 460–476.

de Besi, M., McCormick, K., 2015. "Towards a Bioeconomy in Europe: National, Regional and Industrial Strategies" *Sustainability* 7(8), 10461–10478.

Di Muzio, T., 2015. *Carbon Capitalism: Energy, Social Reproduction and World Order*. Rowman & Littlefield International, London.

Efken, J., Dirksmeyer, W., Kreins, P., Knecht, M., 2016. "Measuring the importance of the bioeconomy in Germany: Concept and illustration" *NJAS - Wageningen Journal of Life Sciences* 77, 9–17.

Egenolf, V., Bringezu, S., 2019. "Conceptualization of an Indicator System for Assessing the Sustainability of the Bioeconomy" *Sustainability* 11(2), 443.

Eichenauer, E., 2018. „Energiekonflikte – Proteste gegen Windkraftanlagen als Spiegel demokratischer Defizite," in: Radtke, J., Kersting, N. (Eds.), *Energiewende. Politikwissenschaftliche Perspektiven*. Springer VS, Wiesbaden, 315–342.

Eichenauer, E., Reusswig, F., Meyer-Ohlendorf, L., Lass, W., 2018. „Bürgerinitiativen gegen Windkraftanlagen und der Aufschwung rechtspopulistischer Bewegungen," in: Kühne, O., Weber, F. (Eds.), *Bausteine der Energiewende*. *RaumFragen: Stadt – Region – Landschaft.* Springer VS, Wiesbaden, 633-651.

Enríquez, J., 2002. *The Biotechonomy (1.0): A Rough Map of Bio-data Flow.* Harvard Business School Working Paper N° 03-028, August 2002, Cambridge, MA.

Enríquez, J., 1998. "Genomics and the World's Economy" *Science Magazin* 281(5379), 925–926.

Enríquez, J., Goldberg, R.A., 2000. "Transforming Life, Transforming Business: The Life-Science Revolution" *Harvard Business Review* 78(2), 94 –104.

European Commission, 2019. *The European Green Deal*. European Commission, Brussels.

European Commission, 2012. *Innovating for Sustainable Growth: A Bioeconomy for Europe.* European Commission, Brussels.

European Commission, 2018. *A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment: Updated Bioeconomy Strategy.* European Commission, Brussels.

Eversberg, D., 2020a. "The social specificity of societal nature relations in a flexible capitalist society" *Environmental Values*, Available at (27 06 2020) https://doi.org/10.3197/096327120x15916910310581

Eversberg, D., 2020b. "Who can challenge the imperial mode of living? The terrain of struggles for social-ecological transformation in the German population." *The European Journal of Social Science Research* 33(2), 233–256.

Eversberg, D., 2020c. *Bioökonomie als Einsatz polarisierter sozialer Konflikte? Zur Verteilung sozial-ökologischer Mentalitäten in der deutschen Bevölkerung 2018 und ihren Unterstützungs- und Widerstandspotentialen gegenüber Bioökonomie als gesellschaftlichem Wandel*, Working Paper Nr. 1 der BMBF-Nachwuchsgruppe "flumen". Friedrich-Schiller-Universität, Jena.

Fund, C., El-Chichakli, B., Patermann, C., Dieckhoff, P., 2015. *Bioeconomy Policy (Part II): Synopsis of National Strategies around the World. A report from the German Bioeconomy Council.* Bioökonomierat, Berlin.

Gawel, E., Pannicke, N., Hagemann, N., 2019. "A Path Transition Towards a Bioeconomy — The Crucial Role of Sustainability" *Sustainability* 11(11), 3005.

Geiger, T., 1972. *Die soziale Schichtung des deutschen Volkes, Soziologische Gegenwartsfragen*. Wissenschaftliche Buchgesellschaft, Darmstadt.

Georgescu-Roegen, N., 1971. *The entropy law and the economic process*. Harvard University Press, Cambridge, MS.

Giampietro, M., 2019. "On the Circular Bioeconomy and Decoupling: Implications for Sustainable Growth" *Ecological Economics* 162, 143–156.

Giampietro, M., Funtowicz, S.O., 2020. "From elite folk science to the policy legend of the circular economy" *Environmental Science & Policy* 109, 64–72.

Giurca, A., 2020. "Unpacking the network discourse: Actors and storylines in Germany's wood-based bioeconomy" *Forest Policy and Economics* 110, 101754.

Giurca, A., Metz, T., 2018. "A social network analysis of Germany's wood-based bioeconomy: Social capital and shared beliefs" *Environmental Innovation and Societal Transitions* 26, 1–14.

Graefe, S., 2019. *Resilienz im Krisenkapitalismus: Wider das Lob der Anpassungsfähigkeit*. transcript, Bielefeld.

Grunwald, A., 2020. "Bioeconomy: Key to Unlimited Economic and Consumption Growth?" in: Pietzsch, J. (Ed.), *Bioeconomy for Beginners*. Springer, Berlin, Heidelberg, 203–209.

Grunwald, A., 2016. "Diverging pathways to overcoming the environmental crisis: A critique of eco-modernism from a technology assessment perspective" *Journal of Cleaner Production* 197(2), 1854-1862.

Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., 2015. „How Circular is the Global Economy? An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005" *Journal of Industrial Ecology* 19, 765–777.

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Fishman, T., Hausknost, D., Krausmann, F.P., Leon-Gruchalski, B., Mayer, A., Pichler, M., Schaffartzik, A., Sousa, T., Streeck, J., Creutzig, F., 2020. "A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights" *Environmental Research Letters* 15(6), 065003.

Hackfort, S., 2015. „Bioökonomie," in: Bauriedl, S. (Ed.), *Wörterbuch Klimadebatte*. transcript, Bielefeld, 37–42.

Hausknost, D., Schriefl, E., Lauk, C., Kalt, G., 2017. „A Transition to Which Bioeconomy? An Exploration of Diverging Techno-Political Choices" *Sustainability* 9(4), 669.

Hempel, C., Will, S., Zander, K., 2019a. "Societal Perspectives on a Bio-economy in Germany: An Explorative Study Using Q Methodology" *International Journal on Food System Dynamics* 10(1), 21 –37.

Hempel, C., Will, S., Zander, K., 2019b. *Bioökonomie aus Sicht der Bevölkerung*. Thünen-Institut für Marktanalyse, Braunschweig.

Hickel, J., Kallis, G., 2020. "Is Green Growth Possible?" *New Political Economy. 25(4), 469-486.*

Hilgartner, S., 2007. "Making the Bioeconomy Measurable: Politics of an Emerging Anticipatory Machinery" *BioSocieties* 2, 382–386.

Iost, S., Labonte, N., Banse, M., Geng, N., Jochem, D., Schweinle, J., Weber, S., Weimar, H., 2019. „German Bioeconomy: Economic Importance and Concept of Measurement" *German Journal of Agricultural Economics* 68(4), 275–288.

Issa, I., Delbrück, S., Hamm, U., 2019. „Bioeconomy from experts' perspectives – Results of a global expert survey" *PLOS ONE* 14(5), e0215917. Available at (01 05 2020) https://doi.org/10.1371/journal.pone.0215917

Jander, W., Wydra, S., Wackerbauer, J., Grundmann, P., Piotrowski, S., 2020. „Monitoring Bioeconomy Transitions with Economic–Environmental and Innovation Indicators: Addressing Data Gaps in the Short Term" *Sustainability* 12(11), 4683.

Kleinschmit, D., Arts, B., Giurca, A., Mustalahti, I., Sergent, A., Pülzl, H., 2017. "Environmental concerns in political bioeconomy discourses" *International Forestry Review* 19(1), 41 –55.

Konrad, W., Scheer, D., Weidtmann, A. (Eds.), 2020. *Bioökonomie nachhaltig gestalten: Perspektiven für ein zukunftsfähiges Wirtschaften, Technikzukünfte, Wissenschaft und Gesellschaft / Futures of Technology, Science and Society*. VS Verlag für Sozialwissenschaften, Wiesbaden.

Konstantinis, A., Rozakis, S., Maria, E.-A., Shu, K., 2018. „A Definition of Bioeconomy through the Bibliometric Networks of the Scientific Literature" *AgBioForum* 21(2), 64–85.

Korhonen, J., Giurca, A., Brockhaus, M., Toppinen, A., 2018. "Actors and Politics in Finland's Forest-Based Bioeconomy Network." *Sustainability* 10(10), 3785.

Krausmann, F., Fischer-Kowalski, M., 2010. *Gesellschaftliche Naturverhältnisse: Energiequellen und die globale Transformation des gesellschaftlichen Stoffwechsels*., Universität Klagenfurt, Klagenfurt.

Kröger, M., Raitio, K., 2017. "Finnish forest policy in the era of bioeconomy: A pathway to sustainability?" *Forest Policy and Economics* 77, 6–15.

Kuosmanen, T., Kuosmanen, N., El Meligi, A., Ronzon, T., Gurria Albuzac, P., Iost, S., M'Barek, R., 2020 *How big is the Bioeconomy? Reflections from an economic perspective*, JRC Technical Report. Publications Office of the European Union, Luxemburg.

Latham, J., Wilson, A., 2007. Does the Bio-Economy Add Up? Available at https://jonathanlatham.net/does-the-bio-economy-add-up/ (accessed 29 09 2020).

Leipold, S., Petit-Boix, A., 2018. "The circular economy and the bio-based sector – Perspectives of European and German stakeholders" *Journal of Cleaner Production* 201, 1125–1137.

Levidow, L., Birch, K., Papaioannou, T., 2013. "Divergent Paradigms of European Agro-Food Innovation: The Knowledge-Based Bio-Economy (KBBE) as an R&D Agenda" *Science, Technology & Human Values* 38(1), 94–125.

Levidow, L., Birch, K., Papaioannou, T., 2012. "EU agri-innovation policy: two contending visions of the bio-economy" *Critical Policy Studies* 6(1), 40–65.

Levidow, L., Nieddu, M., Vivian, F.-D., Béfort, N., 2019. Transitions towards a European Bioeconomy: Life Sciences versus agroecology trajectories, in: Allaire, G., Daviron, B. (Eds.), *Ecology, Capitalism and the New Agricultural Economy: The Second Great Transformation*. Routledge, London, 181–203.

Levidow, L., Papaioannou, T., 2014. "UK Biofuel Policy: Envisaging Sustainable Biofuels, Shaping Institutions and Futures" Environment and Planing: A: *Economy and Space* 46(2), 280 –298.

Lewandowski, I., 2015. "Securing a sustainable biomass supply in a growing bioeconomy" *Global Food Security* 6, 34–42.

Liobikiene, G., Chen, X., Streimikiene, D., Balezentis, T., 2020. "The trends in bioeconomy development in the European Union: Exploiting capacity and productivity measures based on the land footprint approach" *Land Use Policy* 91, 104375.

Lovrić, M., Lovrić, N., Mavsar, R., 2020. "Mapping forest-based bioeconomy research in Europe." *Forest Policy and Economics* 110 (C), 101874.

Lühmann, M., 2020. "Whose European bioeconomy? Relations of forces in the shaping of an updated EU bioeconomy strategy" *Environmental Development* 35, 100547.

Lynch, D.H.J., Klaassen, P., Broerse, J.E.W., 2017. "Unraveling Dutch citizens' perceptions on the bio-based economy: The case of bioplastics, bio-jetfuels and small-scale bio-refineries" *Industrial Crops and Products* 106, 130–137.

Malm, A., 2016. *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*. Verso, London.

Malm, A., 2012. "China as Chimney of the World: The Fossil Capital Hypothesis" *Organization & Environment* 25, 146–177.

Martin, J.L., 2003. "What Is Field Theory?" *American Journal of Sociology* 109, 1–49.

McCormick, K., Kautto, N., 2013. "The Bioeconomy in Europe: An Overview" *Sustainability* 5(6), 2589–2608.

Meyer, R., 2017. "Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates" *Sustainability* 9(6), 1031.

Ministry of Employment and the Economy, Ministry of the Environment, Ministry of Agriculture and Forestry, 2014. *Sustainable Growth from Bioeconomy: The Finnish Bioeconomy Strategy*. Ministry of Employment and the Economy, Helsinki.

Mitchell, T., 2013. *Carbon democracy: political power in the age of oil*. Verso, London.

Mittra, J., Zoukas, G., 2020. "Unpacking the Concept of Bioeconomy: Problems of Definition, Measurement, and Value" *Science & Technology Studies* 33(1), 2–21.

Motta, R., Meinicke, M., 2020. Soziale Bewegungen für eine Agrar- und Ernährungswende. Blog des Wissenschaftsjahres 2020/21: Bioökonomie. Available at https://www.wissenschaftsjahr.de/2020-21/aktuelles-aus-der-biooekonomie/koepfe-des-wandels/soziale-bewegungen-fuer-eine-agrar-und-ernaehrungswende (accessed 23 09 2020).

Neukirch, M., 2018. „Die Energiewende in der Bundesrepublik Deutschland (1974-2017) – Reform, Revolution, oder Restauration? Makroperspektive auf einen Dauerkonflikt“ *sozialpolitik.ch – Journal des Fachbereichs Soziologie, Sozialpolitik, Sozialarbeit, Universität Fribourg* 1,Article 1.3.Neukirch, M., 2016. „Protests against German electricity grid extension as a new social movement? A journey into the areas of conflict” *Energy, Sustainability and Society* 6(1), 1–15.

OECD, 2009. *The Bioeconomy to 2030: Designing a Policy Agenda*. OECD Publishing, Paris.

Peltomaa, J., 2018. “Drumming the Barrels of Hope? Bioeconomy Narratives in the Media” *Sustainability* 10(11), 4278.

Petersen, A., Krisjansen, I., 2015. “Assembling ‘the bioeconomy’: Exploiting the power of the promissory life sciences” *Journal of Sociology* 51(1), 28-46.

Pfau, S., Hagens, J., Dankbaar, B., Smits, A., 2014. “Visions of Sustainability in Bioeconomy Research” *Sustainability* 6(3), 1222–1249.

Pichler, M., Brand, U., Görg, C., 2020. “The double materiality of democracy in capitalist societies: challenges for social-ecological transformations” *Environmental Politics* 29(1), 193–213.

Pietzsch, J., Schurr, U., 2020. Introduction, in: Pietzsch, J. (Ed.), *Bioeconomy for Beginners*. Springer, Berlin [et al.], 1–10.

Priefer, C., Jörissen, J., Frör, O., 2017. “Pathways to Shape the Bioeconomy” *Resources* 6(1), 10.

Priefer, C., Meyer, R., 2019. “One Concept, Many Opinions: How Scientists in Germany Think About the Concept of Bioeconomy” *Sustainability* 11(15), 4253.

Puder, J., 2019. “Excluding migrant labor from the Malaysian bioeconomy: Working and living conditions of migrant workers in the palm oil sector in Sabah” *Austrian Journal of South-East Asian Studies* 12(1), 31–48.

Pülzl, H., Kleinschmit, D., Arts, B., 2014. “Bioeconomy – an emerging meta-discourse affecting forest discourses?” *Scandinavian Journal of Forest Research* 29(4), 1–26.

Pungas, L., 2019. “Food Self-Provisioning as an Answer to the Metabolic Rift: The Case of ‘Dacha Resilience’ in Estonia” *Journal of Rural Studies* 68, 75–86.

Pyka, A., 2017. “Dedicated innovation systems to support the transformation towards sustainability: creating income opportunities and employment in the knowledge-based digital bioeconomy” *Journal of Open Innovation: Technology, Market, and Complexity* 3, 27.

Pyka, A., Prettner, K., 2018. “Economic Growth, Development, and Innovation: The Transformation Towards a Knowledge-Based Bioeconomy” in: Lewandowski, I. (Ed.), *Bioeconomy*. Springer, Cham, 331–342.

Richardson, B., 2012. "From a Fossil-Fuel to a Biobased Economy: The Politics of Industrial Biotechnology." *Environment and Planning C: Government and Policy* 30(2), 282 –296.

Robert, N., Giuntoli, J., Araujo, R., Avraamides, M., Balzi, E., Barredo, J.I., Baruth, B., Becker, W., Borzacchiello, M.T., Bulgheroni, C., Camia, A., Fiore, G., Follador, M., Gurria, P., la Notte, A., Lusser, M., Marelli, L., M'Barek, R., Parisi, C., Philippidis, G., Ronzon, T., Sala, S., Sanchez Lopez, J., Mubareka, S., 2020. "Development of a bioeconomy monitoring framework for the European Union: An integrative and collaborative approach" *New Biotechnology* 59, 10–19.

Ronzon, T., M'Barek, R., 2018. "Socioeconomic Indicators to Monitor the EU's Bioeconomy in Transition" *Sustainability* 10(6), 1745.

Ronzon, T., Piotrowski, S., M'Barek, R., Carus, M., 2017. "A systematic approach to understanding and quantifying the EU's bioeconomy" *Bio-based and Applied Economics* 1(6), 1 –17.

Ronzon, T., Piotrowski, S., Tamosiunas, S., Dammer, L., Carus, M., M'barek, R., 2020. "Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU" *Sustainability* 12(11), 4507.

Rubik, F., Müller, R., Harnisch, R., Holzhauer, B., Schipperges, M., Geiger, S., 2019. *Umweltbewusstsein in Deutschland 2018. Ergebnisse einer repräsentativen Bevölkerungsumfrage.* Umweltbundesamt; Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Dessau-Roßlau; Berlin.

Rudolph, K., 2018. "Barriers to Acceptance of Bio-Based Substitutes: How Schema Incongruity Can Hinder the Purchase of Bio-Based Products" in: Leal Filho, W., Pociovalisteanu, D.-M., Borges de Brito, P.R., Borges de Lima, I. (Eds.), *Towards a Sustainable Bioeconomy: Principles, Challenges and Perspectives, World*. Springer, Cham, 117–133.

Sanz-Hernández, A., Esteban, E., Garrido, P., 2019. "Transition to a bioeconomy: Perspectives from social sciences" *Journal of Cleaner Production* 224, 107–119.

Schneider, F., Kallis, G., Martinez-Alier, J., 2010. "Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue" *Journal of Cleaner Production* 18, 511–518.

Sijtsema, S.J., Onwezen, M.C., Reinders, M.J., Dagevos, H., Partanen, A., Meeusen, M., 2016. "Consumer perception of bio-based products—An exploratory study in 5 European countries" *NJAS - Wagening. Journal of Life Sciences* 77, 61–69.

Simon, F., 2019. Circular economy erected as 'number one priority' of European Green Deal. www.euractiv.com. Available at https://www.euractiv.com/section/circular-economy/news/circular-economy-is-number-one-priority-of-european-green-deal/ (accessed 18 11 2019).

Smil, V., 2017. *Energy and civilization: a history*. The MIT Press, Cambridge, MS.

Staffas, L., Gustavsson, M., McCormick, K., 2013. "Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches" *Sustainability* 5(6), 2751–2769.

Stegmann, P., Londo, M., Junginger, M., 2020. "The circular bioeconomy: Its elements and role in European bioeconomy clusters" *Resources, Conservation and Recycling* X 6, 100029.

Teixeira, M.A., Motta, R., 2020. "Unionism and feminism: alliance building in the Brazilian Marcha das Margaridas" *Social Movement Studies*. Available at (28 05 2020) https://doi.org/10.1080/14742837.2020.1770430

The White House, 2012. "National Bioeconomy Blueprint, April 2012" *Industrial Biotechnology* 8(3), 97–102.

Tittor, A., Backhouse, M., 2019. „Ungleiche Pestizidbelastung in der globalen Bioökonomie: Das Beispiel Glyphosat" in: Fischer, K., Grandner, M. (Eds.), *Globale Ungleichheit. Über Zusammenhänge von Kolonialismus, Arbeitsverhältnissen und Naturverbrauch*. Mandelbaum Verlag, Wien, 321–325.

Tittor, A., Toledo López, V., 2020. "Struggling against the consequences of bioethanol production: Narratives of a local environmental justice movement in Córdoba, Argentina" *ERDE – Journal of the Geographical Society of Berlin* 151, 142–153.

Unruh, G.C., 2000. "Understanding carbon lock-in" *Energy Policy* 28(12), 817–830.

Unruh, G.C., Carrillo-Hermosilla, J., 2006. "Globalizing carbon lock-in" *Energy Policy* 34(10), 1185–1197.

Vester, M., Oertzen, P. von, Geiling, H., Hermann, T., Müller, D., 2001. *Soziale Milieus im gesellschaftlichen Strukturwandel*. Suhrkamp, Frankfurt am Main.

Vivien, F.-D., Nieddu, M., Befort, N., Debref, R., Giampietro, M., 2019. „The Hijacking of the Bioeconomy" *Ecological Economics* 159, 189–197.

Weber, G., Cabras, I., 2017. "The transition of Germany's energy production, green economy, low-carbon economy, socio-environmental conflicts, and equitable society" *Journal of Cleaner Production* 167, 1222–1231.

Welzer, H., 2011. *Mental Infrastructures: How Growth Entered the World and Our Souls*. Heinrich-Böll-Stiftung, Berlin.

Wesseler, J., von Braun, J., 2017. "Measuring the Bioeconomy: Economics and Policies" *Annual Review of Resource Economics* 9, 275–298.

Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Streeck, J., Pichler, M., Mayer, A., Krausmann, F.P., Brockway, P., Schaffartzik, A., Fishman, T., Hausknost, D., Leon-Gruchalski, B., Sousa, T., Creutzig, F., Haberl, H., 2020. "A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping" *Environmental Research Letters* 15(6), 063002.

Zeug, W., Bezama, A., Moesenfechtel, U., Jähkel, A., Thrän, D., 2019. "Stakeholders' Interests and Perceptions of Bioeconomy Monitoring Using a Sustainable Development Goal Framework" *Sustainability* 11(6), 1511.

ZIRIUS, 2020. TechnikRadar 2020. *Was die Deutschen über Technik denken*. acatech; Körber-Stiftung, München; Hamburg.